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FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

REMEDIAL INVESTIGATION AND FEASIBILITY STUDY

VOLUME 1 OF 5

JUNE 1994

U.S. DEPARTMENT OF ENERGY
FERNALD FIELD OFFICE

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AEC	U.S. Atomic Energy Commission
ARAR	applicable or relevant and appropriate requirement
ASL	analytical support level
ASTM	American Society for Testing Materials
AWWT	advanced wastewater treatment
BMP	best management practices
BNL	Brookhaven National Laboratory
BSL	biodenitrification surge lagoon
CD	Consent Decree
CDC	Centers for Disease Control
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CIS	Characterization Investigation Study
CLP	Contract Laboratory Program [U.S.EPA]
CMSA	Consolidated Metropolitan Statistical Area
COC	constituent of concern
COPC	constituent of preliminary concern
CPC	constituent of potential concern
CPID	closure plan information and data
CRDL	contract required detection limit
CSF	cancer slope factor
CT	central tendency
CWA	Clean Water Act
D&D	decontamination and decommissioning
DBH	diameter at breast height
DC	detected constituent
DFO	Director's Findings and Orders
DOE	U.S. Department of Energy
DOW	Division of Wildlife [Ohio]
DQO	data quality objective

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EE/CA	engineering evaluation/cost analysis
EIS	environmental impact statement
EM	Environmental Monitoring [Program]
EO	Executive Order
EPA	U.S. Environmental Protection Agency
ERMA	Environmental Resource Management and Analysis Systems
ESA	Endangered Species Act
ET	evapotranspiration
eV	electron volt
EWMF	Engineered Waste Management Facility
FEMP	Fernald Environmental Management Project
FERMCO	Fernald Environmental Restoration Management Corporation
FFCA	Federal Facility Compliance Agreement
FICWD	Federal Interagency Committee for Wetland Delineation
FIDLER	field instrument for detecting low energy radiation
FMPC	Feed Materials Production Center
FOC	fractional organic carbon
FR	Federal Register
FS	feasibility study
FWS	Fish and Wildlife Service
FY	fiscal year
GIS	geographical information system
GMP	groundwater monitoring plan
GO/UGMAS	Glacial Overburden/Upper Great Miami Aquifer System [model]
gpd	gallons per day
gpm	gallons per minute
HELP	Hydraulic Evaluation of Landfill Performance [model]
HI	hazard index
HQ	hazard quotient
HSL	Hazardous Substance List

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HWMU	hazardous waste management unit
IAWWT	Interim Advanced Wastewater Treatment
IDW	investigation derived waste
ILCR	incremental lifetime cancer risk
ISA	Initial Screening of Alternatives
ISCLT2	Industrial Source Complex Long Term 2 [version 93109 model]
IT	IT Corporation
KPA	kinetic phosphorescence analysis
keV	kiloelectron volt
LRA	leading remedial alternative
MDC	minimum detectable concentration
MMI	Modified Mercalli Intensity
msl	mean sea level
MUSLE	modified universal soil loss equation
NAAQS	National Ambient Air Quality Standards
NBS	National Bureau of Standards
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NISM	National Institute of Standard Measures
NLO	National Lead Company of Ohio
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NPL	National Priority List
NRC	Nuclear Regulatory Commission
NRHP	National Register of Historic Places
NTS	Nevada Test Site
NTU	nephelometric turbidity unit
NWS	National Weather Service
OAC	Ohio Administrative Code

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ODAST	One-Dimensional Analytical Solute Transport [model]
ODH	Ohio Department of Health
ODNR	Ohio Department of Natural Resources
OEPA	Ohio Environmental Protection Agency
ORAU	Oak Ridge Associated Universities
ORNL	Oak Ridge National Laboratory
OSP	Ohio State Planar
OU	operable unit
PAH	polynuclear aromatic hydrocarbon
PASA	Production and Additional Suspect Areas
PCB	polychlorinated biphenyl
PET	potential evaporation transpiration
PIC	Pressurized Ionization Chamber
PP	proposed plan
PRG	preliminary remediation goal
PRRS	Paddys Run Road Site
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
QC	quality control
RAC	Radiological Assessment Corp.
RAGS	Risk Assessment Guidance for Superfund
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RFC	reference concentration
RfD	reference dose
RI	remedial investigation
RI/FS	Remedial Investigation/Feasibility Study
RM	river miles
RME	reasonable maximum exposure

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RMI	Reactive Metals, Inc.
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
S.R.	state route
SCQ	Sitewide CERCLA Quality Assurance Project Plan
SCS	Soil Conservation Service
SED	sitewide environmental database
SHPO	State Historic Preservation Officer
SI	saturation index
SOWC	Southwestern Ohio Water Company
SPIT	South Plume interim treatment [facility]
SSOD	storm sewer outfall ditch
STAR	stability array
SWIFT	Sandia Waste Isolation Flow and Transport [model]
SWOAPCA	Southwestern Ohio Air Pollution Control Agency
SWRB	storm water retention basin
TAL	target analyte list
TBC	to be considered
TCLP	toxicity characteristic leaching procedure
TEF	toxic equivalent factors
TFV	threshold friction velocity
THQ	target hazard quotient
TLD	thermoluminescent dosimeter
TOC	total organic carbon
TON	total organic nitrogen
TOX	total organic halogens
TSIL	Task Sample Inventory List
TSP	total suspended particles
TSS	total suspended solids
UAP	uranyl ammonium phosphate

LIST OF ACRONYMS
(Continued)

UCL	upper confidence limit
UNH	uranyl nitrate hexahydrate
USCS	Unified Soil Classification System
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USLE	universal soil loss equation
UST	underground storage tank
VOC	volatile organic compound
WEMCO	Westinghouse Environmental Management Company of Ohio
WMCO	Westinghouse Materials Company of Ohio

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Adsorption	Process whereby a dissolved ion or molecule becomes attached to the surface of a preexisting solid substrata.
Anions	Negatively charged ions in solution.
Anisotropic	The geologic unit whose properties vary with direction.
Applicable or relevant and appropriate requirements (ARARs)	Requirements set forth in regulations that implement environmental and public health laws and must be attained or exceeded by a selected remedy unless a waiver is invoked. ARARs are divided into three categories: chemical-specific, location-specific and action-specific, depending on whether the requirement is triggered by the presence or emission of a chemical, by a vulnerable or protected location, or by a particular action.
Aquiclude	A saturated but poorly permeable bed, formation, or group of formations that does not yield water freely to a well or spring. However, an aquiclude may transmit appreciable water to or from adjacent aquifers.
Aquifer	A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield economical quantities of water to wells and springs.
Aquitard	A saturated geologic unit that yields inappreciable quantities of water compared to an aquifer, but through which appreciable leakage of water is possible.
Baseline risk assessment	The study undertaken to characterize the current and potential threats to human health and the environment that may be posed by contaminants within Operable Unit 5. The baseline risk assessment provides a framework for designing information necessary to assist in designing remedial alternatives, and considers the risks that currently exist at the site if no further response actions or institutional controls are applied. There are four steps in the baseline risk assessment process: data collection and analysis; exposure assessment; toxicity assessment; and risk characterization. The baseline risk assessment contributes to the site characterization and subsequent development, evaluation, and selection of appropriate response alternatives.
Bedrock	Any solid rock exposed at the surface of the earth or overlain by unconsolidated material.
Cations	Positively charged ions in solution.
Chronic reference dose (RfD)	An estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. Chronic RfDs are specifically developed to be protective for long-term exposure to a compound.

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Code verification	Testing computer codes against known solutions to verify that they produce the correct results.
Conceptual models	Models that are constructed to describe or represent various phenomena under a specific set of conditions or assumptions to estimate the resultant effect(s). As applied to risk assessment, conceptual models are used as a basis for calculational fate and transport analysis and exposure assessment. Standard industry-accepted calculational models (computer codes) are used for this purpose by the FEMP RI/FS.
Cone of depression	A depression in the groundwater surface that has the shape of an inverted cone and develops around a well from which water is being withdrawn.
Confined aquifer	An aquifer that is confined under pressure by overlying and underlying aquitards and aquicludes; water levels in wells rise above the top of the aquifer.
Consent agreement	An agreement between the U.S. EPA and the U.S. DOE for the cleanup of the FEMP. The Consent Agreement, signed in April 1990, amended the July 1986 Federal Facility Compliance Agreement, which established the original framework for the FEMP environmental investigation and cleanup. An amended Consent Agreement, signed in September 1991, included a renegotiated framework and schedules for developing, implementing, and monitoring appropriate response actions at the facility.
Constant boundary heads	Hydraulic heads at the cell faces along the external edges of a model which are held constant during model runs.
Contaminant	A substance that when introduced to either surface water or groundwater causes a degradation in the water quality.
Constituent of preliminary concern (COPC)	A detected constituent with a concentration higher than the background and toxicity screening level concentrations.
Constituent of potential concern (CPC)	A COPC that passes the travel time, decay, and vadose zone transport screening. CPCs are constituents that require complete and detailed contaminant fate and transport modeling.
Constituent of concern (COC)	A CPC that has been predicted to be able to pose unacceptable impacts to human and/or environmental receptors.

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Critical subpopulation	Populations at high potential risk from radionuclide or chemical exposure due to increased sensitivity, special behavior patterns, and/or current or past exposures from other sources. Critical subpopulations include infants and children, the elderly, pregnant and nursing women, individuals with chronic illnesses, and individuals previously exposed to chemicals or radionuclides during occupational activities or by residing in industrial areas.
Darcy velocity	Volume of groundwater flow per unit area of porous medium.
Data verification	A procedure by which the available data are tested for validity.
Decay chain	The succession of elements generated as a radioactive "parent" element gives off particles or energy and decays to a "progeny" element which, if radioactive, becomes the next "parent" element in the chain.
Diffusion	The migration of a chemical species due to a gradient in its concentration.
Discharge rate	The rate of flow of a certain volume of water per unit of time.
Dispersion	The spreading and mixing of chemical constituents in groundwater caused by diffusion and mixing due to microscopic variations in velocities within and between pores.
Dispersion coefficient	An approximated numerical value that represents dispersion in a modeled aquifer system.
Dispersivity	A parameter that describes the amount of spreading of a solute plume as the groundwater carries the solute away from its source.
Distribution coefficient	A parameter that describes the proportion of a solute that is absorbed onto the solids in a porous material. Retardation of solute movement increases as the distribution coefficient increases.
Drawdown	The distance between the water level surrounding a well before pumping started and the surface of the cone of depression.
Ecological risk assessment	A site-specific analysis of the potential risks (current and future) to ecological receptors. The ecological risk assessment determines whether facility-derived constituents in environmental media on or adjacent to the facility currently have or may potentially have adverse ecological impacts. Also referred to as an environmental risk assessment.
Effective porosity	The volume of void spaces through which liquids can travel divided by the total volume of the solid material.
Evapotranspiration	Loss of water in an area due to evaporation from soil or transpiration of plants.

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Exposure assessment	The determination or estimation (qualitative or quantitative) of the magnitude, frequency, duration, and route of exposure.
Exposure pathway	The course a chemical or physical agent takes from a source to a receptor organism. Each exposure pathway includes a source or release from a source, an exposure point, an exposure route, and a receptor. If the exposure point differs from the source, a transport medium (e.g., air) or media (in cases of intermedia transfer) also is included.
Exposure scenario	A chain of events and conditions defining a combination of exposure pathways and processes that are used to estimate reasonable maximum exposure of individuals or groups.
Fate and transport modeling	Modeling used to assess contaminant movement from source areas to receptor locations through various media (e.g., groundwater, air). Used in conjunction with monitoring data, these models estimate contaminant concentrations at exposure point locations where measured contaminant concentration data is not available, such as off-property locations or contaminant distribution in the future.
Feasibility study (FS)	The study that fully evaluates and develops remedial action alternatives to prevent or mitigate the migration or release of hazardous substances, pollutants, contaminants, or hazardous constituents at and from the site. The FS is generally performed in conjunction with the remedial investigation (RI) and uses data gathered during the RI to develop remedial action alternatives and to undertake an initial screening and detailed analysis of the alternatives. The RI data are used to define the objectives of the response action, to develop remedial action alternatives and to undertake an initial screening and detailed analysis of the alternatives. The FS includes a report that describes remedial action alternatives and documents the selection process.
FEMP	The Fernald Environmental Management Project, the present name (beginning August 23, 1991) for the former Feed Materials Production Center near Fernald, Ohio.
Finite-difference method	A numerical method used to solve the groundwater flow equation. In this method, the study area is divided into rectangular grids.
Future potential land use	The hypothesized use of property at a site that describes plausible use of the property in the future for purposes of assessing potential human health risks. These categories may include: residential; agricultural; commercial/industrial; and recreational.

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Geochemical modeling	Mathematical techniques used to simulate chemical behavior in the subsurface, including chemical speciation, precipitation, and possibly adsorption and ion exchange.
Glacial overburden	Silt, sand, gravel and clay deposited by glacial action on top of the Great Miami Aquifer and surrounding bedrock highs.
Glaciofluvial	Pertaining to the meltwater streams that flow from retreating glaciers and to the deposits and landforms produced by such a stream.
Great Miami Aquifer	Glaciofluvial sand and gravel deposited by the meltwaters of Pleistocene glaciers within the entrenched ancestral Ohio and Miami rivers. This is also termed a buried channel or sand and gravel aquifer.
Groundwater	Water in a saturated zone or stratum beneath the surface of land.
Groundwater contour	A line that connects equal groundwater elevation on a map.
Groundwater elevation	The height of the groundwater surface above mean sea level.
Groundwater model	A mathematical representation of a groundwater system that behaves in a manner similar to the real system.
Half-life	The time it takes for one half of the atoms in a radioactive sample to decay.
Homogeneous	Uniform in structure or composition throughout an area of interest.
Hydraulic conductivity	A parameter that describes the rate at which water can move through a porous medium. May vary with the direction of the flow.
Hydraulic gradient	The rate of change of hydraulic head per unit of distance of flow in a given direction.
Hydraulic head	The height above mean sea level to which water will rise in a well screened at a specific depth.
Hydrodynamic dispersion	The process by which groundwater containing a solute is diluted with uncontaminated groundwater as it moves through the aquifer.
Hydrogeology	The science that deals with subsurface water and related geologic materials and their interaction with surface water.
Hydrograph	A graph showing a characteristic of water, such as surface water flow or groundwater levels, versus time.
Induced infiltration	Infiltration from a streambed caused by pumping wells near the stream.
Infiltration	The natural flow of water downward from the land surface or stream into and through the upper soil layers or streambed.

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Institutional controls	Measures that generally limit human activities at or near facilities where hazardous substances, pollutants, or contaminants exist or will remain on site. Active institutional controls include engineering controls and an active security program. Passive institutional controls include monuments, land and resource restrictions, deed restrictions, permitting programs, zoning, government ownership, and deed notices. Institutional controls may supplement engineering controls (e.g., treatment and/or containment of source material) to provide protection of human health.
Intake	A measure of exposure. For chemicals, it is expressed as the mass of a chemical in contact with the exchange boundary of a receptor per unit body weight per unit time (e.g., mg chemical/kg body weight-day). For radionuclides, it is expressed as the activity of a radionuclide (e.g., Bq or Ci) taken into an organism. Intake by inhalation, ingestion, and dermal absorption are the three most important exposure routes for both chemicals and radionuclides.
Interbed	A relatively thin layer of material contained within a thicker layer of material of different composition.
Isoconcentration map	A contour map showing lines of equal concentration. Depicts the concentrations in a plume.
Isotopes	Atoms of an element that have the same number of protons but different members of neutrons in the atomic nucleus.
Isotropic	Said of a medium whose properties are the same in all directions.
Kriging	A statistical method of interpolating values between points on a map.
Lacustrine	Deposits produced by or formed in a lake.
Leading remedial alternative	The remedial alternative which, based upon all available data and best professional judgment, is the most likely to be selected as the response action for an operable unit. The leading remedial alternative does not represent the preselection of a remedy and is used only for the purpose of estimating and evaluating the risk presented by the entire site during the FS/Comprehensive Response Action Risk Assessments for Operable Units 1-5. The leading remedial alternative is modified as necessary to reflect new data and information and in no way prescribes or restricts the selection of the remedy for the Operable Units 1-5 RODs.
Leaky aquifer	An aquifer which is separated from overlying or underlying aquifers by a confining layer of lower permeability (aquitard) which allows the movement of water out of the aquifer.

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Loess	A widespread homogeneous fine-grained blanket deposit believed to be windblown dust of Pleistocene Age.
Lower aquifer	The portion of the Great Miami Aquifer below the clay interbed elevation.
Lysimeter	A small-diameter device with a porous cup at the lower end. Allows for a vacuum to be applied to subsurface unsaturated soil to extract porewater from the vadose zone.
Mass loading	The mass of material added to a system per unit of time.
Model calibration	The adjustment of parameter input to a mathematical model, within an acceptable range, until the model is an adequate representation of the real system. It involves selecting parameters for successive trial computer runs until the known hydraulic heads and/or solute concentrations are adequately matched with observed values.
Model verification	Testing a groundwater model against hydrologic input that was not used in the original calibration to verify that it may be used for predictive purposes.
Monitoring well	A well that is used to collect groundwater samples to monitor the water quality. It may be used to monitor groundwater level fluctuations.
New Haven Trough	Buried channel of the ancestral Ohio River which forms the portion of the Great Miami Aquifer directly beneath and to the west of the FEMP.
Normalized concentrations	Contaminant concentration at a given point divided by the concentration at the source.
Overshoot/Undershoot	Describes erroneously high values of concentration encountered as a sharp concentration front is approached from the upgradient side in a finite-difference model. Analogous behavior on the downgradient side is called undershoot.
Oxidation/Reduction potential	A measure of the ability of the groundwater environment to bring about an oxidation or reduction reaction. These reactions involve the transfer of electrons.
Parameter	A numerical value that characterizes an element of the system being modeled; e.g., hydraulic conductivity, recharge rate, and stream leakage coefficient.
Pathway	The route along which contaminants could move in the environment from a source to a receptor.

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Perched groundwater	Perched groundwater exists in geologic environments where a low permeability clay overlies a more permeable sand which leads to the formation of an unsaturated zone both above and below a saturated zone within the clay.
Piezometer	Small-diameter well used to measure the hydraulic head.
Pleistocene	Period in geologic history when glacial ice covered much of North America, periodically advancing southward and retreating northward.
Porosity	The ratio of volume of void spaces in a rock or soil to the total volume of the rock or soil.
Potentiometric surface	An imaginary surface representing the total head of groundwater in an aquifer that is defined by the level to which water will rise in a well.
Radiation	Release of a particle of energy by an atom.
Radioactive nuclides	Atoms that disintegrate by emission of corpuscular or electromagnetic radiations. The rays most commonly emitted are alpha, beta, or gamma rays.
Reasonable maximum exposure (RME)	The exposure that is reasonably expected to occur at a site under both current and future land-use conditions and defined by conservative exposure parameters. The intent of the RME is to estimate a conservative exposure case (i.e., well above the average case) that is still within the range of possible exposures. It does not embrace all hypothetical possibilities, but rather is limited to situations and conditions that "are likely to occur." RMEs are estimated for individual pathways. If a population is potentially exposed via more than one pathway, an RME must be estimated for the combination of pathways.
Receptors	Individuals or organisms that are or potentially could be impacted by contamination.
Recharge	The addition of water to the zone of saturation; also, the amount of water added.
Recharge rate	Rate at which water enters the top of an aquifer due to downward percolation of rainfall or snowmelt.
Regional aquifer	Great Miami Aquifer.

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Remedial action	A comprehensive response action that provides a permanent remedy to mitigate risks associated with hazardous waste under CERCLA and to remedy any condition that could lead to future risks. A remedial action should include a monitoring system to ensure that such action protects the public health and welfare and the environment and, where appropriate, to confirm post-removal site control activities.
Remedial investigation (RI)	The investigation conducted to fully determine the nature and extent of the release or threat of release of hazardous substances, pollutants, contaminants, or hazardous constituents. The RI emphasizes data collection and site characterization. The RI, which includes sampling and monitoring, as necessary, also includes the gathering of sufficient information to support the feasibility studies and the risk assessments.
Removal action	The cleanup or removal of released hazardous substances from the environment. This occurs in the event of a release or the imminent threat of release of hazardous substances into the environment.
Retardation, retardation factor	A measure of the reduction in the rate of movement of a solute plume due to adsorption of the solute onto solids in an aquifer. It is related to the distribution coefficient.
Risk characterization	The part of the risk assessment that summarizes and combines outputs of the exposure and toxicity assessments to characterize baseline risk, both in quantitative expressions and qualitative statements. During risk characterization, chemical-specific toxicity information is compared against both measured contaminant exposure levels and those levels predicted through fate and transport modeling to determine whether current or future risk levels at or near the site are of potential concern.
River leakage factor	A parameter that describes the rate of transfer of water between a stream and an aquifer in response to the difference between the water level in the stream and the hydraulic head in the aquifer.
Saturated	A condition where all voids in a solid matrix are filled with liquid.
Sediment	The unconsolidated inorganic and organic material that is suspended in surface water and is either transported by the water or has settled out and become deposited in beds.
Semiconfining layer	A layer of subsurface material that is much less permeable than the layer above or below and impedes the upward or downward movement of groundwater.
Sensitivity analysis	The identification and evaluation of variables which, when changed slightly, cause large changes in the result.

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GLOSSARY
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Slope factor	A plausible upper-bound estimate of the probability of a response per unit intake of a chemical or radionuclide over a lifetime. The slope factor is used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen.
Soil	All unconsolidated materials normally found on or near the surface of the earth including, but not limited to, silt, clay, sand, gravel, and small rocks.
Solute	A dissolved constituent.
Source loading	The rate at which a chemical constituent is added to an environmental system such as groundwater.
Specific yield	The ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of the rock or soil.
Steady state	Not varying with time. In steady-state flow models, hydraulic head does not vary with time. Time does not enter the calculations.
Stratigraphic	The arrangement of similar rocks in layers or beds.
Statistical outlier	An analytical result that has been statistically determined to be inconsistent with results of other samples.
Storage coefficient	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in hydraulic head.
Surface water	All water that is open to the atmosphere and subject to surface runoff.
Till	A mixture of boulders, cobbles, sand, silt, and clay deposited directly from glacial ice; generally of low permeability.
Tolerance limit	The upper value of a tolerance interval that would be expected to include 95 percent of observations when randomly taken.
Transient model	Not a steady-state model. In a transient solute transport model, concentrations vary with time.
Transmissivity	Hydraulic conductivity of an aquifer multiplied by the thickness of the saturated unit (aquifer). It describes the rate at which water can move through a unit width of the aquifer.
Type 1 well	Well or piezometer screened in water-bearing zones within the glacial overburden.
Type 2 well	Well screened over an interval from 5 feet above to 10 feet below the water table in the Great Miami Aquifer.

GLOSSARY
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Type 3 well	Well screened over a 10-foot interval just above the clay interbed or at an equivalent elevation in the Great Miami Aquifer.
Type 4 well	Well screened over a 10-foot interval ending 10 feet above the bedrock bottom of the Great Miami Aquifer.
Unconfined aquifer	An aquifer where the water table is exposed to the atmosphere through openings in the overlying materials.
Unsaturated	The condition where the voids in a solid matrix are not 100-percent filled with liquid.
Uranium envelope	Term used to describe the area in which uranium contamination will drive the selection of the remedial solution even though other contamination is present at above-background levels. Individual uranium envelopes are defined for uranium concentrations that represent specified risk levels.
Vadose zone	The unsaturated zone of a stratigraphic unit.
Vertical seepage	The vertical migration of groundwater from an upper permeability stratigraphic unit to a lower stratigraphic unit.
Water balance	A quantification of all the sources of water and the corresponding discharges with respect to an aquifer, a drainage basin, or a well.
Water table	The surface of an unconfined aquifer at which the pressure in the water is equal to the atmospheric pressure. This usually occurs at or near the top of the saturated subsurface material.
Zone of influence	The area within an aquifer impacted by pumping from a well placed in the aquifer.

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EXECUTIVE SUMMARY

This report documents the Remedial Investigation phase of the Fernald Environmental Management Project (FEMP) Operable Unit 5 Remedial Investigation/Feasibility Study (RI/FS). The FEMP, formerly known as the Feed Materials Production Center, is a 1050 acre U.S. Department of Energy (DOE) facility located northwest of downtown Cincinnati near the small rural community of Fernald, Ohio. The site lies on the boundary of Hamilton and Butler counties. The primary mission of the FEMP during its 38 years of operation, between 1951 and 1989, was the processing of "feed" materials to produce high-purity uranium metal. These high purity uranium metals were then shipped to other DOE or U.S. Department of Defense facilities for use in the nation's weapons program.

In 1986 the U.S. Environmental Protection Agency (EPA) and DOE entered into a Federal Facility Compliance Agreement covering environmental impacts associated with the FEMP. In response to the Federal Facility Compliance Agreement, a site-wide RI/FS was initiated pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendment and Reauthorization Act (SARA). On June 29, 1990, a Consent Agreement between the two agencies became effective. This agreement established an operable unit concept for executing the RI/FS while maintaining the underlying objectives of the Federal Facility Compliance Agreement.

The Consent Agreement was amended the following year to revise the schedules for completing the remediation of the five operable units and to provide for integration of the operable units to ensure compliance with the residual risk requirements of the National Contingency Plan.

The Ohio Environmental Protection Agency is participating in the FEMP CERCLA process through direct involvement in review meetings, public meetings, and technical review of project deliverables.

The primary objective of the remedial investigation is to define the nature and extent of contamination in Operable Unit 5 in a manner sufficient to perform baseline and ecological risk assessments and develop and evaluate viable remedial alternatives. Following the remedial investigation, but being prepared in parallel with the RI, a feasibility study report will be issued which documents the evaluation of available cleanup alternatives to address identified environmental concerns. The remedial investigation is conducted to support specific informational needs of the alternative

evaluation process of the feasibility study. Consistent with the Amended Consent Agreement and following consideration of comments received from the public and other interested parties, selection of the preferred cleanup remedy will be documented in a Record of Decision.

Scope of the Remedial Investigation

Operable Unit 5 consists of the following environmental media and biological receptors that have been potentially impacted by site activities:

- Groundwater (both perched and the Great Miami Aquifer)
- Surface water
- Soil (except that associated with other operable units)
- Surface water sediment
- Flora
- Fauna.

The source of contamination in environmental media at the FEMP and surrounding area can be attributed to process operations and waste management practices. Primary release mechanisms included air emissions (point source emissions, fugitive emissions, nonroutine events, evolution of radon gas, and direct radiation), wastewater discharges (both process wastewater and storm water), and unmonitored production releases. The conclusion of production operations in 1989 eliminated or reduced many of the primary sources of contaminant release to the environment. Secondary release mechanisms and the resulting contaminant migration are the primary focus of this remedial investigation.

Release Mechanisms

The predominant constituent in airborne releases from the former production processes at the FEMP was uranium. Approximately 179,000 kilograms (394,000 pounds) of uranium were released to the atmosphere from these operations from 1951 through 1993. Approximately 97 percent of the emissions were in a form considered minimally to moderately leachable in rainwater. Since process operations at the site have ceased, airborne uranium emissions decreased dramatically to 0.2 kilograms (10.4 pounds) in both 1992 and 1993. Airborne emissions are expected to remain at low levels, although an increase is possible due to resuspension of particulates as contaminated materials are moved for final disposition. However, control measures will be instituted to minimize such releases.

Liquid wastes generated at the FEMP consisted of process wastewater, sanitary sewage, and storm water runoff. Process wastewater was generated in virtually all of the processing plants and treated before discharge to the Great Miami River through the general sump and the waste pits. At present, no wastewater is discharged to the waste pits from the general sump but storm water entering the waste pits is treated before monitoring and discharge to the Great Miami River. Approximately 80,200 kilograms (177,000 pounds) of uranium were discharged in FEMP wastewater to the Great Miami River from 1952 through 1993.

Storm water runoff has been and continues to be a significant pathway for migration of contaminants in environmental media. Storm water runoff from the perimeter of the waste pits and from the former production area historically flowed to Paddys Run. Since 1986, storm water runoff from the former production area has been directed to a storm water retention basin and allowed to settle before being pumped to the Great Miami River. In 1992 a system was installed as part of a removal action under the Amended Consent Agreement to collect storm water runoff from the waste pit perimeter areas and route it to treatment facilities before monitoring and discharge to the Great Miami River.

The production process at the FEMP contributed to the incidence of unmonitored releases of contaminants to the environment. Several processes involved the use of acid or caustic material in combination with tanks, sumps, piping, drums, and other containers to collect, store and transport materials. The locations of unmonitored leaks and spills which occurred over the years are unknown. Some of the process equipment was used beyond its design life or for processes it was not designed to accommodate. In addition, the base or foundations for some facilities, including the waste pits and Plant 6, are excavated into or almost through the glacial overburden, which may provide an enhanced pathway for migration of contaminants. As a result of the production process, 137 operations were identified in 1988 that were suspected of previous, unmonitored discharges to the environment.

Routine operations at the FEMP produced large quantities of by-product and waste materials. Before 1984, solid and slurried wastes from plant operations were disposed of in on-property facilities. Materials stored in these facilities range from high-specific-activity, radium-bearing residues (K-65 material) stored in silos, to a host of by-product waste and off-specification materials deposited in the waste pits. Combustible wastes were burned in several on-site incinerators and in the burn pit. Nonradiologically contaminated wastes were deposited in the solid waste landfill, the lime sludge ponds, or one of the two flyash piles.

Thirty removal actions and other measures have been completed or are on-going to abate, minimize, stabilize, mitigate, or eliminate releases of hazardous materials before final remediation.

STUDY AREA INVESTIGATIONS

The remedial investigation began in 1987 with sampling in and around identified source areas. The investigations were systematically expanded to fully define the limits of environmental media contamination. Over 30 addenda were issued to the original RI/FS Work Plan covering all operable units, and resulting in the completion of over 1300 soil borings, the installation of over 750 wells, and collection of over 14,000 individual samples for analysis.

The sources of information for characterization of Operable Unit 5 included:

- Data collected pursuant to the RI/FS Work Plan and issued addenda including all operable units
- FEMP Environmental Monitoring Program
- Characterization Investigation Study
- RCRA Groundwater Program
- CERCLA removal actions
- FEMP litigation support study
- Best Management Practices Program
- CERCLA/RCRA Background Soil Study
- Hydrogeologic Study of the FEMP Discharge to the Great Miami River
- Miami University ecological studies.

Collected environmental data were used to describe the nature and extent of contamination in and around the FEMP. All data used to support the baseline risk assessment underwent a rigorous validation process to ensure the quality and usability of the information.

PHYSICAL CHARACTERISTICS OF THE STUDY AREA

The advance and retreat of continental glaciers not only shaped the topography at the FEMP but determined the hydrogeologic setting as well. The topography of the FEMP includes gently rolling uplands with steep hillsides along major streams such as the Great Miami River. The production and waste storage areas rest on a relatively level plain. Surface drainage on the FEMP is from east to west and south into Paddys Run, with the exception of the northeast corner which drains east toward the Great Miami River.

Paddys Run originates north of the site, drains southward along the west side of the FEMP, and eventually enters the Great Miami River approximately 1.5 miles south of the FEMP. The stream

loses flow to the underlying Great Miami Aquifer along much of its course on and south of the FEMP due to its highly permeable channel bottom which is eroded into the Great Miami Aquifer. Because of this, the southern portion of Paddys Run (south of the K-65 silos) is an intermittent stream that flows primarily between January and May.

A principal drainage feature of the FEMP is a tributary to Paddys Run known as the storm sewer outfall ditch. This drainage course, which receives flow from the former production area, flows southwest across the southern portion of the site and enters Paddys Run near the southwest corner of the property. Much of the stream bottom of this drainage course is composed of sand and gravel in contact with the Great Miami Aquifer. Like Paddys Run, the storm sewer outfall ditch loses flow to the aquifer and is, therefore, generally dry in the summer and fall, with flows occurring during and immediately following precipitation.

Groundwater beneath the FEMP is found in two principal geologic units: the glacial overburden (ranging in thickness between zero and 50 feet) and the sand and gravel of the Great Miami Aquifer. Groundwater occurring in the glacial overburden is considered perched, in that it is contained within silty sand interbeds residing within a low permeability, clay-rich glacial till. The underlying Great Miami Aquifer is the principal drinking water supply for the region and is regulated as a sole-source aquifer.

In general, there is only minor recharge to the Great Miami Aquifer in the general area of the FEMP because of the very low hydraulic conductivity of the glacial overburden. However, in areas where streams have cut through the glacial overburden, such as Paddys Run and the storm sewer outfall ditch, or where the overburden is absent, there is a greater potential for infiltration to the aquifer. Because these streams lose surface water to the underlying aquifer, Paddys Run and the storm sewer outfall ditch are considered direct pathways for contaminant transport to the aquifer.

The principal geochemical processes that control groundwater chemistry are dissolution of minerals and solids in the soil by rainwater and adsorption/ion exchange reactions between the groundwater and soil particles. The composition of groundwater in the glacial overburden and Great Miami Aquifer is dominated by calcium and magnesium cations and the bicarbonate anion.

There is no indication that the FEMP has had any discernable effects on the fish communities in the Great Miami River. No federally listed or endangered species were observed on the FEMP or in its immediate vicinity.

NATURE AND EXTENT OF CONTAMINATION

Since the FEMP processed more than 362 million kilograms (398,00 tons) of uranium metal during its production lifetime, uranium is the primary contaminant likely to be found in the site environment. Thorium and several fission and activation products, including technetium-99, are also present. Predominant inorganic chemicals associated with the production processes included magnesium fluoride, nitric acid, hydrochloric acid, hydrofluoric acid, magnesium metal, calcium hydroxide, calcium-magnesium carbonate, arsenic, calcium, iron, magnesium, phosphorus, sodium, thorium, and vanadium.

Organic chemicals used in production activities included kerosene, tributyl phosphate, lubricants, cutting oils, coolants, water soluble oil, polychlorinated biphenyls (PCBs) from lubricants and electrical equipment, pesticides, herbicides, and various solvents.

Air and Direct Radiation

The maximum radon concentration recorded along the FEMP fenceline during the period 1988 through 1993 was 2.9 pCi/L in 1988 at the southwest corner of the former production area. None of the observed concentrations exceeded either the DOE guideline of 3.0 pCi/L above background or the EPA guideline of 4.0 pCi/L for indoor radon concentrations.

The average annual concentration of airborne uranium at each fence line monitoring station was well below the DOE guideline of 0.1 pCi/m^3 during the period 1988 through 1993. Data show a general decrease in airborne uranium concentrations along the FEMP fence line since production operations ceased in 1989.

The annual dose from direct radiation to the nearest off-site neighbor was estimated to be 1.0 mrem in 1993, well below background and DOE's guideline of 100 mrem per year.

Surface Water and Sediment

From the beginning of production at the FEMP through 1986, when the storm water retention basin was installed, the storm sewer outfall ditch served as the primary receptor of storm water runoff from the production area storm sewer collection system. Because the storm sewer outfall ditch and perimeter areas of the waste pits flowed to Paddys Run, it has been the primary pathway for off-property migration of contaminated surface water from the FEMP. Paddys Run and the storm sewer outfall ditch have eroded through the glacial overburden and flow directly on the Great Miami Aquifer into the valley fill deposits. Thus, in addition to facilitating the off-property migration of FEMP surface water, Paddys Run and the storm sewer outfall ditch are a direct pathway for contaminants to enter the Great Miami Aquifer.

The Great Miami River is the ultimate receptor for groundwater and surface water discharged from the FEMP. The three principal pathways for FEMP discharges to enter the river are effluent from the outfall line, surface water flow from Paddys Run, and surface water runoff from the northeastern corner of the FEMP property.

During the period from 1986 to 1993, the highest annual average concentration of uranium in the Great Miami River was 2.5 μg/L of uranium, detected downstream of where Paddys Run enters the Great Miami River. The data indicate that since 1991, annual concentrations at all sampling locations have been below 2 μg/L. Sediment sampling data show no discernable difference between total uranium concentrations in sediment from locations upstream and downstream of the FEMP outfall line.

Soil

Above-background concentrations of uranium were detected in surface soil across much of the FEMP, with the highest concentrations residing within the former production area and adjacent to the sewage treatment plant. Surface soil containing uranium at concentrations slightly above background were detected on properties surrounding the FEMP, with higher levels generally to the north and east of the facility, the major downwind direction.

Elevated uranium concentrations in excess of five times background were detected to depths exceeding 20 feet under portions of the former production area, in portions of the laboratory area and the K-65/Clearwell line (west of the production area). Subsurface soil contamination is typically aligned

with areas where large quantities of acids or other liquids were historically used in the uranium purification process. Radium-226 contamination is limited to process areas and storage areas where elevated levels were expected. The Plant 1 area and scrap metal pile are the two areas evidencing radium-226 activity greater than 1000 pCi/g. The only area of significant radium-226 contamination in the subsurface soil is the area west of the K-65 silos. The source of this contamination is likely the K-65 decant tank or spills associated with the filling of the silos. Elevated concentrations of thorium were detected in surface soil in areas adjacent to former thorium processing and storage facilities.

The occurrence of above-background concentrations of nonradioactive inorganic constituents were noted in surface soil, and sporadically in subsurface soil, at widespread locations across the former production area. Volatile and semivolatile organic constituents and PCBs were detected in select samples collected in the vicinity of the major FEMP processing facilities. The lateral extent of this contamination is encompassed within areas exhibiting elevated uranium concentrations.

Perched Groundwater Contamination

There are seven geographically separate on-property areas where uranium and other contaminants are present at above-background concentrations in perched groundwater:

- Production area
- Sewage treatment plant area
- South Field/flyash pile area
- K-65 silos area
- Waste pit/Solid waste landfill area
- Fire training area
- Lime sludge ponds area.

Total uranium was detected at above-background concentrations in 268 of 295 wells with concentrations ranging from 0.4 to 436,000 μg/L. Almost every other above-background parameter occurs within the area of uranium contamination.

Thorium-232 was detected at above-background concentrations in perched groundwater as isolated occurrences. Other radium and thorium isotopes, that were a part of uranium and thorium ores, were detected in perched groundwater as small plumes or isolated occurrences. Technetium-99 was determined to be the most prevalent above-background fission/activation product in perched groundwater in terms of frequency of detection above background, having been detected in 64 of 170

wells analyzed in the 1993 data set. Perched groundwater concentrations of technetium-99 ranged from 15.8 to 6130 pCi/L.

Several metals were determined to occur in groundwater in trends indicative of groundwater contamination plumes. The greatest degree of metals contamination was found in the southwest quadrant of the production area, beneath the K-65 silos, beneath Plants 6 and 9, and adjacent to the waste pits.

Organic compounds detected in perched groundwater were primarily degreasers and solvents. Organics were generally found at low concentrations and were found throughout the production area, waste storage area, sewage treatment plant area and fire training area.

Great Miami Aquifer Contamination

There are slight differences between this report and past portrayals of uranium contamination that (in the 1990-1991 timeframe) were largely based on model projections. The extent of contamination described here is based on empirical data. Six contaminant plumes were identified in the Great Miami Aquifer, each with a distinct line or point source. The plumes are:

- The waste storage area A plume which is a result of leaks from the Operable Unit 1 waste pits. The principal contaminants detected with sufficient frequency to be discerned as plumes are: total uranium, technetium-99, calcium, iron, magnesium, potassium, sodium, ammonia, chloride, nitrate and sulfate.

- The waste storage area B plume which is a result of surface water infiltration along Paddys Run. The only contaminant detected with sufficient frequency to be discerned as a plume was total uranium.

- The Plant 6 plume which is a result of leaks through the glacial overburden beneath Plant 6 and the sewage lift station. The principal contaminants detected with sufficient frequency to be discerned as plumes are: total uranium, cadmium, calcium, cobalt, and sulfate.

- South Plume A which is a result of leachate and surface water that infiltrates in the vicinity of the Operable Unit 2 flyash piles and the South Field. The principal contaminants detected with sufficient frequency to be discerned as plumes are: total uranium, calcium, chromium, and magnesium.

- South Plume B which is a result of surface water infiltration along the storm sewer outfall ditch and Paddys Run. The principal contaminants detected with sufficient frequency to be discerned as plumes are: total uranium, calcium, and magnesium.

- South Plume C which is a result of surface water infiltration along the southern stretch of Paddys Run. The only contaminant detected with sufficient frequency to be discerned as a plume was total uranium.

In addition to the above, other radionuclides, inorganics, and organics occur as isolated above-background detections in each plume.

Groundwater Contamination Due to Low-level Surface Soil Contamination

The low-level surface soil uranium contamination detected on- and off-property has potentially been leached such that it has entered the groundwater system. The resultant groundwater contamination is generally less than 10 μg/L in the Great Miami Aquifer and less than 20 μg/L in the perched groundwater. The potential for this contamination is limited in extent to the perched groundwater system and upper portion of the Great Miami Aquifer inside the maximum lateral extent of surface soil contamination.

Biota

In general, the isotopes of uranium were detected at low concentrations in select samples from aquatic and terrestrial vegetation, benthic macroinvertebrates, fish and small mammals from on and off the FEMP property. The fission products examined (i.e., strontium-90 and cesium-137) were generally not detected above laboratory analytical limits although cesium-137 was detected in select samples of grass roots and a single cucumber sample.

Limited analysis of samples was completed for inorganics including metal and sulfates and organics. These constituents were detected in collected samples of grass roots and leaves and small mammals. Background values for these constituents have not been established.

Baseline Risk Assessment

As part of the remedial investigation effort, a baseline risk assessment was performed to evaluate the risks to hypothetical human and ecological receptors as a result of environmental conditions present at the site. The baseline risk assessment assumes that no cleanup actions have been implemented and thus provides an evaluation of the risks accompanying the "no action" remedial alternative. The results of the baseline risk assessment are compared to risk-based goals established by federal environmental regulation to determine whether cleanup activities are warranted. The results of the baseline risk assessment also serve as a measure against which the reduced risk associated with various remedial action alternatives may be compared during the feasibility study.

Risk-based goals are established by EPA for both carcinogenic and noncarcinogenic constituents. The predominant constituents of concern associated with Operable Unit 5 are considered carcinogenic by nature; therefore, discussions in this Executive Summary are directed to carcinogenic-related risks.

Risks resulting from carcinogenic contaminants are assessed in terms of the incremental lifetime cancer risk they present to human populations over and above that to which humans are already exposed. Statistical evidence indicates humans have about a one in three (33 percent) risk of acquiring cancer. As established by federal regulation, risks to human health from waste sites should generally not add greater than 1 in 10,000 (1×10^{-4}) to 1 in 1,000,000 (1×10^{-6}) probability of acquiring cancer over the average lifetime of a potentially exposed human.

To assess whether conditions at a hazardous waste site exceed these risk goals, a formalized baseline risk assessment process has been established by EPA guidance. The process requires completion of both a human health and ecological risk assessment. For the human health risk assessment, risks are not only assessed for current contamination levels in the environment, but also for future conditions in the event that no mitigative cleanup actions are implemented at the waste site. To accomplish this objective, EPA has developed a concept called reasonable maximum exposure (RME) to support human health risk assessment. Within the baseline risk assessment, the maximum exposure that a human could reasonably be expected to receive from a hazardous waste site is evaluated. This evaluation typically examines the risk associated with a number of land-use scenarios.

The baseline risk assessment for Operable Unit 5 examines the current land use of the site as an industrial waste management facility and a range of future land uses for the site, including a family farm and the creation of a government reserve. For the current land use, risks to human receptors were assessed with and without public access controls in place.

To assess the risks under these land-use scenarios, assumptions were made regarding the setting of potential human receptors and mechanisms by which they are exposed to site contaminants. For the current land-use scenario, which assumes the site remains an industrial facility, human receptors considered include a trespassing youth, a groundskeeper, a visitor, an off-property farmer, an off-property user of surface water, and a consumer of milk and meat from cattle allowed to graze at specified on-property locations. For the scenarios including future land use of the site as an agricultural facility, human receptors included an on-property farmer, an on-property resident child,

an off-property farmer, and an off-property user of surface water. For the future land-use scenario involving establishment of a government reserve, the receptors included a groundskeeper, an "expanded trespasser" that couples the exposures of an off-property child with a trespassing youth, and an off-property farmer.

To assist in evaluating the potential risks to each of these receptors, a number of mathematical models were employed to estimate the concentration of contaminants that will be transported through the environment. Potential migration pathways through environmental media were evaluated over a timeframe beginning today and extending 1000 years into the future. The models provide information on contaminant migration to off-property locations which are not currently monitored, and allow future exposure predictions by extrapolating from known field data. Conservative assumptions were used in the models to provide a "reasonable worst case" picture of the fate of contaminants in the environment. These models assist in predicting the affects that the physical processes of nature will have on the movement of contaminants through the environment. Modeling was conducted to evaluate the movement of contaminants through the air, groundwater and surface water pathways. Following application of these models, assumptions were made, based on EPA guidance, regarding the quantity of contaminants to which the receptors would be exposed through ingestion, inhalation, and direct contact.

All models used for Operable Unit 5 contaminant fate and transport modeling are improved or newly developed according to a previously submitted overall model improvement plan and the requirements of the Operable Unit 5 baseline risk assessment. Development and applications of these models have been presented to EPA and OEPA in a series of technical information exchange meetings beginning in January 1993. Both technical defensibility and consistency with previous models for other operable units were emphasized in the modeling process.

For the purposes of this Executive Summary, one land-use scenario (the future family farm) and one receptor (the on-property farmer) were selected to provide a relative indication of the maximum baseline risks associated with Operable Unit 5. This land use scenario represents the most conservative "no-action" scenario considered under the risk assessment. No such resident farmer currently exists at the facility, and the calculated risks represent the maximum that the hypothetical receptor can reasonably be expected to receive during a lifetime. For purposes of this risk assessment, the on-property resident farmer was assumed to reside within the FEMP production area,

grow his crops in the soil present in this area, and use perched groundwater for agricultural and domestic use.

For this hypothetical on-property resident farmer, the maximum contribution of risk came primarily from direct radiation from the contaminated soil. The maximum reasonable exposure from this and other pathways results in an incremental lifetime cancer risk of 6×10^{-2}, or about 6 chances in 100 of developing cancer in the lifetime of the hypothetical on-property farmer.

Ecological Risk Assessment

An ecological risk assessment was performed as part of the baseline risk assessment to determine if contaminants associated with media at the FEMP represent a current or future risk to ecological receptors inhabiting this facility and nearby off-property areas. The ecological risk assessment focused on those on- and off-property areas not likely to be remediated, based on human-health concerns.

This method was agreed upon pursuant to discussion with the Region 5 EPA representatives. The results of this assessment determined that uranium contamination in surface soil east of the former production area represented the single greatest source of risk to terrestrial ecological receptors, both in terms of total radiological dose and exposure to heavy metals. Other soil contaminants were present in various on-property locations, but with the exception of manganese, appeared to be relatively limited in distribution.

Although no toxicologically based criterion could be identified for uranium in sediment, the concentrations present in sediment collected from on-property locations in Paddys Run may pose a risk to benthic organisms inhabiting this portion of the creek. In addition, these benthic organisms are at risk as a result of exposure to inorganics in the sediment. Terrestrial organisms exclusively using the on-property reach of Paddys Run or drainageways in select on-property areas as a source of drinking water, may be at risk. Terrestrial biota ingesting water from off-property locations in Paddys Run may also be at risk.

Terrestrial ecological receptors relying exclusively on the portion of the Great Miami River upstream of the FEMP outfall line may also be at risk due to the cumulative impacts of ammonia and mercury. Those types of receptors relying exclusively on the portion of the Great Miami River between the

FEMP outfall line and the confluence with Paddys Run as a source of drinking water may also be at risk due to exposure to cadmium, iron, and lead.

The relatively large number of surface water contaminants associated with the portion of the Great Miami River downstream of the confluence with Paddys Run, including aluminum and silver, also represent a significant risk to terrestrial biota that rely exclusively on this section of the river as a source of drinking water.

Conclusions

Investigations conducted as part of the remedial investigation and other site programs characterized the physical, chemical and radiological properties of the contaminants residing in environmental media at the FEMP. Further, these investigations established the lateral and vertical extent of these contaminants within site media. These investigations confirmed prior process knowledge regarding known and suspected releases from the facility during its more than 38-year uranium production mission.

The data, as assembled in this report, are sufficient to meet the stated objectives of the remedial investigation by providing a detailed understanding of the nature and extent of the contamination, its impact on the surrounding environment, and the associated risks posed to human health and the environment, both at present and for future postulated conditions.

The remedial investigation is sufficient to meet the information needs of the Operable Unit 5 feasibility study and to support the detailed analysis of potential cleanup actions. For purposes of the RI, it has been assumed that Operable Units 1 through 4 have been remediated. No additional site characterization activities are necessary to support the RI/FS decision-making process.

Based on the results of the site investigations and risk calculations, the risks associated with Operable Unit 5 exceed generally accepted regulatory thresholds, thereby necessitating the implementation of remedial actions. Viable remedial action alternatives will be evaluated in a feasibility study report to be issued for Operable Unit 5.

1.0 INTRODUCTION

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1.1 PURPOSE OF REPORT

This report documents the results of the Remedial Investigation (RI) phase of the Remedial Investigation/Feasibility Study (RI/FS) for Operable Unit 5 at the U.S. Department of Energy's (DOE) Fernald Environmental Management Project (FEMP). This phase of the RI/FS process includes data collection and analysis, fate and transport modeling, and baseline and ecological risk assessments.

The FEMP is a contractor-operated government facility that provided high-purity uranium metal products to support U.S. defense programs from 1951 to 1989. The facility was officially closed as a production facility in 1991.

The RI/FS process at the facility began in 1986 in accordance with a Federal Facility Compliance Agreement (FFCA) between DOE and the U.S. Environmental Protection Agency (EPA). The purpose of the process, which is currently being conducted pursuant to the terms of a 1990 Consent Agreement (as amended) with EPA, is to identify the most feasible actions to address identified environmental concerns. These environmental concerns have been identified by DOE, EPA, the Ohio Environmental Protection Agency (OEPA), and members of the community living near the facility. The concerns have included the potential impacts on human health and the environment from past releases of hazardous materials from the FEMP site to the air, water, and surrounding soil; continuing releases of hazardous materials to the air, Paddys Run and the Great Miami River; and the on-property accumulation of a large inventory of uranium process materials and low-level radioactive and hazardous wastes.

In accordance with DOE policy, National Environmental Policy Act (NEPA) values are being integrated into the RI/FS process consistent with DOE Order 5400.4. This RI Report will function as an integral part of the overall NEPA documentation for the remedial activities at the FEMP site. The integration of NEPA with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) is discussed in more detail in Section 1.5.2.

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To promote a more structured and expeditious cleanup of the FEMP site, the facility and associated environmental issues have been segmented into five operable units. The term operable unit is employed under federal environmental regulation to identify a logical grouping of environmental issues at a cleanup site. Separate RI/FS documentation, including RI and FS Reports, a Proposed Plan (PP), and a Record of Decision (ROD), is being issued for each of the five operable units.

Operable Unit 5 comprises the following environmental media at the FEMP site and surrounding impacted area:

- Groundwater (both perched and the Great Miami Aquifer)
- Surface water
- Soil (except soil located within Operable Units 1, 2 and 4, which will be characterized, evaluated, and remediated as part of the respective operable unit)
- Sediment
- Flora
- Fauna.

One objective of this RI study is to develop a detailed understanding of the nature and extent of environmental media contamination and the threat that the Operable Unit 5 contaminated media pose to human and environmental receptors. This detailed understanding is developed to the degree necessary to support the decision of whether remedial action is warranted and to support the evaluation of available remedial action alternatives. This RI Report for Operable Unit 5 achieves the stated objective by describing the investigations undertaken at the FEMP site to provide a detailed understanding of the existing situation relative to the operable unit. Following the RI Report, the draft FS Report, which will evaluate the range of available cleanup alternatives for the contaminated environmental media in Operable Unit 5, and the draft PP are scheduled to be issued in November 1994. The draft ROD is scheduled to be issued in August 1995.

The remainder of this section presents a description and history of the FEMP site, describes operations and practices at the FEMP site and their associated impacts on the environmental media, and describes both prior Operable Unit 5-related studies and other relevant, environmental investigations. The objective of this section is to provide both a historical and regional perspective essential to fully evaluate the environmental or human health impacts associated with Operable Unit 5. An overview of the remaining sections of the RI Report is provided at the end of this section.

Because the English system is the traditional standard for geologic and geographic information, Operable Unit 5 RI/FS documents will use inches, feet, miles, etc., throughout text, tables and figures. Because the metric system is used by the laboratories in reporting on the testing of FEMP site samples and these data are entered in the database in metrics, all concentration units will be reported and discussed in metrics. Also, because historical uranium production data was reported in metric units (kilograms and metric tons), this convention will be maintained.

1.2 DESCRIPTION AND HISTORY OF THE FEMP SITE

The following provides a brief discussion of the FEMP site and its operational history.

1.2.1 Overview

The FEMP site is a 1050 acre, government-owned, contractor-operated facility located in southwestern Ohio, about 18 miles northwest of downtown Cincinnati. The facility is located just north of Fernald, Ohio, a small farming community, and lies on the boundary between Hamilton and Butler counties (Figure 1-1). The site was used for agricultural purposes before construction of the production facilities in 1951 and the area remains predominantly agricultural. Of the total site area, 850 acres are in Crosby Township of Hamilton County, and 200 acres are in Morgan and Ross townships of Butler County.

As stated above, the FEMP site has been segmented into five operable units in accordance with an agreement between DOE and the EPA (see Section 1.5.1). The five FEMP operable units are illustrated by Figure 1-2 and described as follows:

- Operable Unit 1 - Waste Pits 1 through 6, the Clearwell, the burn pit, berms, liners, and associated contaminated soil within the operable unit boundary.
- Operable Unit 2 - The active and inactive flyash piles, the South Field area, the lime sludge ponds, the solid waste landfill, berms, liners, and associated contaminated soil within the operable unit boundary.
- Operable Unit 3 - The former production area and production associated facilities and equipment (includes all above- and below-grade improvements) including, but not limited to all structures, equipment, utilities, drums, tanks, solid waste, waste product, thorium, effluent lines, K-65 transfer line, wastewater treatment facilities, fire training facilities, scrap metal piles, feedstocks, and the coal pile.
- Operable Unit 4 - Silos 1, 2, 3 and 4, berms, the decant tank system, and associated contaminated soil within the operable unit boundary.

- Operable Unit 5 - Perched and regional groundwater, surface water, soil not associated with other operable units, sediment, flora, and fauna.

Production operations at the FEMP site were limited to a fenced 136-acre tract of land known as the production area, located near the center of the site. Large quantities of liquid and solid wastes were generated by the various operations at the FEMP site. Before 1984, solid and slurried wastes from FEMP processes were stored or disposed of in the waste storage area. This area, located west of the production facilities, includes six low-level radioactive waste storage pits; two earthen-bermed concrete silos containing K-65 residues; one concrete silo containing metal oxides; one unused concrete silo; two lime sludge ponds; a burn pit; a Clearwell; and a solid waste landfill.

The waste storage area, shown graphically in Figure 1-3, is addressed under Operable Units 1, 2, and 4. The remaining areas at the site consist of forest and pasture lands.

1.2.2 Integration of FEMP with the U.S. Department of Energy System

The primary mission of the FEMP site during its 38 years of operation was the processing of "feed" materials to produce high-purity uranium metal (thus, the derivation of the site's original title, the Feed Materials Production Center [FMPC]). These high-purity uranium metals were then shipped to other DOE facilities for use in the nation's weapons program. A graphic depiction of the FEMP's integration with other DOE facilities is presented in Figure 1-4.

Feed materials at the FEMP site consisted of pitchblende ores obtained from mines in the former Belgian Congo and Australia; uranium concentrates (yellowcake) obtained from uranium mills in Canada, the United States, and other countries; uranium tetrafluoride (UF_4 - green salt) and uranium hexafluoride (UF_6) obtained from the nation's gaseous diffusion plants; uranium trioxide (UO_3 - orange oxide) as slightly enriched recycled material from DOE's Hanford Plant, near Richland, Washington, and Savannah River Plant, near Augusta, Georgia; and recovered uranium-bearing residues from processing operations at the FEMP site and elsewhere.

As described in Section 1.2.3, these feed materials were converted into high-purity uranium metal, cast into various shapes, machined in some instances, and then transported to other DOE facilities. Depleted uranium metal derbies were transported to the Y-12 Plant in Oak Ridge, Tennessee. Some derbies and flat billets were shipped to the Rocky Flats Plant near Golden, Colorado.

After 1962, uranium ingots were center drilled and then sent to Reactive Metals, Incorporated (RMI) Titanium Company's Extrusion Plant in Ashtabula, Ohio, for extrusion. The resulting extruded billets were then shipped to the Hanford Plant. Extruded uranium tubes, consisting of depleted uranium metal, were returned to the FEMP site for cutting and surface machining to produce target element cores. These depleted uranium metal target cores were shipped to the Savannah River Plant. A more detailed description of the uranium metal products is provided in the next section.

1.2.3 Description of the FEMP Facility and Operations

The following paragraphs provide an overview of the chemical and metallurgical processes used at the FEMP site for the manufacture of uranium metal products (Figure 1-5). In general, these processes occurred in eight of the FEMP's more than 50 production, storage, and support buildings. The physical layout of those buildings is shown in Figure 1-6. Much of the discussion of the refining process is excerpted primarily from the following documents and will not be specifically referenced in all instances in the text:

- "Uranium Processing Technology" (Harrington and Ruehle 1959)
- "K-65 Operations Manual," prepared by Catalytic Construction Company, Inc., (no date)
- "A Closer Look at Uranium Metal Production, A Technical Overview" (FMPC 1988)

The FEMP refinery processed two basic classes of materials: pitchblende ores as they were mined and shipped to the FEMP site and other uranium concentrates that had already been refined to some degree. This second class of materials included uranium concentrates that had already undergone a preliminary refining process at an off-site mill and residues recovered at various stages of FEMP operations.

Uranium-bearing ores, as they are mined, contain not only uranium but also equilibrium concentrations of uranium progeny (i.e., the isotopes of other elements formed through the sequential radioactive decay chains that begin with uranium [U]-235 and U-238). The concepts of radioactive decay chains, progeny products, and enrichment status are discussed in detail in Section 4.1. These progeny, which include radium, are removed in either a preliminary milling process or in the refining process (if the ores are not preprocessed through a mill). Thus, when the FEMP refinery processed pitchblende ores, the refinery wastes contained a high concentration of the radioactive uranium progeny products. These refinery wastes were known as "hot" raffinates. The term "hot" was used to indicate that the materials contained a high concentration of the gamma-emitting radionuclide radium (Ra)-226 and progeny that result in a significant direct penetrating radiation exposure rate.

When the FEMP site processed uranium concentrates that had been preprocessed through a uranium mill, a significant portion of the Ra-226 and the gamma-emitting progeny had already been removed. The thorium progeny of uranium (i.e., thorium [Th]-230, etc.), remained within the uranium concentrates due to the inefficiency of the mill in removing this metal and were thus termed "cold" metal oxides.

Impure starting materials, or feed materials, were first introduced into the process through the sampling plant (Plant 1). Here the materials were sampled to determine their uranium content and uranium enrichment status. Ore concentrates and impure feed materials from the recovery plant (Plant 8) were transferred to the refinery (Plant 2/3) where they were dissolved in nitric acid. The uranium was then purified through solvent extraction to yield a solution of uranyl nitrate. Evaporation and denitration converted the uranyl nitrate solution to uranium trioxide (UO_3) powder.

UO_3 from Plant 2/3 and other DOE sites was transported to Plant 4 (green salt plant), where it was reduced with hydrogen to form uranium dioxide (UO_2) and then converted to UF_4 by reaction with anhydrous hydrogen fluoride. The UF_4 was then transported to Plant 5 (metals production plant), Plant 9 (special products plant), or the pilot plant where it was blended with magnesium metal granules and placed in a closed, refractory-lined steel pot. At approximately 1200°F the UF_4 and the magnesium would initiate an exothermic reaction. The result was a 300 to 375 pound piece of pure uranium metal shaped like a gentleman's hat and referred to as a derby. Magnesium fluoride slag was a by-product of this process.

Some of the derbies were shipped directly to other government facilities, such as the Y-12 and Rocky Flats plants. However, most remained in Plant 5 where they were remelted, along with uranium scrap metal from machining operations, and poured into graphite molds to form cylindrical or flat ingots. All flat ingots consisted of depleted uranium metal. These flat ingots were top-cropped, sampled, analyzed, and inspected in the metals fabrication plant (Plant 6), and shipped to the Rocky Flats Plant.

The cylindrical ingots consisted of depleted, normal or slightly enriched uranium. From plant startup until approximately 1962, these ingots were top-cropped, sampled, analyzed, heat treated, and rolled into rods. The rods were machined into fuel cores and shipped to nuclear reactors at various government sites, including Hanford and Savannah River. This process continued at a reduced level from 1962 to 1970. During the early 1960s, a process was added where these ingots were machined

and cored in Plant 9 and then sent to RMI in Ashtabula, Ohio. At RMI, some of the ingots were upset forged and the resulting billets machined and shipped to the Hanford Plant. Most of the uranium ingots were extruded into tubes at RMI and returned to Plant 6 at the FEMP. There, the tubes were cut into sections, heat treated, machined, and inspected. The resulting target element cores were shipped to the Savannah River Plant.

Small amounts of thorium were processed at the FEMP site on several occasions from 1954 through 1975. Thorium operations were conducted in the sampling plant (Plant 1), the green salt plant (Plant 4), the metals fabrication plant (Plant 6), the scrap recovery plant (Plant 8), the special products plant (Plant 9), and the pilot plant. The FEMP site served as the thorium repository for DOE and storage facilities were maintained for a variety of thorium materials. Thorium materials are no longer being received at the FEMP site for storage. Existing thorium inventories have now been declared waste and are being over-packed for shipment to DOE's Nevada Test Site (NTS) for disposal.

From 1961 through 1989, the FEMP site processed recycle materials in Plants 2/3 and 8 from several DOE facilities, including Paducah, Kentucky; Hanford, Washington; West Valley, New York; and Savannah River, Georgia. These materials contained varying amounts of plutonium (Pu)-239, ranging from 0.2 parts per billion (ppb) to over 1000 ppb (DOE 1985). It is estimated that 1 to 2 grams of Pu-239 was deposited in Waste Pit 5 from the processing of this material.

Beginning in 1962, the FEMP site processed recycle tails (UO_3) in Plants 2/3 and 8 from the Hanford and Savannah River plants. These tails generally contained less than 3 parts per billion (ppb) of transuranics such as Pu-239 and less than 10 parts per million (ppm) of fission products such as technetium (Tc)-99.

1.2.4 Operating History of the FEMP

The Atomic Energy Commission (AEC), predecessor to the U.S. Energy Research and Development Administration and then DOE, established the FMPC in conformance with AEC orders in the early 1950s. In 1951, National Lead Company of Ohio, Inc. (NLCO - later National Lead of Ohio [NLO]) entered into a contract with the AEC as the operations and management contractor for the facility. This contractual relationship lasted, first with the AEC and finally with DOE, until January 1, 1986. Westinghouse Materials Company of Ohio (WMCO), a wholly owned subsidiary of Westinghouse

Electric Corporation, then assumed management responsibilities for the site operations and facilities. In 1991, Westinghouse renamed this subsidiary the Westinghouse Environmental Management Company of Ohio (WEMCO). On December 1, 1992, Fernald Environmental Restoration Management Company (FERMCO) assumed responsibility for the site as the first environmental restoration management contractor (ERMC) for DOE.

The FEMP began operations in 1951 upon completion of the pilot plant, the first operational facility. Plant 6 began operations in 1952, followed by Plants 1, 2/3, 4, 5, and 8 in 1953. Plant 7 and Plant 9 became operational in 1954.

Production peaked in 1960 at approximately 12,000 metric tons of uranium. A product decline began in 1964 and reached a low in 1975 of about 1230 metric tons. During the 1970s, consideration was given to closing the FEMP site and capital improvements and staffing were minimized. The staffing level, which peaked at 2891 in 1956, slowly declined to 662 in 1972 and then to 538 in 1979. In 1981, production levels began to increase significantly and there was a rapid staff buildup for several years. The renewed need for uranium metal resulted in the implementation of a major facilities restoration program. Then, production ceased in the summer of 1989 and plant resources were focused on environmental cleanup activities. In June 1991, the site was officially closed as a federal production facility, its new mission emphasized by a new name, the Fernald Environmental Management Project.

1.3 DESCRIPTION AND HISTORY OF OPERABLE UNIT 5

By definition, Operable Unit 5 encompasses the soil (except that associated with Operable Units 1, 2, and 4), surface water and sediment, groundwater (both perched and the Great Miami Aquifer), flora, and fauna over the entire FEMP property. It extends to areas where contaminants released from the FEMP site have been transported to or deposited on the environmental media, including those beyond the FEMP property line. This description and history of Operable Unit 5 present an overview of the FEMP's former processing operations and waste management practices that led to contamination of the environmental media and an overview of groundwater contamination in the Great Miami Aquifer. Removal actions and other abatement measures addressing Operable Unit 5 environmental media are also described. Figure 1-7 illustrates major features of the FEMP site which will be referred to in the remainder of Section 1.0.

Contamination of environmental media at the FEMP site and its surroundings has multiple sources that resulted in releases of contaminants to the environment over the 38-year operating history of the facility. These sources can be described under two major categories: process operations and waste management practices. Process operations include all those elements of the FEMP production cycle (as summarized in Section 1.2.3). Waste management practices include all those actions associated with the storage and disposal of waste streams from process operations and subsequent interim remedial action efforts.

A variety of primary release mechanisms, including air, wastewater discharge, spills, leaks, and land disposal, provided the vehicle for transport of contaminants to environmental media and, subsequently, to potential human and ecological receptors. Secondary releases, such as air resuspension of contaminated soil contributed to further migration and transport to other media. Table 1-1 summarizes the sources, release mechanisms, affected media, and pathways associated with Operable Unit 5.

1.3.1 Environmental Media Contamination from Process Operations

As previously stated, process operations within the FEMP production cycle resulted in releases of contaminants to environmental media. Under the terms of the 1991 Amended Consent Agreement (see Section 1.5.1), Operable Unit 3 encompasses the former production area and production-associated facilities and equipment. The cessation of production eliminated or reduced many of the primary sources of contaminant release to environmental media; secondary release mechanisms and the resulting contaminant migration are the subject of this Operable Unit 5 RI Report. The remaining primary sources of contamination attributable to the former production area are being addressed under Operable Unit 3 response actions.

Routine operations at the FEMP site resulted in discharges from the process stacks and by-products which were handled in a variety of ways. Figure 1-8 (a schematic flow diagram of the FEMP process) identifies the major by-products. Contamination of environmental media resulted from releases during process operations and from the handling and disposition of the by-products that were treated as waste streams.

The transport of uranium into and through the perched and regional groundwater is influenced by several factors, as discussed in Section 5.0. A significant factor is the form that the uranium existed in when it was discharged to the environment. Of particular importance is the solubility of the

uranium compound, as discussed in greater detail in Appendix E. Table 1-2 summarizes the uranium compounds present at the FEMP site that are leachable, moderately leachable and least leachable. The following descriptions of process operations and waste management practices are presented from a broad perspective of how these activities contaminated the environmental media of Operable Unit 5 by airborne releases, wastewater discharges, storm water runoff, and process operation releases to groundwater. The RI/FS documents describing the CERCLA response actions undertaken for the Operable Units 1, 2, 3, and 4 provide greater detail of releases to the environment from the respective operable units.

1.3.1.1 Airborne Releases

Airborne particles and gases, radioactive and nonradioactive, were generated by production, storage, and handling operations at the FEMP site. Much of the historical information summarized below is excerpted from the following documents and will not be specifically referenced in all instances:

- "A Closer Look at Uranium Metal Production, A Technical Overview" (FMPC 1988)
- "Historical Process Descriptions" (WMCO 1989)
- "History of FMPC Radionuclide Discharges" (Boback 1987 and Addendum [Clark 1989]).

Current storage and remediation activities are also a source of airborne releases. Airborne particles eventually settle to the ground in the general vicinity of the source. This creates a potential for resuspension in the air or surface water, transport with the infiltration of storm water, as well as a potential for direct introduction to the human food chain through soil, grass, produce, and milk. Airborne releases and subsequent deposition on the ground also create exposure routes to flora and fauna through several secondary pathways. For these reasons, the air pathway is considered to have the greatest potential for off-property exposure to the public.

Section 3.0 of this Operable Unit 5 RI report, Physical Characteristics of the Study Area, describes the regional meteorological features that control the dispersion of airborne emissions and Section 4.0, Nature and Extent of Contamination, discusses the results of sampling and analysis programs performed to determine the extent of contaminant migration from air emissions and secondary pathways.

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A discussion of past and current emissions follows.

Past Airborne Emissions

The principal sources of airborne emissions from FEMP processing operations were:

- Dust collector discharges
- Wet scrubber discharges
- Acid-pickling fume stacks
- Nonproduction sources, including:
  - old solid waste incinerator (at the sewage treatment plant)
  - oil burner
  - graphite burner
  - new solid waste incinerator
- Particulate and gaseous emissions during temporary storage of process by-product materials
- Other sources, including:
  - building exhaust
  - laboratory emissions
  - fugitive emissions from waste pits
  - radon emissions from the K-65 silos
  - non-routine events.

Table 1-3 summarizes airborne uranium discharges from the FEMP site. As shown in the table, the estimated airborne release of uranium from 1951 through 1987 was 179,058 kilograms (Boback 1987). These estimates of releases from the FEMP are based upon an evaluation of historical stack monitoring data and production records by FEMP scientific staff members.

Dust collectors controlling emissions from process operations were the principal source of airborne emissions at the FEMP site during this period (approximately 75 percent). The characteristic particulate emissions were less than 10 microns in size and predominantly U_3O_8, with normal to slightly depleted enrichment status (see Section 4.1 for a discussion of enrichment status). Plant 8 operations accounted for the largest single discharge source (6 percent from dust collectors plus 20 percent from wet scrubbers; a total of approximately 26 percent of the total emissions). Plant 2/3 (23 percent), Plant 4 (19 percent), Plant 5 (15 percent), and Plant 7 (8 percent) were also significant sources of airborne emissions. Most (87 percent) of the releases occurred between 1954 and 1969. Of the total airborne emissions from the processing plants, approximately 73 percent was in a form considered minimally leachable (see Table 1-2), 24 percent was in a moderately leachable form, and approximately 2 percent was in a form considered most leachable.

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In November 1993 a draft report entitled "The Fernald Dosimetry Reconstruction Project - Radionuclide Source Terms and Uncertainties" was issued for review by the Radiological Assessments Corporation (RAC) under contract to the Centers For Disease Control (CDC). The report was prepared to support an initiative being undertaken by the CDC to reconstruct the potential radiological doses received by members of the public residing around the FEMP as a result of environmental discharges during the facility's 38 year operational history.

Within the draft CDC report, RAC evaluated the projected quantities and characteristics of radiological contaminants released to the environment from facility operations. The RAC estimates employ a probabilistic approach to projecting these same historical release levels. The probabilistic based estimates completed by RAC included use of Monte Carlo methods to evaluate the propagation of uncertainty in the estimating process. These Monte Carlo simulations were completed for total site dust collector emissions, Plant 8 scrubber emissions, Plant 2/3 scrubber discharges and radon releases from the site. In general, the best estimate of the mass of releases from these sources, as projected by RAC, were an average of approximately 250 percent higher than similar estimates completed by the FEMP. The primary differences are in the estimation of releases from the Plant 8 scrubbers (385 percent higher release estimates) and the site-wide dust collection systems (265 percent higher emission estimates).

No attempt has been made to reconcile the differences between the two estimates of total mass of historical site emissions. For the purposes of this report, it is the chemical forms (species) of the releases that are of significance, not the total mass of contaminants released. Furthermore, actual concentrations of contaminants measured in the environmental media are used for fate and transport modeling and risk assessment purposes.

Table 1-4 summarizes airborne thorium discharges from the FEMP site. The total airborne thorium releases were 6496 kilograms. Plant 8 (25 percent), Plant 9 (27 percent), and the pilot plant (47 percent) accounted for most of the thorium releases, which primarily occurred during the periods 1954-1955 (27 percent) and 1964-1971 (55 percent).

The following paragraphs briefly describe major historical operations in the FEMP processing plants (see Figure 1-6) with emphasis on the process and equipment features which contributed to airborne releases.

Plant 1 (Sampling Plant) - Operations began in 1953. The plant received large quantities of natural, enriched and depleted uranium. The feed materials were dried, crushed, milled, ground, and digested in nitric acid. Drummed K-65 materials were also temporarily stored on the Plant 1 pad in the early 1950s. Plant 1 contained 15 dust collectors. Dust particles were 8 to 24 microns in size. Releases included uranium ore dust (80 percent) and U_3O_8 (20 percent).

Plant 2/3 (Refinery) - Operations began in 1953. Through acid digestion, uranium was converted from ores and ore concentrates to UO_3. From 1953 to 1955, Plant 2/3 also processed pitchblende ore that contained elevated levels of radium. When ores were no longer processed, the feed material was UO_2, uranyl nitrate hexahydrate, scrap from Plant 1, and uranium oxides from Plant 8. Plant 2/3 contained four dust collectors and two scrubbers. Releases included uranium ore dust (87 percent), U_3O_8 (11 percent), small UO_3 particles which penetrated the scrubbers (2 percent), uranyl nitrate hexahydrate, and Ra-226.

Plant 4 (Green Salt Plant) - Operations began in 1953. Plant 4 converted UO_3 to UF_4 (green salt) through reduction and subsequent hydrofluorination. In 1954, thorium tetrafluoride was prepared in Plant 4. The process was discontinued due to mechanical problems. Plant 4 contained 12 dust collectors. Dust particles were 2 to 22 microns in size and ranged from 50 to 81 percent uranium (U_3O_8 [75 percent], UF_4 [24 percent], UO_2F_2, and UO_3).

Plant 5 (Metals Production) - Operations began in 1953. Plant 5 reduced UF_4 to uranium metal through high temperature reaction using magnesium as a catalyst. Uranium metal in the form of derbies was recast to form ingots. Graphite crucibles were machined and the magnesium fluoride slag milled for reuse in reduction pots. Plant 5 contained 17 dust collectors. Dusts in the reduction area were mostly UF_4 and U_3O_8 in magnesium fluoride slag, with some minor amount of UO_2F_2. Remelt area dusts were mostly U_3O_8. Dust particles were 0.5 to >44 microns in size. In total, emissions consisted of U_3O_8 (96 percent) and UF_4 (4 percent).

Plant 6 (Metals Fabrication Plant) - Operations began in 1952. Billets, made by top-cropping ingots from Plant 5, were heat treated in neutral salt and salt-oil baths and shipped off site. The returned products were machined into their final forms and pickled in nitric acid to remove oxide contamination and progeny products. Chips and lathe turnings were crushed, pickled, rinsed, dried, briquetted, and recycled to casting operations. Salvageable fuel cores were returned for processing and all rejects were recycled through Plant 5. Plant 6 contained three dust collectors and three electrostatic precipitators. The principal airborne emission path from Plant 6 was exhaust from the stack which ventilated the pickling tank, two wash tanks, and the exhaust from the briquetting operations. The emitted uranium was primarily in the form of U_3O_8.

Plant 7 - Plant 7 was constructed for the conversion of UF_6 to UF_4 and actual production ran from 1954 to 1956. Plant 7 contained four dust collectors which primarily controlled UF_4.

Plant 8 (Scrap Recovery Plant) - Operations began in 1953. Plant 8 processed impure metals and residues including off-specification UO_3 and UF_4, magnesium fluoride slag, crucible burnout, ingot and cuts, sump cakes, chips, and sawdust. High-grade scrap, such as machining chips and turnings, was oxidized to U_3O_8 in an oxidation furnace or burned in a box furnace. Fine material (<8 mesh) was sent to Plant 2/3; coarse material (>8 mesh) was

further oxidized in a muffle furnace. The furnaces were vented to wet scrubbers before gases were discharged to the atmosphere.

Thorium hydroxide was produced in Plant 8 for six months in 1966 in the reversion system. Thorium tetrafluoride (ThF_4) was reverted to thorium hydroxide by heating it in a reverter tube with hydrofluoric acid. The offgas from the reverter was neutralized in a caustic scrubber. The dried thorium hydroxide was then sent to the pilot plant for digestion. The digestion tanks were vented to the atmosphere, and the oxalate precipitation tanks were vented to a packed tower water scrubber. The pan filter was vented to a packed tower water scrubber and the uranium phosphate furnace was vented to a venturi-type scrubber. The dust from the collectors in Plant 8 was 7 to 10 microns in size and ranged from 11 percent to 69 percent uranium (mostly in the form of U_3O_8 [94 percent], with some amounts of UAP [6 percent] and UCl_4). Airborne thorium releases from the Plant 8 scrubbers included hydroxides and oxalates.

Plant 9 (Special Products Plant) - Operations began in 1954. Plant 9 originally conducted casting and cropping of ingots from Plant 5. Cropped billets from Plant 5 were drilled and machined for further processing in Plant 6. Beginning in 1961, the Zirnlo process was used to dissolve rejected co-extrusion sections from the cladding operation at Hanford. The process used dilute nitric acid to remove copper from uranium cores that were then recycled for remelting. The Zirnlo process has also been used to remove zirconium, copper, nickel, or aluminum from rejected cores by digesting the cladding in hydrofluoric acid, nitric acid, or caustic. Some amounts of uranium can also be dissolved in the process. Later the Zirnlo process was used to pickle derbies to remove potassium and lithium carbonate residues left by the salt-cleaning process. The acid tanks had an exhaust stack with a blower. Core pickling was used from 1961 to 1963. Briquetting of uranium and thorium was performed from 1953 to 1963.

Thorium metal was produced in Plant 9 in 1954 and 1955. Solid thorium nitrate tetrahydrate was reacted to form a zinc-thorium derby, which was dezinced and remelted in a vacuum furnace. The resulting thorium metal ingot was machined to produce the final product. The thorium chips and turnings from this operation were processed and returned to the production process for remelting. Thorium oxalate from Plant 4 was calcined to thoria and returned to Plant 4.

Airborne releases of uranium from Plant 9 were not significant compared to other sources: 2.5 metric tons (1.5 percent of the total uranium emissions) were released between 1957 and 1984. The dust in the one collector sampled was approximately 55 percent uranium (mostly as U_3O_8 [66 percent], with lesser amounts of UF_4 [34 percent] and UO_2F_2). The most likely locations for unmonitored thorium emissions were the dissolution of thorium nitrate tetrahydrate, the precipitation of thorium tetrafluoride, and acid washing of the metal chips. The dissolving tank vented to the atmosphere, the precipitation tank vented to an absorber, and the acid wash vented through a dust collector. The dissolution tank for the thorium nitrate tetrahydrate, the precipitation tank for thorium oxalate, and the calciner (which was assumed to have been vented through a wet scrubber) were emission sources from operations in Plant 9 associated with material prepared for Plant 4.

Pilot Plant - Operations began in 1951. The source material was UF_6 tails from gaseous diffusion plants. Material up to 2.5 percent enrichment could be processed. Conversion of UF_6 to uranium tetrafluoride (UF_4) began by heating the UF_6 in an autoclave to transform the

solid into a gas. The gaseous UF_6 was then reduced with hydrogen to form UF_4. The UF_4 was feed material for Plant 5. Box furnaces were used from 1956 to 1961 to process U_3O_8, enriched uranium turnings, and "sawdust" generated in the production of enriched uranium cores. Crucibles were also plasma coated in the pilot plant. The offgas from the production of UF_4 consisted of hydrogen, nitrogen, hydrogen fluoride, uranium tetrafluoride particulates, and trace uranium hexafluoride. The offgas was passed through two cyclones in tandem and two sintered metal filters to remove uranium tetrafluoride, a carbon trap to remove unreacted uranium hexafluoride, a two-stage refrigerated condenser system to remove anhydrous hydrogen fluoride, and a water scrubber to remove trace aqueous hydrofluoric acid before being vented to the atmosphere. The dust from the collectors in the pilot plant was 9 to 44 microns in size and ranged from 2 to 75 percent uranium (in the form of U_3O_8 [96 percent], UF_4 [4 percent], and UO_3), of which >99 percent was U-238 and <1 percent was U-235. On February 16, 1966 an unmonitored release of approximately 1195 kilograms of uranium (as UF_6) occurred during a one-hour period; winds were from the north/northwest.

From 1964 until 1980 thorium ores, crushed thoria pellets, thorium oxalate, and other thorium materials were processed by digestion and extraction to thorium nitrate, which was shipped as product and feed for other processes. Emissions from the digestion system were either vented directly to the atmosphere or vented through a packed tower scrubber. In 1964 a solvent extraction process was used for thorium. This process was also used in 1966 to purify thorium nitrate crystals. Thoria gel was produced in the pilot plant from 1964 to 1970 and from 1977 to 1979. The thoria gel (thorium hydroxide) was packaged and shipped to another location for calcining to thorium oxide, which was shipped as the final product. The precipitation tank was vented through a water scrubber or directly to the atmosphere. The shelf dryer was vented to a venturi-type scrubber. The plate and frame filter produced thorium emissions inside the building.

Thorium metal was produced in the pilot plant from 1969 to 1971. Hydrofluoric acid was added to thorium nitrate tetrahydrate solution to precipitate thorium tetrafluoride. The dried thorium tetrafluoride was milled and blended with calcium metal and zinc fluoride (zinc chloride was used in the normal reduction process). Argon purge gas was used to prevent the buildup of hydrogen gas produced from the reaction of calcium metal with residual moisture in the thorium tetrafluoride. The zinc-thorium derby was placed in a dezincing furnace to boil off the zinc. The thorium derby was cleaned and saved to produce the final product. The precipitation tank vented to a packed tower water scrubber. The shelf dryer emissions were vented to a caustic wet scrubber, which was apparently not used in 1969. Thorium oxalate was produced in the pilot plant from 1971 to 1976. The thorium oxalate was packaged and shipped to another location for calcining to thoria. The makeup and precipitation tanks used in the production of thorium oxalate were vented to a packed tower water scrubber. The plate and frame filter had an exhaust hood which was a source of thorium emissions to the building.

Current Airborne Emissions

As indicated in Table 1-3, airborne emissions at the FEMP site have decreased significantly since process operations ceased in 1989. The total airborne uranium emissions are currently determined by summing the measured uranium emissions from a number of stacks, vents and processes on site and adding the estimated fugitive and unmeasured emissions. Uranium discharges from monitored stacks

were the only measured emissions. Airborne emissions are expected to remain at these low levels for several years. However, as final remediation of the site occurs, an increase in emissions is possible as contaminated materials are moved for final disposition.

1.3.1.2 Wastewater Discharges

Releases of radiological and nonradiological contaminants to environmental media have occurred as the result of FEMP processes involving the generation, storage, and disposal of wastewater. The discharges of nonradiological contaminants to the Great Miami River were and are monitored and regulated under a National Pollutant Discharge Elimination System (NPDES) permit. Radiological contaminants were and are measured pursuant to DOE orders and compared to DOE guidelines.

Unmonitored releases have also occurred over the FEMP site's history as the result of leaks, spills, and overflows caused by equipment failure or storm events. Such releases resulted in contaminant migration to soil, surface water/sediment and groundwater. The following is an overview of the past and current practices for wastewater management at the FEMP site.

Past Wastewater Management Practices

Liquid wastes generated at the FEMP site consisted of process wastewater, sanitary sewage, and storm water runoff (see Figure 1-9). Process wastewaters were produced in virtually all the plants. Individual treatment facilities capable of pretreating the process liquid wastes were located within the processing plants. In these plant treatment units, a large amount of the uranium compounds dissolved in the liquid wastes were precipitated and removed as sludge or filter cake. These were recycled through the facilities for uranium recovery or, after August of 1986, dried in Plant 8, drummed, and shipped off-property for disposal. The filtrate was then sent to the general sump (see Figure 1-6).

The general sump is a collection of various sizes of vertical tanks and pumps, piping, and valves designed for collection, treatment, and routing of the liquid wastes. This facility is built on a concrete pad with curbs for spill and rainfall containment. Process wastewater was received here in separate batch volumes from the production plants or service facilities, checked for suspended solids content, and segregated or combined as required. If a particular liquid volume did not meet the specification for suspended solids or uranium content, it was sent to Plant 8 for solids recovery and returned to the general sump. Various reagents and coagulation aids were added to the liquid wastes in the tanks as necessary to promote the precipitation of soluble materials. Before 1984, the slurried

contents of the general sump were pumped to the waste pits. After 1984, waste slurries were sent to Plant 8 for filtering on rotary vacuum filters. The filtrate was pumped back to the general sump for subsequent discharge to the Great Miami River in accordance with the NPDES permit and DOE guidelines.

Before 1977, effluent from the general sump was discharged to Waste Pit 3. This waste pit provided the detention time for chemical neutralization and additional settling of solids. The supernatant liquid was collected in a Clearwell constructed as part of Waste Pit 3 and pumped to the Great Miami River.

In 1977, Waste Pit 3 was taken out of service and covered with soil. Waste Pit 5 was constructed to take its place and general sump effluent was sent to Waste Pit 5 until 1987 when it was taken out of service. However, the supernatant from Waste Pit 5 continued to flow to the Clearwell portion of Waste Pit 3, which remained in service. Currently, storm water runoff from the waste pits flows to the Clearwell and is pumped to the biodenitrification surge lagoon (BSL). Storm water runoff from the perimeter of the waste pits flows to a new pumping station and then to the BSL (see Removal Action No. 2 - Section 1.3.4.2). Wastewater flows from the general sump directly to the BSL.

In 1987, a biodenitrification facility was placed on-line to remove nitrates from process wastewaters. This facility consists of an 8.5-million-gallon equalization basin (the BSL) and four towers containing microorganisms that remove the nitrates from the liquid waste passing through the facility. The effluent is subsequently discharged to the biodenitrification facility effluent treatment plant for reduction of biochemical oxygen demand (BOD) and total suspended solids (TSS) before discharge to the Great Miami River. In 1989, a high-nitrate holding tank was added to the system to better equalize influent nitrate streams.

Sanitary sewage from the sanitary sewer system and, after 1987, process wastewater from the biodenitrification facility were pumped to the sewage treatment plant for treatment. The sewage treatment plant effluent was analyzed for TSS, pH, total fecal coliform bacteria, residual chlorine, and biochemical oxygen demand in compliance with the terms and conditions of the NPDES permit. This effluent was discharged to the Great Miami River via Manhole 175.

Wastewater from the FEMP water treatment facility and boiler plant and the decant from the coal pile runoff collection basin were historically sent to the general sump for treatment before discharge.

Although the NPDES permit does not require monitoring of radionuclides in the effluent, concentrations of uranium, thorium and several other radionuclides are monitored per DOE orders. Table 1-5 summarizes the total uranium and thorium in effluent discharged to the Great Miami River from 1952 through 1993. The amount of uranium and thorium discharged generally follows the amount of production of each, with a baseline amount of uranium discharged regardless of production.

The effluent line to the Great Miami River was the subject of several investigations to determine whether wastewater effluent was leaking into soil and groundwater. Pressure-testing of the line did identify one line segment that was potentially leaking. Because of this and the fact the line was not sized to handle estimated future flow, construction of an entirely new outfall line was completed in 1992 as part of the South Plume Removal Action (see Section 1.3.4.3) and the original effluent line was abandoned in place.

Current Wastewater Management Practices

As of April 1994, the FEMP liquid effluents are categorized into 13 basic sources, all of which are monitored and receive some degree of treatment before they leave the site. Figure 1-10 illustrates the flow of effluents and where they are treated and monitored before they are discharged.

The first two sources of liquid effluent are controlled contaminated storm water runoff streams from the waste pits and the perimeter area of the waste pits, which are collected and pumped to the BSL.

The third source of liquid effluent is perched groundwater, which is extracted pursuant to Removal Action No. 1 (see Section 1.3.4.1). This extracted groundwater is treated for volatile organic compounds (VOCs) sent on to the Plant 8 sump for further treatment, and then sent to the contaminated side of the general sump. The solids that are removed at the Plant 8 sump are drummed and stored as a low-level radioactive waste. All liquids from the contaminated side of the general sump are combined and, if treatment is needed, sent to the Plant 8 sump. If treatment is not required, they are sent to the BSL.

At the BSL, storm water runoff from the waste pits mixes with liquid from the contaminated side of the general sump and the combined effluent is treated in the biodenitrification facility to reduce nitrates. From that system the combined treated effluent flows to the interim advanced wastewater

treatment (IAWWT) system (discussed below), where uranium may be removed before the effluent flows to Manhole 175, where it is monitored before discharge to the Great Miami River.

The combination of plant effluent and pad storm water is the fourth source of effluent. This stream is sent directly to the contaminated side of the general sump.

The fifth through eighth sources of effluent are all collected in the noncontaminated side of the general sump. Boiler plant blowdown and coal pile runoff are collected in the coal pile runoff basin and, after clarification, are sent to the general sump. Water plant effluent and lime sludge pond decants are sent directly to the general sump. After settling, the liquids are sent to Manhole 175 and the sludge is sent to the north lime sludge pond.

The ninth and tenth sources of effluent are sanitary sewage and liquid from the laundry, which are processed at the sewage treatment plant to remove biological contaminants. After treatment, the effluent is sent to Manhole 175 and on to the Great Miami River.

The 11th and 12th sources of effluent are produced from storm water runoff from the former production area and the parking lot. Storm water runoff from the former production area is collected by a network of storm sewers that converge at Manhole 34. This runoff is permitted to flow from Manhole 34 to the storm water retention basin (SWRB). Here it mixes with runoff from the parking lot storm sewers and is allowed to settle. From the SWRB, the effluent is treated at the IAWWT before it is eventually pumped to Manhole 175 and on to the Great Miami River. If necessary due to a spill or other similar event, water from the storm sewers is pumped by the storm sewer lift station to the general sump.

The 13th source of effluent is South Plume groundwater, which is extracted pursuant to Removal Action No. 3 (see Section 1.3.4.3). This water is treated at the South Plume Interim Treatment (SPIT) facility before monitoring and discharge through Manhole 176-B. Backwash of IAWWT and SPIT filters is sent to the general sump.

In summary, the FEMP controls liquid effluents and provides appropriate treatment before they are discharged. Twenty-four hour, composite samples are taken before the effluent flows to the Great Miami River and the data are reported to EPA. As indicated on Table 1-5, the amount of uranium

discharged through the effluent line has not decreased significantly since production operations ceased in 1989, and is not expected to decrease significantly in the near future. This is because additional contaminated streams are being routed through the treatment system that were not previously being discharged (South Plume groundwater) or were discharged through a drainage ditch (storm water runoff from the waste pits, former production area and parking lot).

1.3.1.3 Storm Water Runoff

Storm water runoff has been and continues to be a significant pathway for the migration of contaminants in environmental media. Soil contaminated through air deposition, waste storage areas (piles, pads, etc.), and the waste pits are all sources that release contaminants via storm water runoff. The runoff then conveys the contaminants into surface water, groundwater, or as described above, wastewater effluent. Section 3.0 provides greater detail regarding the characteristics of storm water runoff. The following is a summary of past and current practices pertaining to the management of storm water runoff at the FEMP site.

Past Storm Water Management Practices

Major sources of contaminants available for transport by storm water runoff included the former production area soil, waste storage facilities, and the waste pit area. The major pathways for migration were from the perimeter of the waste pits directly into Paddys Run at the northwest corner of the FEMP site, and from the production area via the storm sewer outfall ditch (SSOD) leading into Paddys Run at the southwest corner of the FEMP site (see Figure 1-7).

The FEMP storm sewer system collected surface runoff from the majority of the 136-acre former production area and other adjacent developed areas. During dry weather, infiltration/inflow into the storm sewer flowed to Manhole 34 and was pumped by the storm sewer lift station to Manhole 175, where it combined with other plant effluent before it was monitored and discharged to the Great Miami River (Figure 1-7). However, during periods of heavy precipitation, the capacity of the storm sewer lift station was often exceeded and the water in the storm sewer system overflowed directly to the SSOD.

The SSOD flows southwest across the southern portion of the site. Its drainage area includes nearly the entire eastern and most of the southern portions of the FEMP, including the former production area, the sewage treatment plant and old solid waste incinerator, and a large area off-property to the

south. Much of the stream bottom of this drainage course is composed of highly permeable sand and gravel. Because it carries storm water runoff from several more contaminated areas, loss of flow to the underlying aquifer through the stream bottom is considered a significant pathway.

Except for a small drainage ditch in the northeast corner of the site which flows to the Great Miami River, natural surface drainage from the FEMP site is toward Paddys Run. In addition to the SSOD, the primary drainage ditches into Paddys Run were those that carried storm water runoff and associated contaminants from the waste pit area, the perimeter area of the waste pits, the Plant 1 pad in the former production area, an area north of the railroad tracks north of the waste pits, and from the area around the pilot plant.

Paddys Run originates north of the FEMP site, flows southward along the western boundary of the facility, and enters the Great Miami River approximately 1.5 miles south of the southwest corner of the FEMP property. The stream is approximately 8.8 miles long and drains an area of approximately 15.8 square miles. As with the SSOD, Paddys Run has, in places, cut through the geological deposits upon which the facility is built. The highly permeable channel bottom allows loss of flow to the Great Miami Aquifer and provides another direct pathway for contaminants to enter the aquifer (see Section 3.2.2 for further details).

Current Storm Water Management Practices

In the mid-1980s, the FEMP began a phased, long-term initiative to better control storm water runoff. The basic strategy was to first collect the runoff, then install the facilities necessary to remove the contaminants from the storm water runoff and other liquid waste streams. The individual components of the strategy were:

- Prevent contaminated storm water runoff from reaching the SSOD and reduce the amount of contaminants reaching the Great Miami Aquifer through this pathway. This was accomplished by constructing the SWRB near the discharge point of the FEMP storm sewer system to collect runoff from the production area and parking lot (see Section 1.3.4.8).

- Identify remaining areas where storm water runoff contained significant concentrations of contaminants. This was accomplished through the sampling of drainage ditches as required by the Best Management Practices (BMP) Plan and other less formal sampling efforts. This

sampling showed that improvements were needed to control runoff near the Plant 1 pad (see Section 1.3.4.9) and along the perimeter of the former production area (Removal Action No. 16 - see Section 1.3.4.5). The runoff collected as a result of both of these projects is directed to the SWRB.

- Control additional areas of the site. This was accomplished by installing ditches, curbs, and storm sewers in the waste pit perimeter areas (approximately 26 acres) to collect storm water runoff that previously flowed directly to Paddys Run (Removal Action No. 2 - see Section 1.3.4.2). This storm water, as well as runoff from the waste pit area, which is collected in the Clearwell, is pumped to the BSL.

- Develop long-term capabilities to treat all liquid waste streams at the FEMP. Concurrently with the design and construction of the storm water control projects, the planning and design for the advanced wastewater treatment (AWWT) facility was being conducted (see Section 1.3.4.7).

Even with the completion of these projects, storm water runoff from much of the site remains uncontrolled. This includes the eastern portion of the waste storage area (approximately 26 acres), which did not show high concentrations of contaminants during the BMP sampling program. Therefore, the runoff from this area was directed into the pilot plant drainage ditch, which flows directly to Paddys Run. Although the surface water in the pilot plant drainage ditch does contain elevated concentrations of uranium, the source appears to be near the pilot plant (see Section 1.3.4.10).

The FEMP filed an application for a NPDES storm water permit on September 29, 1992, for the uncontrolled storm water discharges. To date, no response to the application has been received. For completion of the application, sampling was conducted in four discharges to Paddys Run.

The FEMP reports an estimate of the uranium in remaining uncontrolled storm water runoff into Paddys Run to the EPA. Based on a series of grab samples collected in various on-property drainage ditches that convey water into Paddys Run, the FEMP had developed a general estimate of 10 pounds of uranium discharged to Paddys Run for every inch of rain. In November 1992, this estimate was reduced to 6.3 pounds. This change was brought about by the completion of the above-mentioned

Waste Pit Area Runoff Control removal action that now directs contaminated runoff from the waste pit perimeter areas to the BSL and has eliminated that source of contamination to Paddys Run.

1.3.1.4 Production Operation Releases to Groundwater

Production operations were also significant sources of contaminant release to groundwater. This section describes the conditions and practices which resulted in the release of contaminants to groundwater from production operations.

Production Operations

Several characteristics of the FEMP production cycle, facilities, and equipment contributed to the incidence of unmonitored releases of contaminants to groundwater. First, several of the plants used large quantities of acids to digest, extract, and treat the uranium materials. In those instances the uranium was in a more soluble form, facilitating the migration of spilled or leaked material into the underlying groundwater. Plants 2/3 (refinery), 6 (metals fabrication), 8 (scrap recovery), and 9 (special products) all employed large quantities of acids in their respective processes (Figure 1-8).

Second, the process operations involved the use of floor sumps, piping (above- and below-ground), drums, and other containers that were used to collect, store, and transport materials either within the plants or to other plants or waste handling areas. All of these handling operations increased the likelihood of unmonitored leaks and spills.

Third, many of the process facilities and much of the equipment continued to be used in production operations far beyond their design lives. From the mid-1950s to the mid-1980s, maintenance budgets were limited and production goals took precedence over preventive maintenance and upgrades. The emphasis on production and the deteriorating facilities and equipment also fostered practices which were contrary to standard operating procedures designed to promote proper handling of materials. In some cases, materials were contained in floor sumps that were leaking or were not designed to accommodate the part of the process for which they were used. A 1988 report prepared by a WMCO facilities task force identified 137 operations suspected of prior unmonitored discharges to the environment (WMCO 1988).

Finally, the plants in the former production area overlie a perched groundwater system in the glacial overburden. The perched groundwater under and around the plants is contaminated with significant levels of uranium and some VOCs. While the predominance of clay and silt in the glacial overburden tends to confine the contaminant migration within the perched groundwater system, it cannot be conclusively stated that there is no migration to the underlying aquifer. For instance, the foundation of Plant 6 was excavated almost entirely through the glacial overburden, providing a pathway for migration of contaminants to the aquifer. However, the evidence indicates that there is minimal migration between the two zones. Sections 3.0 and 4.0 of this report provide the detail on hydrogeologic features and contaminant migration in the production area.

There are no readily available records from the 1950s to the mid-1980s concerning major or minor incidents of spills or leaks of process materials to groundwater. When WEMCO assumed management of the FEMP site (in 1986), incident records were more rigorously kept. These records do not reveal any major leaks or spills directly affecting groundwater.

Underground Storage Tanks

Underground storage tanks (USTs) are a minor component of the former process operations that contributed relatively small quantities of contaminants to the surrounding soil and groundwater. A total of 14 USTs were identified in the production area (see Table 1-6). Historical records and sampling and analysis data from the removal of some of the USTs indicate that they were all used to store petroleum products, including gasoline for site vehicles and machining oils for process equipment.

Eleven of the 14 USTs are subject to regulation under the Ohio Administrative Code (OAC). Ten of these 11 USTs, their associated piping and surrounding contaminated soil, were excavated and removed. One tank (14) is located underneath Plant 6 and could not be removed without damaging the structure. This tank was abandoned in-place pending final disposition of Plant 6 under CERCLA. Three closure reports covering the eleven removed tanks were submitted to the Ohio State Fire Marshal's office. The reports included all tank closure information required by OAC 1301:7-9-12(L) and requested that any final remedial action be deferred to activities under CERCLA. DOE was subsequently notified by the Fire Marshal's office that these USTs were considered closed, with no additional corrective action, remedial investigation, or reporting required. The three remaining tanks will be removed as part of the final CERCLA remedial actions.

1.3.2 Waste Management Practices

The purpose of this section is to provide an overview of the FEMP waste management practices that resulted in primary and secondary releases of contamination to the environmental media comprising Operable Unit 5.

Waste management activities at the FEMP site are being conducted pursuant to both the CERCLA and Resource Conservation and Recovery Act (RCRA) statutes. As previously stated, CERCLA response activities are being managed as five operable units based on similarities of waste material and disposal methods. RCRA activities are managed in accordance with a consent decree with the OEPA and under the terms of a Part B permit application.

1.3.2.1 Process and Production Waste Generation

Routine operations at the FEMP site produced by-products that were handled in a variety of ways. Figure 1-8 (a schematic flow diagram of the FEMP process) identifies the major by-products produced. Several of the by-product streams identified were treated as waste streams:

- General Sump Sludge: The general sump consisted of a series of batch tanks that received an average of 1.6 million gallons per month of filtrates from the various processing plants, wastewater from the laboratory (0.3 to 0.9 million gallons per month), and general decontamination and cleanup water.

  Before discharging the filtrate to the general sump, the waste streams from the individual processing plants were neutralized and filtered to remove the uranium. The filtrates were than analyzed to determine if the uranium content was within allowable discard limits (generally <0.0004 pounds total U per gallon). If so, the filtrates were discharged to the general sump (Figure 1-9).

  Filtrate in the general sump was neutralized with lime (calcium oxide - CaO) to obtain maximum precipitation of radioactive materials and other elements, then mixed with air to maintain the solids in suspension for discharge to the waste pits as slurry. After 1984, the solids were settled and the remaining liquid was pumped to the waste pits. The settled solids were transferred to Plant 8 for filtering and packaging for disposal. The filtrate from the Plant 8 filtering operation was returned to the general sump.

  Although the general sump discharged into Waste Pit 2 before Waste Pit 3 was opened in December 1958, the majority of the flow from the general sump was discharged to Waste Pits 3 and 5. It has been assumed that the general sump discharged to Waste Pit 1 before the opening of Waste Pit 2 in 1957, but no records exist to verify this.

- Neutralized Raffinate: In the refinery operation, uranium-bearing feed materials were digested in nitric acid to solubilize the uranium. The uranium was then extracted from the nitric acid. The remaining nitric acid, impurities associated with the materials being

processed, and small quantities of insoluble, nonextractable uranium are referred to as "raffinate" solution. Before 1960 these raffinates were calcined (cold metal oxide) before disposal. If the raffinate resulted from the processing of ores or ore concentrates with high radium concentration, it was called "hot raffinate" and was neutralized and pumped, as a slurry, to Silos 1 and 2. Otherwise, the calcined raffinate was called "cold metal oxide" most of which was placed in Silo 3. After 1960, the process gradually progressed to lime neutralization of the raffinate slurry, resulting in "neutralized raffinates." The neutralized raffinates primarily contained the impurities from the ore concentrates and residues, nitrates, lime, and approximately 0.5 percent total uranium (wet weight basis [1.67 percent dry basis]). The raffinates were pasty in consistency and ranged in color from yellow to blue, including brown, orange, and red. The color depended on the primary impurities included. The neutralized raffinates were deposited in slurry form to Waste Pits 3 and 5, with a small amount deposited in Waste Pit 2.

- Magnesium Fluoride (MgF_2): The reduction of UF_4 (green salt) to produce depleted uranium metal generates MgF_2 slag. Part of this material was recycled and used as reduction pot liner for subsequent metal production; however, the bulk of the MgF_2 was not required for this purpose and became waste. This material was generated in three forms:

  - *Depleted Slag*: The reduction of depleted UF_4 in Plants 5, 9, and the pilot plant generated depleted MgF_2 slag. A small amount of C-oxide was deposited in Waste Pits 1 and 2 from 1955 to 1963. C-oxide was generated when dolomite was used to line the reduction pots, before magnesium fluoride was used for that purpose. The C-oxide contained (dry weight basis) approximately 5 percent uranium, a trace of magnesium metal, and 47.5 percent MgF_2 and 47.5 percent dolomite.

    The remainder of the depleted slag was deposited in Waste Pits 4 and 6. On a dry weight basis, the composition of the depleted slag is approximately 94.6 percent MgF_2, 5.4 percent uranium in various oxidation states, and trace amounts of elemental magnesium. The waste material was white to black in color, granular, and 0.03 to 1 inch in size.

  - *Trailer Cake*: Before 1965, MgF_2 slag from the reduction of normal and enriched UF_4 was transferred to Plant 8 to recover the uranium. In Plant 8, the uranium was recovered by first being dissolved in hydrochloric acid and then precipitated. The insoluble materials remaining after the acid digestion were filtered out and the resulting trailer cake transported to Waste Pits 1, 2, 3, and 4.

    The FEMP also received depleted C-oxide and interim reprocessing plant residues (IRP tailings) from Mallinckrodt Chemical Works from 1959 to 1965. These residues had already been processed to recover some of the uranium. Both of these materials were reprocessed to recover as much uranium as possible. The resultant residue (14,955,000 kilograms) was transported to Waste Pit 3 as trailer cake.

    Trailer cake (dry weight basis) is approximately 96.5 percent MgF_2, 3 percent filter aid (diatomaceous earth, which is primarily silicone dioxide [SiO_2]), and 0.5 percent uranium, with some chlorides. The trailer cake was white to gray in color and granular, with 100 percent less than 0.03 inches in diameter and 90 percent smaller than 50 microns in diameter.

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- *Slag Leach Slurry*: After 1965, milled MgF_2 slag from the reduction of normal and enriched UF_4 was transferred to the refinery for recovery of uranium. The uranium was recovered by dissolving it in nitric acid, followed by extraction and denitration. The insoluble materials left over after the acid digestion were filtered out, reslurried, mixed with lime (calcium oxide) to a pH of around 11, and pumped to the waste pits. This material, known as slag leach slurry, was deposited in Waste Pit 3 from 1965 until Waste Pit 5 was completed in October 1968, and then in Waste Pit 5.

  The composition of slag leach (dry weight basis) is approximately 96.5 percent MgF_2, 3 percent filter aid (diatomaceous earth), and 0.5 percent uranium, with some calcium compounds from the neutralization step and some nitrates. The material was white to gray in color and granular, with 100 percent less than 0.03 inch in diameter and 90 percent smaller than 50 microns in diameter.

- Other Waste Streams: Other waste generated in the former production area and deposited in the waste pits in significant quantities or whose presence may be of concern from an environmental stand point includes:

  - *Depleted Residues*: Various residues were generated from the processing of depleted materials and deposited directly in the waste pits. Residues from the processing of normal and enriched materials with uranium content above the economic discard limit were reprocessed. The depleted residues were a wide variety of material size, density, and uranium content and included rags, paper, polyethylene, asbestos, dust collector bags, scrap salts, off-spec UF_4 and ThF_4, soil, rocks, sand, brick, ceramics, sludges, solid metal, etc.

  - *Water Treatment Sludge*: Sludge from the softening of water for use in the production process was placed in the waste pits to further neutralize and solidify the contents. A total of approximately 300 tons per year of this material was placed in Waste Pits 3 and 5 over a 20 year period beginning in the mid-1960s.

  - *Graphite and Ceramics*: Graphite was used in the production process in crucibles and ingot molds. This graphite was replaced regularly. The waste graphite from the processing of normal and enriched uranium was burned in the graphite burner to concentrate the uranium for reprocessing. Waste graphite from the processing of depleted uranium was deposited in Waste Pits 1, 2, and 4.

  - *Uranyl Ammonium Phosphate Filtrate*: Uranyl ammonium phosphate (UAP) filtrate was generated from 1953 through 1964 in Plant 8. This process was a method of recovering uranium from magnesium fluoride slag. This filtrate contained various impurities.

  - *Thorium Wastes*: Thorium wastes were generated at the site from two sources: an impurity in the uranium ore concentrates and thorium processing. Total thorium (mostly Th-230) in the ore concentrates ranged from 0.001 percent to 1.06 percent and was concentrated in the raffinate. In the early 1950s, thorium (Th-232) was refined at the site. Most of the residues were stored and later transported off-site, but some were deposited in the waste pits as raffinates, solids, and liquid wastes.

- *K-65 Material*: When the plant was designed, a substantial amount of radium-bearing pitchblende was anticipated; therefore, equipment for handling "hot" feeds was provided. After being washed with kerosene to remove residual solvent, the hot raffinate stream was filtered on a precoat rotary vacuum filter to remove the suspended solids. Most of the radioactivity was caused by radium and its progeny, which form insoluble silicates and sulfates. Thus, the bulk of the radioactivity was removed in the filter cake. The cake was reslurried, neutralized with lime, and pumped to the K-65 storage silos where it settled. After settling, the supernatant water was decanted and returned to the reslurry operation. The K-65 material consists primarily of siliceous matter but also contains metallic compounds such as lead, molybdenum, vanadium, and others.

- *Ash*: As previously mentioned, all contaminated combustibles such as wooden pallets, paper, general trash, graphite, oils, etc., were burned or incinerated on site. The purpose of this activity was to reduce the volume to be ultimately disposed of and to concentrate any recoverable uranium. The incinerators included the sewage treatment plant incinerator, the security incinerator, and the Trane incinerator. The burners included the graphite burner, the oil burner, and the burn pit.

  The ash from these burning activities was collected and sampled for uranium content and isotopic level. If these levels were above the economic discard limit, the ash was processed to recover the uranium. In this case, the ash would have become part of the raffinate, and been deposited in Waste Pits 2, 3, or 5. If the uranium content was below the discard limit, the ash would have been deposited directly in Waste Pits 1, 2, 4, or 6.

  Records indicate that approximately 25 metric tons of incinerator ash were received from the K-25 Plant at Oak Ridge, Tennessee between 1970 and 1982. This ash had uranium contents of 2 to 85 percent and contained 0.8 to 10 percent U-235. Because of the uranium content, this material was processed to recover the uranium and the residue became part of the slag leach or neutralized raffinate and was discarded in Waste Pit 5.

- *Flyash:* Flyash was generated from the on-site, coal-fired boiler. This material usually was deposited in one of two flyash storage piles (Operable Unit 2). Some of the flyash, however, was used as cover material for Waste Pit 3. Records indicate that some of this flyash also was deposited in the burn pit before 1959.

Before 1984, on-site disposal of solid and slurried wastes at the FEMP site occurred in waste pits and silos. Transport of solid wastes to the waste pits was dependent on the type of wastes generated and the type of storage containers. In general, drummed wastes were transported on flat-bed trailers, metal dumpsters were carried by dumpster vehicles, bulk wastes were transported by dump trucks and trailers, and drummed pyrophoric metal was conveyed on four-wheeled flat-bed trailers pulled by tow tractors (NLO 1978).

At the waste storage area, dump trucks, dump trailers, dumpster units, and drummed wastes were emptied directly onto the waste pits' edges. The material was then pushed into the waste pits by either a bulldozer or a dragline scraper. Loose contamination was washed from bulldozers, the dragline scraper, vehicles, dumpsters, and fork trucks with water at the waste pits. Empty drums were washed in a drum washing facility that was located near Silos 1 and 2 (NLO 1977). This facility is no longer in existence.

Liquid wastes were transported between the general sump and the waste pits and Clearwell via two 6-inch-diameter pipes (Dames and Moore 1982). Beginning in 1990, such wastes were drummed and stored for off-site disposal. Production process effluent was sent to the general sump for analysis before discharge to the Great Miami River. If treatment was necessary to meet NPDES limits, it was performed in the recovery plant (Plant 8). Waste streams from Plant 8 were returned to the general sump for analysis and eventual discharge. Storm water runoff from the process areas was analyzed and discharged to the Great Miami River.

1.3.2.2 Operable Unit 1

Large quantities of liquid and solid wastes were generated by the various operations at the FEMP site. Before 1984, solid and slurried wastes from FEMP processes were disposed of in the on-property waste storage area. This area, located west of the production facilities (Figure 1-3), includes six low-level radioactive waste storage pits, the burn pit and the Clearwell and is addressed in the RI for Operable Unit 1. Major contaminants are uranium, thorium, radium, and technetium. These waste units are described below and their contents are summarized in Table 1-7.

- Waste Pit 1 - constructed in 1952 into existing native clay and then lined with an additional 4 feet of clay. The maximum internal depth of the pit is 18 feet below the cover and contains an estimated 44,059 tons of waste, 60 tons of which is estimated to be uranium. Waste Pit 1 has been out of service since 1959, when it was backfilled, covered, and graded to encourage surface drainage away from the waste pit surface.

- Waste Pit 2 - constructed in 1957 and lined with native clay with a 14-foot average internal depth below the cover. It contains an estimated 28,412 tons of waste, of which 1350 tons are estimated to be uranium. Waste Pit 2 has been out of service since 1964 when it was backfilled and covered.

- Waste Pit 3 - constructed in 1959 into an existing clay layer and lined with an additional foot of clay. The maximum cover depth is 14 feet below grade. The maximum internal depth of the waste pit is 27 feet below the cover. Waste Pit 3 contains an estimated 133,191 tons of waste with an estimated quantity of uranium at 124 tons and

approximately 800 pounds of thorium, with a total waste volume of 237,000 cubic yards. Waste Pit 3 has been out of service since 1977 when it was backfilled and covered.

- Waste Pit 4 - a clay-lined pit, constructed in 1960 with a 25-foot maximum internal depth below the cover and containing an estimated 3300 tons of uranium. In 1984, an interim cap providing an additional cover of compacted clay overlain by a 45-mil-thick Hypalon liner was installed to minimize vertical migration of water.

- Waste Pit 5 - constructed in 1968 and served as a settling pond for slurried waste from various production processes. It contains an estimated 55 metric tons of uranium and 19 metric tons of thorium. It is a maximum 29-foot-deep surface impoundment lined with a 60-mil-thick elastomeric membrane. Waste Pit 5 has been out of service since 1987. Only rainfall currently enters Waste Pit 5, flowing by gravity from the waste pit through a closed pipe to the Clearwell.

- Waste Pit 6 - constructed in 1979 and contains approximately 10,929 tons of waste, with an estimated 950 tons of uranium. The waste pit, a 24-foot-deep surface impoundment lined with a 60-mil-thick elastomeric membrane, has been out of service since 1985 and has not been covered. Standing water remains trapped within the berms of the waste pit. As with Waste Pit 5, only rainfall currently enters Waste Pit 6.

- Burn Pit - excavated in 1953 as a clay borrow pit for lining Waste Pits 1 and 2. The depth and size of the pit are not precisely known, but it is believed to be approximately 20 to 26 feet deep. The pit was subsequently used for the disposal and burning of laboratory chemicals, waste oils, and other low-level radioactivity-contaminated materials such as wooden pallets. The residual waste quantities are not known. The burn pit is not lined, but it is covered. The actual depth of the cover is not known.

- Clearwell - served as a settling basin for process water and storm water runoff from the waste pits. Most recently, the Clearwell was used as a final settling basin for process water that passed through Waste Pit 5 before its discharge to the Great Miami River via the NPDES permitted discharge. This use was terminated in March 1987 when Waste Pit 5 was removed from the process water treatment scheme. The Clearwell currently receives surface water runoff from the majority of the surfaces of Waste Pits 1, 2, and 3 and from the entire surface of Waste Pit 5. Water of varying depth remains in the Clearwell at all times. The sediment resulting from material deposition was removed on at least one occasion during the late 1960s or early 1970s. Measurements indicate the presence of approximately 11 feet of sludge at the bottom of the Clearwell.

1.3.2.3 Operable Unit 2

Addressed under Operable Unit 2 are the following waste units (Figures 1-3 and 1-7): the solid waste landfill; the lime sludge ponds; an inactive flyash pile; an active flyash pile for the disposal of flyash from the FEMP coal-fired boiler plant; and the South Field, an area between and adjacent to the flyash piles. The contents of their waste units are described below and presented in Table 1-8.

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- Active Flyash Pile - until recently, received flyash from the coal-fired boiler plant at the FEMP site (flyash is currently disposed in a local landfill). This disposal area is located east of the running track and on the east side of the south construction road, as shown in Figure 1-3. The active flyash pile is a roughly hexagonal area of approximately 50,000 square feet with a maximum height of 30 feet and contains approximately 58,800 cubic yards of fill volume. The SSOD runs along the southeast side of the area. Waste oils were periodically sprayed onto this flyash pile for dust control. Data from samples of the surficial materials confirm that radiological contaminants are present in the active flyash pile, most likely from the spreading of these oils.

- Inactive Flyash Pile - located approximately 3000 feet south/southeast of the waste storage area, northwest of the active flyash pile, and west of the South Field. The inactive flyash pile is no longer used and contains approximately 78,500 cubic yards of flyash from the coal-fired boiler plant. It is sparsely covered with soil and vegetation. Waste oils were applied to the flyash for dust control resulting in approximately 2200 pounds of uranium present due to the spreading of these oils.

- South Field - located between the two flyash piles where construction rubble was dumped on the surface of the glacial overburden. The thickness of the overburden in this area ranges from 0 to 10 feet. The thickness of the fill increases at the western and southern edges of the area to approximately 20 feet, because material was dumped down the natural slope of an old meander scar. A review of the shallow trenches through the fill indicates that the material is predominately soil with some rock and concrete and occasional pieces of wood. The construction rubble deposited in the South Field contained low levels of radioactive materials; results of trenching activities indicate that these buried materials are within the top 4 feet of soil.

- Solid Waste Landfill - located on a 1-acre tract at the northeast corner of the waste storage area and northwest of the former production area. The landfill is organized into five cells which are full and out of service. The total volume of waste in the five cells is estimated to be 19,600 cubic yards with approximate dimensions of 280 by 175 feet and a depth of 13 feet. The solid waste landfill is not lined. Some waste was buried east of the cells, but this waste is considered part of the landfill. The total volume of materials in the landfill, including cover, is 25,000 cubic feet.

  The solid waste landfill was used through early 1986 for the disposal of cafeteria wastes, rubbish, and other wastes from nonprocess areas. Other materials reportedly disposed of at the landfill include: burnable wastes (bagged trash and wood); possibly burnable wastes (respirator cartridges, asphalt roofing materials, medical wastes, firehoses, and rubber hoses/belts; and nonburnable wastes (unidentified high-activity waste, medicine vials, bagged asbestos, ceramic tile, possibly magnesium fluoride, glass acid bottles, steel cables/cans, paint cans, and copper tubing).

- Lime Sludge Ponds - consist of two ponds, north and south. The north lime sludge pond is an active, unlined pond located near the southeast corner of the waste storage area with approximate dimensions of 125 by 225 feet by 5.3 feet deep, with a total volume of approximately 5500 cubic yards. This pond is approximately 90 percent full, is partially covered with water, and contains an estimated 150,000 gallons of liquid, with the depth ranging from 1 to 7 feet. Spent lime sludges (primarily lime-alum and boiler plant

blowdown) from the FEMP water treatment plant operations have been conveyed to this active pond.

The south lime sludge pond is an inactive, dry, unlined pond located directly south of the north pond. The approximate dimensions of the pond are 125 by 225 feet by 11.3 feet deep, with a total volume of approximately 11,700 cubic yards. This pond is retired and overgrown with grass. The use of this pond was similar to that of the north lime sludge pond.

Data gathered in Operable Unit 2 indicate the areas hold large volumes of solid waste into which small volumes of radiological and/or chemical wastes may have been codisposed. A review of the RI/FS sampling data for the active and inactive flyash piles and the South Field indicates concentrations of uranium-238 in all media.

1.3.2.4 Operable Unit 3

As previously mentioned in Section 1.2, Operable Unit 3 includes the former production area and all above- and belowground production-associated facilities and equipment encompassing structures, utilities, drums, tanks, solid waste, product, thorium, effluent lines, wastewater treatment and fire training facilities, scrap metal piles, feedstock, and the coal pile. In total, the operable unit includes 11 component categories (types of buildings, piping, or other structure) and approximately 227 separate components.

1.3.2.5 Operable Unit 4

Waste units in this operable unit consist of two earthen-bermed concrete silos (Silos 1 and 2) containing K-65 residues, which are high-specific-activity, radium-bearing residues resulting from the pitchblende refining process; one concrete silo containing metal oxides (Silo 3), and one unused concrete silo (Silo 4), all located in the southwest portion of the waste pit area (Figure 1-3). The domed waste storage silos measure 80 feet in diameter, 36 feet high to the center of the silo dome, and 27 feet to the top of the vertical walls. The walls are 8-inch-thick concrete as are the outer part of the domes, which taper to 4 inches in thickness at the center. The floor of the silos consists of a 4-inch layer of concrete overlying an 8-inch layer of gravel containing a leachate collection system of 2-inch-diameter slotted pipe. Silos 1 and 2 are surrounded by an earthen berm to a height of approximately 26 feet, while Silos 3 and 4 are freestanding.

Silos 1 and 2 were used for the storage of radium-bearing residues formed as by-products of uranium ore processing from 1952 to 1958. Waste raffinates were pumped into the silos, where the solids

would settle. The free liquid was decanted through a series of valves placed at various levels along the height of the silo wall. Settling and decanting continued until the silos were filled to approximately 4 feet below the top of the vertical wall. Table 1-9 details the volumes and types of waste associated with Operable Unit 4.

Corrective actions have been performed to maintain the integrity of Silos 1 and 2. These included repairing the walls and constructing a berm on a 1-1/2 to 1 slope (mid-1960s) and enlarging the berm to a 3 to 1 slope in the early 1980s. In 1985 a structural assessment was performed that revealed that the walls and base slabs were structurally stable and could function as containment of dry solids for a period of 10 to 15 years. However, the center 20-foot section of the domes was determined to be structurally unsound for a load greater than the existing static load. Remedial actions taken since 1985 include placement of protective covers of steel and plywood over the center portion of each silo dome and in 1987, placing three inches of rigid polyethylene foam topped by a 45-mil waterproof, ultraviolet-resistant, urethane-finish coating over each silo dome to provide weather protection and insulation. A radon treatment system was implemented for this project to reduce radiation exposure to the workers during the installation process. In 1991, a layer of bentonite clay was inserted over the residues in Silos 1 and 2 to reduce the radon levels and to provide protection in the event of silo dome collapse. This was done under Removal Action No. 4 (see Table 1-14).

Silos 3 and 4 were constructed in 1952 and were designed to receive dry materials only. Waste raffinate slurries from refinery operations were dewatered in an evaporator and spray calcined to produce a dry waste form for storage in the silo. The waste was blown in under pressure to fill Silo 3, but Silo 4 was never used and remains empty today (DOE 1990). Major contaminants in Operable Unit 4 are radium, thorium, lead, radon, and arsenic.

1.3.2.6 RCRA Regulated Units

The RCRA program at the FEMP originally identified a total of 53 hazardous waste management units (HWMUs); 46 not currently being used for hazardous waste management (inactive) and 7 still in use (active). The HWMU term is used at the FEMP to indicate a unit used to treat, store, or dispose of hazardous wastes and therefore regulated under RCRA and State of Ohio regulations. Depending on the location, configuration and operational history of these units, they represent potential sources of contamination to the environmental media of Operable Unit 5.

Seven of the inactive units were recently reclassified, with concurrence from OEPA, from HWMUs to solid waste management units. This redesignation was the result of additional investigations conducted at the FEMP. Table 1-10 summarizes the pertinent information for these units. The following paragraphs outline the currently anticipated approach to HWMU closures at the FEMP.

Inactive HWMUs

Closure plan information and data (CPID) documents have been submitted for 17 of the 39 inactive HWMUs, in compliance with RCRA closure requirements identified in the Stipulated Amendment to the Consent Decree of January 1993. CPID documents specify procedures to be followed to accomplish closure of HWMUs and each plan constitutes a partial closure of the FEMP facility.

These 17 units, on the basis of process knowledge or structural configuration, are anticipated to have limited or no associated contaminated environmental media as a result of releases from the units. Clean closure is anticipated to be complete before initiation of CERCLA remedial activities. Final dismantlement of the structural components of these 17 HWMUs will be performed concurrently with the implementation of CERCLA response actions for Operable Unit 3. In the event that significant quantities of contaminated environmental media are detected during the closure process of one of these 17 units, further attempts to clean close the unit(s) will be suspended. In such case, final cleanup of the environmental media associated with the unit(s) will be undertaken through an integrated closure-response action process (see Section 1.5.3). Table 1-11 summarizes pertinent information on these 17 HWMUs.

The remaining 22 inactive HWMUs are currently planned to be closed through an integrated process coupling OEPA hazardous waste regulations with the CERCLA response action process (see Section 1.5.3). Table 1-12 summarizes the pertinent information for these HWMUs. These 22 units were identified for consideration for use of an integrated closure-response action process because the majority of these units are integral components of the former production area structures or facilities. Therefore, it is impractical from the standpoints of cost, schedule, and potential for releases to the environment to pursue clean closure apart from remediation of these structures and facilities. The planned approach will integrate the remedial actions being undertaken by Operable Units 1, 3 and 5. Subject to the terms of an Interim ROD for Operable Unit 3, decontamination and dismantling of the former production area buildings and facilities will begin before completion of the Operable Unit 3 RI/FS. As the decontamination and dismantling activities involve HWMUs, RCRA closure

requirements will be an integral part of the CERCLA interim action. Where the excavation of contaminated soil is necessary to fulfill closure requirements, the treatment, storage, disposal, and closure certification activities will require coordination between Operable Units 1 or 3 and Operable Unit 5 efforts. The Operable Unit 5 FS and Remedial Design/Remedial Action Work Plans must reflect an accommodation of HWMU closure considerations.

Active HWMUs

The seven active HWMUs, used for storage of hazardous wastes and listed in the FEMP RCRA Part B Permit Application, are needed to support initial CERCLA remedial actions. Table 1-13 summarizes the pertinent information for these units. Final decontamination and demolition of these units will be deferred until such storage is no longer required. At such time, a notice of intent to close these units will be submitted to OEPA.

1.3.3 History of Contamination in the Great Miami Aquifer

In November 1981, Ohio Department of Health (ODH) sampling and analysis of private wells south of the FEMP site detected elevated beta activity at three locations. ODH notified NLO, DOE's site operating contractor at the time. OEPA and NLO resampled two of the original wells for independent analysis (the third original well could not be resampled due to a damaged hand pump). Two additional wells were also sampled. Subsequent NLO analysis of the two original wells high in beta activity showed that the beta was due to potassium-40. However, one of the two additional wells sampled was analyzed and found to contain uranium at a concentration of 190 ppb. In December 1981, 10 additional off-property wells were sampled and subsequent analysis showed that two contained uranium at concentrations of 54 and 320 ppb. All affected homeowners were notified and NLO continued periodic sampling and analysis, reporting results to the ODH.

In 1982, DOE entered into an Interagency Agreement with the United States Geological Survey (USGS). During 1982 and 1983 the USGS collected hydrogeologic data from wells in the FEMP vicinity and conducted additional sampling and analysis, verifying the suspected off-property contamination of groundwater.

In 1985, NLO determined the potential source of the off-property contamination. The production area, waste pit area, and active and inactive flyash piles were identified as potential sources. As discussed in Section 1.3.1.3, the runoff from these areas originally discharged directly to the SSOD

and Paddys Run and it was known that portions of these streams recharged the Great Miami Aquifer. In addition, maps of a uranium plume indicated that the highest level of contamination began in the South Field near the intersection of Paddys Run and the SSOD (Dames and Moore 1985).

Continued groundwater monitoring over the past several years has led to the identification of the South Groundwater Contamination Plume, an area immediately south of the FEMP site with known levels of uranium contamination. Contamination from the site flows with the groundwater, generally to the east and south, toward the Great Miami River. Greater detail on the hydrogeology of the FEMP site is found in Section 3.0. Additional information concerning the actions taken by DOE to manage the plume are provided in Section 1.3.4.

Since July 1990, DOE has provided alternate potable water supplies to homeowners whose private wells have been impacted by the South Plume. This action is, however, considered only a temporary solution. The preferred alternative is to provide homeowners whose wells withdraw water from the South Plume portion of the aquifer with water from a permanent, reliable and safe public water supply. Accordingly, DOE has committed to providing its fair share of the cost for installation of public water mains in the South Plume area. This funding is in conjunction with the Hamilton County Department of Public Works, the agency responsible for coordinating all water supply within Hamilton County.

The overall project involves the installation of approximately 14 miles of pipeline within Hamilton and Butler counties and the construction of a water storage tank. The estimated duration of the entire project is two years. The overall schedule is contingent on Hamilton County's construction schedule, but the tentative completion date of the public water supply is currently estimated for early 1995.

1.3.4 Removal Actions and Other Contamination Abatement Measures

Removal actions, as discussed in Part 40 CFR Title 300.415, are primarily intended to abate, minimize, stabilize, mitigate or eliminate a release of hazardous substances, pollutants, or contaminants before a final remedial action. These actions are typically initiated during the RI/FS to accelerate cleanup actions to address releases of hazardous substances. Thirty removal actions and other abatement measures have been completed or are underway at the FEMP site to reduce discharges of hazardous substances.

Table 1-14 provides a list of removal actions identified at the FEMP site. The following section briefly introduces the removal and abatement actions which directly impact Operable Unit 5. Additional detail on the projects is available in the Administrative Record.

1.3.4.1 Contaminated Water Beneath FMPC Buildings (Removal Action No. 1)

This removal action was initiated to minimize the potential for uranium-contaminated groundwater to infiltrate the underlying aquifer from the perched water zones located beneath some former production buildings. "Perched" water is present in isolated pockets within the layers of clay-rich glacial soil that exist above the Great Miami Buried Valley Aquifer near the FEMP site.

Perched water zones beneath Plants 2/3, 6, 8, and 9 are of concern due to the discovery of significant concentrations of uranium and VOCs. To minimize the potential for the movement of contaminated water in these zones to the underlying aquifer, a series of wells were installed to extract the perched groundwater for treatment. The extracted water is then treated.

A treatment system installed at Plant 8 uses activated carbon filters to remove volatile organic compounds from the extracted water. The water is then processed through the FEMP's existing water treatment system for the removal of uranium and is eventually discharged to the Great Miami River. Treatment of perched groundwater will continue in this manner until the AWWT system is operational and replaces this function in early 1995.

This removal action was conducted pursuant to the terms of the Amended Consent Agreement and in accordance with authorities granted to DOE under Section 104 of CERCLA by Executive Order 12580.

1.3.4.2 Waste Pit Area Runoff Control (Removal Action No. 2)

This removal action involved the installation of a runoff control system to collect storm water runoff from the waste pit area (approximately 26 acres, including the Operable Unit 4 study area) and direct it through treatment systems at the FEMP site before discharge to the Great Miami River. Storm water sampling initiated in the late 1980s indicated that significant concentrations of radionuclides were flowing to Paddys Run in storm water runoff from areas surrounding the waste pits that did not flow to the Clearwell. An engineering evaluation/cost analysis (EE/CA) that evaluated options for controlling surface water discharge to Paddys Run from the waste pit perimeter and identified the

preferred alternative area was approved by EPA in September 1990. This led to a project that later became a removal action to control this runoff. The project consisted of a series of trench drains, curbs, gutters, and storm sewers that direct the storm water runoff from the waste pit perimeter areas to a central collection sump. From the sump, the runoff is pumped to the BSL for treatment and discharge. This removal action was completed in the summer of 1992 pursuant to the terms of the Consent Agreement and in accordance with authorities granted to DOE under Section 104 of CERCLA by Executive Order 12580.

1.3.4.3 South Groundwater Contamination Plume (Removal Action No. 3)

An EE/CA document was prepared by the FEMP to support the identification of the most feasible alternative to prevent or minimize the further migration of contamination within the South Plume toward additional receptors farther south and to protect public health by limiting access to existing areas of contamination within the plume. The EE/CA, as supplemented by the Explanation of Significant Differences, was approved by the EPA in January 1992.

The EE/CA provided for the implementation of the removal action in five parts. Part 1 provides for an alternate water source to an industry affected by the contamination plume. This portion of the project involved the installation of production wells outside the plume area and a water supply system to the affected industry. Construction was completed in December 1992 and OEPA approval to begin operation was received in March 1993. A 60-day operating acceptance period was successfully completed May 24, 1993. Another affected industry, which uses a minimal amount of water, will be provided with an alternate water supply by being connected to the proposed public water system (see Section 1.3.3).

In Part 2, DOE would provide a hydraulic barrier to prevent further migration of the contamination plume. This involved the installation of a groundwater recovery well system to extract and pump groundwater from the South Plume through a force-main pipeline back to the FEMP site for monitoring and subsequent discharge to the Great Miami River. The groundwater recovery well system became operational August 27, 1993. The present pumping rate of the system is 1500 gpm.

A new effluent outfall pipeline was also installed under Part 2. Use of the FEMP's original effluent outfall pipeline to the Great Miami River was discontinued as of May 1, 1993, due to its age and

limited capacity to handle future flow. The new outfall pipeline parallels the original outfall pipeline to the Great Miami River. Other Part 2 work also included increasing the pumping out capacity at the SWRB to reduce the potential for future overflow of the basin. This work was completed in July 1993.

In the draft EE/CA document issued to the public for review, DOE stated that the water from these recovery wells would be of such low uranium concentrations (fewer than 30 parts of uranium per billion part of water) that it would not be economically feasible to treat this water. Therefore, DOE suggested to the public and to the EPA and OEPA that the groundwater be pumped and discharged directly to the Great Miami River without treatment. As a result of a public comment period and regulatory agency comments on the EE/CA, DOE agreed that the additional pounds of uranium that would be entering the river was unacceptable. DOE then developed the "equivalent mass concept" with support from the EPA and OEPA. This concept calculated the amount of uranium discharged from the FEMP in recent years and the amount of additional uranium the South Plume and other removal actions would contribute to that total. The objective of the "equivalent mass concept" was to ensure that uranium discharges to the river would not increase due to the removal actions, and in fact that they would be reduced and continue to decrease progressively in future years.

This led to the addition of Part 3 to the removal action. Part 3 involves construction of an IAWWT system that removes additional uranium from site wastewater streams and, thereby, reduces the amount of uranium discharged to the Great Miami River. This treatment capacity compensates for the additional discharges of uranium from the South Plume and other removal actions.

Two trailer-mounted ion-exchange IAWWT facilities and associated support systems comprise the treatment unit located near the SWRB. This system became operational in July 1992. A second IAWWT unit is located at the FEMP's existing biodenitrification effluent treatment building.

Part 4 of the removal action involves groundwater monitoring and institutional controls to prevent the use of contaminated groundwater. This activity is being implemented through the FEMP's existing groundwater monitoring program, including more frequent monitoring of private wells located near areas of known contamination.

Part 5 involves additional groundwater investigations in the vicinity of the South Plume to identify the location and extent of any remaining contamination attributable to the FEMP site in the groundwater south (downgradient) of the recovery wells installed under Part 2. Because the EPA has issued a proposed limit of 20 ppb for uranium in drinking water, the Part 5 investigation is attempting to identify the location of the leading edge of the plume exceeding the 20 ppb level.

This removal action was also conducted pursuant to the terms of the Amended Consent Agreement and in accordance with authorities granted to DOE under Section 104 of CERCLA by Executive Order 12580.

1.3.4.4 Contaminated Soil Adjacent to the Sewage Treatment Plant Incinerator (Removal Action No. 14)

Removal Action No. 14 was initiated in August 1992 to address contaminated soil with elevated levels of uranium adjacent to a retired incinerator at the FEMP sewage treatment plant. The removal action is also being conducted under the terms of the Amended Consent Agreement and in accordance with authorities granted to DOE under Section 104 of CERCLA by Executive Order 12580. The scope of the action is to remove soil exhibiting uranium concentrations above a project-specific threshold. On-property excavations were completed in November 1993. A localized area of contamination was detected off-property adjacent to the incinerator. Excavation of the localized off-property contaminated soil was completed in January 1994. All excavated soil was containerized and transferred to the controlled area at the FEMP site for storage. Verification sampling, however, indicated the presence of additional off-property contamination. Excavation of this additional material is currently scheduled for July 1994.

1.3.4.5 Collect Uncontrolled Production Area Runoff (Removal Action No. 16)

Removal Action No. 16, completed in August 1993, included the installation of drainage control structures and regrading to control the storm water runoff from additional areas around the perimeter of the production area. Storm water from these areas was redirected to the existing storm water system and the SWRB. This removal action was also conducted pursuant to Section 104 of CERCLA and the Amended Consent Agreement.

1.3.4.6 South Plume Interim Treatment

The DOE agreed to conduct a supplemental environmental project with the objective of reducing uranium discharges from the FEMP site to the Great Miami River. As part of this project, one

additional IAWWT unit will be installed to treat 200 gallons of water per minute of South Plume discharge. This system was started up in March 1994 and is further reducing uranium discharges to the river.

In addition, the lifespan of the existing IAWWT unit at the SWRB will be extended and this unit will be converted to treat additional South Plume water instead of storm water, which will be treated at the AWWT facility beginning in January 1995. The treatment capacity of this unit, scheduled to go on line in January 1995, will be increased from 300 gpm to 400 gpm. This effort is also expected to further reduce uranium discharges.

For approximately six months per year when no storm water is available, effluent from the South Plume water treatment will be treated through Phase I of the AWWT. This will provide an additional 350 gpm of treatment capacity.

DOE will also eliminate treatment of low-uranium streams from Phase II of the AWWT project. This includes the sewage treatment plant and the "clean side" of the general sump. The additional capacity will be used to treat South Plume water at a rate of 200 gpm, which will further reduce uranium discharge to the river beginning in March 1995.

1.3.4.7 Advanced Wastewater Treatment (AWWT) System

To achieve compliance with DOE Order 5400.5, "Radiation Protection of the Public and Environment," the FEMP initiated construction of the AWWT plant. The plant will consist of the two treatment trains with a capacity of 700 (Phase I) and 400 gpm (Phase II), respectively. Each train consists of clarification with flocculation, filtration, carbon filtration and ion exchange. The 700-gpm train will primarily treat collected storm water. When no storm water is available the train will treat the South Plume groundwater. The 400-gpm train will treat existing wastewater, future remediation wastewater flow, and South Plume groundwater. The scheduled operational date of the AWWT plant is January 1995.

1.3.4.8 Storm Water Retention Basin

Consistent with the terms of the Ohio Director's Findings and Orders, the FEMP constructed a SWRB to collect storm water runoff from the production area and the parking lot to provide retention

for a 10-year, 24-hour duration storm event. Only in the event of an overflow of the SWRB would storm water from the production area and parking lot enter the SSOD.

The system consists of a two-chambered basin with a total capacity of 10 million gallons. The west chamber of the basin was operational in December 1986 and the second chamber in December 1988. Storm water is pumped to the IAWWT facility before monitoring and discharge to the Great Miami River via the FEMP outfall pipeline. Beginning in January 1995, the storm water collected in the SWRB will be treated at the AWWT facility. Cleaning and repairs to liners were performed at both chambers of the SWRB in the spring of 1994.

1.3.4.9 Surface Water Control of the Plant 1 Pad

Before this project was undertaken in 1988, the majority of storm water runoff that is now controlled in the Plant 1 pad area flowed west through the waste storage area and into Paddys Run. Sampling results from the BMP showed contamination levels high enough to warrant immediate action. The Plant 1 storage pad was modified to include a curb around its periphery. In addition, flow in drainage ditches in the vicinity was reversed or blocked and several new connections to the existing storm sewer system were installed.

1.3.4.10 Pilot Plant Warehouse Sump (Removal Action No. 24)

Historically, the storm water discharges from the southwest corner of the former production area (the area surrounding the pilot plant) were discharged to a drainage ditch directly west of the pilot plant and subsequently directly to Paddys Run. It is assumed that this was done because the topography would not allow gravity flow to the storm sewer system, which discharged to the SSOD. In 1962, the runoff in this drainage ditch was found to contain elevated levels of radionuclides. Actions were then taken to collect this flow and pump it to the general sump for treatment.

It was noted several times that the pumping system was not operating. In 1989, actions were taken to investigate the flows discharging to the sump. In October 1991, the sump overflow was plugged but the pump was not operational. It is suspected that water accumulating in the sump and in the saturated ground surrounding the sump continued to migrate to the overflow line by seeping around the plug or by flowing directly into the line downstream of the plug. In May 1994, the pump was repaired and tested but proper procedures for its operation are not yet in place.

1.4 PRIOR INVESTIGATIONS AT THE FEMP SITE

Numerous environmental investigations have been conducted in and around the FEMP site by DOE and other organizations. The following paragraphs describe the most pertinent of these studies that were used in scoping the RI/FS and in the preparation of the RI/FS Work Plan.

1.4.1 Geologic Investigations

Geologic investigations of the area that surrounds and includes the FEMP site have contributed substantial information to the RI/FS investigation. Fenneman (1916) performed an extensive survey of the geology in the Cincinnati area. This report is among the first that describes in detail the interbedded limestone and shale bedrock and its mantle of glaciofluvial and alluvial sediments that constitute the buried-channel aquifers in southwestern Ohio. Later investigators such as Durrell (1961) supported Fenneman's observations. The shape of the buried-channel aquifer was further refined by Watkins and Spieker (1971) via geophysical surveys of the area around Fernald. More recent information includes various maps of the geology of Hamilton and Butler counties, Ohio, as well as individual quadrangle maps of areas located in those counties (Leow 1985; Vormelker 1985; Ford 1974; Swinford 1990). Maps showing the extent and age of glacial till in the Operable Unit 5 study area have also been produced (Brockman 1988).

1.4.2 Surface Water and Sediment Investigations

The Miami Conservancy District has maintained precipitation and runoff records for the Miami River Valley since the early 1900s (Houck 1921). Precipitation records have also been kept at the Greater Cincinnati/Northern Kentucky International Airport. Flood information for the Great Miami River and Paddys Run is available from the Federal Emergency Management Agency (FEMA 1982). Additional information on most Ohio streams, including the Great Miami River and Paddys Run, has been well documented with respect to flow duration and water quality (Cross and Hedges 1959; OEPA 1982).

Flow from the drainage basin is monitored by the USGS using a gauging station on the Great Miami River at Hamilton, Ohio. Flow regulation on the Great Miami River has been studied by Spieker (1968a); Paddys Run data have been compiled by Dames and Moore (1985). Realignments and other modifications of Paddys Run and its tributaries on the FEMP site have been documented by Dove (1961) and WMCO (1987). Surface water quality data have been collected for the FEMP area for the

period 1979 through the present as part of the site environmental monitoring program at the FEMP. The OEPA collected water quality data during the period of 1977 through 1983.

In 1988, under the terms of a Director's Findings and Orders issued by the State of Ohio, sampling was performed by FEMP personnel from a series of drainage ditches and storm water manholes on the FEMP property. Data from this study were primarily used to support projects and removal actions to better control runoff but also used to support the description of the nature and extent of contamination described in Section 4.0.

1.4.3 Surface Soil Investigations

The Soil Conservation Service (SCS) has performed detailed soil surveys of Butler and Hamilton counties, including the environs of the site (USDA 1980, 1982). Also, during 1986 and 1987, a comprehensive environmental investigation, the Characterization Investigation Study (CIS) (Weston 1986, 1987), was performed at the FEMP site. The CIS involved the investigation of the FEMP waste storage areas. During the CIS, samples were collected from the waste units themselves and the surrounding surface soil and drainage ditches leading to Paddys Run. The results of validated surface soil and sediment samples collected during the CIS have been used to support the description of the nature and extent of contamination presented in Section 4.0.

1.4.4 Hydrogeologic Investigations

Dove (1961) and Spieker (1968a) have extensively described the hydrology and hydrogeology of the Great Miami Aquifer in the lower Great Miami River Valley. These studies document recharge rates, permeabilities of various lithologies, and other aquifer characteristics. Both studies also discussed groundwater/surface water interactions, specifically for the Great Miami River and Paddys Run. Other studies of the regional valley-fill aquifer in the vicinity of the FEMP site include a study by the Miami Conservancy District (1985), several studies by the Ohio Department of Natural Resources (Walker 1986; Walton and Schaefer 1956), and various contracted studies (GeoTrans 1985; Dames and Moore 1985; ATEC Associates, Inc. 1982). Two other studies by Spieker (1968b, c) deal with the potential effects of increased pumping of the groundwater and future development of the groundwater resources, respectively.

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1.4.5 Environmental Surveys and Studies

Several environmental surveys and studies have been performed at the FEMP site and in the surrounding area since the plant began operations in 1951. The site's environmental monitoring program began — albeit on a very limited basis — in the early 1950s. Air samples were collected around the perimeter of the production area by using gum papers, and the collected particulates were analyzed for uranium. Sampling of the Great Miami River coincided with the beginning of operations, and the results were forwarded to the ODH. The program has expanded over the years in response to the evolving standards and DOE administrative orders. Today, the program samples a variety of environmental media in addition to biological resources. The results are presented in the Annual Site Environmental Report and are discussed in applicable sections of this RI Report.

Many of the studies focused on the Great Miami River and, to a less extent, Paddys Run. In 1951, Tarzwell studied the populations of fish at three locations in the Great Miami River before the FEMP site began operations. At each location, he made several collections for both large and small fish by netting and seining. He made two collections at the Venice bridge, where Route 126 crosses the river. The second sampling location was just downstream of New Baltimore, where he made three separate fish collections. Tarzwell's third collection point was just below the Miamitown bridge. Tarzwell also seined three sections of Paddys Run in late summer of 1951 to collect fish for species identification and uranium analysis. Samples were collected upstream and downstream from the proposed FEMP site and just above the confluence with the Great Miami River. Results including species, weight, and length have been summarized in Appendix J.1.

Pomeroy (1977) analyzed fish species composition in the river above, adjacent to, and below the FEMP effluent discharge. He also surveyed fish species and benthic macroinvertebrates present in a section of Paddys Run at the northwest corner of the FEMP property. Species diversity was used to gauge stream health.

A total of 106 species of fish, including six hybrids, have been recorded from the Great Miami River from 1900 to 1978 (Trautman 1981). Bauer et al. (1978) sampled the entire length of Paddys Run for diversity and species abundance. A total of 22 species was recorded with shiners and darters dominating the stream community. The phytoplankton in the New Baltimore area of the Great Miami River was sampled and described by the USGS between 1974 and 1982 (USGS 1992).

The OEPA conducted intensive fishery surveys along 91 miles of the Great Miami River and the lower reaches of five tributary streams in 1980 and 1989 (OEPA 1982, 1989c). Fish collected from the lower mainstem of the Great Miami River and five tributaries are presented in Appendix J.1, Table J.1-7.

The biological assessment of the Great Miami River conducted by the OEPA contained a relative abundance analysis which examined percent similarity (which reveals areas of similar and dissimilar community composition) and relative species composition based on numbers and weight. These analyses were applied to all reaches along the river, including the segment (Segment 10 - RM 24.7 to RM 9.2) that could potentially be affected by FEMP effluent and runoff. The FEMP effluent line lies at RM 24.1, and is one of only two significant industrial point source discharges downstream from the Hamilton-Fairfield area. Paddys Run, which receives uncontrolled runoff from the FEMP site, enters the Great Miami River at RM 19.5. Data compiled (July 1989 through September 1989) by the OEPA Ecological Assessment Section reveal similar findings for the fish community from RM 8.2 through 23.4 (OEPA 1992a).

For more than 10 years, the environment in and around the FEMP site has been closely monitored by DOE (Battelle et al. 1977; DOE 1985a, 1987), Oak Ridge Associated Universities (ORAU 1985), various FEMP-related committees (WMCO 1986, 1987; Fleming and Ross 1984), and various contracted agencies (IT Corporation 1986; Weston 1986; Battelle 1981). A continuous sampling and analysis program to comply with RCRA requirements is ongoing at the FEMP site.

Furthermore, from January 1985 through 1988, the ODH — through a cooperative agreement with DOE — conducted a special environmental monitoring program on and around FEMP property. The Ohio Department of Health and the FEMP continue to conduct a split-sampling program; sediment samples are split on an annual basis, while surface water, groundwater (private homeowner wells near the site), and milk samples are split on a quarterly basis. These results are published in the Annual Site Environmental Report.

1.4.6 Vegetation and Wildlife Studies

Vegetation and wildlife in the FEMP study area have been studied and characterized by WEMCO, NLO, and OEPA. WEMCO performed two studies of the fish that are indigenous to Paddys Run and the Great Miami River in the vicinity of the FEMP site (WMCO 1986, 1987). The OEPA (1982)

performed a more comprehensive study of the aquatic environment in the Great Miami River. A recent study by Facemire et al. (1990), under contract to the site operator, described the general terrestrial and aquatic environments of the FEMP site and surrounding areas. The database compiled in this study is the most complete characterization of the environmental resources available.

1.4.7 Contaminant Releases at the FEMP

Dove and Norris (1951) were the first to describe the possible fate of chemical and radionuclide releases that infiltrate the groundwater in the Great Miami Aquifer. Publications released in the last several years document radionuclide migration from the FEMP site into the environment. These studies are from either DOE (1985) or are internal NLO/WMCO documents (Boback et al. 1985, 1986; Clark et al. 1989; WMCO 1986, 1987, 1988, 1989, 1990, 1991; WEMCO 1992; FERMCO 1993). Spieker and Norris (1962) investigated radionuclide contamination of the groundwater and the transport of the contaminated water through the Fernald, Ohio area. Additionally, the ODH has documented radionuclide contamination in private wells in the FEMP area (ODH 1988). Sedam (1984) investigated the occurrence of uranium in the groundwater in the vicinity of the FEMP site for the DOE. Starkey et al. (1962) and NLO (Spenceley 1983) performed internal investigations to distinguish between FEMP and non-FEMP contamination.

1.5 PROJECT BACKGROUND

This section of the report describes the regulatory history of the site. This description along with earlier portions of Section 1.0 will explain the logic used to identify data needs that provided the stimulus for the Operable Unit 5 RI.

1.5.1 Regulatory Agency Agreements

Over the past ten years, DOE has worked with EPA and OEPA to develop a framework to achieve environmental compliance at the FEMP site. The following is an overview of these efforts.

EPA

On March 9, 1985, the EPA issued a Notice of Noncompliance to DOE identifying its concerns regarding potential environmental impacts associated with the FEMP site's past and present operations. Between April 1985 and July 1986, conferences were held between DOE and EPA representatives to discuss the issues and to identify the steps DOE proposed to take to achieve and maintain environmental compliance.

On July 18, 1986, the Federal Facility Compliance Agreement (FFCA), detailing actions to be taken by DOE to assess environmental impacts associated with the FEMP site, was signed by DOE and EPA. The FFCA was entered into pursuant to Executive Order 12088 (43 FR 47707). The FFCA was intended to ensure that environmental impacts associated with FEMP activities would be thoroughly and adequately investigated so that appropriate remedial response actions could be formulated, evaluated, and implemented. As required by the FFCA, a site-wide RI/FS was initiated in July 1986 pursuant to CERCLA.

In November 1989, the FEMP site was placed on the National Priorities List (NPL) for investigation and remediation under CERCLA. This placement, in addition to progressive findings in the RI/FS program, necessitated the amendment of the existing agreement between DOE and EPA. The 1986 FFCA was amended by a Consent Agreement under Sections 120 and 106(a) of CERCLA (Consent Agreement) providing for the implementation of the operable unit concept for the FEMP RI/FS and revising the milestone commitments for the RI/FS program without modifying the underlying objectives in the FFCA. The Consent Agreement was signed on April 9, 1990, and became effective on June 29, 1990, following a period of public comment. The Consent Agreement also provided for the implementation of removal actions.

In early 1991, an initial version of the Operable Unit 5 RI Report was prepared. However, an Amended Consent Agreement signed by DOE and EPA on September 20, 1991 significantly expanded the definition of Operable Unit 5 through the addition of soil and perched groundwater inside the former production area (Operable Unit 3) and revised the schedules for completing the RI/FS for the five identified operable units. This 1991 Amended Consent Agreement became effective on December 19, 1991, following a period of public review. This rescoping of Operable Unit 5 required the preparation of a revised RI Report.

OEPA

On March 11, 1986, OEPA filed a complaint against the DOE citing various RCRA violations. Subsequently, OEPA issued Director's Findings and Orders (DFOs) on June 26, 1987. The DFOs identified regulatory requirements including proper storm water management, BSL liner replacement and operation, restrictions for placement of waste in Waste Pit 5 and the Clearwell, a best management practices plan, implementation for the control of industrial and other wastes to be

managed and potentially discharged from the FEMP site, and a study of environmental impacts associated with wastewater discharged off site.

After demonstrating progress on addressing the DFOs and upon further negotiations, OEPA and DOE entered into a Consent Decree (CD) without the admission or adjudication of any issue of fact or law (CD, December 1988). The CD included requirements for proper waste characterization, control of wastewater and runoff in the waste pit area, characterization of Waste Pit 5, hazardous waste management, and groundwater assessment.

On April 5, 1990, OEPA filed contempt of court charges against DOE and WEMCO for violation of the CD. As a result of these charges, DOE and WEMCO entered into negotiations and the CD was revised; the Stipulated Amendment to Consent Decree was signed on January 22, 1993, and includes specific schedules for hazardous waste evaluations, Plant 1 pad management requirements, revisions to the RCRA Part A and B permit applications, and additional hazardous waste requirements.

Director's Findings and Orders - Alternate Monitoring Program

In 1993, the FEMP RCRA groundwater assessment monitoring program underwent significant change. The change came as a result of negotiations between OEPA and DOE regarding the integration of the RCRA Groundwater Assessment Monitoring Program with the ongoing site remediation being conducted under CERCLA.

During the first six months of 1993, the controlling document for the RCRA groundwater assessment monitoring program was the RCRA Groundwater Monitoring Plan (GMP), Revision 1 (DOE 1992). As work progressed under the RCRA GMP, there occurred considerable duplication of effort and competition for resources with reporting activities and field investigations being conducted through the CERCLA process. To foster integration between the RCRA GMP and the CERCLA investigative process, DOE proposed an alternate monitoring program as allowed through OAC 3745-65-90 (D) in May 1993.

The alternate monitoring program is comprised of two components as described below:

- Conducting groundwater characterization activities under CERCLA as defined by the Operable Unit 5 RI/FS Work Plan and addenda

- Providing quarterly groundwater monitoring of the downgradient property boundary under the routine monitoring program as defined in the "Project Specific Plan for the Routine Groundwater Monitoring Program Along the Downgradient Boundary of the FEMP."

The Operable Unit 5 Work Plan and addenda define a program for characterization of the nature, rate and extent of contaminant migration sufficient to select a remedial alternative. This information is provided to OEPA and EPA in this Operable Unit 5 RI report.

The routine monitoring program consists of quarterly sampling of 33 wells located along the facility property boundary to assess the magnitude of off-property releases from the FEMP site. Results from the routine monitoring program will be provided annually in the groundwater section of the FEMP's RCRA Annual Report.

On September 10, 1993, following negotiations with the DOE, OEPA issued the DFOs in response to DOE's proposed alternate monitoring program, defining the requirements for the program. These requirements included groundwater monitoring guidelines and reporting specifications for the groundwater data collected under the routine monitoring program. The DFOs also stated that the guiding document of the routine monitoring program should be updated to reflect the OEPA orders. This revised project-specific plan was submitted in October 1993.

1.5.2 CERCLA/NEPA Integration

Consistent with DOE Order 5400.4, it is DOE policy to integrate the values of NEPA into the documentation being prepared to support the RI/FS process. On May 15, 1990, a Notice of Intent (NOI) was published (55 FR 20183) indicating that DOE planned to prepare an environmental impact statement (EIS) to evaluate the environmental impacts associated with planned cleanup activities at the site. Two scoping meetings were held in the potentially affected communities located near the FEMP site on June 12 and 13, 1990.

As identified in the NOI, the FS for the lead FEMP operable unit (Operable Unit 4) will be issued as a feasibility study/proposed plan (FS/PP), written to incorporate NEPA values at the level of an EIS, resulting in an integrated FS/PP-EIS. The Operable Unit 4 RI Report and the Site-Wide Characterization Report (DOE 1993) support the description of the affected environment and the impact analysis of implementing the site-wide no-action alternative required in an EIS. Furthermore,

the RI/FS documents for the remaining operable units will also be written to include NEPA values and will tier from the Operable Unit 4 FS/PP-EIS.

The NEPA/CERCLA integration strategy is outlined in the Implementation Plan for the NEPA/CERCLA integration activities at the FEMP which was finalized in January, 1993 and placed in the Administrative Record and public reading rooms. The purpose of the Implementation Plan is to record the results of the scoping process and to provide guidance to DOE for the preparation of the lead FS/PP-EIS for Operable Unit 4 and NEPA/CERCLA documents for the remaining operable units.

The RI report for Operable Unit 5 contains specific characterization data for environmental media that supports the description of the affected environment for NEPA purposes. In addition, the RI report contains a baseline risk assessment addressing the impact on human health that would be associated with the no-action alternative for this unit. The baseline risk assessment includes additional human health risk information that has been obtained since the Site-Wide Characterization Report was issued (DOE 1993). The preliminary baseline ecological risk assessment contained in the Site-Wide Characterization Report addresses the entire FEMP site and is based on data collected in each operable unit before December 1991. Additional data have been collected since December 1991. These data, along with earlier data, were used to prepare the final baseline ecological risk assessment included in this Operable Unit 5 RI Report.

The FS documents prepared for Operable Unit 5 will contain the NEPA evaluation within the detailed analysis of each remedial alternative. The evaluation of environmental impacts will include a discussion of the impacts to biological resources and cultural resources, as well as a floodplain/ wetland assessment pursuant to the requirements of 10 CFR 1022, as appropriate.

In addition, if the leading remedial alternative (LRA) for Operable Unit 5 changes from the LRA evaluated in the Cumulative Environmental Impact Analysis for the Operable Unit 4 FS/PP-EIS, the Operable Unit 5 FS/PP-NEPA evaluation will be supplemented to incorporate an updated evaluation of the cumulative environmental impacts. The Cumulative Environmental Impact Analysis will evaluate the consequences of implementing the Operable Unit 5 LRA with the leading remedial candidates for each of the other FEMP operable units. This discussion of the NEPA impact analysis related to potential remedial actions for the five operable units will be updated in each operable unit-

specific FS/PP-NEPA document, as appropriate, in sequence as each operable unit progresses through the RI/FS process.

In accordance with both CERCLA and NEPA processes, these documents are made available to the public for comment. Public involvement is an important factor in the decision-making process for site remediation. Public comments will be considered in remedy selection for each operable unit. The DOE's CERCLA/NEPA integration policy is not intended to represent a statement on the legal applicability of NEPA to remedial actions under CERCLA.

The DOE is currently preparing a programmatic EIS for environmental restoration and waste management nationwide. The draft document will be issued for public comment. All proposed remedial actions at the FEMP site are considered to qualify as interim actions for the programmatic EIS under the conditions established in 40 CFR 1506.1(c). Presently, the FEMP's operable unit remedial actions are considered an allowable interim action because they are: justified independently of the program, accompanied by an adequate NEPA document, and not prejudiced to the ultimate decision on the program by determining subsequent development or limiting alternatives.

1.5.3 RCRA/CERCLA Integration

RCRA regulates treatment, storage, and disposal of hazardous waste. OEPA has been delegated the authority to enforce most RCRA regulations for the FEMP site. Because the FEMP currently stores hazardous wastes, the site submitted a Part B permit application to the State of Ohio in March 1993 for the storage of wastes under the terms of Ohio hazardous waste regulations. The majority of the units included in the application are structures or facilities integral to the former production area and therefore are being managed as components within the physical boundary of CERCLA Operable Unit 3.

DOE and OEPA have recently initiated planning for a strategy to address closure of 22 inactive HWMUs (see Section 1.3.2.6) in a manner which integrates RCRA closure requirements with the remedial actions conducted under CERCLA. In particular, the integration is focusing on those HWMUs where the management of contaminated media can be addressed in coordination with CERCLA actions for Operable Units 1, 3 and 5. Representatives of DOE and OEPA involved in coordinating this integrated closure-response action process are presently contemplating issuance of a DFO to formally document the final agreed upon integration strategy. The DFO is envisioned to

contain details on the strategy to implement the adopted integration approach as well as language to address the approach to attain final clean closure of the 17 inactive HWMUs (see Section 1.3.2.6) and document the intent to seek a permit for the seven active hazardous waste storage facilities.

1.5.4 Natural Resource Trustees

CERCLA as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, Executive Order 12580, and the National Oil and Hazardous Substances Pollution Contingency Plan (commonly known as the National Contingency Plan or NCP) collectively require that DOE act as a Trustee for natural resources at its federal facilities. These same documents also appoint other departments, such as U.S. Department of Commerce and U.S. Department of the Interior as Trustees for natural resources, as well as state and Indian tribe representatives. The Trustees' role is to act as guardian for natural resources at or near the site.

As the CERCLA lead agency, DOE is required to inform the other natural resource Trustees when there has been a release of a hazardous substance or a discharge of oil. To help fulfill this role, the Interior Department generated a set of guidelines (43 CFR Part 11 and 59 FR 14281) that lay out the steps one may follow in the event of a release or discharge.

DOE recently met with the other natural resource Trustees for the Fernald site. The meeting was a preliminary workshop to establish how the Trustees would work together in the future. It was determined that one aspect of the Trustees' future work may be to review the ecological risk assessment and other information within the Operable Unit 5 RI Report to evaluate the extent of injury, if any, to natural resources. The Operable Unit 5 FS will contain the latest information on Operable Units 1, 2, 4, and 5 and will quantify injury to natural resources, to the extent possible, in the Cumulative Impact Analysis, specifically in the "Irreversible and Irretrievable Commitment of Resources" section.

1.5.5 FEMP RI/FS

As previously discussed, the FEMP site-wide RI/FS was initiated in July 1986 pursuant to the terms of the FFCA. Consistent with the terms of agreement, DOE prepared and submitted a site-wide work plan for the RI/FS in December 1986. Following review by EPA and OEPA, a series of technical discussions were held between the involved organizations that led to the modification of the original

work plan. The site-wide FEMP RI/FS Work Plan (DOE 1988) received EPA approval in May 1988.

The RI/FS Work Plan provides the overall technical approach, identifies a number of investigative areas, develops objectives for each of the specified investigations, and establishes overall objectives for the evaluation of data collected during the RI activities. The Work Plan includes the following detailed plans that established specific procedures for the completion of the RI/FS for the FEMP:

- Sampling Plan
- Health and Safety Plan
- Community Relations Plan
- Data Management Plan
- Quality Assurance Project Plan.

The Sampling Plan contains objectives, sampling locations, and sampling procedures for the following:

- Radiation measurements
- Surface soil
- Groundwater
- Subsurface soil
- Surface water and sediment
- Biological resources.

The Sampling Plan has been amended on a number of occasions through the document change request procedure of the Quality Assurance Project Plan (QAPP). Section 2.0 of this report documents the sampling activities conducted according to the Sampling Plan, subsequent document change requests and project specific plans.

The Work Plan identified 27 units of the FEMP site to be investigated in the RI/FS. Several modifications to the list eventually increased this total to 39 units, including several off-property suspect areas investigated by the Operable Unit 5 RI. In the course of the investigation, it became apparent that the 39 units needed to be categorized into groups of a more manageable size for technical and administrative purposes. The concept of operable units was introduced into the program to allow the remedial action process to proceed to completion for the most well-defined units, while data collection and analysis continued for other operable units. The operable unit concept was formalized in the 1990 Consent Agreement and later refined by the 1991 Amended Consent Agreement.

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In an effort to supplement available guidance and promote consistency among the operable units, the 1991 Amended Consent Agreement also added a number of work elements to the ongoing RI/FS. Those elements pertinent to Operable Unit 5 included the formulation of a comprehensive site-wide operable unit, the issuance of a Risk Assessment Work Plan Addendum, and the issuance of the Site-Wide Characterization Report.

The comprehensive site-wide operable unit added by the Amended Consent Agreement will evaluate the remedies selected for the five operable units on a site-wide basis. This addition was intended to ensure that the combined remedial actions implemented for the five operable units are protective of human health and the environment on a site-wide basis as required by CERCLA and the National Oil and Hazardous Substance Pollution Contingency Plan.

The Site-Wide Characterization Report was prepared to compile site-wide data available as of December 1991, to identify the leading remedial alternatives for the five operable units for the purpose of estimating and evaluating risk, and to complete a preliminary site-wide baseline risk assessment. The preliminary baseline risk assessment quantitatively evaluated risk from the FEMP site as a whole for the existing, preremedial action conditions based on the data available at that time. The Site-Wide Characterization Report was conditionally approved by EPA in January 1993.

The original version of the Operable Unit 5 Initial Screening of Alternatives (ISA) Report was approved in early 1991. As the result of the redefinition of Operable Unit 5 in the Amended Consent Agreement, the ISA was revised. DOE received EPA approval of the revised ISA Report, pending incorporation of minor comments, on January 19, 1993. The final document was issued on March 26, 1993. The ISA Report summarizes viable remedial technologies potentially applicable to Operable Unit 5. Viable technologies were assembled into remedial alternatives in the ISA Report and screened to remove inappropriate alternatives. As identified in the approved ISA Report, the following alternatives in addition to no action were recommended for detailed analysis in the FS report.

Groundwater

- Alternative GW-2: Institutional Controls, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Ion Exchange, Surface Water Discharge

- Alternative GW-5: Institutional controls, Extraction/Injection Wells, Extraction Wells and Wellpoint system, Air Stripping, Adsorption, Ion Exchange, Reinjection Discharge

- Alternative GW-6: Institutional Controls, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Precipitation, Surface Water Discharge

- Alternative GW-7: Institutional Controls, Extraction/Injection Wells, Extraction Wells and Wellpoint System, Air Stripping, Adsorption, Precipitation, Reinjection Discharge

Soil/Sediment

- Alternative SS-2: Institutional Controls, Excavation, Intermediate Storage

- Alternative SS-3: Institutional Controls, Excavation, Disposal (Option 1: On Site; Option 2: Off Site)

- Alternative SS-4: Institutional Controls, Excavation of Contaminated Sediment, Multilayer capping of Soil/Sediment

- Alternative SS-6: Excavation, Soil Washing, Disposal of Residuals (Option 1: On Site, Option 2: Off Site)

- Alternative SS-7: Institutional Controls, Excavation, Batch Vitrification, Backfilling of Vitrified Residuals

- Alternative SS-8: Institutional Controls, Excavation, Soil Washing, Batch Vitrification, Disposal (Option 1: On Site; Option 2: Off Site)

- Alternative SS-9: Institutional Controls, Excavation, Soil Washing, Batch Vitrification of Residuals, Backfilling of Vitrified Residuals

- Alternative SS-10: Institutional Controls, Excavation, Soil Washing, Batch Vitrification of Residuals, Disposal (Option 1: On Site; Option 2: On Site)

Several viable treatment technology process options have been identified for the remediation of soil . These include soil washing, vitrification, vapor extraction, plasma arc incineration, hydrocyclonic separation, and cement stabilization. A literature review has been completed for the soil washing process. This process revealed that water washing with extractive agents is applicable for cleaning nonvolatile hydrophilic and hydrophobic organics and heavy metals from soil and has been successfully used on soil contaminated with radionuclides. Information was not found on its application to soil containing radionuclides, inorganics, and organics that characterize Operable Unit 5 soil. Therefore, due to the lack of information available to adequately address the overall effectiveness of this process, as well as the other EPA evaluation criteria necessary during the detailed analysis of alternatives, a decision was made to proceed with treatability testing of the soil washing process.

In late 1992, DOE received EPA approval of the Operable Unit 5 Treatability Study Work Plan. The plan described proposed treatability investigations to be performed by DOE to evaluate the performance of soil washing technologies on the Operable Unit 5 contaminated soil and sediment.

1.6 OVERVIEW OF THE REPORT

This RI Report consists of the following, in accordance with EPA guidance:

- Executive Summary, which provides a brief overview of the content and conclusions of the RI.

- Section 1.0 - Introduction, which summarizes the purpose and organization of the report; presents a description and history of the FEMP site; describes operations at the FEMP site; describes prior Operable Unit 5-related studies and other relevant, prior environmental investigations at the FEMP site. The objective of this section is to provide both a historical and regional perspective essential to fully evaluate environmental or human health impacts associated with Operable Unit 5.

- Section 2.0 - Study Area Investigation, which includes a description of the specific data objectives and methods employed for each data collection and analysis procedure as it relates to Operable Unit 5; the RI quality program; the data validation process; and the usability of data collected to support both the assessment of the nature and extent of contamination, the baseline risk assessment, and the evaluation of remedial alternatives in the FS.

- Section 3.0 - Physical Characteristics of the Study Area, which describes the physical characteristics of the site and Operable Unit 5 study area.

- Section 4.0 - Nature and Extent of Contamination, which presents the data gathered during the RI and relevant previous studies and discusses the nature and extent of contamination associated with Operable Unit 5.

- Section 5.0 - Contaminant Fate and Transport, which summarizes the physical and chemical characteristics of the contaminants found in Operable Unit 5 and evaluates probable fate and transport scenarios.

- Section 6.0 - Baseline Risk Assessment, which summarizes the significant findings from the baseline risk assessment and the site-wide ecological risk assessment conducted for Operable Unit 5. The details of the baseline risk assessment are included as a separate, stand-alone document to accompany the Operable Unit 5 RI Report as Appendix A. The details of the ecological risk assessment are included as a separate, stand-alone document to accompany the Operable Unit 5 RI Report as Appendix B.

- Section 7.0 - Summary and Conclusions, including a discussion of data limitations.

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TABLE 1-1

OPERABLE UNIT 5 ENVIRONMENTAL MEDIA CONTAMINATION

Potential Source	Release Mechanisms	Affected Media/Pathways
Process Operations (OU3)	Air emissions	Air
Dust collectors	Process emissions	Suspended particulates
Scrubbers	Building exhausts	Radon gas
Fugitive emissions	Fugitive emissions	
Wastewater discharges		
Storm water discharges		→ Direct radiation
Process material handling		→ Air resuspension
Underground storage tanks		Soil
Process piping	Wastewater/storm water discharges	→ Groundwater via leaching
Sewage treatment plant		→ Storm water runoff
		↓
		Surface water/sediment
		↓
	Land disposal/storage practices	Groundwater recharge
Waste Management		
OU1		
OU2		Surface water/sediment
OU4		↓
Regulated units	Spills/Leaks	Groundwater recharge
Soil/debris piles	Process materials	
Scrap metal piles	Wastewater	
		Direct radiation

TABLE 1-2

LEACHABILITY OF URANIUM SOLIDS IN RAINWATER

Most Leachable	Moderately Leachable	Least Leachable
Uranyl nitrate hexahydrate ($UO_2(NO_3)_2 \cdot 6H_2O$)	Uranium tetrafluoride (UF_4)	Uranium oxide (U_3O_8)
Uranium hexafluoride (UF_6)	Sodium diuranate ($Na_2U_2O_7$)	Uranium dioxide (UO_2)
Ammonium diuranate ($(NH_4)_2U_2O_7$)		Hydrate uranium trioxide ($UO_3 \cdot 2H_2O$)
Uranyl ammonium phosphate ($NH_4UO_2PO_4$)		

TABLE 1-3

URANIUM EMISSIONS FROM FEMP AIRBORNE RELEASES

	Uranium Emissions (kg) by Source														
	Dust Collectors														
Calendar Year	Plant 1	Plant 2/3[a]	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Pilot Plant	Total	Plant 8 Wet Scrubbers[b]	Non-production Sources[c]	Other Sources[d]	Total Emissions	% of Total
1951	-	-	-	-	-	-	-	-	123	123.0	-		2	125.0	0.1
1952	-	-	-	-	6	-	-	-	493	499.0	-		44	543.0	0.3
1953	3.8	6	1473	90	12	-	-	-	493	2077.8	-		105	2,182.8	1.2
1954	46.2	281	5890	4119	28	4261	201	0	271	15,097.2	217	15	157	15,486.2	8.7
1955	46.2	1113	12,450	10,410	53	7268	877	0	443	32,660.2	948	118	167	33,893.2	19.0
1956	43.4	1978	5145	3501	27	1743	1316	0	32	13,785.4	1442	118	174	15,519.4	8.7
1957	49.4	3730	814	3664.4	35	-	791	0.4	18	9102.2	1575	118	230	11,025.2	6.2
1958	407.4	3520	661	715	161	-	875	679	27	7045.4	1650	118	242	9,055.4	5.1
1959	46	3929	1428	478.4	127	-	260	417	34	6719.4	2100	118	240	9,177.4	5.2
1960	20	4233	212	202.8	268	-	298	219	718	6170.8	2604	118	260	9,152.8	5.1
1961	52.8	3707	262	76.2	119	-	209	67.4	174	4667.4	2371	118	271	7,427.4	4.2
1962	14	2137	703	356	59	-	618	135	174	4196.0	2304	138	304	6,942.0	3.9
1963	82.6	0	1469	783	181	-	994	159	51.8	3720.4	2171	145	339	6,375.4	3.6
1964	18	0	545	330.4	34	-	1051	252	13	2243.4	2865	145	330	5,583.4	3.1
1965	4.1	192.7	334.7	226.5	42.6	-	390	68	10	1268.6	5810	146.2	269	7,493.8	4.2
1966	12.2	514	227.7	76.7	11.3	-	327	48.5	1213[e]	2430.4	926	152	222	3,730.5	2.1
1967	20.4	646.8	279.9	147.9	2.7	-	417	76.2	11.8	1602.7	1790	152	181	3,725.7	2.1
1968	0.5	1119.5	267.2	88	30.4	-	901	121.0	3.6	2531.2	3082	152	120	5,885.2	3.3
1969	27.2	698.2	49.4	119.3	2.7	-	424	12.7	3.6	1337.1	3123	128	120	4,708.1	2.6
1970	4.5	356.7	29.9	53.1	0	-	569	13.6	0	1026.8	666	105	185	1,982.8	1.1

TABLE 1-3 (Continued)

	Uranium Emissions (kg) by Source														
	Dust Collectors														
Calendar Year	Plant 1	Plant 2/3[a]	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Pilot Plant	Total	Plant 8 Wet Scrubbers[b]	Non-production Sources[c]	Other Sources[d]	Total Emissions	% of Total
1971	9	306	0	0	0	-	91	0	0	406.0	541	105	40	1,092.0	0.6
1972	28.4	1360	9	33	0	-	5	24	0	1459.4	-	105	37	1,601.4	0.9
1973	1	1396	57	79	0	-	14	15	0	1562.0	39	105	33	1,739.0	1.0
1974	1.4	2445	24.4	40	0	-	11	38	0	2559.8	-	105	32	2,696.8	1.5
1975	5.6	2844.7	119.8	19	0	-	3.5	0	0.4	2993.0	-	105	40	3,138.0	1.8
1976	2.7	3339.2	26.1	13.7	2.4	-	7.2	2.8	0	3394.1	-	105	40	3,539.1	2.0
1977	0.6	756.2	11.8	53.3	0	-	4.6	0	10.4	836.9	-	105	36	977.9	0.5
1978	1.8	0	11.9	29.1	0	-	0	72	2.2	117.0	-	105	39	261.0	0.1
1979	0.8	0	46.3	12.3	0	-	0	2.3	0	61.7	-	93	45	199.7	0.1
1980	13.4	2.7	133.8	89.5	0	-	5.1	0	3.3	247.8	11	7.7	50	316.5	0.2
1981	1.3	30	432.1	135.6	0	-	0	0	0	599.0	10	8.2	60	677.2	0.4
1982	2.1	52.3	21	121.8	0.5	-	81.2	5.1	0	284.0	37	8.8	65	394.8	0.2
1983	6.4	130	42.9	41.4	0	-	24.7	0	0	245.4	58	7.8	65	376.2	0.2
1984	12.1	574.3	39.6	83.9	1.0	-	8.1	170.9	28	917.9	38	16.8	66	1,013.5	0.6
Sub-Total	985.3	41,398.3	33,216.5	26,189.3	1,203.6	13,272.0	10,773.4	2,598.9	4,326.0	133,963.3	36,378.0	3,086.5	4,610.0	178,037.8	99.4%
% of Sub-Total	0.6%	23.3%	18.7%	14.7%	0.7%	7.5%	6.1%	1.5%	2.4%	75.2%	20.4%	1.7%	2.6%	100.0%	
1985	1.1	133.9	10.2	12.4	0.0	-	4.0	2.2	6.5	170.3	24.7	-	64.0	259.0	0.1%
1986	0.0	167.0	5.6	6.7	0.0	-	2.5	1.2	3.4	186.2	105.5	-	68.0	359.7	0.2%
1987	0.0	200.0	0.9	1.0	0.0	-	0.9	0.1	0.3	203.2	32.2	-	60.0	295.4	0.2%
1988	0.0	66.4	2.2	1.6	0.5	-	0.6	0.2	1.2	72.7	15.6	-	17.8	126.1	0.1%
1989	0.1	0.0	0.3	0.4	0.4	-	0.3	0.2	-	1.7	3.8	-	6.7	12.1	0.0%

TABLE 1-3 (Continued)

	Uranium Emissions (kg) by Source														
	Dust Collectors														
Calendar Year	Plant 1	Plant 2/3[a]	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8	Plant 9	Pilot Plant	Total	Plant 8 Wet Scrubbers[b]	Non-production Sources[c]	Other Sources[d]	Total Emissions	% of Total
1990	-	-	-	-	-	-	-	-	-	0.0	-	-	1.7	1.7	0.0%
1991	-	-	-	-	-	-	-	-	-	0.0	-	-	0.2	0.3	0.0%
1992	-	-	-	-	-	-	-	-	-	0.0	-	-	0.1	0.2	0.0%
1993	-	-	-	-	-	-	-	-	-	0.0	-	-	0.2	0.2	0.0%
Total	986.5	41,965.6	33,235.7	26,211.4	1204.5	13,272.0	10,781.8	2602.8	4337.4	134,597.5	36,559.7	3086.5	4828.7	179,072.5	100%
% of Total	0.6%	23.4%	18.6%	14.6%	0.7%	7.4%	6.0%	1.5%	2.4%	75.2%	20.4%	1.7%	2.7%	100%	

[a]Includes emissions from gulping of uranium trioxide.
[b]Data are on a fiscal year basis: 1952-1976, July 1 - June 30; 1976 transition and; 1977 and after, October 1 - September 30
[c]Consists of:

Old solid waste incinerator (1954-1979)	2474.7	kg
Old burner (1962-1979)	462.9	kg
Graphite burner (1965-1984)	124.6	kg
New solid waste incinerator (1980-1984)	<20	kg
Liquid organic waste incinerator (1983-1984)	<20	kg
	3086.5	kg

[d]Includes other process emissions, buildings exhausts, laboratory emissions, fugitive emissions from waste pits, and nonroutine events.
[e]Includes 1195 kg unmonitored release of UF_6 on February 14, 1966.
Source: Boback, et al., 1987, "History of FMPC Radiological Discharges," FMPC-2082, prepared for DOE, Oak Ridge Operations Office, Oak Ridge, TN.
Clark, et al., 1989, "History of FMPC Radionuclide Discharges - Revised Estimates of Uranium and Thorium Air Emissions from 1951-1987," Addendum to FMPC-2082, prepared for DOE, Oak Ridge Operations Office, Oak Ridge, TN.

TABLE 1-4

THORIUM EMISSIONS FROM FEMP AIRBORNE RELEASES

	Process														
			Plant 8		Plant 9		Pilot Plant								
Year	Plant 2/3 Test	Plant 4 ThF_4	Hydroxide	Oxalate	Metal	Briquetting	Extraction	Gel	TNT Crystals	Metal	Oxalate	Process Emissions (kg)	Fugitive Emissions[a] (kg)	Total Emissions (kg)	% of Total
1951												0	0	0	0%
1952												0	0	0	0%
1953												0	0	0	0%
1954		✓			✓	✓						815	0	815	12.5%
1955					✓	✓						933	0	933	14.4%
1956												0	0	0	0
1957												0	0	0	0
1958												0	0	0	0
1959												0	0	0	0
1960												0	0	0	0
1961												0	1	1	<0.1%
1962												0	2	2	<0.1%
1963												0	2	2	<0.1%
1964							✓	✓				246	2	248	3.8%
1965							✓	✓				246	2	248	3.8%
1966			✓				✓	✓	✓			335	2	337	5.2%
1967							✓	✓				246	2	248	3.8%
1968	✓						✓	✓				246	2	248	3.8%
1969				✓			✓	✓		✓		1030	2	1032	15.9%
1970				✓			✓	✓		✓		869	2	871	13.4%
1971				✓			✓			✓	✓	356	2	358	5.5%
1972							✓				✓	106	2	108	1.7%

TABLE 1-4 (Continued)

	Process														
			Plant 8		Plant 9		Pilot Plant								
Year	Plant 2/3 Test	Plant 4 ThF_4	Hydroxide	Oxalate	Metal	Briquettin g	Extraction	Gel	TNT Crystals	Metal	Oxalate	Process Emissions (kg)	Fugitive Emissions[a] (kg)	Total Emissions (kg)	% of Total
1973							✓				✓	38	2	40	0.6%
1974							✓				✓	75	3	78	1.2%
1975							✓				✓	2	3	5	<0.1%
1976							✓				✓	0	4	4	<0.1%
1977							✓	✓				292	4	296	4.6%
1978							✓	✓				291	4	295	4.5%
1979							✓	✓				291	4	295	4.5%
1980							✓	✓				0	4	4	<0.1%
1981												0	4	4	<0.1%
1982												0	4	4	<0.1%
1983												0	4	4	<0.1%
1984												0	4	4	<0.1%
1985												0	4	4	<0.1%
1986												0	4	4	<0.1%
1987												0	4	4	<0.1%
1988 through 1993 - no data															
Total	Negligible	Unknown	89	1550	1520	228	Negligible	2596	Negligible	204	230	6417	79	6496	100.0%
% of Total			1.4%	23.9%	23.4%	3.5%				3.1%	3.5%	98.8%	1.2%	100.0%	

✓ Indicates thorium emissions

[a] Includes: Current fugitive emissions from: process buildings (through doors, windows, and exhaust fans which are not considered point sources and which consist primarily of particulates and fumes from leaks in piping and tanks), fly ash piles, landfill, waste pits, tank farms, and waste drums; and resuspension of past emissions (i.e. uranium deposited on roadways, fields, and storage areas from spills, accidents, and air emissons).

Source: Boback et al. 1987, "History of FMPC Radiological Discharges," FMPC-2082, prepared for DOE, Oak Ridge Operations Office, Oak Ridge, TN.
Clark et al. 1989, "History of FMPC Radionuclide Discharges - Revised Estimates of Uranium and Thorium Air Emissions from 1951-1987," Addendum to FMPC-2082, prepared for DOE, Oak Ridge Operations Office, Oak Ridge, TN.

TABLE 1-5

URANIUM AND THORIUM DISCHARGE IN FEMP WASTEWATER TO GREAT MIAMI RIVER

Year	Uranium[a] (kg)	Thorium[b] (kg)
1952	11	0
1953	106	0
1954	347	0
1955	657	0
1956	1485	0
1957	2595	0
1958	3712	0
1959	6488	0
1960	4445	0
1961	5486	0
1962	3543	0
1963	4566	0
1964	10,504	0
1965	3730	0
1966	3740	0
1967	2305	27
1968	1855	128
1969	2290	63
1970	1914	29
1971	1637	30
1972	1140	18
1973	1126	9
1974	1066	18
1975	1852	6.4
1976	1054[c]	5.5

TABLE 1-5 (Continued)

Year	Uranium[a] (kg)	Thorium[b] (kg)
1977	965	5.1
1978	880	5.5
1979	1175	7.0
1980	685	2.1
1981	576	3.0
1982	755	3.8
1983	564	2.1
1984	1054	4.5
1985	645	100.9
1986	475	5.0
1987	770	3.3
1988	819	0.8
1989	843	6.7
1990	786	4.6
1991	663	0.5
1992	436	0.0
1993	474	0.9
Total	80,219	489.7

[a]Fiscal year basis:
- 1952-1976, July 1 - June 30
- 1976 transition
- 1977-Present, October 1 - September 30

[b]Calendar year basis

[c]179 kg for period July 1 - September 30, 1976

Sources: Boback, et. al. 1987, "History of FMPC Radiological Discharges," FMPC-2082, prepared for DOE, Oak Ridge Operations Office, Oak Ridge, TN; FEMP Environmental Monitoring Reports.

TABLE 1-6

UNDERGROUND STORAGE TANKS AT THE FEMP

Designation	Regulated Under OAC?[a]	Location	Status
Tank 1	Yes	Building 31, garage	Removed and closed
Tank 2	Yes	Building 31, garage	Removed and closed
Tank 8	Yes	Building 31, garage	Removed and closed
Tank 9	Yes	Building 31, garage	Removed and closed
Tank 10	Yes	Building 31, garage	Removed and closed
Tank 11	Yes	Truck dock	Removed and closed
Tank 12	Yes	Truck dock	Removed and closed
Tank 13	Yes	Truck dock	Removed and closed
Tank 14	Yes	Under Plant 6	Abandoned in place
Tank 5	No	East of Bldg. 31A	To be removed under CERCLA
Tank 7	No	North of Bldg. 9A	To be removed under CERCLA
Tank 17	No	North of Bldg. 46	To be removed under CERCLA
Tank 3	Yes	Building 24A	Removed and closed
Tank 6	Yes	Building 12	Removed and closed

[a] Ohio Administrative Code 1301:7-a-12(L)

5696

TABLE 1-7

OPERABLE UNIT 1 WASTES

Waste Pit	Surface Area (ft^2)	Radioactive Waste (tons)	Total Waste Volume (yd^3)	Types of Waste
1	83,000	60 U[a] 4 Th[b]	35,000	Trailer cake, depleted residues, graphite, general sump sludge, drums
2	45,000	1350 U 0.4 Th	18,500	Trailer cake, flyash, graphite, sump liquor, depleted slag, drums, uranium, thorium
3	240,000	124 U 0.4 Th	237,000	Raffinate, general sump sludge, depleted slag, cake, flyash, lime sludge, UAP filtrate, graphite
4	84,000	3300 U 68 Th	54,000	Trailer cake, graphite, depleted slag, trash, asbestos, barium chloride, general sump sludge, slag, flyash leach
5	161,000	55 U 19 Th	102,500	Raffinates, slurries, general sump sludge, flyash, slag leach, water treatment sludge, thorium-232 wastes
6	32,400	950 U	11,500	Depleted slag, depleted residue, process residues
Burn Pit	22,000	Unknown	9000	Laboratory chemicals, waste oils, cafeteria wastes, drums, pallets
Clearwell	25,500	Unknown	5000	Process water settleable solids, uranium

[a]Uranium
[b]Thorium

a 0 0 6

TABLE 1-8

OPERABLE UNIT 2 WASTES

Study Area	Surface Area (ft^2)	Waste Volume (yd^3)	Types of Waste
Active flyash pile	50,000	58,800	Flyash, waste oils, construction rubble, asphalt, masonry, steel, uranium
Inactive flyash disposal area	Unknown	78,500	Flyash, waste oils, construction rubble, asphalt, masonry, steel, uranium
South Field	479,000	109,000	Construction rubble
Solid waste landfill	40,700	19,600	Cafeteria wastes, sanitary rubbish, asbestos, construction rubble
North lime sludge pond	28,100	5500	Spent lime sludge
South lime sludge pond	28,100	11,700	Spent lime sludge

TABLE 1-9

OPERABLE UNIT 4 WASTES

Study Area	Waste Volume (yd^3)	Types of Waste
Silo 1	5076	Residues containing radium, uranium, thorium, radon, decay products, precious metals
Silo 2	4441	Residues containing radium, uranium, thorium, radon, decay products, precious metals
Silo 3	5111	Uranium, thorium, silica, radium, other metal oxides
Silo 4	Unknown	Small amounts of rainwater seepage

TABLE 1-10

UNITS RECLASSIFIED FROM HAZARDOUS WASTE MANAGEMENT UNIT (HWMU) TO SOLID WASTE MANAGEMENT UNIT

HWMU	HWMU Identification	Approximate Dimensions	Basis for Initial Listing	Function	Basis for Reclassification	Date of OEPA Concurrence
39	Clearwell	Surface area: 30,600 ft^2 Depth: 25 ft Capacity: 4 million gal	Listed Waste (F001/F002 - trichloroethane)	Storage	Mixture rule exclusion (OAC 3745-51-03(A)(2)(e))	06/07/93
43	Lime sludge ponds	100 ft (x) 200 ft each	Listed Waste (F001/F002 - trichloroethane)	Storage	Mixture rule exclusion (OAC 3745-51-03(A)(2)(e))	06/07/93
44	Coal pile runoff basin	107 ft (x) 54 ft Depth: 11 ft	Listed Waste (F001/F002 - trichloroethane)	Storage	Mixture rule exclusion (OAC 3745-51-03(A)(2)(e))	06/07/93
45	Underground Storage Tank No. 5	3 ft in diameter 6 ft long	Listed Waste (F001/F002 - trichloroethane)	Storage	WWT exclusion (OAC 3745-50-10)	11/01/93
2	Parts cleaner in welding shop - Building 12	4 ft (x) 6 ft (x) 6 ft	Listed Waste (F001/F002 - trichloroethane)	Treatment	Empty container (OAC 3745-51-07)	11/01/93
23	Well drilling storage area	29 ft (x) 56 ft	Characteristic Waste (D008 - lead)	Storage	Reevalaution of records - no hazardous wastes stored	11/01/93
24	Equipment storage area	45 ft (x) 145 ft	Various, unspecified materials	Storage	Stored battery was reused/reclaimed	11/01/93

TABLE 1-11

INACTIVE REGULATED HAZARDOUS WASTE MANAGEMENT UNITS (HWMUs) TO BE CLEAN CLOSED UNDER RCRA

HWMU	HWMU Identification	Approximate Dimensions	Basis for Listing	Function	CPID Submittal Date
30	Barium chloride salt treatment facility	75 ft (x) 50 ft.	Characteristic Waste (DOO5 - barium)	Treatment	04/19/90[g]
3	Waste oil storage in garage	10 ft (x) 10 ft	Listed Waste (F001/F002 - trichloroethane)	Storage	07/08/92
5[a]	Drum storage area south of W-26 (laboratory)	31 ft (x) 41 ft	Various, unspecified materials	Storage	10/06/92
4[a,b]	Drum storage area near loading dock (laboratory)	76 ft (x) 22-40 ft	Various, unspecified materials	Storage	04/04/93
7[b]	Drummed hydrogen fluoride (HF) residue storage northwest of Plant 4	25 ft (x) 30 ft	Listed Waste (U134 - hydrogen fluoride)	Storage	04/30/94[h]
9[c,e]	Nitric acid tank car and area	10 ft wide (x) 40 ft long (x) 15 ft high	Characteristic Waste (D002 - corrosive)	Storage	10/21/93[g]
26[b]	Detrex still	2 ft (x) 3 ft	Listed Waste (F001/F002 - trichloroethane, tetrachloroethene, trichloroethene)	Storage	11/05/93
31/32[a,d]	Bulk storage tanks T5 & T6	15 ft tall (x) 10 ft in diameter each	Listed Waste (F001/F002 - trichloroethane)	Storage	11/18/93
52[a,b]	North and south solvent tanks (pilot plant)	13 ft (x) 23 ft dike and two tanks	Characteristic (D001 - ignitable)	Storage	12/30/93
36[a,b]	Storage pad north of Plant 6	8 ft (x) 40 ft	Characteristic (D008 - lead) and Listed Wastes (F001/F002 - trichloroethane)	Storage	12/30/93
6	Drummed hydrogen fluoride (HF) residue storage inside Plant 4	4 ft (x) 17 ft	Listed Waste (U134 - hydrogen fluoride)	Storage	01/21/94[g]

TABLE 1-11 (Continued)

HWMU	HWMU Identification	Approximate Dimensions	Basis for Listing	Function	CPID Submittal Date
38[a]	hydrogen fluoride (HF) tank car	10 ft wide (x) 34 ft long (x) 15 ft high	Listed Waste (D002 - corrosive)	Storage	03/15/94
8	Drummed hydrogen fluoride (HF) residue storage south of cooling tower	10 ft (x) 32 ft	Listed Waste (U134 - hydrogen fluoride)	Storage	4/30/94[h]
21[d]	Hilco oil recovery	20 ft (x) 12 ft	Characteristic Waste (D001 - ignitable)	Treatment	To be determined
53[b]	Safe geometry digestion sump (Plant 1)	1 ft long (x) 8 in. in diameter	Characteristic Waste (D008 - lead)	Storage	08/31/94[h]
13	Wheelabrator dust collector Building 66	30 ft (x) 17 ft	Characteristic Waste (D008 - lead)	Treatment	07/18/94

a Need to evaluate potential media contamination issues. Depending on extent of contamination, unit may be included in integrated RCRA/CERCLA process.
b DOE will implement field closure actions for these units in FY94 independent of closure plan information and data (CPID) approvals. Certification of the closures will occur after OEPA approves CPID documents submitted.
c Media contamination issues have been confirmed or are anticipated based on process knowledge.
d HWMU determination being re-evaluated; may be reclassified and withdrawn from list of HWMU.
f Combined RCRA CPID and CERCLA Removal Action No. 25 work plans.
g Actual date of closure certification.
h Correspondence to OEPA requesting concurrence with clean closure verification.

TABLE 1-12

REGULATED HAZARDOUS WASTE MANAGEMENT UNITS (HWMUs) TO BE CLOSED UNDER CERCLA

HWMU	HWMU Identification	Approximate Dimensions	Basis for Listing	Function	CPID Submittal Date
42[c]	Waste Pit 5	4.2 acres/184,000 ft^3	Listed Waste (F001/F002 - trichloroethane)	Treatment	09/26/91
27[c,d]	Waste Pit 4	Surface dimensions: 170 ft (x) 400 ft (x) 320 ft 24 ft deep	Characteristic (D005 - barium)	Treatment	09/15/89 Certification of interim closure
47[a]	UNH (dilute uranyl nitrate) tanks north of Plant 2	Three tanks: 18 ft in diameter (x) 15 ft high Containment area: 63 ft (x) 40 ft	Characteristic Waste (D002 - corrosive; D005 - barium; D007 - chromium)	Storage	06/22/93
50	UNH tanks - raffinate building (2 locations)	A) Three tanks: 8 ft in diameter (x) 8 ft high Area: 14 ft (x) 50 ft B) One tank: 2200 gal Area: 15 ft (x) 30 ft	Characteristic Waste (D002 - corrosive; D005 - barium; D007 - chromium)	Storage	06/22/93
49	UNH tanks - digestion area (2 locations)	A) Four tanks: 3500 gal One tank 23,500 gal Area: 20 ft (x) 127 ft B) Two tanks: 3500 gal One tank 23,500 gal Area: 20 ft (x) 127 ft	Characteristic Waste (D002 - corrosive; D005 - barium; D007 - chromium)	Storage	06/22/93
46[a]	UNH tanks - NFS storage area	A) Four tanks: 10 ft in diameter (x) 44 ft long B) One tank: 3 ft in diameter (x) 4 ft high	Characteristic Waste (D002 - corrosive; D005 - barium; D007 - chromium)	Storage	06/22/93

TABLE 1-12 (Continued)

HWMU	HWMU Identification	Approximate Dimensions	Basis for Listing	Function	CPID Submittal Date
48[a]	UNH tanks - southeast of Plant 2	Tank: 25,000 gal Containment area: 55 ft (x) 45 ft	Characteristic Waste (D002 - corrosive; D005 - barium; D007 - chromium)	Storage	06/22/93
10[a]	Nitric acid recovery system components	13,250 ft^2	Characteristic Waste (D002 - corrosive; D007 - chromium)	Storage	06/30/93
1[b,c,f]	Fire training facility	105 ft (x) 134 ft 85 ft (x) 68 ft	Characteristic and Listed Wastes (F001/F002 - methylene chloride, trichloroethane, trichloroethene; F003 - acetone, ethyl benzene, xylene; F005 - toluene)	Disposal	08/06/93
28[a]	Trane incinerator	Building 39A: 32 ft (x) 15 ft Building 39B: 16 ft (x) 26 ft Pad/Gravel: 120 ft (x) 40 ft	Characteristic (D008 - lead) and Listed Wastes (F001/F002 - trichloroethane)	Treatment	To be determined
14[a]	Box furnace	18 ft (x) 14 ft	Characteristic (D005 - barium; D007 - chromium; D008 - lead; D011 - silver;) and Listed Wastes (F001/F002 - tetrachloroethene, trichloroethane, trichloroethene)	Treatment	To be determined
16[c]	Primary calciner	13 ft in diameter (x) 40 ft high	Listed Waste (F001/F002 - trichloroethane)	Treatment	To be determined
15	Oxidation furnace No. 1	85 ft^2	Characteristic (D005 - barium; D008 - lead) and Listed Wastes (F001/F002 - trichloroethane)	Treatment	To be determined

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TABLE 1-12 (Continued)

HWMU	HWMU Identification	Approximate Dimensions	Basis for Listing	Function	CPID Submittal Date
22[c,g]	Abandoned sump west of pilot plant	2ft in diameter (x) 14 ft deep	Characteristic (D008 - lead) and Listed Wastes (F003 - xylene; F001/F002 - trichloro-ethane, tetrachloroethene)	Storage	To be determined
12[c]	Wheelabrator - Building 66	24 ft (x) 20 ft	Characteristic Waste (D006 - cadmium)	Storage	To be determined
25	Plant 1 storage - Building 67	40 ft (x) 100 ft	Various, unspecified materials	Storage	To be determined
51[c,e]	Experimental treatment facility	20 ft (x) 48 ft 2,400 ft^3 capacity	Listed Waste (F001/F002 - trichloroethane)	Treatment	To be determined
11[a]	Tank farm sump	Surface dimensions: 24ft (x) 27 ft (x) 11 ft (x) 18 ft (x) 14 ft	Characteristic Waste (D002 - corrosive)	Treatment	To be determined
17[c]	Plant 8 east drum storage pad	18,300 ft^2	Various, unspecified materials	Storage	To be determined
18[c]	Plant 8 west drum storage pad	12,000 ft^2	Various, unspecified materials	Storage	To be determined
40[c]	Bio-surge lagoon	Surface area: 160,000 ft^2 Depth 9 ft	Listed Waste (F001/F002 - trichloroethane)	Treatment	To be determined
41[c]	Sludge drying beds	79 ft (x) 92 ft	Listed Waste (F001/F002 - trichloroethane)	Treatment	To be determined

[a] Need to evaluate potential media contamination issues.
[b] DOE will implement field closure actions for these units in FY94 independent of closure plan information and data (CPID) approvals. Certification of the closures will occur after OEPA approves CPID documents submitted.
[c] Media contamination issues have been confirmed or are anticipated based on process knowledge.
[d] Under stipulation agreement with OEPA, final CPID for Waste Pit 4 is to be integrated with final ROD (predated OU1 and OU5 designations).
[e] HWMU determination being reevaluated, may be reclassified and withdrawn from list of HWMUS.
[f] Combined RCRA CPID and CERCLA Removal Action 28 work plans.
[g] Field work under Removal Action 24 was completed in October 1993. The sump was excavated and the drain line to the sump was capped. DOE is evaluating additional actions necessary to complete closure of the HWMU and anticipates completing closure through CERCLA response actions.

TABLE 1-13

ACTIVE REGULATED HAZARDOUS WASTE MANAGEMENT UNITS (HWMUs) TO BE CLOSED UNDER RCRA PART B

HWMU	HWMU Identification	Approximate Dimensions	Basis for Listing	Function	Closure Schedule Submittal/Action
20[a]	Plant 1 storage pad	480,000 ft^2	Various, unspecified materials	Storage	03/29/93
33	Pilot plant warehouse - Building 68	7 ft (x) 62 ft	Various, unspecified materials	Storage	03/29/93
19	CP storage warehouse - Building 56	50 ft (x) 180 ft	Various, unspecified materials	Storage	03/29/93
34	KC-2 warehouse - Building 63	346 ft (x) 82 ft	Various, unspecified materials	Storage	03/29/93
35	Plant 9 warehouse - Building 81	80 ft (x) 100 ft	Various, unspecified materials	Storage	03/29/93
37	Plant 6 warehouse - Building 79	100 ft (x) 170 ft	Various, unspecified materials	Storage	03/29/93
29	Plant 8 warehouse - Building 80	60 ft (x) 170 ft	Various, unspecified materials	Storage	03/29/93

[a]Media contamination issues have been confirmed or are anticipated based on process knowledge.

TABLE 1-14

REMOVAL ACTIONS IDENTIFIED AT THE FEMP

Removal Action No.	Removal Action Title (Status)	Objective(s) of Removal Action
1	* Contaminated Water Beneath FMPC Buildings (In progress)	To minimize the potential of uranium-contaminated groundwater to infiltrate the underlying aquifer from perched water zones beneath some former production buildings.
2	Waste Pit Area Runoff Control (Completed July 1992)	To collect and treat potentially contaminated storm water runoff from the waste pit area to prevent it from reaching Paddys Run.
3	* South Groundwater Contamination Plume (In progress)	To protect public health by limiting access to the use of uranium-contaminated groundwater in an area south of the FEMP.
4	Silos 1 and 2 (Completed November 1991)	To install bentonite clay over radium-bearing radioactive waste material in the K-65 silos.
5	K-65 Decant Tank (Completed April 1991)	To remove and treat 8,000 gallons of contaminated water from the K-65 decant sump tank.
6	Exposed Materials at Pit 6 (Completed December 1990)	To eliminate the potential of airborne contamination from approximately 373 square yards of uranium residues and asbestos exposed above the water level in Waste Pit 6 by distributing the material below the water level.
7	Plant 1 Pad (In progress)	To protect surface soil and regional groundwater from continuing releases of hazardous materials resulting from waste management activities on the 8-acre Plant 1 storage pad.
8	Inactive Flyash Pile Control (Completed December 1991)	To limit access to the inactive flyash pile/other South Field disposal areas until final remedial alternatives were selected.
9	Removal of Waste Inventories (In progress)	To characterize, overpack, and dispose of low-level radioactive waste materials.
10	Active Flyash Pile Controls (Completed June 1992)	To mitigate potential wind and water erosion at the active flyash pile.

TABLE 1-14 (Continued)

Removal Action No.	Removal Action Title (Status)	Objective(s) of Removal Action
11	Pit 5 Experimental Treatment Facility (Completed March 1992)	To dismantle an experimental treatment facility built in 1984 to test the feasibility of thermal drying sludge material from Waste Pit 5.
12	Safe Shutdown (In progress)	To ensure the safe and permanent shutdown of production facilities, including the removal of uranium and other process/raw materials from equipment and lines in the former production area.
13	Plant 1 Ore Silos (In progress)	To remove and containerize material remaining in the silos and place in safe storage; dismantle the Plant 1 ore silos and their support structures.
14	Contaminated Soil Adjacent to Sewage Treatment Plant Incinerator (In progress)	To isolate or remove and dispose of contaminated soil with elevated levels of uranium in the vicinity of an out-of-service solid waste incinerator at the sewage treatment plant.
15	Scrap Metal Piles (In progress)	To address the stabilization and disposition of low-level radioactive waste scrap stockpiled outdoors at the FEMP.
16	* Collect Uncontrolled Production Area Runoff (Completed August 1993)	To collect storm water runoff from perimeter areas of the 136-acre former production area which are not presently draining into the storm water retention basin.
17	Improved Storage of Soil and Debris (In progress)	To improve storage and management of contaminated soil and debris generated as a result of performing cleanup at the FEMP.
18	Control Exposed Material in Pit 5 (Completed December 1992)	To eliminate the possibility of airborne contamination resulting from exposed materials in Pit 5.
19	Plant 7 Dismantling (In progress)	To decontaminate and dismantle Plant 7 which is presently being used for the storage of empty cans and drums.
20	Stabilization of Uranyl Nitrate Inventories (In progress)	To process uranyl nitrate to a stable form through neutralization, with the subsequent solids to be drummed and stored in warehouses pending final disposition.
21	Expedited Silo 3 (Completed January 1992)	To remove an out-of-service dust collector and hopper assembly from the dome of Silo 3.
22	Waste Pit Area Containment Improvement (Completed October 1993)	To minimize the potential for wind or water erosion of contaminated materials from access roads and exposed surfaces in the Operable Unit 1 area.

TABLE 1-14 (Continued)

Removal Action No.	Removal Action Title (Status)	Objective(s) of Removal Action
23	Inactive Flyash Pile (In progress)	To remove a small amount of contaminated debris (soil and transite material) from the inactive flyash pile and place in appropriate containers for storage.
24	Pilot Plant Sump (Completed October 1993)	To address contaminated liquids and sludges remaining in an out-of-service sump at the FEMP pilot plant.
25	Nitric Acid Tank Car and Area (Completed October 1993)	To remove the residual contents of a nitric acid railroad tank car, decontaminate and dispose of the tank car itself, and address potentially contaminated surrounding soil related to the tank car.
26	Asbestos Removals (Asbestos Program) (In progress)	To document ongoing asbestos abatement activities at the FEMP to mitigate the potential for contaminant release and migration.
27	Management of Contaminated Structures at the FEMP (In progress)	To provide a mechanism to perform accelerated cleanup actions to mitigate any potential threat to human health and the environment associated with select contaminated structures at Fernald.
28	Fire Training Facility (In progress)	To remove, decontaminate and dispose of, treat or store all buildings, structures, tanks and equipment.
29	Inactive Flyash Pile Erosion Control (Completed September 1993)	To stabilize the east bank of Paddys Run adjacent to the Inactive Flyash Pile and prevent further erosion.
30	* KC-2 Warehouse/Well 67 (In progress)	To mitigate a potential adverse impact to the Great Miami Aquifer from a sediment-like material discovered in Well 67 in Bay 2 of the KC-2 Warehouse.

* Operable Unit 5 removal actions.

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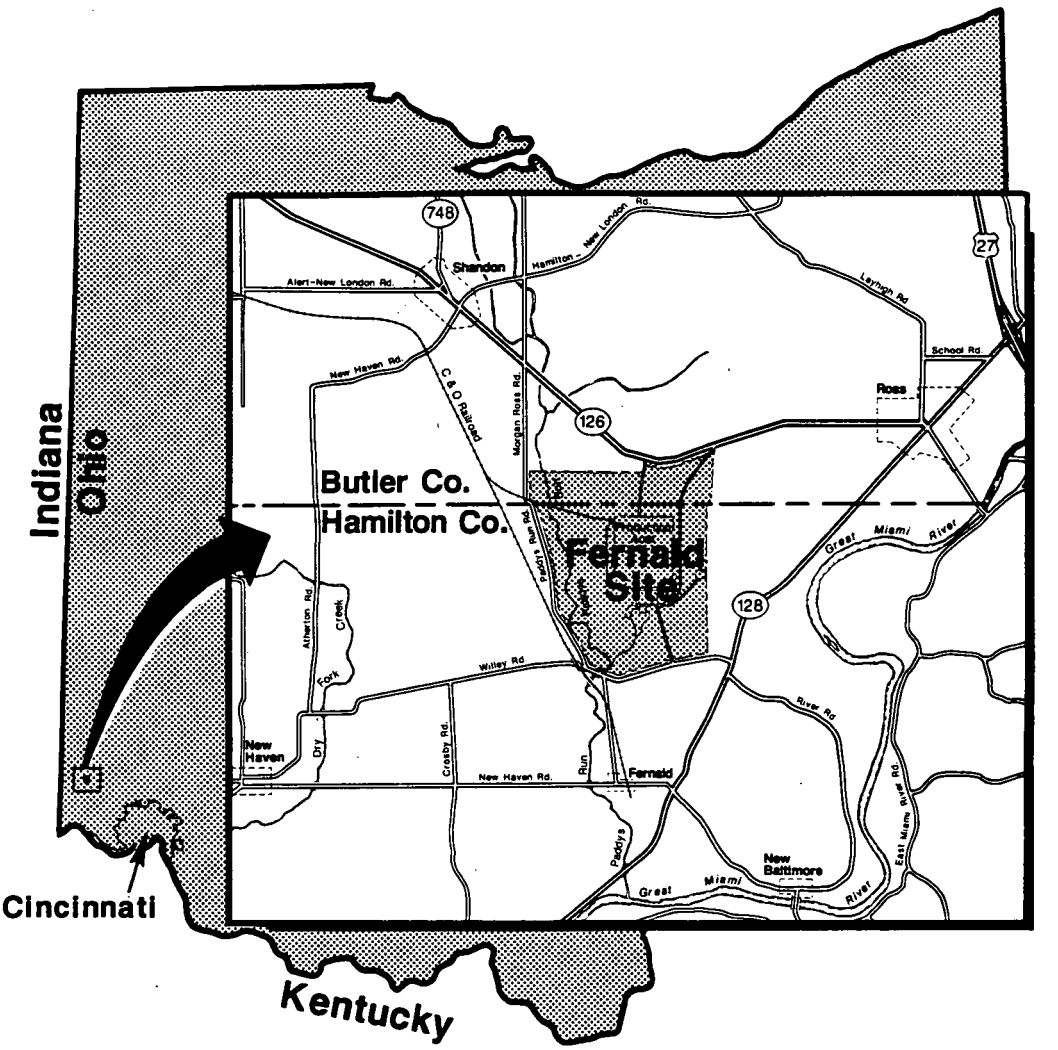

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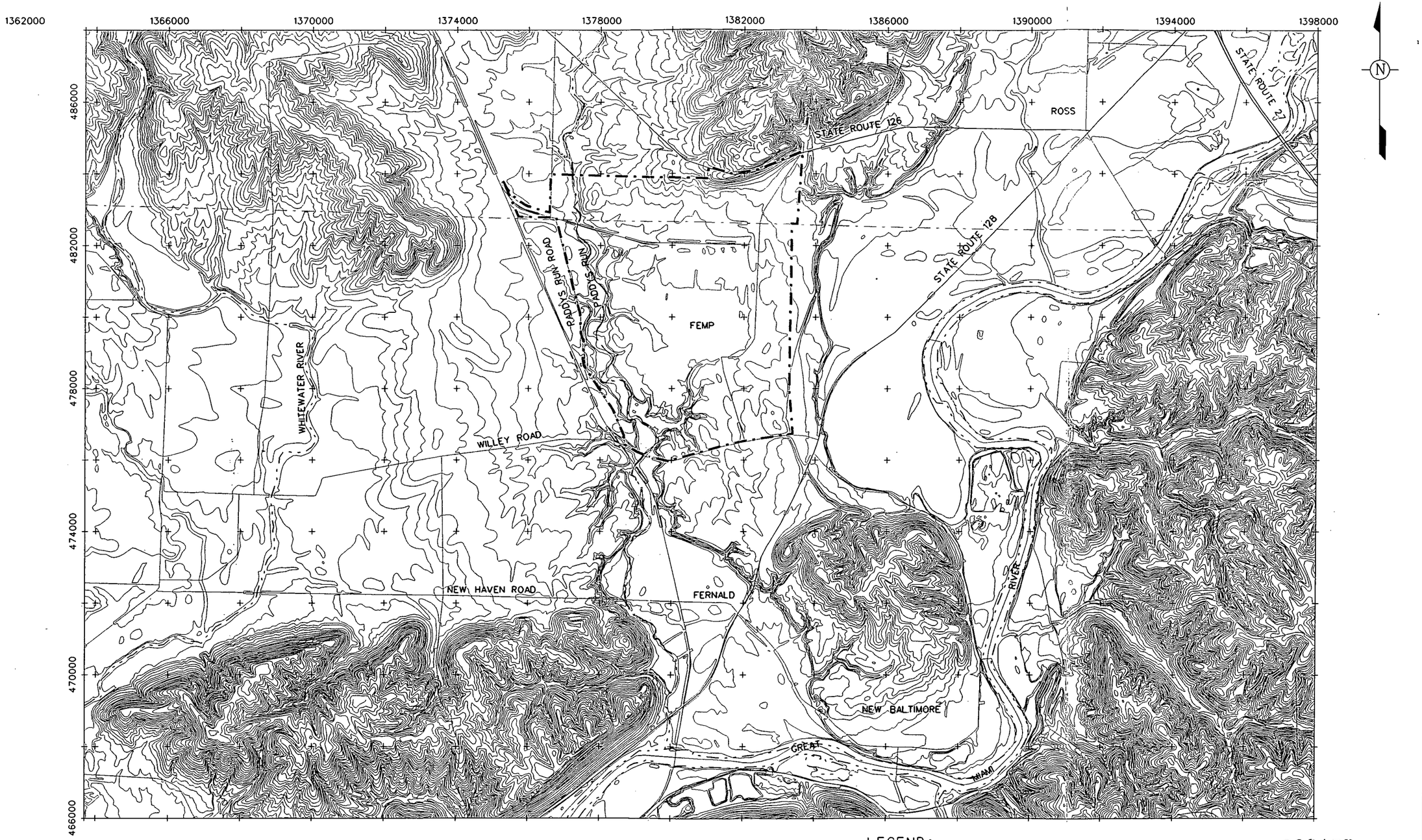
FIGURE 1-1. FEMP SITE LOCATION MAP



LEGEND:

FEMP BOUNDARY

SCALE

2750 1375 0 2750 FEET

000152

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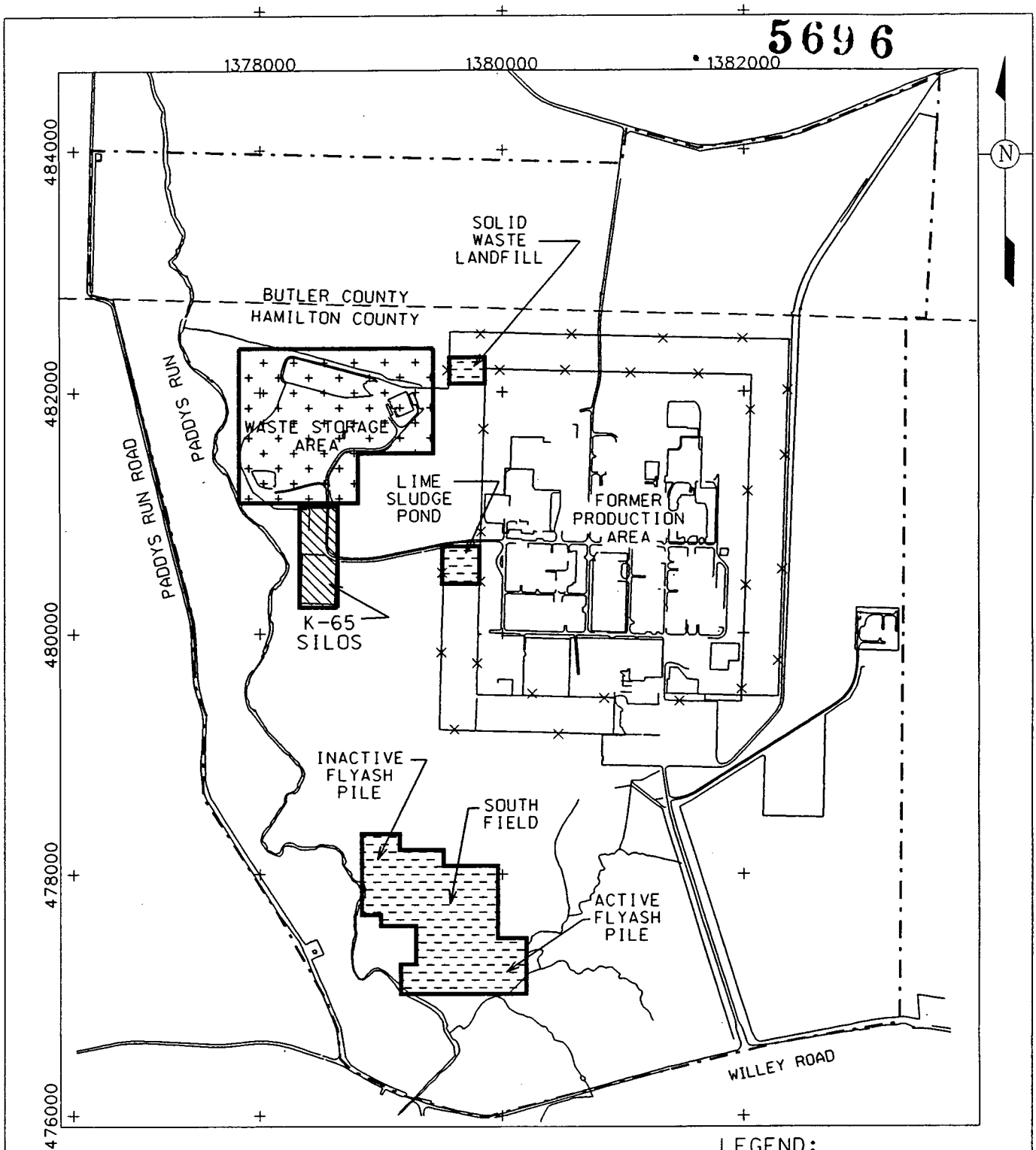
USR/ERMA3/5ARN1/DGN/MAP/HOR/DPTH/C110072.DGN
FER 005 RIDATA 5-31-94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 1-2. FEMP LOCATION MAP



LEGEND:

- OPERABLE UNIT 1
- OPERABLE UNIT 2
- OPERABLE UNIT 4
- FEMP BOUNDARY
- COUNTY LINE

NOTE:
OPERABLE UNIT 3 INCLUDES ALL BUILDINGS, PIPELINES, AND ABOVEGROUND STRUCTURES IN THE FORMER PRODUCTION AREA. OPERABLE UNIT 5 INCLUDES GROUNDWATER, SURFACE WATER, SOILS, SEDIMENTS, FLORA AND FAUNA WITHIN THE REGIONAL AREA AS WELL AS THE FORMER PRODUCTION AREA.

SCALE
120 60 0 120 FEET

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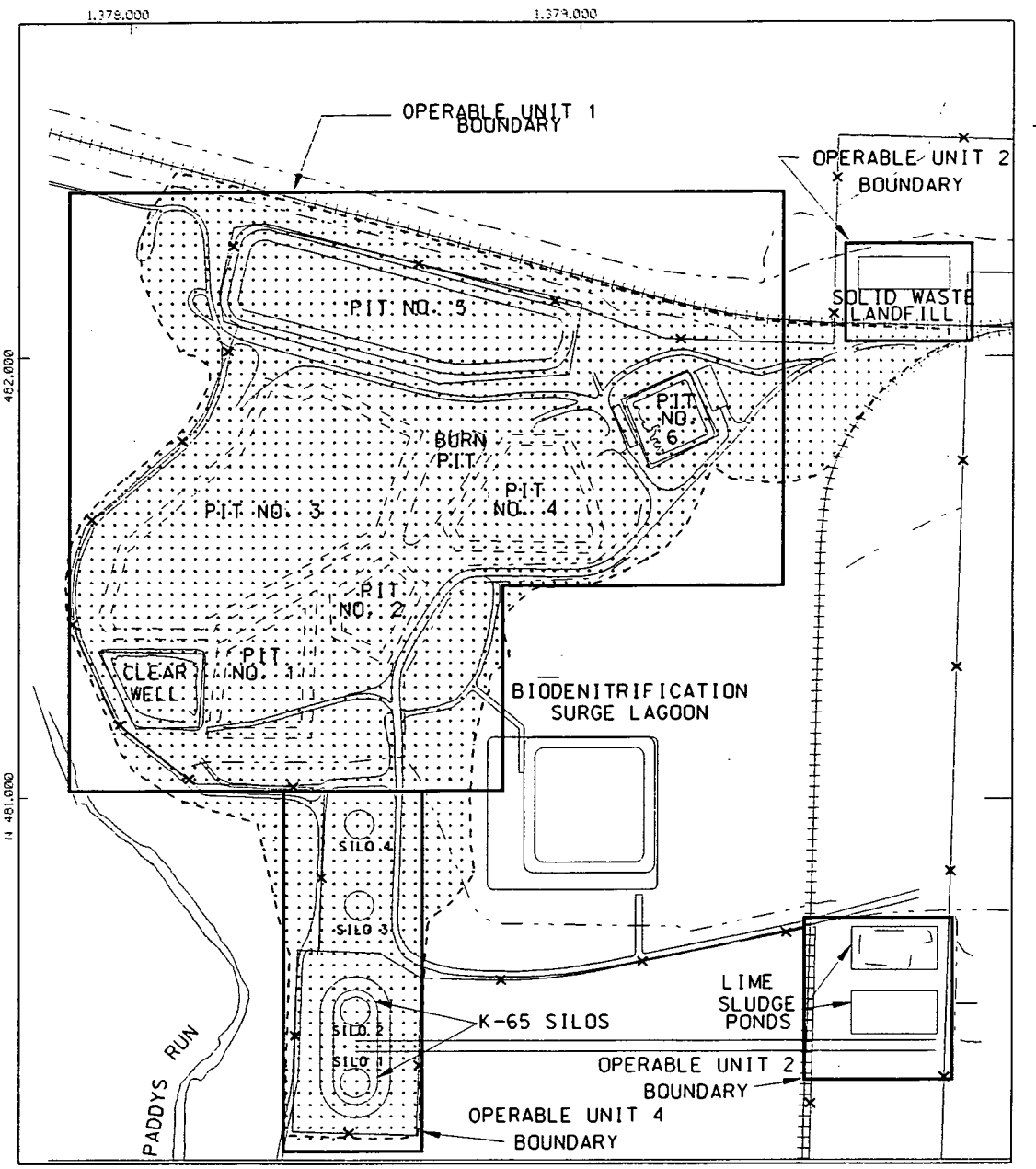
A005.DGN FER OUS RIDATA DATE STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 1-3. RI/FS OPERABLE UNITS WITHIN THE FEMP

A006.DGN FER OU5 RIDATA DATE STATE PLANAR COORDINATE SYSTEM 1927



NOTE:

PITS 1, 2, 3 AND THE BURN PIT ARE COVERED.

PIT 4 HAS AN INTERIM CAP.

LEGEND:

REMOVAL ACTION 2 AREA

OPERABLE UNIT BOUNDARY

SCALE

40 20 0 40FEET

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FIGURE 1-4 FEMP WASTE STORAGE AREA

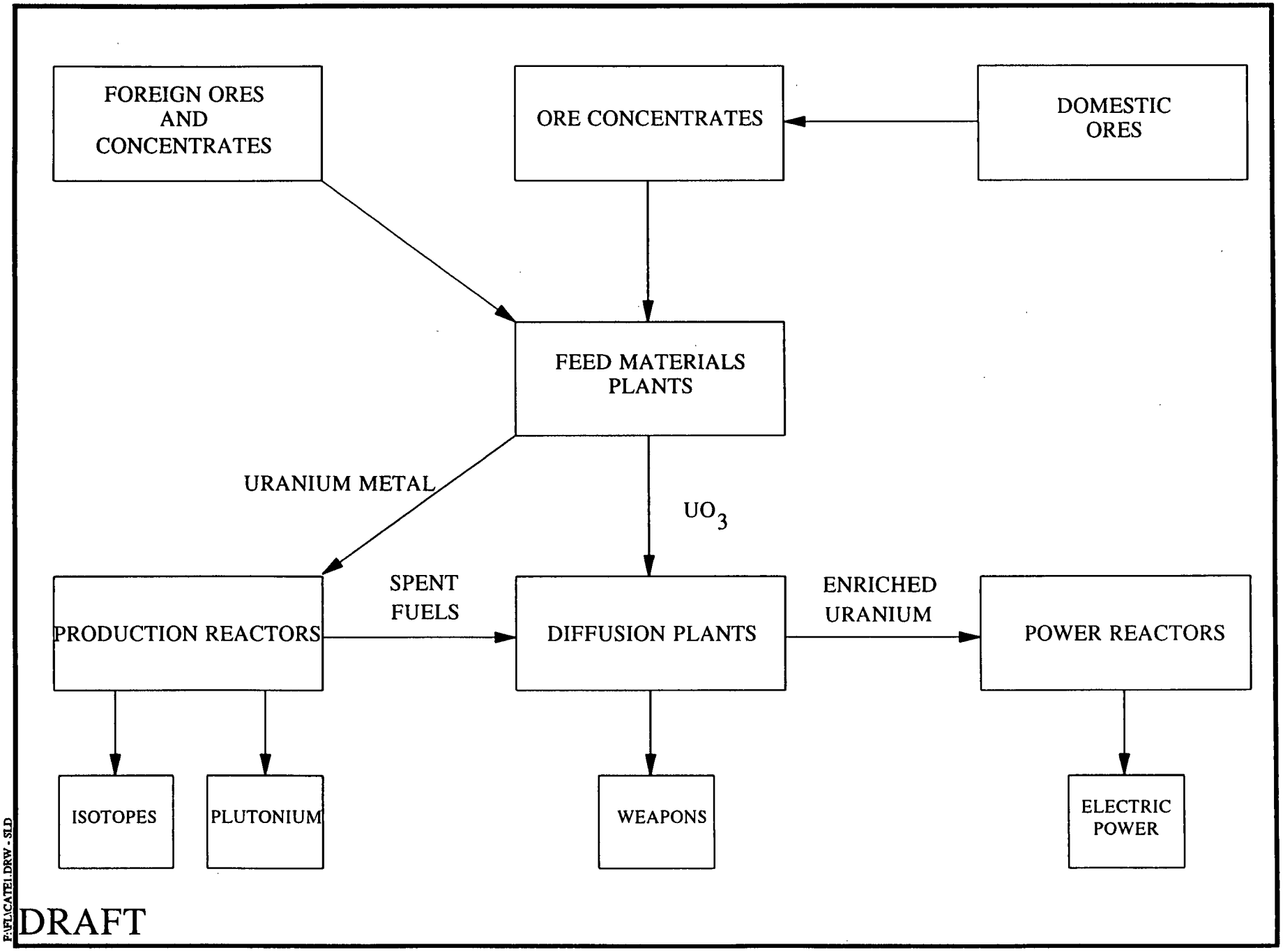

FIGURE 1-5. FEED MATERIALS RELATIONSHIP TO AEC PRODUCTION SYSTEMS

F:\FL\CATE1.DRW - SLD

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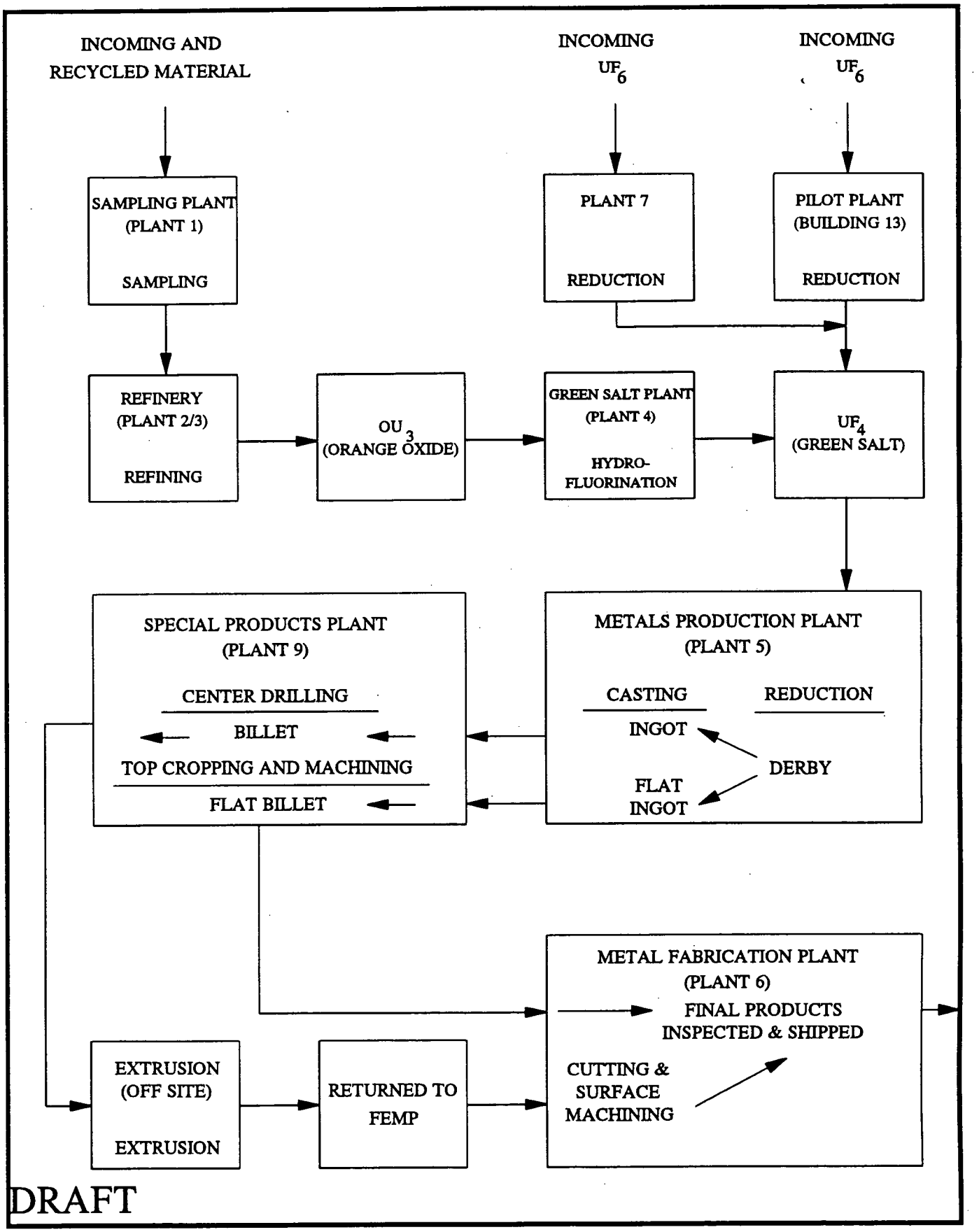
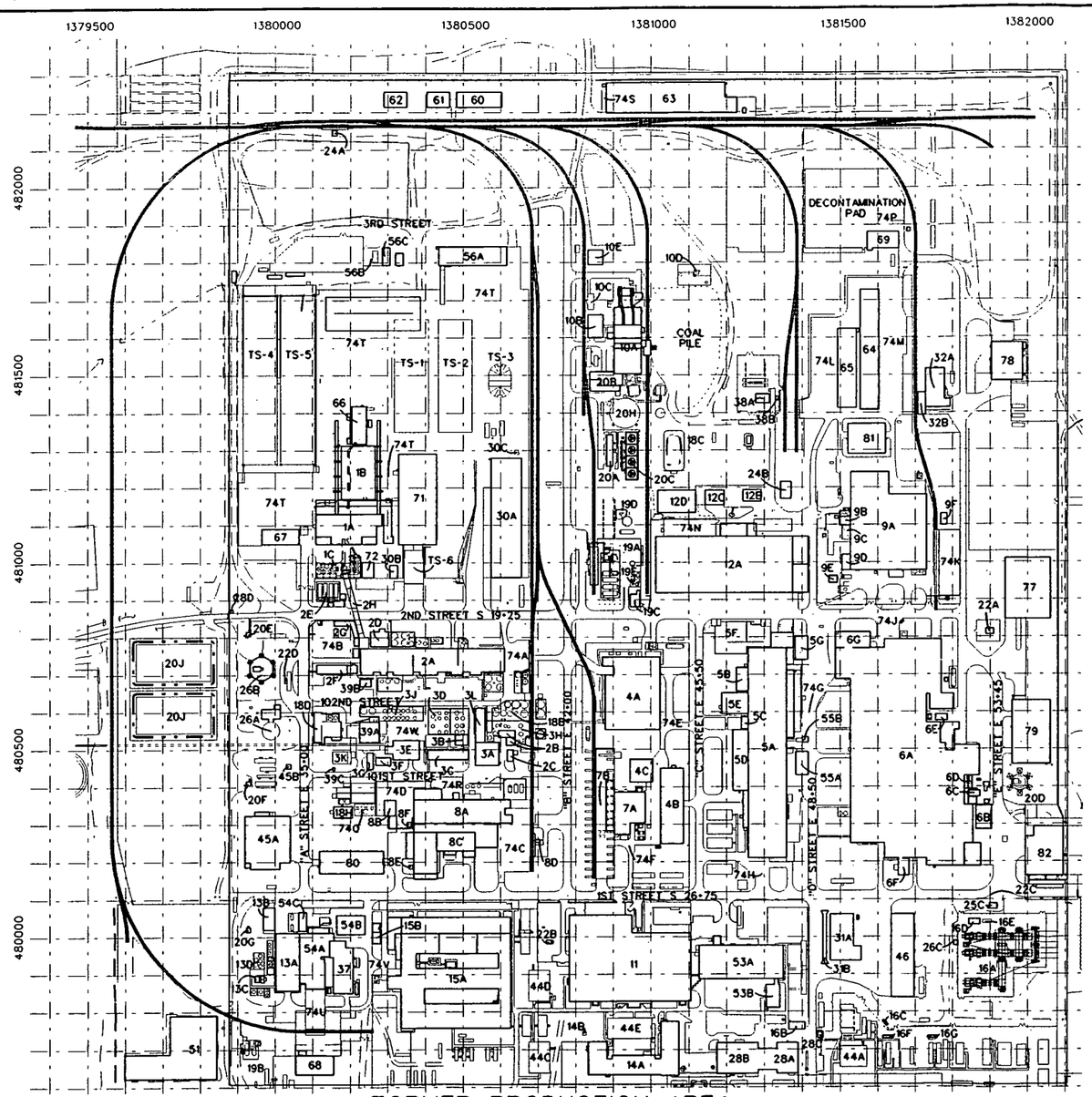


FIGURE 1-6. URANIUM METAL PROCESS DIAGRAM



FORMER PRODUCTION AREA

FEMP SITE INDEX

TS-1 TENSION SUPPORT STRUCTURE #1
TS-2 TENSION SUPPORT STRUCTURE #2
TS-3 TENSION SUPPORT STRUCTURE #3
TS-4 TENSION SUPPORT STRUCTURE #4
TS-5 TENSION SUPPORT STRUCTURE #5
TS-6 TENSION SUPPORT STRUCTURE #6
1A PREPARATION PLANT
1B PLANT 1 STORAGE BLDG.
1C PLANT 1 ORE SILOS
2A ORE REFINERY PLANT
2B GENERAL/REFINERY SUMP CONTROL BLDG.
2C BULK LIME HANDLING BLDG.
2D METAL DISSOLVER BLDG.
2E NFS STORAGE AREA & PUMP HOUSE
2F COLD SIDE ORE CONVEYOR
2G HOT SIDE ORE CONVEYOR
2H CONVEYOR TUNNEL (FROM PLANT 1)
3A MAINTENANCE BLDG.
3B OZONE BLDG.
3C NAR CONTROL HOUSE
3D NAR TOWERS
3E HOT RAFFINATE BLDG.
3F HARSHAW SYSTEM
3G REFRIGERATION BLDG.
3H REFINERY SUMP
3J COMBINED RAFFINATE TANKS
3K OLD COOLING WATER TOWER
3L ELECTRICAL POWER CENTER BLDG.
4A GREEN SALT PLANT
4B PLANT 4 WAREHOUSE
4C PLANT 4 MAINTENANCE BLDG.
5A METALS PRODUCTION PLANT
5B PLANT 5 INGOT PICKLING
5C PLANT 5 ELECTRICAL SUBSTATION
5D WEST DERBY BREAKOUT/SLAG MILLING
5E PLANT 5 FILTER BLDG.
5F PLANT 5 COVERED STORAGE PAD
5G PLANT 5 INGOT STORAGE SHELTER
6A METALS FABRICATION PLANT
6B PLANT 6 COVERED STORAGE AREA
6C PLANT 6 ELECTROSTATIC PRECIPITATOR (SOUTH)
6D PLANT 6 ELECTROSTATIC PRECIPITATOR (CENTRAL)
6E PLANT 6 ELECTROSTATIC PRECIPITATOR (NORTH)
6F PLANT 6 SALT OIL HEAT TREAT BLDG.
6G PLANT 6 SUMP BLDG.
7A PLANT 7
7B PLANT 7 OVERHEAD CRANE
8A RECOVERY PLANT
8B PLANT 8 MAINTENANCE BLDG.
8C ROTARY KILN/DRUM RECONDITIONING
8D PLANT 8 RAILROAD FILTER BLDG.
8E DRUM CONVEYOR SHELTER
8F PLANT 8 OLD DRUM WASHER
9A SPECIAL PRODUCTS PLANT
9B PLANT 9 SUMP TREATMENT FACILITY
9C PLANT 9 DUST COLLECTOR
9D PLANT 9 SUBSTATION
9E PLANT 9 CYLINDER SHED
9F PLANT 9 ELECTROSTATIC PRECIPITATOR
10A BOILER PLANT
10B BOILER PLANT MAINTENANCE BLDG.
10C WET SALT STORAGE BIN
10D CONTAMINATED OIL/GRAPHITE BURN PAD
10E UTILITIES HEAVY EQUIP. BLDG. (PROPOSED)
11 SERVICE BLDG.
12A MAIN MAINTENANCE BLDG.
12B CYLINDER STORAGE BLDG.
12C LUMBER STORAGE BLDG.
12D MAINTENANCE BLDG. WAREHOUSE (PROPOSED)
13A PILOT PLANT WET SIDE
13B PILOT PLANT MAINTENANCE BLDG.
13C SUMP PUMP HOUSE
13D PILOT PLANT THORIUM TANK FARM
14A ADMINISTRATION BLDG.
14B BLDG. 14 EOC GENERATOR SET
15A LABORATORY
15B LABORATORY CHEMICAL STORAGE BLDG.
16A MAIN ELECTRICAL STATION
16B ELECTRICAL SUBSTATION
16C ELECTRICAL PANELS & TRANSFORMER
16D MAIN ELECTRICAL SWITCH HOUSE
16E MAIN ELECTRICAL TRANSFORMERS
16F TRAILER SUBSTATION #1
16G TRAILER SUBSTATION #2
16H 10 PLEXS NORTH SUBSTATION
16J 10 PLEXS SOUTH SUBSTATION
18A BDN SURGE LAGOON
18B GENERAL SUMP
18C COAL PILE RUNOFF BASIN
18D BIODENITRIFICATION TOWERS
18E STORM WATER RETENTION BASINS
18F PIT #5 SLUICE GATE
18G CLEARWELL PUMP HOUSE
18H BDN EFFLUENT TREATMENT FACILITY
18J METHANOL TANK
18K LOW NITRATE TANK
18L HIGH NITRATE TANK
18M HIGH NITRATE STORAGE TANK
18N WASTE PIT AREA STORM WATER RUNOFF CONTROL
18P DISSOLVED OXYGEN BLDG.
18Q IAWWT VALVE HOUSE
19A MAIN TANK FARM
19B PILOT PLANT AMMONIA TANK FARM
19C TANK FARM CONTROL HOUSE
19D OLD NORTH TANK FARM
19E TANK FARM LIME SLITTER BLDG.
20A PUMP STATION & POWER CENTER
20B WATER PLANT
20C COOLING TOWERS
20D ELEVATED POTABLE STORAGE TANK
20E WELL HOUSE #1
20F WELL HOUSE #2
20G WELL HOUSE #3
20H PROCESS WATER STORAGE TANK
20J LIME SLURRY PITS
22A GAS METER BLDG.
22B STORM SEWER LIFT STATION
22C TRUCK SCALE
22D SCALE HOUSE & WEIGH SCALE
22E UTILITY TRENCH TO PIT AREA
23 METEOROLOGICAL TOWER
24A RAILROAD SCALE HOUSE
24B RAILROAD ENGINE HOUSE
25A CHLORINATION BLDG.
25B M.H. #175/EFF. LINE/SAMPLING BLDG.
25C SEWAGE LIFT STATION BLDG.
25D U.V. DISINFECTION BLDG.
25E DIGESTER & CONTROL BLDG.
25F SLUDGE DRYING BEDS
25G PRIMARY SETTLING BASINS
25H TRICKLING FILTERS
25J 10 PLEXS SEWAGE LIFT STATION
26A PUMP HOUSE-HP FIRE PROTECTION
26B ELEVATED WATER STORAGE TANK
26C MAIN ELECTRICAL STRAINER HOUSE
28A SECURITY BLDG.
28B HUMAN RESOURCES BLDG.
28C GUARD POST ON SOUTH END OF "D" STR.
28D GUARD POST ON WEST END OF "2ND" STR.
30A CHEMICAL WAREHOUSE
30B DRUM STORAGE WAREHOUSE
30C OLD TEN TON SCALE
31A ENGINE HOUSE/GARAGE
31B OLD TRUCK SCALE
32A MAGNESIUM STORAGE BLDG.
32B BLDG. 32 COVERED LOADING DOCK
34A K-65 STORAGE TANK (NORTH)
34B K-65 STORAGE TANK (SOUTH)
34C RTS BLDG.
35A METAL OXIDE STORAGE TANK (NORTH)
35B METAL OXIDE STORAGE TANK (SOUTH)
37 PILOT PLANT ANNEX
38A PROPANE STORAGE
38B CYLINDER FILLING STATION
39A INCINERATOR BLDG.
39B WASTE OIL DECANT SHELTER
39C INCINERATOR SPRINKLER RISER HOUSE
39D SEWAGE TREATMENT PLANT INCINERATOR
44A TRAILER COMPLEX (6-PLEX)
44C TRAILER COMPLEX (7-PLEX S.)
44D TRAILER COMPLEX (7-PLEX N.)
44E TRAILER COMPLEX (10 PLEX)
45A RUST ENGINEERING BLDG.
45B UTILITY SHED EAST OF RUST TRAILERS
46 HEAVY EQUIPMENT BLDG.
51 SIX TO FOUR REDUCTION FACILITY #2
53A HEALTH & SAFETY BLDG.
53B IN-VIVO BLDG.
54A SIX TO FOUR REDUCTION FACILITY #1
54B PILOT PLANT SHELTER
54C PILOT PLANT DISSOCIATOR SHELTER
55A SLAG RECYCLING BLDG.
55B SLAG RECYCLING PIT/ELEVATOR
56A CP STORAGE WAREHOUSE
56B STORAGE SHED (WEST)
56C STORAGE SHED (EAST)
60 QUONSET HUT #1
61 QUONSET HUT #2
62 QUONSET HUT #3
63 KC-2 WAREHOUSE
64 THORIUM WAREHOUSE
65 (OLD) PLANT 5 WAREHOUSE
66 DRUM RECONDITIONING BLDG.
67 PLANT 1 THORIUM WAREHOUSE
68 PILOT PLANT WAREHOUSE
69 DECONTAMINATION BLDG.
71 GENERAL IN-PROCESS WAREHOUSE
72 DRUM STORAGE BUILDING
73A FIRE BRIGADE TRAINING CENTER BLDG.
73B FIRE TRAINING POND
73C FIRE TRAINING TANK
73D FIRE TRAINING BURN TROUGH
73E CONFINED SPACE BURN TANK
74A PLANT 2 EAST PAD
74B PLANT 2 WEST PAD
74C PLANT 8 EAST PAD
74D PLANT 8 WEST PAD
74E PLANT 4 PAD
74F PLANT 7 PAD
74G PLANT 5 EAST PAD
74H PLANT 5 SOUTH PAD
74J PLANT 6 PADS
74K PLANT 9 PAD
74L BUILDING 65 WEST PAD
74M BUILDING 64 EAST PAD & R.R. DOCK
74N BUILDING 12 NORTH PAD
74P DECONTAMINATION PAD
74Q PLANT 8 OLD METAL DISSOLVER PAD
74R PLANT 8 NORTH PAD
74S BUILDING 63 WEST PAD
74T PLANT 1 STORAGE PAD
74U PILOT PLANT PAD
74V LABORATORY PAD
74W INCINERATOR BLDG. PAD
77 FINISHED PRODUCTS WAREHOUSE (4A)
78 D & D BUILDING
79 PLANT 6 WAREHOUSE
80 PLANT 8 WAREHOUSE
81 PLANT 9 WAREHOUSE
82 RECEIVING/INCOMING MAT'LS. INSP.
88 CLEARWELL LINE
89 PARKING LOTS
T76 INTERIM OFFICE SPACE
T77 INTERIM OFFICE SPACE
T80 INTERIM OFFICE SPACE
T81 INTERIM OFFICE SPACE

LEGEND:

- ROADWAY
- FENCE LINES
- BUILDING OUTLINES
- CSX RAIL LINES
- INDICATES PROPOSED LOCATIONS OF STRUCTURES

SCALE

100 0 100 200 300 FEET

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/res/res2187/fig1-6.dgn

FIGURE 1-7. EXISTING PRODUCTION AREA LAYOUT

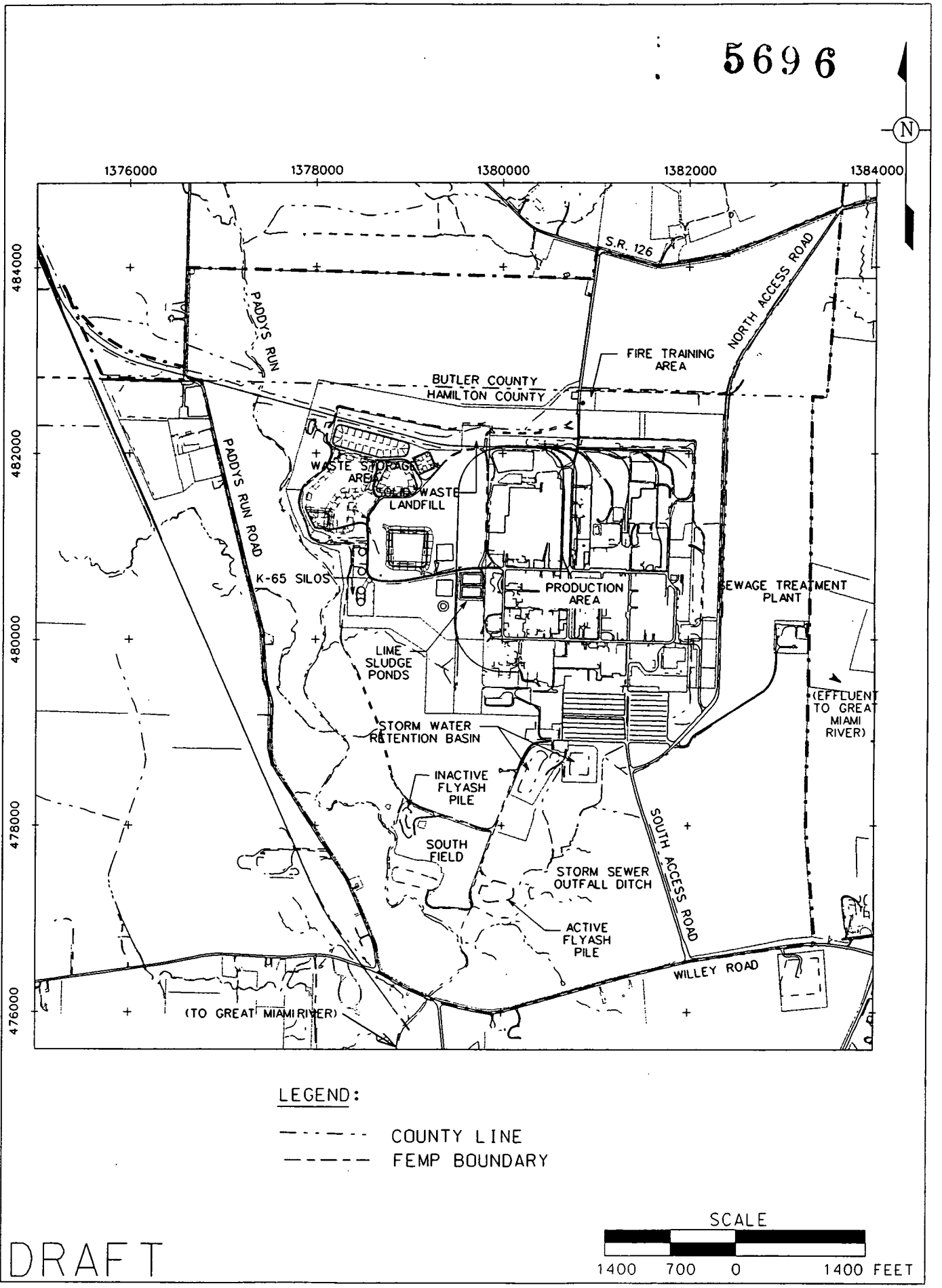

FIGURE 1-8. MAJOR FEATURES OF THE FEMP

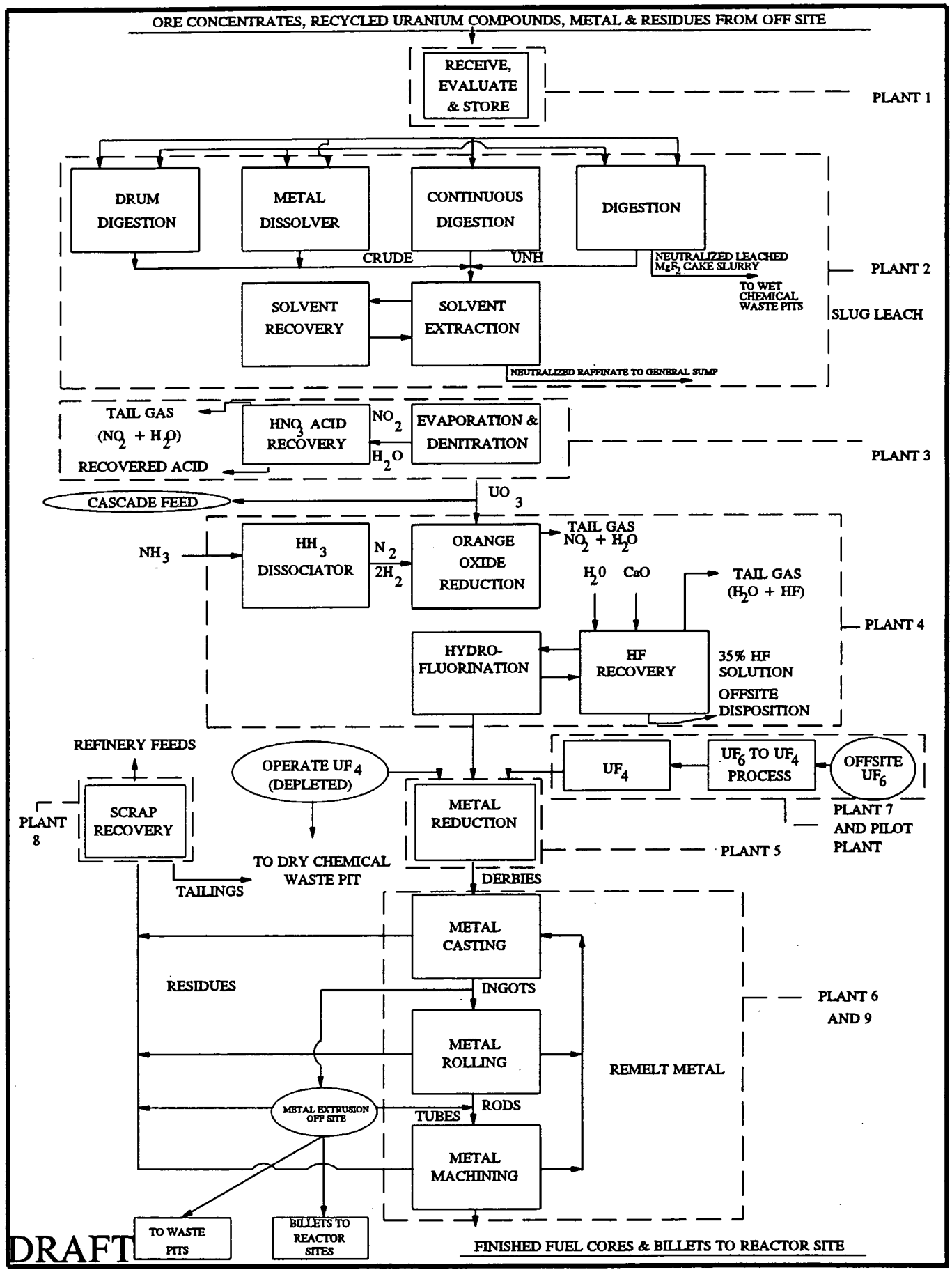

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FIGURE 1-9. SCHEMATIC DIAGRAM OF THE FEMP PROCESS

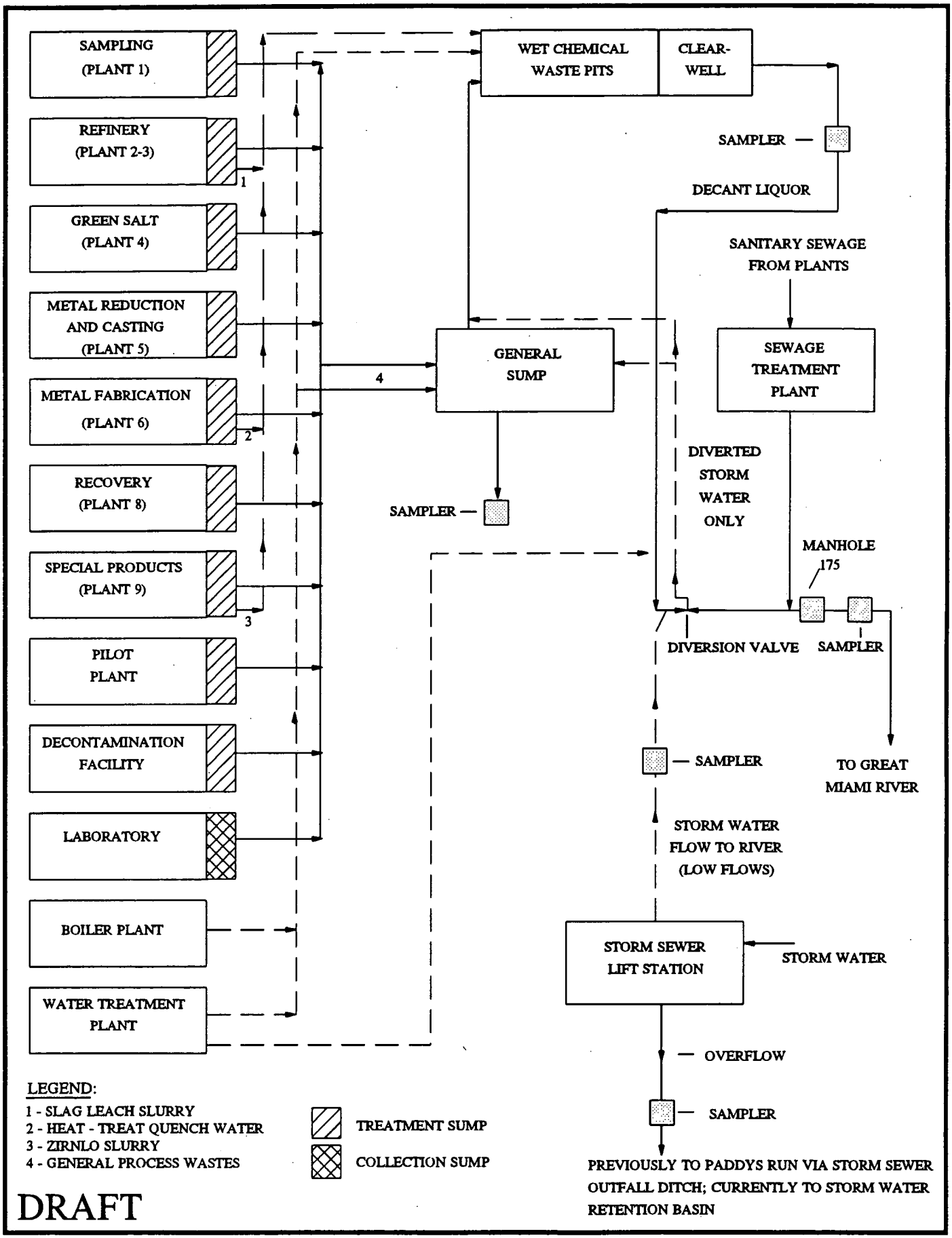

FIGURE 1-10. HISTORICAL LIQUID WASTE FLOW DIAGRAM

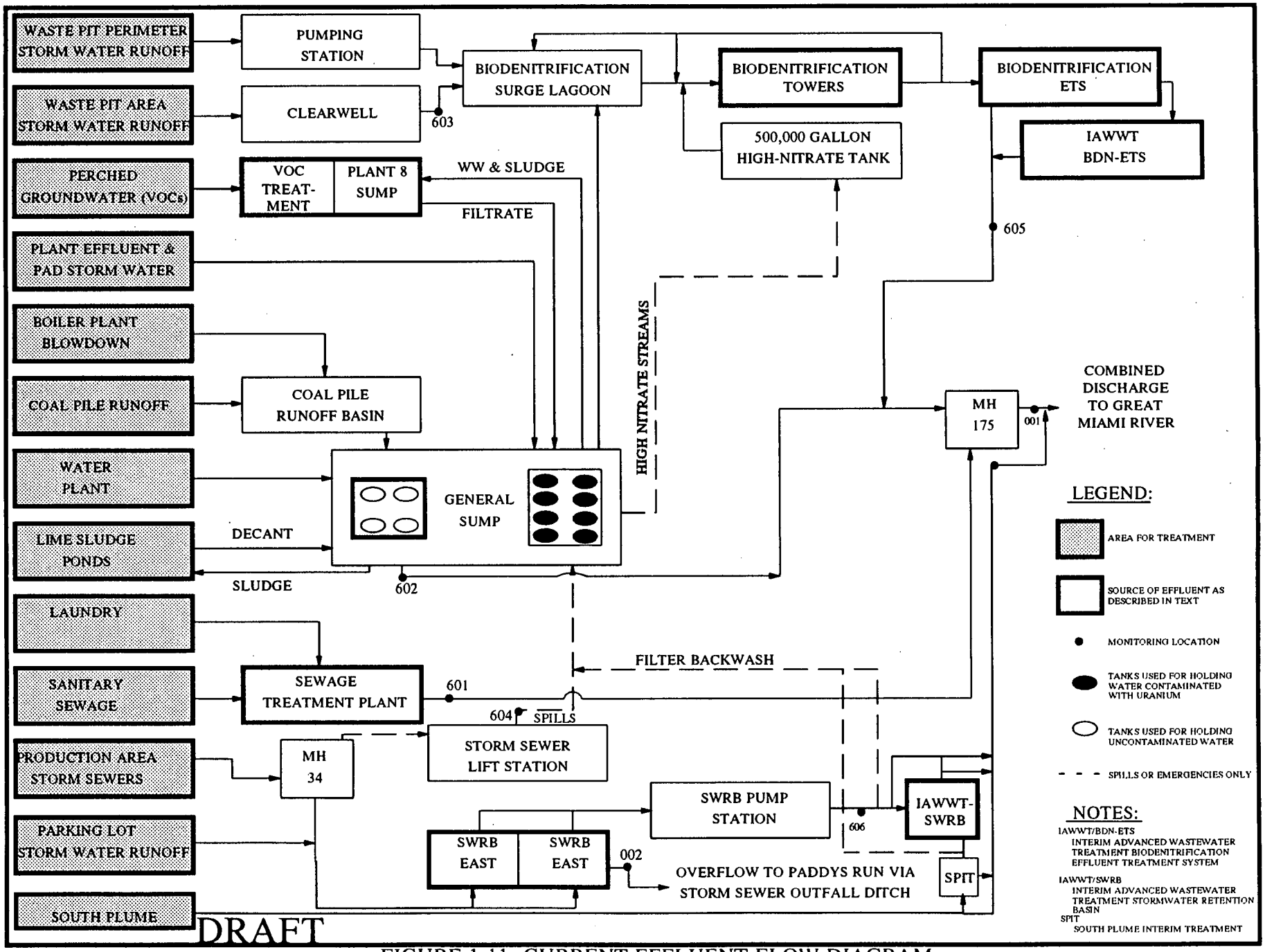

FIGURE 1-11. CURRENT EFFLUENT FLOW DIAGRAM

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2.0 STUDY AREA INVESTIGATIONS

This section introduces the site investigations conducted to develop a detailed understanding of the physical setting of the Fernald Environmental Management Project (FEMP), the nature and extent of any existing contamination at the site, and the associated risks to human health and the environment. These investigations were completed as part of the remedial investigation/feasibility study (RI/FS), the FEMP environmental monitoring program, and other site programs to characterize the physical, chemical, and radiological properties of contaminated environmental media and to evaluate the potential for further migration of these contaminants. Further, these investigations identified and characterized key environmental and human receptors potentially impacted by the presence of these contaminants. Site investigations targeted the environmental media and viable pathways of exposure to receptors, including surface water and sediment, surface and subsurface soils, groundwater, and direct radiation. Potentially impacted biological and cultural resources were also inventoried and examined.

This section provides an overview of each major data set relied upon in compiling this RI Report. Also discussed in this section are the pertinent elements of the data validation effort performed to assure the quality and usability of individual data sets and values. The intent of this section is not to provide an exhaustive discussion on the evolution of each of these field programs, but rather to highlight the objectives, sample collection methods, and types of analysis associated with each data set to a level of detail sufficient to permit meaningful review of the remainder of this report. A more thorough discussion of data sets can be found in the individual Environmental Protection Agency (EPA)-approved sampling plans and reports supporting each study. These plans and reports are available in the Administrative Record.

2.1 DATA REQUIREMENTS FOR THE REMEDIAL INVESTIGATION

Site investigations associated with Operable Unit 5 were designed and implemented to provide an understanding of the nature and extent of contaminants within environmental media at the site and the physical setting in which these contaminants reside. These investigations were conducted to acquire data detailed enough to conduct an assessment of the risks to human health and the environment in the absence of remedial actions, and evaluate viable remedial action alternatives for the feasibility study (FS).

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2.1.1 General Requirements

The evaluation of the specific data needs necessary to support these objectives began with the development of the RI/FS Work Plan in July 1986. This Work Plan provided a summary of known or suspected sources of potential hazardous substance releases at the FEMP and assessed the sufficiency of environmental characterization data, available at that time, to adequately fulfill the informational needs of the RI/FS process. On the basis of this scoping process, distinct known or suspected sources of contamination and a number of areas exhibiting environmental media contamination were identified. The original RI/FS Work Plan, approved in May 1988, described an initial field program designed to: (1) verify the presence of these sources or areas of media contamination; (2) characterize the type and concentration of contaminants present; and (3) provide direction to further site investigations. On this basis, the RI/FS process at the FEMP adopted a phased approach to collecting the appropriate type and quantity of characterization data necessary to satisfy the previously identified RI objectives. Phased characterizations are typically employed at sites involving multiple sources, contaminants, and exposure pathways where there are significant cross-media impacts and where complex technical and regulatory issues exist like those present at the FEMP. Field implementation of the RI site investigations was initiated in July 1987 with sampling in and around identified source areas. The investigations then systematically expanded from those areas to define the limits of environmental media contamination. The operable unit concept was introduced at the FEMP in 1989. Five operable units were created based on similarity of suspected contaminants. Data from these field investigations were progressively evaluated, with plans for additional studies subsequently defined and implemented.

Individual plans prepared to support this phased characterization process, including the original RI/FS Work Plan, were provided to the EPA and the Ohio Environmental Protection Agencies (OEPA) for review, comment and approval. In total, over 30 addenda were issued to the original RI/FS Work Plan discussing characterization efforts to be undertaken by FEMP to provide data to support the objectives of the 5 operable units. In 1992, Operable Unit 3 was rescoped so that Operable Unit 5 inherited the soil and groundwater that underlies the former production area. Operable Unit 5 now encompasses those areas not covered by Operable Units 1, 2, 3 and 4. Between July 1987 and December 1993, over 750 wells were installed under the RI to supplement existing data to describe the nature and extent of environmental media contamination associated with the FEMP site. Appendix S presents a brief synopsis of each of the site investigation programs conducted to support

the operable units. Additional studies aimed at assessing the viability of select treatment technologies to address identified contaminants are presently underway to support the Operable Unit 5 FS.

Site investigations were generally designed to characterize the extent and concentrations of contaminants in environmental media, the mechanisms for transport of these contaminants through the environment, and the viable pathways of exposure to human or environmental receptors. Figure 2-1 presents a conceptual diagram illustrating this concept and the major elements involved in the Operable Unit 5 site investigations. The RI focused on the FEMP property and any adjacent areas where environmental media contamination was known or suspected to reside. Figure 2-2 provides an overview of the investigation area for Operable Unit 5. The media or pathways addressed by the Operable Unit 5 site investigations included:

- Surface and subsurface soils on and off of the FEMP property
- Surface water and sediment associated with on- and off-property drainage ditches, Paddys Run, and the Great Miami River
- Water quality and flow characteristics of the perched groundwater system on the FEMP property
- Regional groundwater quality and flow characteristics in the Great Miami Aquifer under and off the FEMP property
- Air quality on and off of the FEMP property
- Direct radiation areas on and immediately adjacent to the FEMP property
- Surface water infiltration to the Great Miami Aquifer and on-property perched groundwater
- Terrestrial ecology on the FEMP property and adjacent areas
- Aquatic ecology in the wetlands on FEMP property as well as in Paddys Run and the Great Miami River.

In general, releases to air and water historically occurred from a variety of sources including production-related stacks and equipment, underground piping, and waste storage containers and pits on the FEMP property. The discontinuation of production and mitigative measures implemented at the facility have significantly reduced ongoing releases from these sources that are being addressed under Operable Units 1-4. These releases have resulted in contamination of the environmental media surrounding each of the sources. This existing contamination in the media can also be considered a

secondary source in that the contaminants present may continue to move through the environment, confined only by the limits imposed by natural forces. Contaminants residing on surface soil are available for resuspension and transport by wind as dust particles, movement to surface water channels by contact with rainfall, or vertical transport through the soil column to underlying groundwater systems.

Table 2-1 summarizes the data evaluation approach applied to each of the major elements pertinent to the Operable Unit 5 RI. The reference table summarizes: (1) the informational needs of the RI; (2) the data available from sources other than RI/FS employed to support these needs; and (3) site investigations specifically conducted as part of the RI to fulfill these specific informational requirements. The table identifies the ultimate use of the individual data sets in the RI and the section of the report in which the data set is introduced. As identified in Table 2-1, a variety of data sources have been relied upon for the characterization of Operable Unit 5, in addition to the data set collected pursuant to the RI/FS Work Plan and issued addenda. These additional sources of data include:

- FEMP Environmental Monitoring (EM) Program
- Resource Conservation and Recovery Act (RCRA) Groundwater Program
- Removal actions performed in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
- Final Interim Report (litigation support study)
- Hydrogeologic Study of the FEMP Discharge to the Great Miami River
- Miami University studies
- Characterization Investigation Study (CIS).

In general, all contaminant concentration data to support the definition of "source term concentrations" employed in the quantitative baseline risk assessment were subjected to a rigorous data validation process discussed later in this section. Data rejected by this process were removed from the data sets before initiation of the risk assessment process. The validated data sets and other select unvalidated data sets were used, as appropriate, to support the description of the nature and extent of contamination, as identified in Table 2-1, and as discussed in Section 4.0 of this report.

The following sections describe sampling activities and the objectives, methods, and analyses associated with each resulting data set. Additional details on these data sets are available in the individual sampling plans and reports in the Operable Unit 5 Administrative Record files.

Each of the site investigation activities completed in accordance with the RI/FS Quality Assurance Project Plan (QAPP) that involved the collection of discrete solid or liquid matrix samples used similar analytical parameter lists. The analytical parameters listed in Table 2-2 show the distinctions among the various analytical lists used in the RI/FS. Standard Contract Laboratory Program (CLP) protocols were followed for samples that were analyzed for the RI/FS investigations.

Due to the extreme number of samples (approximately 14,000) and the extended collection period (1987 to 1993) associated with the RI, it is impossible to identify here the specific analytical lists associated with each Operable Unit 5 sampling event or location. Therefore, within the discussions of the field investigations, there is a general reference to the type of analyses conducted for each program (Table 2-3). Specific analyses associated with each sample collected under the RI/FS can be found in the RI/FS Work Plan and addenda, which are available in the Administrative Record. A full tabulation of sampling results for the Operable Unit 5 RI, by discrete sample number, can be found in Appendices G through H, I, and J.

2.1.2 General Sampling Methods (Surface Water, Sediment and Surface and Subsurface Soils)

Investigations and sampling programs were conducted in accordance with the requirements of the RI/FS (QAPP), Volume V of the RI/FS Work Plan (DOE 1988) or the replacement CERCLA Sitewide Quality Assurance Project Plan (SCQ) (DOE 1993). Any variance from the field or analytical procedures identified in these quality assurance plans are recorded in the specific project files and were considered during the data validation and analysis processes.

Other data sets employed by the RI, but not conducted as part of the RI/FS, were either completed under the terms of the RI/FS QAPP, the SCQ, or their own project-specific quality programs and an assessment was completed on the quality of these data sets. The factors examined to assure the adequacy of the data sets for use in the RI/FS process included consideration of the age of the data, analytical methods used, detection limits of methods, and the available documentation regarding QA/QC procedures and data collection methods.

The general sampling methods followed during RI/FS investigations are discussed below by media.

2.1.2.1 Surface Water Sampling

These sampling methods apply to samples from streams, ponds, rivers, and springs. The collection or grab bottle was rinsed with the water to be collected. Surface water samples from Paddys Run and the Great Miami River were collected by placing a precleaned sample bottle approximately 6 inches below the water surface. The mouth of the bottle was positioned toward the current flow, away from the hand of the collector, the river banks, and the side of the sampling platform or boat. The water in the grab bottle was then transferred to individual precleaned sample containers. In the event more than one grab bottle volume was required to fill the necessary sample containers, the water from the grab bottles was composited in a holding container before filling the individual sample containers to provide homogeneity of collected samples. Sampling crew members were positioned downstream from the collection point to prevent any possible contamination from disturbance of sediment during sample collection. The sampling sequence progressed from downstream to upstream locations to prevent similar interferences from disturbed sediment. If filtered samples were taken, a 0.45 micron filter was used.

Seep sampling is not specifically explained in either the QAPP or SCQ. The following methods were outlined in the project-specific plan. The uppermost 1 to 2 inches of vegetation were removed with a shovel before sampling. A vertical slice was cut into the edge of the slope where the seep was located. A large stainless steel bowl was placed against the newly created vertical face of the seep. Plastic was draped over the bowl so that airborne particulates and/or precipitation did not affect sample integrity. Water was first collected until it was free of visible turbidity. This water was properly discarded. The stainless steel bowl was replaced at the vertical face and a representative sample collected. Sample bottles were filled directly from the stainless steel bowl. A 0.45 micron filter was used for sample filtration, if required.

2.1.2.2 Sediment Sampling

Sediment samples from the flowing water courses were collected below the water surface using a stainless steel scoop or Ponar dredge. Samples from Paddys Run during periods of dry stream channels were collected by using a stainless steel scoop to scrape away debris and collect the upper inch of sediment. Five scoops were collected from each location. For Paddys Run, sediment samples were collected at quarterpoints across the channel and composited. The samples were collected to a depth of 6 inches below the sediment/water interface. In the Great Miami River sediment samples were collected from several points along a transect at each location. There were five sampling points

along each transect: one near each bank, one one-quarter of the way in from each river bank, and one at the center. Laboratory analysis was performed on the sample that, based upon field observation, would have the highest probability for contamination. In most cases, the sediment sample submitted for analysis corresponded to the most likely depositioned or floodplain area across the transect. This location would exhibit the lowest energy environment and contain the highest proportion of finer grained sediment.

2.1.2.3 Surface Soil Sampling

Surface soil samples were collected using a stainless steel hand trowel, scoop, or hand augering device. Surface soil samples were generally collected at 2- or 6-inch intervals. Samples were transferred directly from the trowel, scoop, or hand auger tip to the appropriate glass sample containers. Volatile organics analysis samples should be placed in 40 mL vials and filled completely to minimize head space in the containers.

Surface soil samples were also collected during subsurface boring advancement. In general, surface soil samples were collected from the first split-spoon sample collected during the auger drilling process. Three 6-inch-depth increment samples were collected at each auguring location from the first 18-inch split-spoon sample.

Immediately upon opening each split-spoon sampler, the soil was screened for volatile organics using a photoionization detector, a HNu™ with 10.2 or 11.7 MeV lamps or a Microtip organics detector. If a volatile release was detected, a sample of the core was transferred to two standard vials for further analysis.

If volatile organics were determined to be present in the soil sample from the borings, a representative portion of the sample was collected and analyzed for full HSL parameters. This sampling was in addition to any scheduled HSL, full HSL, or HSL+ analyses as specified in the project specific or work plan.

The samples were also screened for gross alpha radiation using an alpha scintillation probe and for beta and gamma radiation using a Ludlum detector. After the surface boring was completed and soil samples were collected, the samples were screened again for radionuclides using a large volume

scintillation detector for confirmatory purposes. Any soil samples that were not sent to the laboratory were archived for possible future use.

2.1.2.4 Subsurface Soil Sampling

The sampling and logging of subsurface materials were conducted in accordance with the RI/FS Work Plan, the QAPP and the SCQ. Continuous soil samples were collected in the glacial overburden. Outwash sand and gravel and Great Miami Aquifer material were sampled at 5-foot intervals or at changes in lithology, as determined by the project site geologist. Any samples that were not sent to the laboratory were archived. At locations where more than one well was installed, subsurface soil samples were collected only once through the geologic column, in the deepest borehole. Relatively undisturbed soil samples were collected using standard 18-inch split-spoon samplers, in accordance with American Society for Testing Materials (ASTM) Method D1586-84. Typically, activities associated with well drilling were completed using cable tool techniques while borings/piezometers were accomplished using hollow-stem auguring.

The subsurface soil samples were examined and described by a project site geologist who classified them based on their color (Munsell Soil Color Charts), texture (Unified Soil Classification System [USCS]), estimated water content, and depth from land surface. All field observations were recorded on standard visual classification of soil forms described in the QAPP and the SCQ. Copies of these field forms describing the characteristics of the subsurface soil are in Appendix P.

Immediately upon opening each split-spoon sampler, the samples were screened for volatile organics using a photoionization detector, HNu™, with 10.2 or 11.7 eV lamps or a Microtip organics detector. If a volatile release was detected, a sample of the core was transferred to two standard 40-mL vials.

If volatile organics were determined to be actually present in the soil sample, a representative portion of the sample was collected and analyzed for full HSL parameters. At locations where more than one well was installed and volatile organics were present, at the first well installed, a confirmation sample was commonly collected from the second boring. This sampling was in addition to any scheduled HSL, full HSL, or HSL+ analyses as specified in the project specific or work plan.

The samples were also screened for gross alpha radiation using an alpha scintillation probe, and for beta and gamma radiation using a Ludlum detector. These measurements were recorded on the visual

classification of soil log. After the boring was completed and subsurface soil samples collected, the samples were screened again for radionuclides using a large-volume scintillation detector for confirmatory purposes. Any soil samples that were not sent to the laboratory were archived for possible future use.

2.1.2.5 Trench Sampling

The trenches were excavated using a track-mounted backhoe with an 18- to 24-inch bucket. The trenches were dug to depths ranging from 5 to 18 feet. Material retrieved with the backhoe was screened for volatile organics using a photoionization detector, HNu™, with 10.2 or 11.7 eV lamps or a Microtip organics detector. If a volatile release was detected, a soil sample was collected for HSL volatiles or full HSL analysis. The samples were also screened for gross alpha radiation using an alpha scintillation probe, and for beta and gamma radiation using a Ludlum detector. These measurements were recorded on the visual classification of soil log. After the trenching was completed and samples collected, they were screened again for radionuclides using a large-volume scintillation detector for confirmatory purposes. The subsurface soil samples were examined and described by a project site geologist. The geologist described and classified the samples based on their color (Munsell Soil Color Charts), texture (USCS), estimated water content, and depth from land surface. All field observations were recorded on standard visual classification of soil forms described in the QAPP and the SCQ. Copies of these field forms describing the characteristics of the subsurface soil are in Appendix P.

2.1.3 General Sampling Methods (Groundwater)

See Section 2.1.2 for a discussion of general sampling methods and quality standards.

2.1.3.1 Well and Piezometer Installation Methods

Borehole advancement into the Great Miami Aquifer was performed using cable-tool drilling techniques. The use of mud rotary or continuous flight hollow-stem augers was determined to be inadequate for advancing through the glacial overburden because of the potential for perched groundwater contamination in the glacial overburden. Continuous flight auger drilling techniques were used as part of the RI to collect soil samples and to install borings and piezometers in the glacial overburden.

The primary consideration when selecting the drilling technique was the prevention of cross contamination during boring advancement; i.e., the transport of contaminants from the glacial overburden through the unsaturated sand and gravel outwash into the Great Miami Aquifer. The cable-tool technique advances a temporary steel casing with a drive shoe at the bottom. This seals the upper borehole and prevents the migration of contaminants to the deeper units. This temporary casing also maintains an open borehole without the use of drilling muds, which could introduce foreign material into the subsurface environment. The temporary steel casing was a nominal 10-inch diameter to allow for construction of a 4-inch well. The temporary casing in wells deeper than 150 feet were sometimes telescoped with a nominal 8-inch diameter casing.

A drill hammer was used to dislodge the soil inside the temporary casing. Potable water was added to the boring when necessary to facilitate cuttings removal when drilling in unsaturated material. In the glacial overburden and unsaturated sand and gravel outwash, the soil cuttings and potable water were removed from the borehole using a dart bailer. In the saturated sand and gravel material, potable water was not needed to dislodge the soil cuttings. A sand-pump bailer was used to remove the soil cuttings from inside the temporary casing when drilling in the saturated sand and gravel.

On several occasions, sand and fine gravel would heave up into the temporary casing as the drill cuttings were being removed. This occurred when the drill cuttings and water were removed from the temporary casing and a lower hydraulic head was created inside the temporary casing than in the formation. To minimize this situation, additional potable water was added to the borehole to create a hydraulic head that was greater inside the temporary casing than in the formation outside. The result of this practice was that in some borings, significant amounts of potable water were added to the borehole during drilling. Much of this potable water was contained inside the temporary casing and removed as the boring was advanced. Any potable water that did enter the formation was removed during well development.

Before advancing any borings on the FEMP, penetration permits were obtained from the facility engineer. Before advancing any boring off FEMP property, access agreements were obtained by the U.S. Department of Energy (DOE) from the respective property owners. To locate all nearby buried utilities, area utility companies were contacted before drilling began.

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2.1.3.2 Well and Boring Identification System

Wells were installed to four different depths; Figure 2-3 diagrams installation depth and well type. Wells with a screen in the glacial overburden are Type 1 wells. Wells with a screen that straddles the water table in the Great Miami Aquifer are Type 2 monitoring wells. Wells with a screen covering the 10-foot interval above the discontinuous clay interbed layer sometimes present near the middle of the Great Miami Aquifer, or at the equivalent elevation if the clay was not encountered, are Type 3 wells. Wells with a screen set 10 feet above bedrock at the bottom of the aquifer are Type 4 wells.

The left-most digit of a well number indicates the well type while the remaining three or four digits identify the well location. There is no geographic significance to the location numbers; they were assigned sequentially as wells were installed. Wells installed at different levels in the aquifer at the same location have the same three- or four-digit location identifier and constitute a cluster. The Work Plan specified a three-digit identifier (100, 200) that only allowed for 99 locations. The numbering system was quickly expanded to four digits (i.e., 1000, 2000) to allow for additional locations. The current nomenclature which is five digits was adopted in the spring of 1993 to again allow for more locations for wells and borings. The earlier system of 1000-, 2000-, 3000-, and 4000-series well numbers corresponds to the Type 1, Type 2, Type 3, and Type 4 identifiers.

On- and off-property wells used in the pre-RI/FS sampling program were also assigned four-digit well numbers. Table 2-4 lists the previous designation of these wells and the RI/FS numbers assigned. The determination of whether private wells belonged in the Type 2 or Type 3 category was made from the best information available. Figure 2-3 shows a Type 6 well; these were installed at an intermediate depth between Type 2 and Type 3 wells, south of the FEMP as part of the Paddys Run Road Site RI/FS, long after the FEMP numbering system was established. Plates 2-1 through 2-6 show the locations of all five well types that have been used to characterize the FEMP.

Type 1 Wells

The Type 1 wells and piezometers were completed in the glacial overburden, the material most likely to be contaminated by direct contact with wastes and by surface water infiltrating through waste areas and adjacent contaminated soil. The Type 1 wells were screened with 2- to 10-foot lengths of screen in the glacial overburden. The length of the screen was dependent on the thickness of the water-bearing zone. Figures 2-4, 2-5, and 2-6 show the locations of all the Type 1 wells installed or used

by the RI/FS program as of September 30, 1993. Borings drilled in the glacial overburden also were given Type 1 designation.

Type 2 Wells

The sand and gravel outwash deposits underlie the glacial overburden and are hydrologically less complex, more extensive, and constitute a regional-scale buried channel aquifer. Within the FEMP property there is approximately 15 to 20 feet of unsaturated outwash sand and gravels between the base of the glacial overburden and the saturated outwash sand and gravels in the Great Miami Aquifer. Borings drilled to this same depth were also given Type 2 location identifiers.

Fifteen feet of well screen was installed in all the Type 2 wells so approximately 10 feet of screen was below and 5 feet of screen was above the water table, to determine if nonaqueous phase contaminants were present on the water table surface. Groundwater samples collected from the Type 2 wells were intended to determine general groundwater quality at the top of the aquifer, which would be the first zone impacted by vertically infiltrating contaminants. Figure 2-7 shows the locations of the Type 2 wells as of September 30, 1993.

Type 3 Wells

Previous investigations indicated the presence of a possibly significant clay unit near the middle of the Great Miami Aquifer beneath the FEMP (Dames & Moore 1985). This unit was labeled the "clay interbed" and was thought to be a barrier to vertical groundwater flow. Type 3 wells were installed to better define the extent of this clay unit, to determine if the clay layer influenced the migration of contaminants or groundwater flow.

The average depth of the Type 3 wells was 120 to 150 feet. If the clay layer was encountered, the well was constructed so that the bottom of the well screen was at the top of the clay unit. Every effort was made during boring advancement not to penetrate the clay unit, thereby avoiding the development of a new contaminant migration pathway. If the clay was not encountered at the target elevation, the borehole was advanced 10 feet beyond its anticipated depth to ensure that the clay unit was not present. If the clay unit was still not detected, the well was constructed so that the bottom of the well screen was at the target elevation of the clay unit. Borings drilled to the depth of the "clay interbed" are identified with a Type 3 location number. Figure 2-8 shows the locations of the Type 3 wells installed or used by the RI as of September 30, 1993.

Type 4 Wells

All Type 4 wells were advanced until bedrock was encountered. Each boring was advanced several feet into bedrock to determine that it was bedrock and not a large boulder in the outwash sands and gravels. The wells were constructed with the bottom of the screen set 10 feet above the bedrock surface. The locations of the Type 4 wells installed or used by the RI as of September 30, 1993 are shown in Figure 2-9. Borings drilled to bedrock are identified with a Type 4 nomenclature.

2.1.3.3 Well Construction

During well installation, field measurements and information such as the bottom of the boring, screen location, granular backfill interval, seals, grout, and height of riser above ground surface were recorded on the piezometer installation sheet (Appendix P) and monitoring well installation diagram. The quantities of grout, sand, and other material used in the construction of the wells were recorded on the diagram and/or the field activity daily log. After completion, the well was surveyed for horizontal and vertical control.

The details of the construction of these wells and piezometers are shown in Figures 2-10 and 2-11 and are described below:

- Casing was 4-inch-inside-diameter, 316 stainless steel with flush-thread joints for RI/FS wells, and 2-inch-inside-diameter Schedule 40 PVC with flush-thread joints for piezometers
- Two to 15-foot sections of commercial 0.01- or 0.02-inch-slot stainless steel well screen with a minimum 3-square-inch open area per foot of screen were used for RI/FS wells; and 2- to 10-foot lengths of commercial 0.01- to 0.02-inch-slot Schedule 40 PVC were used for piezometers
- The required length of well screen and casing, with end caps, was placed inside the temporary casing at the desired depth
- One-half foot to 2-foot sumps were installed at the bottom of all stainless steel wells; in some cases sumps were installed on PVC piezometers
- Sand pack material, a well-sorted medium or coarse quartz sand, was placed in the annular space between the screen and temporary casing as the temporary casing was removed from the boring. Periodic measurements were made to check the uniform placement of the sand pack. The depth to the top of the sand pack material was also measured to ensure that it was never below the bottom of the temporary casing as it was withdrawn.

- The Type 1 and Type 2 wells were backfilled with a sand pack to a height of 2 to 5-feet above the screen, then a 1- to 5-foot bentonite pellet plug was placed on top of the sand pack. The remaining area above the bentonite plug was grouted to the surface. The Type 3 and Type 4 wells were backfilled with a sand pack to a height of 5 feet above the screen and then grouted to the surface.

- Sodium bentonite pellets and Volclay grout were used in the backfill for Type 1 and Type 2 wells. Only Volclay grout was used in the Type 3 and Type 4 wells. The temporary casing was gradually removed as the grout was pumped into place using a tremie pipe so that the bottom of the temporary casing remained below the top of the grout.

- A 5-foot minimum length, black, 4 3/8- or 10-inch diameter iron pipe extending approximately 2.5 feet above the ground surface was set in the Volclay grout and a concrete apron. A drain hole was drilled in the protective casing 1 foot above the land surface.

- A mixture of approximately 1:2 cement:sand and approved water or sodium bentonite pellets was placed between the well riser and the outer protective casing to a height just below the drain hole mentioned above.

- The top of the inside stainless steel casing was finished with a vented cap that was not more than 6 inches from the top of the protective casing.

- All wells were identified with a number welded into the lid of the protective casing and painted on the inside of the cover with enamel paint. All protective casings were painted with high-visibility orange paint. The cover was installed such that precipitation cannot enter the protective casing. All off-property wells located in agricultural areas, where pesticide/herbicide spraying may occur, are equipped with gaskets and the annular space inside the casing was filled with absorbent material. This was done as added protection to prevent any foreign material from entering the wall.

- A measuring point notch was filed or cut on the inner casing of each well as a reference point for the survey coordinates and all water level measurements.

The major differences in well construction are: Type 1 and Type 2 wells have 2 to 5 feet of sand pack above the screened interval, a 1- to 5-foot seal of bentonite pellets next, then Volclay grout; Type 3 and Type 4 wells have a 5-foot sand pack and then Volclay grout above it.

2.1.3.4 Well Development

After the wells were completed, they were developed to removed fines from the area around the sensing zone. Each well installed during the RI was developed following the same general guidelines; however, development was performed no sooner than 48 hours after the well was grouted.

Well development is conducted to restore the natural hydraulic conductivity of the formation in the vicinity of the well screen. The process removes the sediment from around the well screen and sand pack material so that clear groundwater samples can be obtained. Well development was conducted with a pump and/or bottom discharge bailer, supplemented with a surge block. The methods used to develop each well depended upon the well construction and the type of subsurface material in which the well was completed. Each well was developed until the well water was clear and sediment free, to the fullest extent practical.

The recommended acceptance/rejection value is five nephelometric turbidity units (NTUs). At a minimum, five times the potable water added during boring advancement plus five times the standing water in the borehole were removed during development. The majority of the wells were developed to below the five NTUs criteria before this volume had been removed. Due to the extremely low recovery rates typical of the Type 1 wells, the five NTU requirement often could not be obtained for these wells. All equipment and material used for well development were decontaminated.

2.1.3.5 Groundwater Sampling

Groundwater samples were collected from the RI/FS wells, selected existing wells at the FEMP, and selected off-property private wells. The primary consideration in groundwater sampling is to obtain a sample representative of the groundwater body. To safeguard against collecting nonrepresentative stagnant water from a well or piezometer, the following guidelines and techniques for well purging were followed during sample withdrawal:

- A minimum of three well volumes of water were pumped or bailed from the monitoring wells that could not be pumped or bailed dry before collecting a sample.
- For wells or piezometers that could be pump or bailed dry, the well was evacuated and allowed to recover before sample withdrawal. If the recovery rate was fairly rapid and if time allowed, more than one well-volume of water was evacuated; otherwise, sampling was conducted after sufficient recovery had occurred to allow sampling.
- Samples were collected in accordance with a priority list that was based on the stability and volatility of the parameter being analyzed. Samples to be used for the analysis of parameters that are unstable and volatile, such as HSL volatile organic compounds, pH, specific conductance, and temperature, were collected first. Samples associated with less sensitive parameters were sampled next.
- A stainless steel submersible pump was used to purge the Type 3 and Type 4 wells before sample collection. A stainless steel submersible pump and/or a stainless steel and teflon positive displacement pump was used to purge the Type 2 wells before sample collection.

A stainless steel and/or teflon bailer was used to purge low-yielding Type 1 wells before sample collection. High yield Type 1 wells were purged with a Grundfros or bladder pump.

Sample collection was performed using the following procedures:

- Once the well was purged and allowed to recharge, water samples were collected using a stainless steel submersible pump, stainless steel and teflon positive displacement pump, or teflon bailer.
- During sampling, the pump was operated continuously but the flow rate was recorded to approximately .25 gpm.
- Volatile organic compound samples were always collected with a bailer or a Grundfos Redi Flo2 pump operated at approximately 0.03 gpm.
- Nonvolatile organic compound water samples were collected at the discharge hose if the submersible or positive displacement pump was used. If the water samples were collected with a teflon bailer, the water sample was collected by pouring directly from the bailer into the sample bottle.
- When the pump and lines were removed from a well, they were placed on plastic sheeting to avoid contact with the ground.

When sampling for dissolved metals or radionuclides in water and the samples were to be filtered in the field, the following procedures were used:

- The water sample was either filtered at the well site with hand-pumped portable sample filtering equipment or a centrifugal pump with an inline Geotech filter.
- A Millipore filtration apparatus equipped with a 0.45-micron filter was used.
- The filtering apparatus was cleaned by rinsing thoroughly with deionized water before filtering each sample. The filters were discarded after each use.
- The first 100 to 150 milliliters of filtrate from each sample was discarded to rinse the filter and filtration apparatus of any residual substances.
- After the sample was filtered, it was immediately transferred to the appropriate sample bottle containing the correct preservative.
- Samples that were excessively turbid were refiltered before final filtration with the 0.45-micron filter. The prefilter mesh size depended on the amount of suspended material in the sample.

2.1.3.6 Hydropunch II Sampling Methods

The Hydropunch II sampler is 5 feet long and made of 304 stainless steel and the method allows for groundwater sample collection at specific depths during the drilling process. Hydropunch II samplers can be used with hollow-stem auger and cable-tool drilling rigs and multiple samples can be taken as the borehole is advanced. Typically, the Hydropunch II sampler is used to determine contaminant concentrations over a vertical profile which then can determine the monitoring depth for the well screen placement.

There are two different configurations in which the sampler was used. The first is the groundwater mode. The boring is first drilled to the zone of interest. The Hydropunch II sampler is attached to standard AW drill sampling rods and, using a 140-pound hammer, is driven into the interval of interest. Then the sampler is withdrawn approximately 18 inches to insure that the tip of the tool released and the screen at the base of the tool is exposed. This configuration allows 1 liter of groundwater to be collected from a 6-inch interval. Hydrostatic pressure forces water through a fine mesh 6-inch stainless steel screen into a holding chamber through a one-way valve. A second one-way valve at the top of the sampling chamber prevents entry of water from above the sampler. The sampler is left in place a minimum of 20 minutes to allow time for the groundwater to fill the chamber. The fill time will vary with depth and the nature of the sediment. The sampler is brought back to the surface and the sample is removed from the chamber by means of a stop cock attachment.

The second configuration for the tool is the hydrocarbon mode. This method was originally designed to collect hydrocarbon contamination at or near the top of the water table. The boring is advanced to approximately 2 feet above the proposed sampling interval. The Hydropunch II sampler is connected to teflon-taped EW casing rods and driven 5 to 8 feet with a 140-pound hammer. It is then pulled up or back hammered 3 to 4 feet. This action releases the 48-inch-long slotted PVC or polypropylene screen with its attached tip. A 1-inch bailer is lowered through the EW rods and down into the exposed Hydropunch screen. The sample is retrieved from the bailer. This sampling method can also be used below the water table when a volume greater than 1 liter is required or when fines from the formation silt over the screen of the groundwater mode.

After each use, the Hydropunch is dismantled and cleaned in the same manner as a split-spoon sampler. All the O-ring seals and the screens are replaced with each use. The sampler is either

stored in plastic or in its storage case. Table 2-5 indicates the well and boring numbers for which Hydropunch II sampling was performed.

2.1.3.7 Water Level Measurements

Water level data were generally collected on a monthly basis using the following steps. The well cap was removed. The water-level-detector measuring tape was decontaminated with deionized water as it was lowered down the well until water was reached. This was indicated by a buzz or beep, a meter needle deflection, or a light. The detector probe was raised above the water level and shaken slightly. It was lowered a second time to recheck the initial measurement. The tape was decontaminated with deionized water as the probe and tape were removed. The water depth was measured and recorded to 0.01-foot from the measuring point such as the top of the casing or the top of the well. The well cover was then closed and locked.

2.1.3.8 Hydraulic Testing

Hydraulic testing is performed to help characterize certain properties of hydrogeologic units. These properties include hydraulic conductivity, transmissivity, and storage coefficient. Results of these tests are used to improve the solute transport model for the vadose zone within the glacial overburden. A brief discussion of the methods associated with each of these tests follows.

Slug Tests

Slug tests are used to estimate hydraulic conductivity or transmissivity near the screened zone of a well. At the FEMP, these tests were conducted in Type 1 wells which were screened in the glacial overburden. There were two types of slug tests, a falling head and a rising head test.

Before the start of the falling-head test, a water-level indicator or pressure transducer connected to a computer recording device was used to check the well's static water level. A slug attached to a nylon rope was lowered into the well no more than 1-foot above the base of the well screen and no less than 0.5-foot below the static water level. Water levels within the well were monitored and recorded by one of the two devices throughout the test duration. The test was complete when the well's water level equilibrated back to the static water level that was recorded just before the test's start.

The rising-head test was conducted after the falling-head test. The slug was removed from the well and the water levels were monitored until the static water level was reached.

The slugs were solid cylinders of known volume constructed of PVC and filled with sand. They ranged in length from 1.5 to 5.0 feet. Slugs that were inserted into 4-inch wells had an outside diameter of 2 inches; slugs for 2-inch wells had an outside diameter of 1 inch.

Yield Tests

Yield tests are used to calculate hydraulic conductivity and to interpret hydraulic connection between various water-bearing units. Both short-term and long-term yield tests were performed at the FEMP.

A yield test is a type of drawdown pumping test. A submersible pump was lowered into the screened interval of the test well. The pump discharge hose was connected to a flow meter so an accurate accounting of gallons of water removed could be maintained. Pressure transducers connected to a computer recording device were placed in the test well and in surrounding observation wells. In short-term yield tests, water was pumped at three successively higher pumping rates beginning with 1 gallon per minute (gpm). Each rate was maintained for approximately one hour. The test was complete when water-level stability was reached or if the water-level reached the pump intake. If drawdown or lower water levels were noted in the observation wells, the test was terminated.

A long-term yield test was performed on a well that had favorable results in a short-term yield test. A set pumping rate was selected and maintained for 48 to 72 hours. Pressure transducers connected to a computer recording device were placed in the test well and in surrounding observation wells. The same procedures were follows as for the short-term yield test. The test was complete when water level stability was reached or if the water level reached the pump intake.

Pumping Tests

Pumping tests were performed to calculate hydraulic properties of the water bearing units in the glacial overburden/vadose zone. Data from these tests was used to determine the hydraulic conductivity, storativity, and anisotropic conditions that might have existed in the vicinity of the test wells.

Each pumping test was performed in three stages. The first stage was a step drawdown test that was used to determine the optimum flow rate for the second stage; test methods were the same as those employed in the short-term yield test discussed above. The second stage, a constant-head test, was run to steady state or a maximum of seven days and used the same basic methods as the long-term

yield tests. The third stage consisted of a recovery period monitoring that was accomplished by using pressure transducers with a computer recording device to check the water level in all the wells that were involved in the test. Periodic water-level measurements were also recorded by technicians using a water indicator device.

Packer Tests

Packer tests were performed to estimate the hydraulic conductivity of the fine silts and clays of the glacial overburden. Packer test borings were advanced by spin-casing methods using only fresh potable water. Drilling methods were in accordance with those outlined in Section 2.1.3.1. Continuous split-spoon samples were taken from the surface down to the top of the basal clay layer in the glacial overburden. An undisturbed soil sample was collected using a Shelby tube at the test depth. Drilling stopped at the bottom point for each test and the casing was withdrawn to 1-foot above the test zone. Packer tests were completed in 5-foot intervals within the borehole. The packer test was actually a constant-head-pressure injection test.

A 5-foot section of homogeneous clay was isolated by inflating a packer with nitrogen at the top of the 5-foot interval that was to be tested. A pressure transducer connected at the surface to a computer recording device was suspended in the test zone below the packer. Water was pumped into the test interval at three flow rates to a preset maximum pressure. A flow meter at the surface regulated flow so that five-minute pressures and flow rates within the zone could be measured. After the maximum pressure test stabilized, the pump was shut off and back pressure were recorded. At the end of the test the packer was deflated and removed and drilling continued. This exercise was repeated at each interval tested within the borehole.

Lysimeters

Lysimeters were installed and sampled to determine the extent of saturation in the clay layers of the glacial overburden and in that portion of the Great Miami Aquifer that is above the regional water table.

Drilling techniques were dependent on the total depth of the lysimeter. Shallow lysimeters that were less than 10 feet deep were hand augered; continuous soil samples were collected from the hand augers. Deeper lysimeters were started using the cable-tool method of drilling. The drill casing was left in place in order to seal off any shallow perched zones encountered within the glacial overburden.

The drilling then continued with a hollow-stem auger drilling rig to its final depth. Continuous split-spoon soil samples were collected as the boring was advanced. An undisturbed soil sample was collected using a Shelby tube at specified depths.

Lysimeters are 2-inch diameter vacuum/pressure soil pore water samplers. They allow water to enter a micro-porous ceramic cup at the instrument's base through capillary forces. The ceramic end cup is attached to an 18-inch-long PVC body which is then connected to a PVC riser and head. The head assembly attaches to the riser and connects sample and pressure ports to the lysimeter body via 1/4-inch nylon tubing. Two nylon tubes extend from the lysimeter body through the riser head at the surface and are used for vacuum extraction and pressure sampling. The sample tube extends from the head through the lysimeter to a point just in contact with the inside of the ceramic base.

A 3- to 6-inch-thick slurry of silica flour and distilled water was placed at the bottom of the borehole. The entire assembled lysimeter was placed in the open borehole. Additional slurry was placed 2 to 4 inches above the top of the ceramic cup. Then 80/100-mesh sand was placed 3 - 6 inches above the top of the 18-inch-long lysimeter body. This was followed by a column of Volclay grout tremied to within 3 feet of the ground surface. After the grout was allowed to settle, a cement cap was installed at the surface.

Water samples were collected by attaching a vacuum hand pump to the pressure port of the lysimeter head which lifted the sample into the holding chamber of the lysimeter. Additional pressure was applied to lift the sample to the surface and into a collection container.

2.1.3.9 Decontamination Methods

All sampling equipment was decontaminated before each sampling event or between each use. The decontamination procedures consisted of first removing gross contamination with a deionized water and detergent wash, followed by a deionized water rinse. The sampling equipment was then rinsed with methanol, followed by a final deionized water rinse. After decontamination, the sampling equipment was wrapped in plastic. Drilling rigs and drilling accessories were steam cleaned before or between uses.

2.1.3.10 Custody of Samples Methods

Each sample collected during this investigation was assigned a unique sample number which was used to track the sample from collection through laboratory analysis, as described in the RI/FS Work Plan. Samples were marked for identification from the time of collection and packaging through shipping and storage. Sample identification markings were made on a label attached to the sample container. A sample number system was established for the purpose of identifying the samples according to location and type. All samples were sent to the laboratory for analysis with appropriate chain-of-custody records and request-for-analysis forms.

After the different media samples were collected in precleaned containers and any required preservative was added, the caps were replaced and custody tape was placed around and over the container lid. An identification label was affixed around the bottle. The label contained the project name and number, sample number, sample location including depth and boring or well number, sampling date and time, the sampling team's initials, and the preservative used including temperature requirements. A chain-of-custody form which accompanied the samples from the field to the laboratory provided a record for documentation of the location of the sample, the type and amount of samples collected, the names of the sample collection team, the date and time of all custody transfers, and the signatures of those who relinquished and accepted custody of the samples. Copies of the chain-of-custody form became part of the permanent RI/FS files at the FEMP. The samples were packed in coolers with blue ice, if required, and vermiculite. The original chain-of-custody form was packed with the samples. The coolers were custody taped, secured, and shipped to the off-site laboratory. A request-for-analysis form also accompanied the samples to the laboratory. It contained the project name and number, the date the samples were shipped, the requested analyses, sample identification numbers, sample volumes and preservatives, and the report date and the turnaround times for analysis.

2.2 SURFACE MAPPING

Investigative activities conducted to support the RI/FS process or other site programs included photogrammetric surveys. Because there were no comprehensive topographic or planimetric maps of the FEMP site before the initiation of RI activities, detailed mapping of the FEMP facilities and the Fernald, Ohio area was accomplished through photogrammetric surveys to support facility investigations, design activities, and cleanup operations. The information gathered from this effort was used to support the description of the nature and extent of contamination and fate and transport

modeling with respect to water erosion, surface water hydrology, and wind erosion. More specifically, the three-dimensional mapping produced by this effort served as the foundation upon which all concentration data, volume calculations, and flow contouring was based.

Specific objectives of the photogrammetric surveys included:

- Completion of a high resolution map of the Operable Unit 5 study area capable of supporting data management, fate and transport modeling, graphical presentations, and FS activities
- Provision of appropriate ground control and permanent monuments to establish vertical and horizontal coordinates of sampling and well locations and planimetric features.

Aerial photographs on a scale of approximately 1 inch equals 300 feet were completed in 1988 and 1992. The 1992 flyover was performed to supplement the existing photographs and provide a map of current conditions at the facility. Ground control surveys were performed to establish aerial targets at horizontal and vertical control locations. Employing photogrammetric methods, planimetric mapping with 1-foot topographic contours meeting National Map Accuracy Standards on a scale of 1-inch equals 50 feet was completed for an area of approximately 4800 acres. Permanent survey monuments were established on the FEMP property to facilitate ground surveys required for field sampling operations. A digital database was created of the planimetric map in both Integraph and AutoCAD formats. The resulting map and ground control was based on the Ohio State Planar (OSP) Coordinate System of 1983. Horizontal control was tied to the North American datum of the 1983 OSP Coordinate System, with vertical control tied to the North American vertical datum of 1927.

2.3 METEOROLOGICAL CONDITIONS

Meteorological conditions are monitored by the site meteorological tower (Figure 2-12). Discussions of three of the measurements recorded at the tower follow.

2.3.1 Wind Measurements

Site-specific wind speed and wind direction data were collected at the FEMP site to support the FEMP EM Program and the FEMP emergency preparedness program. These data were collected at the site meteorological tower. Measurements were made at both the 33- and 200-foot heights. The data were used as input into the atmospheric dispersion models used for the fate and transport modeling of airborne contaminants from Operable Unit 5.

Wind speeds were measured using sensors designed to provide low starting thresholds, wide dynamic responses, and high accuracy over a wide range of wind speeds and a variety of environmental conditions. A typical wind speed sensor has a vinyl anemonometer cut set attached to a shaft and 30-hole photochopper assembly. The photochopper interrupts a solid state source to a phototransistor, thereby producing a frequency output proportional to the ambient wind speed.

Wind directions were measured using wind direction sensors designed to provide low starting thresholds, fast dynamic response, and high accuracy under adverse environmental conditions. A typical wind direction sensor has a counterbalanced, lightweight vane attached to a shaft that is coupled to a precision low torque potentiometer. Wind direction via vane position is converted to a proportional direct current voltage by the potentiometer.

Wind speed and wind direction data were automatically recorded by a computer-based data collection system consisting of a remote data logging computer connected to a central microcomputer. The data logging computer scans the analog inputs from wind speed and wind direction sensors for instantaneous values, then scales, averages, and stores these values. The central computer polls the remote data logging computer for the stored data values and reports the wind speed and wind direction data as hourly averages.

Routine calibrations are conducted semiannually on the entire meteorological data collection system. Routine preventive maintenance is conducted quarterly. Other required maintenance is conducted as needed.

2.3.2 Precipitation Measurements

The FEMP meteorological tower records precipitation with a heated tipping bucket rain or snow gauge. Precipitation totals are accumulated using a data logger and then are stored on a micro-vax computer. Data is downloaded thereafter for permanent storage. Radiological Environmental Monitoring (REM) also maintains a National Weather Service rain gauge for use in comparing data recorded from the tipping bucket gauge and for backup in those cases where the tipping bucket may be out of service or down for calibration.

2.3.3 Meteorological Tower Temperature Measurements

Ambient air temperature data were collected at the FEMP to support the FEMP EM program. These data were collected at the FEMP meteorological tower at both the 33- and 200-foot heights. The collected data were used as input into the stability class calculations used in the atmospheric dispersion models for fate and transport modeling of airborne contaminants from Operable Unit 5.

Measurements were made using temperature sensors made up of composited epoxy-coated thermistors protected by a probe casing. Ambient air temperature data were automatically recorded by a computer-based data collection system consisting of a remote data logging computer connected to a central microcomputer. The data logging computer scans the analog inputs from the temperature sensors for instantaneous values, and then scales, averages, and stores these values. The central computer polls the remote data logging computer for the stored data values and reports the temperature data as hourly averages. The difference in temperature between the 200- and 33-foot heights were calculated automatically by the computer system. Routine calibrations are conducted semiannually on the entire meteorological data collection system. Routine preventive maintenance is conducted quarterly. Other required maintenance is conducted as needed.

2.4 SURFACE WATER AND SEDIMENT INVESTIGATIONS

A number of surface water and sediment investigations have been completed. Data from these programs were used to describe the nature and extent of contamination associated with Operable Unit 5 and support the quantification of risk to potential receptors exposed to the affected media.

2.4.1 1986 Radiological Survey and Analysis of Sediment Samples from Paddys Run

A comprehensive radiological survey was performed for Paddys Run in 1986 in support of the FEMP EM program. This data was used to support discussions on the nature and extent of contamination in Section 4.0.

The objectives of the survey were:

- Identification of sediment in Paddys Run exhibiting elevated concentrations of radiological constituents to define the extent of contamination resulting from FEMP operations
- Identification of sediment that may be acting as an intermediate or secondary source of contaminants for transport to the regional groundwater aquifer.

The survey was conducted from the confluence of Paddys Run and the Great Miami River to the railroad bridge located north of the waste storage area survey and included both a comprehensive radiological walkover survey of the creek bottom and banks and the collection of systematic and biased sediment samples. Measurement stations were established at 5-foot intervals (using a surveyor's tape) along the length of the creek adjacent to the Operable Unit 4 study area. At each 5-foot interval along the center line, four direct radiation measurements were taken with an unshielded large volume sodium iodide (NaI) scintillation detector at approximately 5 and 10 feet to the left and right of the center line. At each measurement point, gamma measurements were obtained at contact with the sediment and recorded. Field measurement data were compiled and plotted in the form of an isopleth map.

Due to the elevated radiation fields associated with the K-65 silos, a shielded detector was employed along approximately 2400 feet of Paddys Run adjacent to the silos. Shielding consisted of lead blankets and a 3/8-inch-thick plywood sheeted lead plate.

As a result of concern of shielding efficiency, systematic sediment sampling was conducted along a 1200-foot stretch of Paddys Run directly adjacent to the K-65 silos (Figure 2-13). Sediment samples were collected in such a way that analysis was performed on one sample representing each bank for each 100-foot section within the 1200-foot stretch of the creek. To complete the sampling, 24 discrete samples were collected at 25-foot intervals on both the east and west banks of the creek along the 1200-foot stretch of the creek. These discrete samples were composited so as to yield one sample representing each 100-foot section of both the east and west banks of the creek. Discrete sampling locations were not surveyed. Approximately 4.5 pounds of sediment were collected by a precleaned trowel from a 4-inch-diameter area down to a depth of 4 inches. The samples were sent to an off-site laboratory for analysis.

Additionally, biased sediment samples were collected from the radiological walkover survey at two locations that exhibited gamma activities in excess of 25 microRoentgens per hour (μR/hr). Also, two samples collected along Paddys Run where the survey indicated gamma activity rates were similar to background. All samples collected during the study were analyzed for gross alpha, isotopic uranium, isotopic thorium, and radium-226.

2.4.2 1987 Characterization Investigation Study

The Characterization Investigation Study (CIS) was performed to sample and characterize the waste contained in the waste pits, the flyash piles, the lime sludge ponds, the South Field, and the solid was landfill. The sampling program included water and sediment sampling from the waste storage area.

Ten surface water samples were collected from Pit 4, Pit 5, Pit 6, and the Clearwell using either a portable grab sampler or a Kemmerer sampler. All water samples were analyzed for full radiological parameters. A majority of the water samples were also analyzed for general groundwater quality and HSL parameters. All of the analyses were conducted at off-site laboratories.

Sediment samples were collected in 13 distinct drainage ditches in and around the waste storage area. Approximately 150 sediment samples were collected from these drainages. These samples were analyzed at on-site laboratory using gamma spectroscopy to determine activity concentrations of gamma-ray emitting radioisotopes. Additionally, some of the samples were sent to an off-site laboratory for radiological analysis.

2.4.3 1988 Best Management Practices Program Sampling of Surface Water in On-Property Drainage Ditches and Storm Sewers

In 1988, best management practices (BMP) sampling was conducted pursuant to the terms of the Ohio Director's Findings and Orders (DFOs) in on-property drainage ditches and storm sewers. This data was used to support the description of the nature and extent of contamination.

The objective of the sampling was to provide a snapshot of the chemical and radiological constituents in site drainage ditches and manholes with the intent of identifying active source areas requiring implementation of mitigative actions.

Sampling followed methods in "Sampling Plan for the Characterization of Stormwater Runoff at the FMPC," (Weston 1987a) and "Quality Assurance and Quality Control Plan for the BMP Plan for the FMPC" (Weston 1987b). Storm sewer manholes were sampled using stainless steel, self-tipping bailers with teflon cables. Drainage ditch samples were collected using a dipper or by immersion of the sample bottle, depending on the conditions at the sampling station.

Sixteen manholes and 12 drainage ditches were sampled during the study. Figures 2-14 and 2-15 illustrate the locations of the drainage ditches and manholes, respectively. Manhole samples were

collected during baseflow and a storm event. All samples were analyzed for metals, general water quality parameters, isotopic uranium, and gross alpha and gross beta activity. Select samples were analyzed for trichloroethane, trichloroethene and perchloroethene, and isotopic thorium. Analyses were performed at an off-site contract laboratory.

2.4.4 FEMP Environmental Monitoring Program Surface Water and Sediment Sampling in Paddys Run and the Great Miami River

As part of the FEMP's ongoing EM program, surface water and sediment samples are routinely collected from established sampling points in Paddys Run and the Great Miami River. The data are used to monitor any changing conditions in the streams to assess the potential impacts of FEMP operations on the regional environment.

2.4.4.1 Surface Water

Grab samples using a precleaned sampling bucket are collected at each location in Paddys Run. Water from the buckets is used to fill prelabeled sample bottles. Appropriate chain-of-custody, quality control (QC) sampling, and field documentation procedures are employed to ensure the quality of the collected samples.

Grab samples are collected weekly from six locations (Figure 2-16) within Paddys Run (W-5, W-9, W-10, W-11, W-7, and W-8). As Paddys Run is an intermittent stream, locations W-10, W-11, and W-7 are occasionally dry, thus preventing sampling. Collected samples are submitted to the FEMP laboratory for total uranium analysis. Additionally, bimonthly composite samples from location W-5 and monthly composite samples from W-7 are submitted for isotopic radium analysis in the FEMP laboratory. If insufficient sample is available from location W-7, a monthly composite from W-8 is substituted.

2.4.4.2 Sediment

The specific locations for the collection of the sediment samples at each transect with Paddys Run are based upon the visual observation by the sample technician of the points in the creek with the most recent deposition of sediment. All samples are placed in prelabeled sample bags and sealed with custody tape. Department standard operating procedures guide the field collecting methods, packaging, documentation, and decontamination of the samples and sampling equipment. This program did not use QAPP and/or SCQ procedures.

The frequency and location of sediment sampling in Paddys Run has varied to some degree over the 35-year EM program. Since the mid-1970's, sediment samples have been collected from Paddys Run at locations above and below its confluence with the storm sewer outfall ditch (SSOD). From 1986 to 1990 the sampling was systematic with sampling points at approximately 100 or 200 yard intervals along the same sampling area. In 1991 and 1992, sediment samples were collected from locations in Paddys Run where sediment deposits were noted. Additionally, a sample was collected at the northwestern property line at a location where Paddys Run intersects State Route 126. These collected samples were submitted to the FEMP laboratory or to an off-site laboratory for total uranium and isotopic radium and thorium analyses. Before 1991, the samples were analyzed for full radiological parameters.

2.4.5 Environmental Monitoring Program Sampling of Surface Water and Sediment in Drainage Ditches on FEMP Property

The FEMP EM program routinely collects surface water and sediment samples from a number of on-property drainage ditches. The data has been used to support discussions in Section 4.0 on the nature and extent of contamination. Surface water and sediment samples are collected to determine the distribution and extent of radiological constituents in these media in order to assess potential impacts of FEMP operations on the regional environment.

2.4.5.1 Surface Water

Surface water samples are collected using a precleaned bucket as previously discussed for sampling in Paddys Run. Collected water is subsequently transferred to prelabeled sample bottles. Appropriate chain-of-custody, QC sampling and field documentation procedures are employed to ensure the quality of the collected results.

Weekly grab samples are collected at one location along the drainage ditch originating near the pilot plant and terminating in Paddys Run (location ASIT-10 on Figure 2-17). Collected samples are analyzed for total uranium in the FEMP laboratory.

2.4.5.2 Sediment

Sediment samples from the SSOD are collected with a precleaned scoop, placed into prelabeled sample bags and sealed with custody tape. Specific sampling locations within the ditch at the transect location are selected based upon the visual observation by the sample technician of the point in the

ditch with the most recent deposition of sediment. Standard operating procedures guide the field collection methods.

Sediment samples are collected once a year from each of eight locations spaced at 110-yard intervals along the SSOD. Collected samples were analyzed for total uranium, isotopic thorium, and radium-226 at an off-site laboratory.

2.4.6 RI/FS Surface Water and Sediment Sampling Programs

The objective of surface water and sediment sampling was to characterize the radiological and chemical hazardous substances present in surface water and sediment in Paddys Run and the Great Miami River at locations both upstream and downstream of the FEMP. The RI investigations were designed to make full use of available EM program data by aligning, to the extent practical, the sampling locations of the two programs.

The objective of the RI/FS surface water and sediment sampling was to characterize the surface water, sediment and seep samples that were collected from drainage ditches on the FEMP property and two off-property locations. Figure 2-16 identifies one off-property sample location (SWS-13) from a drainage ditch that transports surface water from the grass field in the northeast corner of the FEMP off-property to the east. In the past few years, some of the drainage ditches have been altered so that water flow is controlled; others remain uncontrolled and flow toward Paddys Run.

RI/FS surface water and sediment sampling focused on all principal drainage ditches on FEMP property including:

- Drainage ditches north of the former production area
  - the area north of the former production area is drained by a ditch that flows to the west from the fire training area, north of the railroad track to Paddys Run (uncontrolled)
- Drainage ditches east of the former production area
  - two small drainage ditches carry surface water from an area near the sewage treatment plant south to the storm water retention basin (uncontrolled)
  - one small drainage ditch which flows east drains the only area onsite which flows to the Great Miami River (uncontrolled)
- Drainage ditches in the former production area

- drainage ditches include a ditch to the east buffer zone of the FEMP, a storm grate servicing the scrap metal pile and decontamination pad, and a drainage running north to south along the west production fence line. (controlled)

- Drainage ditches in the waste storage area
  - all principal drainage ditches in the waste storage area and waste pit perimeters (controlled)
  - the pilot plant drainage ditch flows into Paddys Run south of the K-65 silos and originates west of the pilot plant (uncontrolled)

- Drainage ditches near the South Field and flyash piles
  - drainage ditches that collect surface water from the active and inactive flyash piles and South Field area (uncontrolled).

Sampling methods are discussed in Sections 2.1.2.1 and 2.1.2.2.

2.4.6.1 RI/FS Work Plan

This work plan augmented the FEMP's ongoing surface water and sediment collection program. Surface water samples were collected from Paddys Run at 12 locations (W-5, W-9, W-10, W-11, and W-7; SWS-2, SWS-3, and SWS-5 through 9) as identified in Figure 2-16. At select locations (W-10, 11 and 7) sediment samples were collected with surface water samples for several periods in January and May 1989. Sediment samples were also collected in June and August 1988 and April 1989. Additional surface water samples only were collected from locations W12 through 14, W7 and WY to provide additional characterization data. The lack of surface water in Paddys Run during the three rounds of sediment sampling prevented the concurrent sampling of surface water and sediment. A seep sample collected in Paddys Run is identified in Figures 2-16 and 2-17 as sample location 1422.

Eight locations were established in the Great Miami River for the RI surface water and sediment sampling program (Figure 2-16). In addition to locations W1, 3, and 4, sampling was conducted at these five locations: GMR-1, upstream of effluent outfall line; GMR-2, just downstream of the effluent line; GMR-3, between the effluent line and the New Baltimore bridge; GMR-4, just downstream of the confluence of Paddys Run and the Great Miami River; and GMR-5, upstream of the same confluence. Three surface water and sediment sampling locations (ASIT-001 through 003) in the SSOD were also sampled (Figure 2-17).

Surface water samples were analyzed for full radiological parameter metals and a suite of general water quality parameters. Sediment samples were analyzed for full radiological parameters. Select surface water and sediment samples were analyzed for Hazardous Substance List (HSL) organics

(Table 2-2). Field analysis performed on the surface water samples included pH, temperature, specific conductance, and dissolved oxygen.

Figures 2-17 identify the discrete drainage ditch locations which were sampled as part of the RI/FS work plan. All samples were collected following installation and start-up of the storm water retention basin.

Field analysis including pH, specific conductance, temperature, and dissolved oxygen was performed on all collected surface water and seep samples. Laboratory analysis for surface water and sediment included full radiological parameters. Surface water samples were additionally analyzed for total organic carbon, total organic halogens and general water quality parameters. Additionally, select surface water samples were analyzed for both filtered and unfiltered radiological and general water quality parameters and HSL inorganics.

2.4.6.2 Hydrogeologic Study of the FEMP Discharge to the Great Miami River - 1988 - Surface Water and Sediment Sampling in the Great Miami River

The hydrogeologic study (IT 1988) of the FEMP's EPA approved discharge to the Great Miami River was undertaken to determine if the discharge from the effluent pipeline was located within the "zone of influence" of the production well field operated by the Southwestern Ohio Water Company and to qualitatively and quantitatively determine any associated adverse environmental impact. The study also was to determine the permeability of the stream bed of the Great Miami River and, indirectly, the aquifer characteristics in the area from the Ross bridge to approximately one mile below the FEMP outfall line.

Surface Water

Surface water samples were collected from the Great Miami River using the procedures and protocols defined in the RI/FS Work Plan and QAPP. Samples were obtained using a Kemmerer discrete depth sampler which consists of an open cylinder with spring-loaded end caps. To obtain a sample, the sampler is lowered to the desired depth. The cylinder ends are closed by releasing a weight which falls along the rope from which the sampler is suspended. The weight triggers a spring-loaded mechanism closing the ends of the sampler. The sampler is then raised and a water sample is removed through a port on the bottom of the device.

Three sampling traverses of the channel were performed at the background river water sampling location, Z1-11 (Figure 2-16). Samples obtained during each traverse of the river were mixed in the field to generate three replicate composite samples for laboratory analysis.

River water samples were also collected at nine locations up and downstream of the FEMP outfall at Z1-1 through 5, and 7 through 10 (Figure 2-16). Surface water samples were obtained using the Kemmerer sampler from a single location from the middle of the main portion of the channel at six-tenths the total depth. Two replicate samples were collected at each location.

River water sampling was also completed approximately 100 yards downstream from the FEMP outfall at location Z1-6. The program consisted of discrete sampling at six-tenths the river depth at five locations at equal distances across the channel width. Two sampling traverses of the channel width were performed to provide duplicate samples.

River water samples collected from locations Z1-1 through 11 were tested for gross alpha and beta activity, total uranium, isotopic uranium, cesium-137, ruthenium-106, radium-226, radium-228, and strontium-90. Only total dissolved uranium concentrations were used in the river water quality evaluations. All samples were filtered in the laboratory using a 0.45 micron filter and the addition of nitric acid to prevent precipitation and adsorption of dissolved constituents. Analysis was performed at the RI/FS program off-site laboratory.

Sediment

River bottom sediments were obtained using a Wildco-Eckman bottom dredge. The dredge consists of an open-ended metal box, 1 cubic foot in capacity, with spring-operated jaws which close over the bottom. A messenger weight, dropped along the rope from which the dredge was suspended, is used to trigger the jaws. Three samples were obtained from each bottom sediment sampling location. These samples were composited in the laboratory before analysis.

Sediment samples collected from locations Z1-2, 3, 5, 7, 8 and 9, as shown in Figure 2-16 were analyzed for grain-size distribution using sieve analysis down to a No. 200 U.S. Standard sieve. Grain size analysis was performed by an off-site laboratory.

2.4.6.3 Paddys Run South Seepage Investigation - 1991

This investigation was to determine the influence of relatively short-lived events, such as a severe storm. Surface water was collected from sampling locations W-7, W-8, W-12, W-13, and W-14 (Figure 2-16) and analyzed for full radiological parameters. Sampling methods were as discussed in Sections 2.1.2.1 and 2.1.2.2.

2.4.6.4 Sampling and Analysis Plan for RI/FS Work Plan Addendum - Operable Unit 2 - 1993

Surface water and sediment samples were collected as part of this Operable Unit 2 sampling effort to help characterize the drainages in and around the South Field, the inactive and active flyash piles, the lime sludge ponds, and the solid waste landfill. The sampling locations are shown in Figure 2-18 and 2-19. The sampling methods are discussed in Sections 2.1.2.1 and 2.1.2.2; the samples were analyzed for full radiological and HSL parameters.

2.4.6.5 Pilot Plant Drainage Ditch Seepage and Surface Water Background Investigation - 1993

This investigation was designed to:

- Further define the source of contamination in the pilot plant drainage ditch
- Determine the seepage contribution to the pilot plant drainage ditch and its effect on surface water quality within the drainage ditch
- Establish background surface water quality within Paddys Run at location W-5
- Establish background surface water quality within the Great Miami River by sampling at location W-1.

Figure 2-17 shows the four surface water sampling locations and the nine seep locations. The four surface water samples were analyzed for HSL inorganics, volatiles and semivolatiles, general chemistry, total and isotopic uranium and thorium, and radium-226/228. Figure 2-16 shows the location of W-1 and W-5. The seeps were initially sampled for total uranium. If the uranium value exceeded 20 μg/L, the seeps were resampled for radiological, HSL, and general chemistry parameters. Sampling methods are discussed in Section 2.1.2.1.

2.4.6.6 Snapshot Monitoring Well Sampling and Surface Water and Sediment Sampling - 1993

Because of the completion of surface water runoff control projects, surface water and sediment, especially for Paddys Run, needed further characterization. Samples for both media were obtained from 24 locations on and off of the FEMP. These locations are illustrated on Figure 2-20.

Sediment samples were analyzed for HSL inorganic, volatile and semivolatile parameters, total and isotopic uranium and thorium, and isotopic radium. Surface water was sampled for the same analytes plus general water chemistry. Sampling methods are discussed in Sections 2.1.2.1 and 2.1.2.2.

2.4.6.7 RI/FS Work Plan Addendum - Operable Unit 1 - 1993

This sampling effort was to provide data to more fully determine pathways and flow rates to potential receptors from waste pit area. Three surface water samples were taken: one each from Pit 5, Pit 6 and the Clearwell and were analyzed for full radiological and HSL volatile, inorganic, cyanide, and semivolatile parameters. Sampling methods are discussed in Section 2.1.2.1.

2.4.6.8 Southwest Field Investigation - 1993

This project was to examine the possible presence of contaminants in the southwestern corner of the FEMP property. Three seep locations were sampled for surface water. The samples were sent to the on-site laboratory and analyzed for total and dissolved uranium. The sampling methods are discussed in Section 2.1.2.1.

2.5 SURFACE SOIL INVESTIGATIONS

Investigations of surface soil were conducted both on and off property as part of the 1986 investigation that supported the litigation study, the 1987 CIS, RI/FS, removal actions, and the FEMP EM program.

2.5.1 Air, Soil, Water, and Health Risk Assessment - 1986

This study was conducted by IT Corporation (IT) for National Lead of Ohio (NLO) to support ongoing litigations against the FEMP (IT 1986). The data were used to support the description of the nature and extent of surface soil contamination on and off property. The off-property soil sampling performed under the RI was designed to supplement this data set.

Surface soil sampling was performed to meet these objectives:

- Establish confidence in the data by independently collecting a sufficient number of samples in close proximity to locations sampled by NLO in 1983
- Investigate the variability among uranium concentrations within a 6.6 by 6.6-foot grid by collecting nine samples at the node points of this grid in two locations specifically chosen to represent areas of observed high and low concentration

- Assess the regional distribution of uranium within a 5-mile radius of the FEMP
- Investigate variations in uranium concentration of soil down to approximately 6 inches.

Preliminary sampling locations were identified on a topographical grid map. At the sampling site, a two-point resection was performed using a compass and rangefinder. The distance and azimuth of two fixed distance points were recorded in a log book.

A cup cutter was pressed against the surface to provide a guide to the sampling area. Grass and other vegetation was chopped from the location to be flush with the surface. The cutter was driven into the ground to a depth of 2 inches. The first sample was placed in a double plastic bag and sealed, then bag was placed in a sample container and sealed. Appropriate labeling and chain-of-custody was completed.

A clean cutter was used for each additional depth at each location. The subsequent samples were collected from the sample hole left from obtaining the first sample. Samples were obtained at each location for the 0-2, 2-4, 4-6-inch depths. Sampling procedures are defined in the quality assurance plan for the study (IT 1986).

A total of 939 soil samples were collected at 311 locations on and off FEMP property (Figure 2-21) and analyzed for total uranium. Selected samples were analyzed for isotopic uranium.

Results were evaluated using the geostatistical method of indicator and probability kriging. This method is an application of linear kriging to estimate the conditional probability of concentrations. The objective of this analysis was to identify the required data and spacing of samples to map the concentrations of uranium in the 50,300-acre area defined by the 5-mile radius of the FEMP property.

In 1988, archived samples were retrieved and sent to three separate off-site laboratories for isotopic uranium analyses. The original samples were found to have had problems during analysis.

2.5.2 Characterization Investigation Study Surface Soil Investigations - 1987

The CIS was initiated by the FEMP in 1986 to investigate the nature and extent of contamination associated with inactive waste storage facilities. The original design of the RI/FS Work Plan sampling programs was to supplement the CIS to examine contaminant distributions from a site-wide

perspective. CIS data has been used to support the description of the nature and extent of contamination.

The objective of the CIS surface soil sampling program was to establish the type and distribution of radionuclides present in the surface soil in the waste storage area and in the vicinity of the flyash piles and the South Field.

Surface soil sampling followed the Protocol for Sampling Radium-Contaminated Soils. These techniques included the use of "ring" samplers and stainless steel trowels to obtain samples down to 6 inches. Below this depth, the technicians used trowels and posthole samplers to reach a depth of 18 inches. Before surface samples were collected, a gamma-ray measurement was made on the surface using a field instrument for detecting low energy radiation (FIDLER). If elevated radioactivity was detected, then a 0-2 inch sample was taken, followed by a 2-6-inch sample. The 0-2 inch sample was taken to develop the field correlations of uranium-238 activity concentrations to FIDLER count rates; the 0-2 inch interval was used because the thorium-234 63 kiloelectron volt (keV) photon is self-shielded by the soil below 2 inches.

After the samples were collected to 6 inches, a probe was placed in the cavity and another measurement was made. If the resulting radiation level was higher than expected due to the change in detector-soil geometry, an intermediate depth sample (6 to 12 inches) was collected. This was repeated, as needed, to a depth of 18 inches. Care was taken to prevent cross-contamination between layers. After each sample was taken, the hole was enlarged before continuing downward. Initially the FIDLER probe was used to monitor intermediate soil layers. Because of the 9-inch diameter of the FIDLER housing, too much time was required to enlarge the hole for successive depth readings, so the 2.5-inch scintillation detector (SPA 3) probe was used.

The sample was placed in a plastic bag and homogenized. An aliquot from the bag was then sealed into a 477 mL plastic jar. The sample container was labeled and the sample number, location, date, time, technician, depth, chain-of-custody, laboratory location, and significant comments were recorded in the surface soil sample logbook.

Numerous samples were collected from the waste storage area, flyash piles and South Field area (Figures 2-22 and 2-23). All collected samples were analyzed in an on-site gamma spectrometry

laboratory. The analysis was conducted to provide a relative measure of the concentration of radionuclides present in the surface soil. The detector for the on-site system consisted of a high-purity germanium crystal equipped with a 0.02-inch beryllium window. Each sample was subject to a 10-minute count in the gamma spectrometry system. Results were reported for uranium-238, cesium-137, radium-226, ruthenium-106, and thorium-232. Additional detail on the gamma spectrometry system can be found in the CIS final report (Weston 1987).

Additionally, approximately 10 percent of the soil samples collected under the CIS were submitted to an off-site laboratory for radiological analysis. Radiological analytes were consistent with RI/FS full radiological analyses.

2.5.3 Manhole 180 - Offsite Soil Removed - 1989

A soil removal program was conducted at Manhole 180 on the FEMP discharge line to the Great Miami River in June 1989. The program action involved the excavation of a small quantity of soil adjacent to the manhole that was contaminated due to a series of overflow events. Soil samples were collected following the excavation process to demonstrate that the clean-up goals had been obtained. Surface soil samples, 0-6 inches in depth, were collected from the excavation area adjacent to Manhole 180. Collected samples were transferred to the FEMP laboratory for total uranium and thorium analysis. This data was used in discussions on the nature and extent of contamination. Part of this project was the development of the removal action cleanup criteria.

2.5.4 Removal Actions

Removal actions have played an important role in the sampling efforts at the FEMP. They were not expressly performed to support the RI/FS, but many of the samples that were collected are used for characterization and, in some cases, to support discussions on the nature and extent of contamination. Removal actions were initiated when contamination was known to exist and there was a threat to human receptors offsite. Samples were taken before and sometimes after the actual removal of the contaminated media; in most cases this media was soil. Sampling methods are discussed in Section 2.1.2.3. There were several removal actions in which surface soil samples were collected. The following sections highlight four surface soil removal action sampling plans. The analytical results from this sampling are discussed in Section 4 of this report.

2.5.4.1 Waste Pit Area Runoff Control (Removal Action 2) Hand Augering - 1991

Surface soil was sampled in support of the implementation of the Waste Pit Area Storm Water Runoff Control Removal Action. Samples were collected from areas within the waste storage area potentially affected by regrading and excavation activities to be performed under the removal action. The data were used to support the description of the nature and extent of contamination and the baseline risk assessment.

The objectives of the surface soil sampling conducted as part of the removal action included:

- Determining the chemical constituents present in the surface soil in areas potentially affected by the removal action
- Assessing the potential impacts to worker and public health and safety because of the disturbance of surface soil as a result of the removal action
- Assessing viable storage and disposal options under RCRA for excess soil generated during the removal action.

Samples were collected before removal action activities under two separate sampling efforts. The first involved the collection of surface soil samples to a depth of 6 inches. These samples were used to assist in establishing health and safety requirements for the removal action and to aid in identifying the need and location of additional sampling.

The second sampling activity involved the collection of samples to a depth of 24 inches. Sampling locations were randomly selected within areas potentially affected by the removal action. Sampling locations and collection methods were consistent with the EPA-approved removal action work plan.

Hand augering to 24 inches took place at 44 locations (Plate 2-7). Samples from the 0- to 6-inch interval were submitted to an off-site laboratory for HSL inorganic and pesticide/PCB analysis. Samples from the 18- to 24-inch interval were submitted to the off-site laboratory for HSL volatile and semivolatile organics analysis. Three samples were submitted for screening-level gamma spectrometry analysis to the on-site laboratory; however, this data was not used in the RI Report.

2.5.4.2 Plant 1 Pad Pre- and Post-Excavation Sampling (Removal Action 7) - 1991 and 1992

In order to evaluate the potential presence of HSL and radiological constituents in the top two feet of soil in the area to be affected by excavation activities associated with the Plant 1 Pad Continuing

Release Removal Action, 22 locations were sampled in six-inch intervals. Sampling methods are discussed in Section 2.1.2.10.

The first six-inch interval was analyzed for limited radiological parameters (i.e. isotopic uranium and thorium, radium-226 and -228) and HSL inorganic, pesticides, and PCBs. The 1.5 to 2.0-foot deep interval was analyzed for HSL volatiles and semivolatiles if no elevated HNu readings were encountered. If above-background organic values were detected, that six-inch interval was analyzed for volatiles and semivolatiles. All soil samples that were collected but not sent for analysis were archived.

The post-excavation sampling was the confirmatory portion of this removal action. The samples were to determine if the excavation had removed all the contaminated soils. The samples were taken from a 10.9 x 10.9 yard grid pattern encompassing the excavation area for a total of 90 grid squares. Four six-inch samples were collected from each grid square, one from the center of each of four quadrants. Sampling methods are discussed in Section 2.1.2.3.

Total uranium and thorium were sampled at the on-site laboratory by compositing the four quadrant samples in 75 percent of the total samples collected; the remaining 25 percent were composited and split. One half of the split was analyzed for HSL metals and full radiological parameters at an off-site laboratory and the other half was analyzed for total uranium and total thorium at the on-site laboratory. From the same 25 percent grids, one additional sample was collected from the northeast quadrant and analyzed for HSL plus mercury and cyanide. The 25 percent were chosen by using a random number generator on a common spreadsheet.

The sampling locations for the pre- and post-excavation programs are shown in Figure 2-24.

2.5.4.3 Contaminated Soil Adjacent to the Sewage Treatment Plant Incinerator (Removal Action 14) - 1992

This program was completed in three phases. Phase I identified the soil that required excavation while Phase II involved pre-excavation samples, and Phase III involved post-excavation verification samples. In Phase I, surface samples were collected for radiological walkover instrument correlation purposes and analyzed by gamma spectroscopy for radionuclides. The sample results were used to calibrate the SPA-3 measuring device. Then a radiological walkover survey was performed with this calibrated instrument in the study area. Based on these survey readings, excavations were created and

contaminated soil was removed. After the soil was removed, confirmatory 6-inch samples were collected and analyzed for total uranium, total thorium, and radium-226 at 20 locations; full radiological and HSL parameters at eight locations; and full radiological, HSL, and dioxins/furans at four locations (Figure 2-25). Additional soil removal was based on the results of this confirmatory sampling. Final confirmatory samples were collected in the fall for 1993.

2.5.5 RI/FS Surface Soil Sampling

Surface soil samples were collected on and off property as part of the RI primarily and in conjunction with the completion of borings in the former production area and at other locations. These programs are discussed in Section 2.6.3. In excess of 300 on-property surface soil samples were collected as part of the subsurface borings program. Surface samples were also collected in order to investigate the near-surface soil for possible contamination. In excess of 1000 surface soil samples were collected on and off the FEMP property as part of the RI/FS. These programs are mentioned in the following subsections. Sampling methods are discussed in Section 2.1.2.3; sampling locations are identified in Plate 2-7 (see Plates) along with the parameters analyzed. This information was used to support discussions on the nature and extent of contamination in Section 4 and the baseline risk assessment in Appendix A.

2.5.5.1 RI/FS Work Plan (Surface Soil Sampling Plan) - 1987

The objectives of the RI surface soil investigation were to:

- Supplement data from the CIS, litigation support study, and EM program
- Collect data to support the baseline risk assessment and to determine the nature and extent of contamination of radiological and chemical hazardous substances sufficient to support remedy selection
- Confirm areas of surface radiological contamination identified from RI radiation walkover surveys and determine the concentrations of radiological constituents present
- Collect sufficient data to quantify surface radiation fields.

Biased samples were collected in conjunction with the RI radiation measurements program. To assess radiation levels in the former production area and other FEMP locations and to support the identification of sampling locations, radiation measurements were completed using photon detectors coupled to survey meters. These instruments detect the quantity of radiation emitted by uranium and thorium and other radionuclides. The entire former production area, sewage treatment plant areas,

and perimeter of the waste storage area were surveyed with hand-held photon detectors. In these areas, a 100-foot grid was established (Figure 2-26). For all other areas on FEMP property, a 1000-foot grid was established but not surveyed as part of the measurements.

A walkover survey was performed of each 100-foot grid using portable scintillation survey instruments. Both large and thin large-area sodium iodide probes were used to perform the surveys. Each 100-foot grid was subdivided into 25-foot grids. One integrated measurement was obtained from a walkover of each 25-foot grid. Elevated (peak) values within each grid were marked for soil sampling.

Surface soil samples were collected: in the areas subjected to the radiation measurement program; in the remaining areas within the FEMP boundary at 1000-foot grid points; at locations of borings; at locations at 250-foot intervals along the north and east property lines; at locations at 200-foot intervals due east of the site from the sewage treatment plant; and at 16 additional off-property locations (Plate 2-3).

For areas subjected to the radiation measurement program, two methods were used to determine specific locations for soil samples. First, if the radiation survey identified specific areas with elevated concentrations, the flagged area with the highest reading was sampled. Second, if there were grids with uniform, elevated readings across multiple 100-foot grids, then nonbiased samples were collected at 250-foot intervals.

At all locations within the former production and sewage treatment plant areas, samples were collected from three consecutive 6-inch-depth intervals. At all of the other areas, samples were collected at three 2-inch-depth intervals. The uppermost soil sample was analyzed first at each location. As specified in the work plan, if concentrations of total uranium exceeded 35 pCi/g, then the subsequent depth intervals were analyzed.

In general, sampling consisted of the following steps:

- Vegetation at each location was trimmed to the surface soil level
- A cutter bit was attached to a sampler handle
- The bit was driven into the soil to the specified depth
- Soil was removed from the bit and placed into a sample bag

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- The sample bag was placed into a sample container
- Custody tape was placed over the container lid.

Any soil samples that were not sent to the laboratory were archived for possible future use.

In general, surface soil samples collected were analyzed for full radiological parameters. Select soil samples from areas of known spills and areas adjacent to storage tanks, railroad tracks, and the transformer pads were designated for chemical analysis including HSL parameters and organophosphorus pesticides.

2.5.5.2 CERCLA/RCRA Background Soil Study - 1992

A background soil study was conducted as part of the RI to establish the concentrations of naturally occurring or anthropogenic radionuclides and inorganics in the soil study area. This data is used in this report as a basis of comparison in the description of the nature and extent of contamination and for the calculation of risks due to background in the baseline risk assessment.

The objectives for the background soil study were to:

- Collect surface and subsurface soil samples from an area with geology representative of the FEMP site, and analyze samples for inorganic and radionuclide CPC constituents
- Perform statistical tests to establish the nature of variability of background concentrations with respect to depth and soil type
- Prepare a report to act as a reference for future investigations requiring background values of surface and subsurface soils.

The proposed procedures for sampling, analyses, and statistical calculations are provided in the background study sampling and analysis plan. The results of the study are presented in the CERCLA/RCRA Background Soil Study (DOE 1993b).

The conceptual basis of the background study was to sample and analyze soil with provenance similar to FEMP soil. To minimize the possibility that samples were collected from areas where emissions from the FEMP site would bias the study, all samples were collected from an area near Shandon, Ohio, more than 3 miles northwest of the site. The Shandon area was selected for the background soil sampling because of the following:

- Geologically, the upper portion of the Paddys Run drainage area lies directly within the path of the icelobe that deposited till at the FEMP. Therefore glacial overburden in the upper portion of the Paddys Run drainage must have the same provenance as the glacial overburden that is found at the FEMP.

- Previously measured concentrations of uranium have shown that the area to the northwest of the FEMP has the least variation between sample results.

- The prevailing winds indicate that the area northwest of the FEMP is the least likely area to be significantly impacted by air emissions from the FEMP.

Thirty hand-auger borings were drilled to collect samples. Samples were collected from three depths, 0 to 6, 36 to 42, and 48 to 54 inches at 30 locations (Figure 2-27). The set of surface soil samples represents loess and the most severely weathered soil horizon. The 36- to 42-inch sample set represents till and glaciofluvial sediment, which are at the approximate maximum depth of significant weathering. The deepest sample set represents till and glaciofluvial sediment and was collected from below the maximum depth of significant weathering.

Samples were collected approximately 3 to 7 miles northwest of the FEMP site. Samples were collected from 0 to 6 and 36 to 42 inches at 30 locations and from 48 to 54 inches at 21 locations. QC samples included blind duplicates, equipment rinsates, bottle blanks, and preservation reagent blanks.

Samples were analyzed according to EPA's CLP and radiological analytical methods as defined in the RI/FS QAPP. All analyses were conducted by routine analytical procedures; however, counting times for radiological analyses were extended to achieve lower-than-usual instrument detection limits.

All soil samples and QC blanks were analyzed for full radiological parameters (excluding isotopic plutonium) and actinium-227, lead-210, potassium-40, protactinium-231, and HSL inorganics.

For each constituent, descriptive statistics and histograms were completed on five sample sets: 0 to 6, 36 to 42, and 48 to 54-inches, subsurface glaciofluvial and subsurface till. The Rosners Test for Many Outliers (Gilbert 1987) was used to identify statistical outliers within the sample sets. Each outlier was evaluated to determine if laboratory error or sampling error was responsible for the anomalous analytical result. The descriptive statistics include:

- Distribution type - normal, log normal or undefined
- Arithmetic means and standard deviations for normally distributed sample sets
- Geometric means and standard deviations for undefined and log normally distributed sample sets
- 95 percent confidence intervals on the means
- Upper 95 percent one-sided confidence limits on the means
- Sample medians
- 95 percent confidence intervals on the medians
- Upper 95 percent tolerance limits.

Analyses of variance techniques were used on each constituent to determine if the means of the three sampling depths are statistically different.

2.5.5.3 Operable Unit 5 RI/FS Work Plan Addenda - 1992

Three of the addenda work plans had surface soil samples as part of their scope. They were the Plant 1 pad, the fire training area, and the KC-2 warehouse, scrap metal pile, and electrical substation areas. Sampling locations are shown in Plate 2-7.

Plant 1 Pad

This program was to determine if nonradiological contamination exists below the pad and to further define the downgradient limits of radiological contamination underlying the pad. Fourteen surface soil locations were sampled to a depth of 3 feet. The 0.0 to 1.0- and 2.0- to 3.0-foot intervals were analyzed for full radiological and HSL parameters. Ten of the locations were selected based on the locations most likely to have stored RCRA wastes and the May 1991 pad inspection and photographs. These locations were near cracks and other visible signs of concrete deterioration. The remaining four locations were near Piezometers 1338, 1340, 1343, and 1347.

The samples were collected by first drilling a 10-inch-diameter hole through the concrete. Once the concrete was removed 3-inch-split spoons were used to collect the three 1-foot samples. Additional details on sampling methods are located in Section 2.1.2.3.

Fire Training Area

There were two areas that had not been adequately characterized through previous sampling: the sump and the surface drainages downgradient from the fire training area. Four surface soil samples were collected from the drainage network south of the training area. One additional sample was completed in the sump. Sampling methods are discussed in Section 2.1.2.3. Sampling was done to a

depth of 1.5 feet. The samples from 0.0 to 0.5 and 1.0 to 1.5 feet were analyzed for full HSL and full radiological parameters, dioxins/furans, and organophosphorus pesticides.

KC-2 Warehouse, Scrap Metal Pile, and Electrical Substation

These areas were investigated primarily because of possible polychlorinated biphenyl (PCB) contamination. Sampling methods are found in Section 2.1.2.3. Samples were taken to a depth of six inches. Four sampling locations were along the railroad bed just south of the KC-2 warehouse, five were collected within the scrap metal pile area and 10 within the electrical substation area. All samples were analyzed for PCB aroclors, full HSL, and full radiological parameters.

2.5.5.4 Sampling and Analysis Plan for RI/FS Work Plan Addendum - Operable Unit 2 - 1993

Surface soil samples were collected as part of this Operable Unit 2 effort to help characterize the near-surface soil in and around the South Field, the inactive and active flyash piles, the lime sludge ponds, and the solid waste landfill. The sampling locations are shown in Figure 2-28 and 2-29. The sampling methods are discussed in Section 2.1.2.3. The samples were analyzed for full radiological and HSL parameters; additionally, one sample per area was analyzed for geotechnical parameters.

2.5.5.5 RI/FS Work Plan Addendum - Operable Unit 1 - 1993

This sampling effort was to provide data to more fully determine pathways and flow rates to potential receptors. Before this sampling, there was no validated data available for near-surface soil to the east and southeast of the Operable Unit 1 area. This data was also needed for the fate and transport model.

Thirty surface soil locations were sampled in and around the Operable Unit 1 area at two separate depths (0.0 to 0.5 and 0.5 to 1.0 foot) for a total of 60 samples. Sampling methods are discussed in Section 2.1.2.3. The top sample interval was analyzed for full radiological and HSL parameters. The deeper samples were archived for future use.

2.5.5.6 Surface & Subsurface Soil Sampling Investigation - 1993

This investigation was to further assess contaminant concentrations in surface and subsurface soils at locations on and off FEMP property. Surface soil sampling methods are discussed in Section 2.1.2.3. Surface soil samples were collected from 0.0 to 0.5 and 1.0 to 1.5 feet in the production area. These samples were analyzed for full radiological and HSL parameters.

Fifty-seven surface soil samples from outside of the production area were sampled from 0.0 to 0.5 foot. Analyses varied for these samples. The location and associated sample analysis are shown in Figure 2-30. Additionally, samples from four locations east and northeast of the FEMP property were analyzed for radionuclides, pesticides, and PCBs to verify the data from the 1986 Health Risk Assessment for the FEMP (IT 1986).

2.5.5.7 FEMP Trap Range Investigation

This sampling program was undertaken to identify the dispersion and amount of lead present in the former trap shooting range southeast of the production area. Initially a 25-foot grid that paralleled the sewage treatment plant access road and extended to the southeast was established. Technicians conducted a radiological walkover survey at all intersections on the grid. A total of eight surface soil samples were collected from each side of the trap house and building on the trap range and sent to an off-property contract laboratory for full radiological analysis.

A 50-foot grid with its centerline roughly perpendicular to the road and through the trap building, trap shooting platform, and trap house extended 200 feet northwest and 1000 feet southeast of the trap building in a wedge shape. This zone represents the area of maximum lead shot fallout and is based on trajectory and drift calculations. The metal detector and surface soil sampling programs of the trap range investigation were performed on this grid.

A metal detector survey preceded the soil sampling program; the survey was conducted by the same individual to ensure consistent methods and results. Any location with a reading higher than background was recorded.

Soil samples were taken at 18 locations (Plate 2-7). Eighty percent of the samples were from locations with higher than background metal detector survey results, while twenty percent were from locations with background readings. The eighteen samples were analyzed at the on-site laboratory according to a modified sieve test procedure for composition by percent mass of rocks/grass, soil, trap fragments, and lead shot.

After the sieve test of the 18 surface soil samples was complete, seven samples were analyzed for HSL metals; subsequently seven of the 18 locations were resampled for HSL metals and semivolatiles based on the results of the sieve test.

2.6 SUBSURFACE SOIL

Subsurface soil investigations were conducted on and adjacent to the FEMP property from the early 1950s to the present. The RI subsurface soil sampling program was performed as an integral part of the groundwater monitoring well installation program, as well as during specific soil investigations. Subsurface soil sampling occurred during the drilling process. Subsurface soil samples were collected in the glacial overburden and the Great Miami Aquifer.

2.6.1 Pre-RI/FS Subsurface Soil Programs

Drilling activities performed both on- and off-property have been used to support the description of the physical setting at the site; Table 2-6 lists the subsurface boring programs that predate the RI/FS. Activities included: construction-related geotechnical borings; borings for the siting of a proposed landfill; monitoring wells and production well drilling; 1951 preconstruction drilling; homeowner well drilling in areas adjacent to the FEMP; Southwestern Ohio Water Company (SOWC) well drilling; and the Paddys Run Road Site RI/FS drilling program. The location of each of these borings was tied to the project mapping system and logs acquired. Each log was reviewed by staff geologists and interpreted to support a uniform lithologic mapping nomenclature.

2.6.2 Pilot Plant Sump Removal Action 24 Subsurface Soil Investigation

A removal action was conducted to address the contents, structure, and piping associated with an inground sump at the pilot plant. Subsurface soil samples were collected as part of this removal action and used as part of this RI to describe the nature and extent of contamination and support the baseline risk assessment.

The objective of this sampling was to establish the nature and extent of any radiological or hazardous substances in the soil adjacent to the inground sump.

Soil sampling was performed consistent with RI/FS subsurface sampling protocols. Samples were collected continuously at 1-foot intervals using split spoons at each boring location and screened for organic vapors and radioactive materials. The interval with the highest indication of contamination was submitted for analysis.

Following sump removal, hand-auger samples were collected at two 1-foot intervals from beneath the location of the former sump. Four borings were completed at the four primary compass directions to

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a depth of 12 feet. One sample was collected from each boring and submitted for full HSL, gross alpha/beta activity, isotopic uranium and thorium, radium-226, actinium-227, protactinium-231, and toxicity characteristic leaching procedure (TCLP) metals/volatiles analyses.

Two hand-auger samples were collected from one location beneath the sump for the 10- to 11- and 11- to 12-foot depth intervals. Additionally, one soil sample from the 3- to 4-foot depth interval was collected underneath the sump drain inlet. The collected samples were analyzed for full HSL, isotopic uranium and thorium, and gross alpha/beta activity. The sample beneath the drain inlet was additionally analyzed for radium-226, actinium-227, and protactinium-231.

2.6.3 RI Subsurface Soil Investigations Using Drilling

The Operable Unit 5 subsurface soil sampling program began in August 1987 with the drilling of the first monitoring well consistent with the requirements of the RI/FS Work Plan. In November 1988, the drilling of borings and piezometers was initiated under the RI investigation termed the Production and Additional Suspect Areas Work Plan. The RI-related subsurface soil investigations continued through September 1993. Figures 2-31 through 2-40 and Plates 2-8 through 2-13 show the locations of the borings completed by September 30, 1993. These figures also show piezometers and monitoring well locations. The piezometer and monitoring wells are discussed in Section 2.7 and the sampling methods are discussed in Section 2.1.2.4. A summary of the subsurface soil and the monitoring well installation programs is provided in Appendix S, as are the analytical parameters associated with each program. Tables S-3 and S-4 also give an overview of the subsurface soil sampling programs.

The objectives of the subsurface soil investigations completed as part of the RI were to:

- Determine the subsurface stratigraphy in the FEMP area and its relationship to the distribution of groundwater
- Characterize the lateral and vertical extent of radionuclide and hazardous substance contamination of subsurface soil for assessment of the nature and extent of potential subsurface pathways to groundwater contamination
- Determine the geochemical properties of the subsurface soil that may retard or enhance contaminant movement or define potential pathways, i.e., presence of iron oxides, amounts of sorbed uranium, and cation exchange capacity
- Determine the geotechnical properties of the subsurface soil for use in evaluating the feasibility of remedial alternatives.

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Additional well installation and subsurface soil programs were developed from an ongoing analysis of the results from existing data.

As part of the Production and Additional Suspect Areas Investigation, over 290 borings were completed in the former production area. Specific locations for these borings were determined by two methods: first, borings were systematically spaced on a 250-foot grid across the production area; second, biased borings were completed at areas of suspected subsurface contamination. The location of the biased borings was determined by interviews with long-term site employees, process knowledge on the types of materials handled (e.g., areas with concentrated acid usage) and of the plants operating procedures, and on knowledge of deteriorated systems. For these borings, continuous sampling was performed to a depth of 20 feet or to the first clay layer encountered beneath a perched water zone, whichever occurred first. This depth was selected to minimize the probability of creating a vertical pathway for contaminant migration to the underlying aquifer attributable to drilling activities.

For the borings completed using augering techniques as part of the Production and Additional Suspect Area Investigation, samples were collected at depths of 0 to 0.5, 2 to 2.5, 5 to 5.5, 10 to 10.5, 15 to 15.5, and 19.5 to 20 feet unless a positive reading was encountered on a hand-held vapor analyzer. For locations with positive organic vapor readings, additional samples were collected at the location of the peak reading. All samples collected as part of this boring program were submitted to the FEMP laboratory for total uranium and thorium analysis. Select samples were also submitted to the RI/FS program laboratory for HSL and full radiological analysis.

The RI/FS programs were diverse in the number of samples that were collected and in the types of analyses performed. In general, samples collected during well drilling activities involving cable tool drilling were submitted to the off-site laboratory for full radiological analysis. As previously indicated, samples were collected for analysis at locations of elevated organic vapors or radiological measurements. Samples where positive organic vapors were detected were submitted for HSL analysis. The analyses for each program that included subsurface soil sampling is discussed in the Appendix S program summaries.

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2.6.4 RI Subsurface Soil Investigations Using Trenching

Trenching was used to support the Operable Units 2 and 5 site investigations. For simplicity, trenches are grouped with the borings. The Operable Unit 5 trenches were assigned Type 1 well location numbers. (See Section 2.1.3.2 for a discussion on well location numbers.) This data was used to support the description of the physical characteristics of the study area, the nature and extent of contamination, and the baseline risk assessment.

Trenching was used to define the nature of hazardous and radiological constituents present in construction rubble areas or in a suspected spill or burial area. Trenches were chosen because of the likelihood of encountering debris. Standard sampling equipment such as hollow-stem augers and split-spoon samplers were considered not suitable.

Grab samples were collected from the backhoe bucket at specific intervals and depths in the trenches. The individual RI/FS sampling plans supporting the trenching called for differing numbers of samples and the analytes for which they were sampled. Selected samples were analyzed at the on-site laboratory for total uranium and thorium. The sampling analyses also included full radiological, full HSL, or geotechnical analysis on selected samples. The analyses for each program that included subsurface soil sampling is discussed in the Appendix S program summaries.

The trench locations are shown in Plate 2-14. The following Type 1 well locations were trenching locations: 1455 through 1487, 1192, 1264, and 1677. Those trenches that were not assigned numbers are also shown on Plate 2-14.

2.7 GROUNDWATER INVESTIGATIONS

The purpose of the groundwater investigations was to provide sufficient data to quantify the nature and extent of contamination in the perched water system and the Great Miami Aquifer, support the baseline risk assessment, and provide water table elevation and other hydraulic data to calibrate groundwater models. Groundwater samples and water-level measurements were completed in both the perched groundwater system within the glacial overburden and the Great Miami Aquifer. Groundwater data employed by Operable Unit 5 originated primarily from RI/FS site investigations and the RCRA groundwater program. Well locations are shown in Figures 2-4 through 2-9 and Plates 2-1 through 2-6. The 1988 RI/FS Work Plan well locations were selected to fill data gaps that were noted during review of existing information.

2.7.1 RI Well Installations and Groundwater Quality Investigations

Groundwater investigations which support Operable Unit 5 began in July 1987 and continued with the addition of new wells and the collection of additional samples under a series of specific efforts. These efforts are described individually in Appendix S. Groundwater sampling culminated in the spring and summer of 1993 with a one-time "snapshot" assessment of the distribution of chemical constituents in the groundwater on and adjacent to the FEMP property.

Well-installation programs were proposed and carried out as additional data needs and concerns were identified. Groundwater sampling was performed for all of the monitoring wells and generally included sampling at the time of well installation and once again approximately two months later.

New well installations under the RI culminated with the Additional Monitoring Well Installation and Well Abandonment program of May 1993. This plan included wells completed in the glacial overburden and the Great Miami Aquifer, some of which replaced damaged wells that were plugged and abandoned.

The overall objectives of this RI programs were to:

- Determine the nature and extent of any groundwater contamination in the Great Miami Aquifer resulting from the operations of the FEMP
- Characterize the nature and extent of perched groundwater contamination within the glacial overburden.

The RI/FS Work Plan concentrated on satisfying both local and regional groundwater data requirements concerning groundwater quality, flow direction, and contaminant sources and pathways. Additional work plans were developed based on evaluations of the results from the initial investigation. As of September 30, 1993, a total of 755 monitoring wells and piezometers had been installed and 21 private wells had been sampled to characterize the groundwater around the FEMP. Appendix S discusses analyses performed for the groundwater programs. Tables S-5 and S-6 also highlight groundwater programs.

RI/FS Groundwater Sampling

Wells installed for the RI program, as well as existing on-and off-site wells, were used to begin characterization of water quality and contaminant extent. Subsequent groundwater monitoring

programs were established as sampling results showed the need for additional analytical data. The RI/FS Work Plan specified quarterly sampling until all wells had been sampled four times. All subsequent work plan addenda stated that the wells were to be sampled twice: once after installation and once approximately two months later. The ongoing RCRA monitoring program performs quarterly sampling on selected wells. Also, once a monitoring well was drilled, installed, and developed, it could be sampled by any FEMP group. Some of the more recent RI programs sampled existing wells for different analytical parameters. The final RI groundwater monitoring effort was the Snapshot Monitoring Well Sampling and Surface Water and Sediment Sampling Program which began in April 1993. The sampling included 366 Types 1, 2, 3, or 4 wells. This program was a one-time sampling event designed to characterize the water quality over a wide area in a relatively short period of time to support the baseline risk assessment.

Groundwater samples were collected from the RI/FS wells, selected existing wells at the FEMP, and selected off-property private wells. The primary consideration in groundwater sampling is to obtain a sample representative of the groundwater body. Groundwater sampling methods are discussed in Section 2.1.3.5.

The RI/FS programs were diverse in the number of samples that were collected and sent for analysis and in the analytes for which they sampled. Some programs sampled for total uranium and thorium were analyzed at the on-site laboratory. The sampling analyses included full radiological, full HSL, full HSL plus, Appendix IX, or general groundwater quality parameters. The analyses for each program that included groundwater sampling is discussed in the Appendix S program summaries.

2.7.2 RI Water Level Measurements and Hydraulic Testing

Water level measurements and slug and pumping tests were conducted as part of the RI to provide hydraulic data to support the description of the physical setting of the site and developing the fate and transport models.

The objectives of collecting these measurements and completing these tests were to:

- Define contaminant pathways, potential migration rates and groundwater flow velocities in the Great Miami Aquifer
- Characterize the perched water and Great Miami Aquifer flow systems including hydraulic conductivities, connectivity, and areas of recharge and discharge

- Determine the effects that groundwater pumping would have on groundwater flow and contaminant transport.

Beginning in January 1988, water levels were measured monthly in RI/FS and pre-existing wells. Water level measurements are still collected each month from selected wells screened in the Great Miami Aquifer and glacial overburden. At times, water level measurements were collected more frequently to meet specific monitoring needs.

Water level measurement data is primarily used to determine groundwater flow, direction, and seasonal fluctuation in the water table surface. This is accomplished by preparing hydrographs and maps of the potentiometric surface in the glacial overburden and Great Miami Aquifer. Additionally, water level data is used to examine the structural condition of a well and to evaluate the effects of various pumping and removal actions.

Water levels were measured from surveyed reference points and measurements were completed in the shortest practical time period in order to represent as closely as possible the potentiometric surface at a single point in time. All data were recorded on the appropriate field logs.

For the monitoring wells installed under or used by the RI/FS, Appendix K contains tabulated groundwater elevation data and water table maps for Type 2 and Type 3 wells; and Appendix L contains hydrographs.

A series of hydraulic tests were performed in both the Great Miami Aquifer and the perched water system. These tests included: the South Plume Removal Action pumping test; the alternate water supply pumping test; slug tests and pumping tests, and yield tests for the glacial till.

The South Plume Removal Action pumping test was conducted on Recovery Well 4 in May 1993 to acquire data for calculating hydraulic conductivity and storage capacity of the Great Miami Aquifer. An eight-hour step-type pumping test was completed followed by a 10,000 minute constant test. The eight-hour test attained a maximum pumping rate of 750 gpm, while the constant test was performed at 425 gpm. Eighteen wells in the immediate vicinity of Recovery Well 4 were monitored for changes in water levels using both manual techniques and data loggers with transducers. Additionally, 33 secondary wells were monitored for changes in water levels using manual techniques.

In October 1991, a pumping test was performed on the Albright and Wilson alternate water supply well, located approximately one mile west of the FEMP. In this test, a 335-minute step test was performed attaining a maximum pumping rate of 375 gpm. Additionally, a 72-hour constant rate pumping test was performed at 350 gpm.

Slug tests were conducted at 70 locations in the glacial till. These tests were completed using falling head and rising head tests. For these tests, a solid slug (concrete-filled PVC pipe) was inserted in the well below the water line. Water level measurements were then collected from the wells as the levels returned to equilibrium around the slug. The slug was then removed and similar measurements were collected as the water levels rose to their equilibrium conditions. Methods are discussed in Section 2.1.3.8.

Seven yield tests were performed on wells within the glacial till in the summer of 1993 to determine the yield of varying sediment deposits. These tests were performed at Wells 1274, 1259, 1077, 11214, 1339, 11112, and 1785 and involved an eight-hour step pumping test. Pumping was stepped up to a maximum of 3 gpm. Maximum pumping rates varied by well location due to the heterogeneity of the glacial material. Water level measurements were performed at nearby wells, using both manual techniques and data loggers/transducers to evaluate drawdown. Methods are discussed in Section 2.1.3.8.

Pumping tests were completed in September 1993 on Wells 11214, 1785, and 11112. Each of these are 4-inch diameter wells completed in the glacial till. An eight-hour step test followed by a constant rate test was performed. The pumping rates varied from well to well due to the heterogeneity of the glacial overburden. Due to the low yield of the glacial material, flow rates did not exceed 3 gpm at any location. For each test, approximately six piezometer/well locations in the vicinity of the test well were monitored for changes in water levels. Water level measurements were completed using data loggers/transducers and manual techniques. Methods are discussed in Section 2.1.3.8.

Two packer tests were performed in the summer of 1993 to determine hydraulic conductivity. These tests were done on Borings 11127 and 11134 (Figures 2-32 and 2-40). Methods are discussed in Section 2.1.3.8.

Lysimeters were installed for two programs in 1993 (Figures 2-4, 2-6, 2-32, 2-34 and 2-36). Three 6-foot deep lysimeters were installed along the bank of Paddys Run west of the K-65 silos as part of Operable Unit 4's Additional Characterization of the Vadose and Perched Water in the K-65 Area PSP. Seven lysimeters were installed as part of Operable Unit 5's Glacial Till/Vadose Zone Hydraulic Investigations work plan. Four of the lysimeters were used to determine saturation of the basal clay layer in the glacial overburden. Additionally, three were used to determine saturation in the portion of the Great Miami Aquifer above the regional water table. Methods are discussed in Section 2.1.3.8.

2.7.3 RCRA Groundwater Monitoring

A detection monitoring program was initiated in August 1985 due to the designation of Pit 4 as a hazardous waste management unit as defined under RCRA. The RCRA detection monitoring system triggered an assessment monitoring program in December 1987, due to the determination of a statistical difference in indicator parameters in downgradient wells. The RCRA assessment monitoring program continued through December 1991, when a new groundwater monitoring plan was developed and implemented. Data from this program was used to support the description of the nature and extent of contamination and the baseline risk assessment.

The objectives of the RCRA program included assessing the rate and extent of contaminant migration of RCRA constituents in groundwater associated with regulated units, and providing a routine monitoring program to evaluate changes in water quality over time. Because of the volume of data available through the ongoing RCRA compliance program, only data collected after January 1, 1990, was used in the RI.

The current program, the RCRA Groundwater Assessment Program, quarterly monitors water quality in 43 wells located within the FEMP boundaries; analytical parameters include drinking water standards as well as additional RCRA parameters. Testing is conducted for 24 metals, 36 volatile organic compounds, and 14 water quality parameters. In-depth information on sampling methods and analytical procedures can be found in the RCRA annual reports.

2.8 AIR AND DIRECT RADIATION INVESTIGATIONS

2.8.1 Air Quality Investigations

Air quality monitoring data was used to support the description of the nature and extent of contamination associated with Operable Unit 5. Air particulate samples are collected routinely as part of the FEMP EM program to assess potential impacts the facility may be having on local and regional air quality. The data is used to assess any potential exposures local populations could receive attributable to FEMP operations.

Sixteen monitoring stations equipped with continuous high volume samplers have been established on and off FEMP property (including background locations). A continuous flow of air is pulled across 8- by 10-inch glass fiber filters. Figure 2-41 illustrates the location of the air monitoring stations. The glass fiber filters are collected weekly by sample technicians. Collected samples are analyzed at the FEMP laboratory or at an off-site laboratory for total uranium, gross beta activity and total suspended particulates. A fraction of each weekly sample is composited for an annual analysis for full radiological parameters.

2.8.2 Airborne Radon Measurements

Airborne radon measurements are collected both on and off the FEMP property in support of the FEMP EM program and to assess radon exposure to workers and populations bordering the FEMP. This information has been used to support the description of the concentrations of radon in the atmosphere and to support the determination of the nature and extent of contamination in Operable Unit 5 study area.

Airborne radon measurements are collected at 49 preestablished locations both on and off FEMP property (Figure 2-42). Four of these locations are at monitoring sites representing background locations unaffected by FEMP operations. Measurements are taken using laboratory-supplied track etch radon cups. Typically, two types of cups, "F" and "M" are placed at each measurement location. Type "F" cups employ a filter that is permeable to radon gas but not to progeny or particulates. Type "M" cups employ filters that are permeable to radon and thoron gas but not to progeny or particulates. Type "F" cups are singularly employed at locations surrounding the Operable Unit 4 Silos 1 and 2, on the railing around the base of the silo domes. Radon cups are

changed quarterly and returned to the manufacturer's laboratory for analysis. Field blank radon cups are used to establish radon measurements incidental to the cup collection process.

2.8.3 Direct Radiation Measurements

Direct radiation and radon measurements are collected as part of the FEMP EM and worker health and safety programs. Direct radiation measurements are collected with the use of thermoluminescent dosimeters (TLDs) placed at preselected locations both on and off FEMP property. This information is used to support the description of the direct radiation field associated with the site for use in the description of the nature and extent of contamination and in the baseline risk assessment penetrating radiation pathway.

The objectives of the TLD measurement program in relation to Operable Unit 5 include:

- Establishment of the direct radiation fields associated with FEMP sources
- Support of the determination of the potential radiation doses to on-site and off-site human receptors.

Integrated direct radiation measurements are taken quarterly at 29 on- and off-property locations using TLDs (Figure 2-43) that are placed and collected by FEMP personnel. The TLD badges employed in the program contain two calcium sulfate ($CaSO_4$) elements with lead and plastic filters, one $CaSO_4$ element with a plastic filter, and one lithium borate ($L_2B_4O_7$) element. The array of elements and filters are employed to indicate the relative energies associated with the measured gamma radiation and to provide a basis for converting the radiation to a measure of whole body dose.

TLDs are collected and counted in the FEMP dosimetry laboratory; the data are compiled and issued in the site's Annual Environmental Report.

To enable the TLDs to measure doses of less than 10 milliroentgen (mR) on the lithium borate elements and 5 mR on the calcium sulfate elements, all TLDs are annealed before use. Annealing is a process where the TLDs undergo a controlled-heating process to remove any residual dose from the elements before use.

Following recovery, the exposed TLDs are read on a Panasonic automatic TLD reader in the FEMP dosimetry laboratory in accordance with established site procedures. The automatic reader is

calibrated every six months or immediately following replacement or maintenance on any critical instrument part. Daily QC checks are performed on the reader using previously irradiated TLD badges. The reader displays measurements in units of mR. An algorithm is employed to convert from mR to mrem at a specified depth in tissue.

Collection control TLDs are employed to measure any exposures to the TLDs incidental to the TLD collection process. Control TLDs are also employed during the counting process to monitor the reader's performance. These control TLDs include reader background controls and reader calibration controls.

2.9 BIOLOGICAL RESOURCE INVESTIGATIONS

As discussed in Section 1.3.5, biological resources at and near the FEMP have been characterized in a number of studies. This section presents the objectives, methods, and, when applicable, a description of the sampling and analysis performed as part of the RI/FS investigation. Also discussed are the studies conducted by Miami University of Oxford, Ohio, the biological sampling conducted by the FEMP's EM program, wetlands delineation, and threatened and endangered species surveys.

Additional information on biological resources can be found in the following sections of the RI Report:

- The Site-Wide Ecological Risk Assessment (Appendix B) presents possible risks to ecological receptors posed by contaminants associated with past activities at the FEMP.
- Appendix J.1 contains summarized data from several of the biological studies discussed in this section.

2.9.1 RI Biological Studies

The RI biological studies included sampling and analysis of plants, garden produce, agricultural products, and animals to determine contaminant concentrations. Fish and macroinvertebrate surveys of Paddys Run and the Great Miami River were conducted to determine species/community composition as well as contaminant concentrations. All biological resources sampling conducted as part of the RI/FS was completed in 1 year, except for the second benthic macroinvertebrate survey which was completed between 1988 and 1990.

The biological resource studies were conducted to:

- Determine if radiological or hazardous substances released to the FEMP environs contaminated ecological habitats
- Determine if these releases contaminated agricultural products and crops
- Evaluate if exposure to site contaminants resulted in injury or adverse affects to ecological receptors.

Samples for the biological studies were collected, stored, and shipped in accordance with the Biological Resources Sampling Plan, a supporting document to the approved RI/FS Work Plan (DOE 1988a). Using the 1927 Ohio State Planar Coordinate System, vegetation and soil samples were collected from 1000-foot centers within the FEMP boundary, but outside the production area (see Section 2.5, Surface Soil Investigation).

Sampling of flora as part of the RI/FS biological studies included collecting grasses, broad-leaf plants (forbs), shrubs, pine needles, mosses, and cattails (Figure 2-44). Vegetation samples were collected from 31 locations within the FEMP boundary. For general flora, each location was sampled by placing a 2.7-foot-square frame over the vegetation at the 1000-foot grid stake, and cutting all enclosed shoots at ground level with decontaminated shears. Root samples were collected to a depth of approximately 6 inches at each sampling site. To the extent possible, soil was removed from root samples before packaging. At 84 percent of the sites, a soil sample was collected within 1.6 feet of the vegetation sample to minimize the possibility of spatial variations occurring between soil and vegetation sampling locations.

RI/FS sampling technicians collected garden produce and agricultural crops from the seven sites indicated in Figure 2-45 and also from four control sites located about 19 miles west-northwest of the FEMP in Brookville, Indiana. Produce and crop sampling sites were selected due to their location relative to anticipated average depositional patterns from FEMP stack emissions; that is, test sites were chosen to the north and east of the FEMP, while background samples were collected to the south and west. Under the grower's supervision, the technicians collected samples of available produce (e.g., fruits, leafy vegetables, grains, and root crops) and a representative soil sample. Sample collection and handling for produce and agricultural crops followed the procedures for RI/FS vegetation sampling, except that a quadrant-bounded sample area was not used. The quadrant sampling method is inappropriate for produce sampling because, in general, the fruit, instead of the remaining plant parts, is consumed by humans. Because the RI/FS vegetation sampling method was

written for nonagricultural/cultivated vegetation, a method other than one that required cutting and sampling of all vegetation in an area was employed.

Fauna sampled included small mammals (e.g., deer mouse, shrew, cottontail rabbit and opossum), fish, and benthic macroinvertebrates. The samples were collected from areas where a high potential for contamination existed (i.e., near the inactive flyash pile, incinerator, and waste pits, from a drainage ditch north of the railroad tracks, northern pine plantation, Paddys Run, and the Great Miami River). All faunal samples were collected under Scientific Collecting Permit No. 228 from the Ohio Department of Natural Resources (ODNR), Division of Wildlife (DOW).

Using a combination of live and snap traps, small mammals were captured in nine locations including areas below the flyash pile and near Waste Pit 5, as well as from the pine plantation just north and northeast of the former production area. Larger mammals constituted individual samples, while small mammals were composited for each trap site.

In 1987, fish were collected from four sites (each site was 300 to 500 feet long) on the Great Miami River: near the Bolton Water Treatment Plant upstream from the FEMP effluent line, just below the discharge point of the FEMP effluent line, at the river's confluence with Paddys Run, and approximately 2 miles south of the Miamitown bridge. In addition, fish were collected from four sites on Paddys Run: at the northern property line of the FEMP, where the railroad crosses Paddys Run, west of the waste storage area, and just above the confluence of Paddys Run and the Great Miami River. Technicians also collected three samples of fish from a drainage ditch north of the railroad tracks on the FEMP. A combination of sampling techniques, including seining, hook and line, boat and backpack electrofishing, and dip netting were used to capture fish species for laboratory analysis. The river was relatively low at the time of the sampling, and Paddys Run consisted of a few small pools with short riffle areas. After using the backpack electroshocking unit for approximately one-half hour, seining was used to adequately sample smaller fish species in the shallower waters.

RI/FS benthic macroinvertebrate samples were collected in the Great Miami River and Paddys Run during two separate studies. The first study was conducted in 1987 at the same times and locations that fish samples were collected (Figure 2-46). For the second study, a species/community study,

sampling was conducted five times on the Great Miami River and four times on Paddys Run between October 1988 and August 1990 (Figure 2-47).

In the first study, a sampler with 1-square-foot area was used to collect benthic macroinvertebrate samples, with organisms from three collections composited to produce the final sample for uranium analysis. Crayfish were also sent to the analytical laboratory as benthic macroinvertebrate samples, although results were derived separately for crayfish and the composite samples of other macroinvertebrates.

Biological resource samples were analyzed to determine concentrations of three basic types of contaminants: radiological, organic, and HSL inorganics. Radiological analyses in 1987 included isotopic uranium, strontium-90, and cesium-137. Samples from about 8 percent of the original sampling locations were also analyzed for organic and HSL inorganics.

For an indication of macroinvertebrate community structure and river health, samples were collected from the Great Miami River and Paddys Run during a second macroinvertebrate study using artificial substrate samplers, an Emery pipe dredge, and a Surber sampler (DOE 1992). Specimens were collected from eight stations along Paddys Run and seven stations along the Great Miami River. Organisms collected from each sampling location were preserved, counted, and identified. Organisms were identified to genus where possible. Identification was made using the keys developed by Mason (1973), Merritt and Cummins (1984), Parris (1975) and Pennak (1978). Final identification was made using Pennak (1978). Community compositions of different locations were compared using the OEPA invertebrate community index, organism density, diversity, and evenness. Individual taxa were classified by pollution tolerance (Weber 1973). The invertebrate community index developed by OEPA (1988) was used to evaluate potential effects of the FEMP on the aquatic communities of Paddys Run and the Great Miami River.

2.9.2 Miami University Biological Resource Studies

From 1986 through 1992, researchers from Miami University conducted a series of surveys and studies at the FEMP. The surveys and studies ranged from a comprehensive ecological characterization of species and habitats to studying the effects of environmental stress observed along with genetic evaluations of FEMP plants and animals, and also studies of the reproductive success of

on-property robins and doves. The objectives and methods of the following Miami University studies are discussed in this section:

- Facemire et al. (1990)
- Osborne and Jones (1991)
- Osborne et al. (1992)
- Guttman (1990)
- Guttman (1992)
- Reding and Guttman (1991)

The objectives of the Miami University studies were to:

- Identify species and habitats on the FEMP property
- Determine distribution and abundance of species
- Determine possible stress-induced differences (genetic, reproductive, and morphometric) between on- and off-property plant and animal populations.

Sampling methods used by Facemire et al. (1990) are described in detail in the Biological and Ecological Site Characterization of the Feed Materials Production Center. For their study of terrestrial ecology, the authors divided the FEMP study area into six distinct habitats: riparian, deciduous woodlots, pine plantations, inactive flyash pile, and grazed and ungrazed pastures. Permanent sampling transects or lines were set up in each habitat. The number of transects per habitat was proportional to the percentage of the FEMP covered by that habitat type. All on-property sampling locations for the Facemire et al. (1990) study were selected in relation to these transects and sampling stations unless otherwise noted. Off-property populations were used for comparison for benthic organisms, fish, amphibians, birds, and plants.

Herbaceous vegetation was characterized using a focal-point surveying procedure, and trees and shrubs were counted using a 1/10-acre-circle method. The focal point survey was performed by placing a spotting scope at 3.3-foot intervals along the marked transects and recording the number and types of plants seen through the viewfinder. Walkover surveys identified herbaceous plants not seen through the scope. Trees in the inactive flyash pile, the three woodlots, and two riparian habitats were surveyed by marking out 1/10-acre plots adjacent to the transects and recording the type and size of each living tree within the boundary. Shrubs were surveyed in the center 1/100-acre of each tree plot.

FEMP bird populations were censused using a fixed-width line along each of the established transects. Breeding birds were counted 12 times between June 25 and July 25, 1986. Wintering birds were surveyed eight times between February 5 and March 6, 1987. For each species, percent frequency of occurrence was calculated by dividing the number of censuses during which the species was present by the total number of censuses and multiplying by 100. Populations of eastern screech owls, great horned owls, and barred owls were censused from December 5, 1986 to February 4, 1987 using standard playback techniques (Facemire et al. 1990). Prerecorded tapes of each species' calls were played at fixed intervals along each transect. Responses were mapped and used to delineate breeding territories.

Small mammal populations, which include rats, mice, and shrews, were assessed by trapping along the established transects. Traps were baited and set each evening and morning for three consecutive nights in several different habitats. Populations for white-tailed deer, bobwhite quail, and fox squirrel were estimated. Bobwhite quail density was estimated with a modification of the call-count technique. The trail-count method was used to estimate white-tailed deer density on the FEMP. The gray squirrel time-area count was adapted for use with fox squirrels on the FEMP.

Facemire et al. (1990) did not conduct a census of amphibians and reptiles. However, the authors present a record of incidental sightings of amphibians and reptiles.

In early July 1986, the authors used a sweep net to collect samples of terrestrial arthropods along the permanently established transects in each habitat. Identification was made to family in most cases. Nymphs were identified to family for groups with incomplete metamorphosis (e.g., Orthoptera, Homoptera, Hemiptera, Thysanoptera) and only to order otherwise.

For their study of aquatic communities, Facemire et al. (1990) established eight on-property sampling stations along Paddys Run. The authors used a combination of electrofishing and seining to collect representative fish samples, which were identified to species and counted. Catch data for each pool and riffle were used to calculate an index of the catch per unit effort, the proportion of catch, and the density for each fish species. The calculated values were used to establish the abundance of each species throughout the stream.

Benthic macroinvertebrates were taken from designated riffle and pool areas of Paddys Run and an off-property stream, Harkers Run. At each riffle sampling location, technicians used a stream-bottom sampler to collect three samples from the riffle immediately above or below the chosen pool. The technicians collected two samples from each pool. In each case, the top 2 inches of substrate was removed with a stainless-steel sampler. Subsamples were then washed using a No. 35 standard testing sieve, and the collected organisms were placed in jars and preserved for sorting by family, counting, and storing in the laboratory. Densities were calculated for organisms found in both the riffle and pool areas of the streams, as were community similarity indices.

Between 1986 and 1990, Miami University researchers studied several FEMP plant and animal species to determine levels of genetic variability. Researchers theorized that low variability or extreme changes in variability between generations would be seen if FEMP organisms were exposed to unusual levels of environmental stress. Gene coding for specific enzymes was studied to determine how many variants of each gene could be found in FEMP and other populations. Allele types (variants of specific genes) regulating the production of the different enzymes was identified by electrophoretic analysis, a method of distinguishing different molecular structures by their different rates of migration through a fluid when an electric field is applied. In 1986 and 1987, Facemire et al. compared the genetic structure of on- and off-property populations of milkweed, dandelions, mayflies, grasshoppers, spring peepers, American toads, and several species of fish common to Paddys Run. Samples were collected from FEMP property and from off-property locations near Oxford, Ohio. Results of electrophoretic analysis were used to calculate allele frequencies, deviation from expected proportions, and amount of genetic variation present in each population.

Guttman (1990) conducted a study of the spring peeper, *Hyla crucifer*, to further investigate the distribution of an unusual inactive allele identified in FEMP populations by Facemire et al. (1990). In the spring of 1990, 783 spring peepers were collected from off-property locations within 13 miles of the FEMP. Genetic structure of these specimens was analyzed to evaluate the frequency of occurrence of the inactive (null) allele in populations surrounding the FEMP.

Guttman (1992) attempted to determine if the genetic mutation responsible for the null allele had originated in the FEMP spring peeper population; 864 FEMP spring peepers collected in 1991 were analyzed for enzymatic composition. Guttman simultaneously sampled control populations at Fort

Jefferson, Ohio (48 miles north of the FEMP) and Greensburg, Indiana (44 miles west of the FEMP), and noted reports of the incidence of the null allele in spring peeper populations at Wheeling, West Virginia (east) and Rice Run, Kentucky (south).

Reding and Guttman (1991) studied genetic and morphologic variability in the 1987 generation of on- and off-property populations of the periodical cicada, *Magicicada cassini*. The cicada was chosen because its life cycle includes extended developmental stages spent underground, allowing for analysis of the effect of long term exposure to FEMP soils. In May 1987 at least 50 newly emerged cicadas were gathered from each of eight on-property and four off-property locations. Of these, 20 individuals were analyzed against morphological standards; at least 30 were frozen upon collection and later analyzed by horizontal starch gel electrophoresis. Enzymes were classified according to monomericism or dimericism. Statistical analysis was performed on all morphologic and electrophoretic results to compare the different populations.

Facemire et al. (1990) studied growth and reproductive success of American robins and mourning doves at the FEMP during the 1987 breeding season. Doves, who eat primarily plant seeds, and robins, who feed primarily on earthworms and beetles, were chosen to evaluate the effects of FEMP emissions on different levels of the food web. Populations studied were located in the northern and southern FEMP pine plantations, at Houston Woods State Park north of Oxford and at the Miami University campus.

Osborne and Jones (1991) conducted a follow-up study to determine if growth of FEMP American robins during the 1990 season showed the same suppression as was found in 1987. Reasons for growth stunting were not investigated.

Osborne et al. (1992) attempted to determine the cause of the robin growth effects at the FEMP during a 1991 study. American robin populations were examined at the FEMP and at five off-site locations selected for similarity of landscape and mowing practices. Robin growth parameters and reproductive success were measured at all locations. In addition, earthworm and soil samples were collected at each location and analyzed for uranium, heavy metals, herbicides and pesticides.

2.9.3 Environmental Monitoring Program Biological Studies

The FEMP's EM program began with air sampling and surface water sampling in the Great Miami River in the 1950s, and has gradually expanded to include fish, milk, vegetation, produce and soil and grass sampling in the FEMP vicinity. In this section, the objectives, methods, and sampling and analysis of the grass, produce, milk, and fish sampling conducted for the site environmental program are discussed.

As mentioned previously, the FEMP is required by DOE orders to monitor environmental media in order to assess the potential impacts of the site's operation on the regional environment. Furthermore, the site is required to estimate possible radiation doses to off-property residents from ingesting food that may be contaminated due to site operations. The EM program is designed to meet these objectives.

Methods used to sample produce, grass, milk, and fish are described in FEMP Environmental Monitoring Procedures.

In general, grass samples are collected annually in the early summer as part of the soil and grass sampling program. Grass is clipped near ground level until an approximate 1-pound composite sample is collected. Standard operating procedures guide the field collector methods, packaging, documentation, and decontamination of the samples and sampling equipment.

Garden produce and agricultural crops have been collected annually since 1973 from local farms and roadside stands. In recent years, samples have been collected from farms and gardens west and south of the FEMP in Indiana and Kentucky, respectively, as a control measure. Produce samples collected include corn, tomatoes, beets, potatoes, apples, lettuce, pumpkins, cucumbers and peppers.

The milk sampling program began in the early 1980s because a dairy is located just off property. Milk samples are collected monthly from the nearby dairy and also from a control dairy. Presently, the control dairy is located in Indiana about 23 miles west of the FEMP.

The EM program has sampled fish in the Great Miami River in conjunction with the University of Cincinnati since 1984. Personnel from both programs electrofish at four sites between Hamilton and

the Paddys Run outlet each year. Fish are first identified by University of Cincinnati researchers and then sent to independent laboratories for uranium analysis.

All of the biological samples collected by the EM program are analyzed at off-site labs. Many grass sampling locations have remained consistent through the years of sampling (grass sampling began in 1984 with 20 locations); however, a few locations are generally added or deleted every year. Approximately 34 locations were sampled in 1992. Currently, grass samples are analyzed for total uranium; fluoride analysis was discontinued in 1991 after production operations ceased. Produce samples collected from more than 20 locations in 1991 were analyzed for total uranium. Percent wet weight is also provided. Milk is analyzed for total uranium. In some years, one monthly sample is also analyzed for radionuclides. Fish collected from the Great Miami River are analyzed for total uranium.

2.9.4 Wetlands and Floodplains Surveys

Wetlands delineations were performed in 1990 and 1993 to comply with the Clean Water Act, Executive Order (E.O.) 11990, Protection of Wetlands, and other regulations. Additionally, compliance with E.O. 11988, Floodplain Management, required that the floodplain boundaries be determined. Executive Orders 11990 and 11988 are implemented by DOE in 10 CFR 1022, Floodplain/Wetland Environmental Review Requirements. Therefore, any actions affecting floodplains or wetlands within Operable Unit 5 will meet the compliance requirements of 10 CFR 1022.

Jurisdictional wetlands were identified and delineated at the FEMP to support the evaluations in the Site-Wide Ecological Risk Assessment (Appendix B), and support the FS in the assessment of compliance with state and federal wetland applicable or relevant and appropriate requirements (ARARs).

A preliminary determination of FEMP wetland locations was made in 1990 using the off-site delineation method described in the "Federal Manual for Identifying and Delineating Jurisdictional Wetlands" (Federal Interagency Committee for Wetland Delineation [FICWD] 1989). The off-site method is based on the review of USGS topographical information, National Wetland Inventory maps, soil surveys, aerial photographs, and site-specific vegetation, soils, and hydrological information.

For the 1990 study, the topography of the project area was reviewed using the USGS 7.5 minute series, Shandon, Ohio topographic quadrangle, as well as slope classifications listed in the Soil Survey of Butler (Hamilton) County, Ohio" (USDA et al. 1980, 1982). From the surveys, areas within the site boundaries mapped as somewhat poorly drained to very poorly drained soil and known hydric soil areas were identified for field investigation. Site-specific soil profile data recorded from RI/FS soil borings were examined for relevant soil chroma and saturation information.

A set of eight site-specific aerial photographs interpreted by the EPA's Environmental Photographic Interpretation Center (Sitton 1988) was evaluated for signs of wetlands such as hydrophytic vegetation, surface water, flooded pasture, and stressed crops. The photographs were reviewed for the presence, locations and directions of flow of water bodies and water courses, as well as changes in water courses, ditches, swamps, and ponds during the period covered (1950-1988).

Site-specific vegetation data collected at the FEMP during the summer of 1986 and the spring of 1987 (Facemire et al. 1990) were reviewed and analyzed in a wetlands context. Areas characterized by dominant plant species normally found in wetlands were marked for further study.

A limited field investigation, conducted during April 1990, focused on those areas where soils, vegetation, or hydrological data indicated a potential for the presence of wetlands. Potential wetlands were examined visually for the presence of hydrophytic vegetation, hydric soils, and indications of wetland hydrology. If all criteria were satisfied, the area was mapped as wetland.

In December 1992-January 1993, an on-property wetland delineation was conducted using the three-parameter method presented in the 1987 Corps of Engineers Wetlands Delineation Manual. This method requires that an area exhibit hydrophytic vegetation, hydric soils, and wetland hydrology in order to be classified as a wetland. The 1987 manual was used rather than the more recent 1989 Manual (FICWD 1989) because federal law (Energy and Water Development Appropriations Act of 1992) prohibits the use of the 1989 manual.

For the 1993 wetlands delineation, field investigation areas were chosen according to historical data, topographic maps, soil characterization maps, and the 1990 wetlands delineation report. Soil samples from 133 locations were examined for color, mottling, texture, organic content, and other indications of hydric soils. Vegetation and hydrologic features were also examined at 40 of these stations. Area

vegetation was classified as hydrophytic if more than half of the dominant plant species at the sampling station were wetland indicators on the National List of Plant Species that Occur in Wetlands (1988 Reed). Presence or absence of wetland hydrology was established by examination of drainage patterns, depth to standing water in bore holes, saturated or inundated soil, drift lines, watermarks, and sediment deposition.

To satisfy E.O. 11988, Parsons conducted a study (1993) to determine the boundaries of the 100-year floodplain of Paddys Run. The 100-year floodplain determination for the Great Miami River was based on Flood Insurance Rate and Hazard Boundary Maps prepared for the National Flood Insurance Program (FEMA 1982).

2.9.5 Threatened and Endangered Species Surveys

Section 121 of CERCLA requires that remedial actions at hazardous waste sites meet the substantive — but not the administrative or permitting — requirements of other federal and state environmental laws, including the Endangered Species Act (ESA) of 1973. Section 7(a)(2) of the ESA, as amended, requires federal agencies to ensure that their actions are "not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of the critical habitat of such species..." Further, EPA guidance on ecological investigations at CERCLA sites (EPA 1988a, 1989a) emphasizes identification of the threatened and endangered species resident on the site, including delineation of any critical habitat essential to the survival of these organisms.

No federally listed threatened or endangered species were observed on the FEMP or in its immediate vicinity by Facemire et al. (1990). However, two federally listed endangered species, the Indiana bat and the running buffalo clover, have ranges overlapping the area of the FEMP (DOE 1993e). Several state-listed threatened and endangered species of plants and animals are also known to occur in this area or have been recorded at the FEMP during previous ecological surveys (DOE 1993e; Facemire et al. 1990). The following paragraphs describe the various species being investigated by the FEMP.

The cave salamander (*Eurycea lucifuga*) is a state-listed endangered species. An initial survey was performed from May to August 1988 as part of the RI/FS to locate potential cave salamander habitat and look for individuals at the FEMP and in the vicinity. Based on location information from the ODNR, information from local investigators, prior documented populations and museum accessioned

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specimens, investigators determined possible habitats. The areas which appeared to be potential cave salamander habitat were thoroughly investigated for individuals and larvae. Detailed surveys were performed in the former Girl Scout camp (located in the northeastern portion of the study area), Camp Fort Scott (located in the southeastern portion of the study area near the Great Miami River), Paddys Run, and in the deciduous woodland in the northern part of the FEMP (Figure 2-48).

A follow-up survey was completed in August and September 1993 (Davis 1994). Suitable on-property habitats in a ravine in the north woodlot and in a limestone-lined well (1124) at an old homestead east of the east access road were visually examined for adult and larval salamanders. The on-property well was also investigated by lowering a camera into the well to examine between crevices in the walls of the well. A limestone-lined well (1060) south of the FEMP property was also visually examined.

The Indiana bat (*Myotis sodalis*), a federally listed endangered mammal, is characteristically a summer inhabitant of mature wooded areas lining both sides of small- to medium-sized streams (Humphrey et al. 1977). Potential summer habitat areas near the FEMP are found along the banks of Paddys Run and the Great Miami River. A survey was conducted for the RI/FS from June through August 1988 to evaluate potential habitats and determine the presence and distribution of the Indiana bat (DOE 1993e).

The riparian habitat was visually surveyed and classified according to suitability for use by the Indiana bat (Figure 2-49). Eight mist nets were set up (including three on FEMP property) and monitored on 13 nights from June through August 1988. Captured bats were identified to species, age, and sex and were temporarily marked for individual recognition before they were released at the site of capture. In addition, five echolocation detectors were used at five net sites for eight nights and at five unnetted sites for five additional nights. Scientists measured bat activity at the monitors by counting bat passes. One pass consisted of a series of echolocation pulses separated from other series by more than 2 seconds.

The Sloan's crayfish (*Orconectes sloanii*) was included in the macroinvertebrate survey of Paddys Run in 1986-87 (Facemire et al. 1990). This crayfish is classified as state-listed threatened, referring to a species whose survival in Ohio is not in immediate jeopardy but to which a threat exists. Continued or increased stress of this species will result in its becoming endangered (ODNR 1992). A

followup survey was completed in September 1993 (St. John 1993). Qualitative seining was conducted in three locations along Paddys Run during a period when the stream was extremely dry. The two on-property locations were in pools under the train trestle at the northern edge of the FEMP property. The off-property location was in a pool south of New Haven Road. An additional survey was completed in May 1994 which focussed on the entire section of Paddys Run that runs through the FEMP as well as the off-property location at New Haven Road (St. John 1994). This survey was completed during a period when water flowed throughout the length of the creek.

The cobblestone tiger beetle (*Cicindela marginipennis*) is found in the area of the FEMP, associated with dry gravel bars in river floodplains. This species was found along the Great Miami River during the RI/FS survey for the Indiana bat in 1988 (DOE 1993e). This species is found on sparsely vegetated gravel floodplains, which are frequently flooded. Because of the fragile habitat, this beetle is listed as a federal category two species, as well as a special interest species for the state of Ohio. Category two species are considered appropriate for federal listing as threatened or endangered; however, biological data on the distribution and life history of this species are insufficient to support the protection of the cobblestone tiger beetle under the ESA.

The running buffalo clover (*Trifolium stoloniferum*) is a federally listed endangered species. Running buffalo clover has been observed approximately 1.5 miles southwest of the FEMP at Miami Whitewater Forest (ODNR 1992). The FEMP has areas of similar habitat where this species might occur. In 1992, a limited survey of habitats suitable for this species was conducted using random transects on the FEMP property.

Slender fingergrass (*Digitaria filiformis*), a state-listed endangered crabgrass, was reported during the 1986 botanical survey (Facemire et al. 1990). This species is found in native prairie habitat. The established transects were used for quantitative plant surveys.

Mountain bindweed *(Polygonum cilinode)* was also reported in the botanical survey in 1986 (Facemire et al. 1990). The ODNR states that the only other populations of this state-listed endangered plant have been reported from two counties near Lake Erie.

The spring coralroot (*Corallorhiza wisteriana*) is a state-listed threatened orchid. It is found locally at Miami Whitewater Forest in forested wetlands (ODNR 1992). Northern areas of the FEMP appear to

be appropriate habitat for this species. Surveys were completed in May 1994, using transects along the northern woodlot and along the riparian areas of Paddys Run (RUST Environmental and Infrastructure, Inc. 1994).

The northern harrier (*Circus cyaneus*), a state listed endangered species, was sighted on one occasion northeast of the production facility in 1990. The dark-eyed junco (*Junco hyemalis*), a state listed endangered species, was observed throughout the FEMP during the winter of 1986-1987 by Facemire et al. (1990). The northern waterthrush (*Seiurus noveboracensis*), a state listed endangered species, was recorded as a spring migrant along the riparian woodlands. The red-shouldered hawk (*Buteo lineatus*), listed as a state species of special interest, has been sighted once over the northern deciduous forest habitat of the FEMP. The Cooper's hawk (*Accipiter cooperii*), previously listed as a threatened breeding species in Ohio, has since been removed from the ODNR list. Facemire reports observing the hawk over the introduced pine woodlands and pasture habitat throughout the FEMP.

2.10 QUALITY ASSURANCE PROGRAM ELEMENTS USED FOR CONTROL AND VERIFICATION OF RI/FS SITE INVESTIGATIONS

The project's need for quality assurance (QA) programs and QAPPs are identified in Guidelines and Specifications for Preparing Quality Assurance Project Plans (EPA 1983) and DOE Orders 5400.1 and 5700.6c, General Environmental Protection Program and Quality Assurance, respectively. QAPP requirements are developed to provide for internal control and independent review by management to assess the extent of implementation and effectiveness of project work plans. These guidance documents were used to identify quality work elements for incorporation into the RI/FS Work Plan. The quality elements provided the requirements for field and sampling activities and laboratory analysis for the RI/FS programs.

The quality program elements identified in the RI/FS QAPP included:

- Quality program description
- Field procedures
- Sample collection procedures
- Laboratory analytical procedures
- Data reduction/data validation/data reporting
- Quality assurance audits
- Nonconformance/corrective action reporting.

These quality program elements established working procedures for performing, documenting, and determining the quality of work on the site investigations. Additional program task-specific quality requirements were identified in document change requests (DCRs) as necessary to ensure data quality objectives (DQOs) were attained. Contractor quality programs were specified in the QAPP and DCRs as appropriate, to cover field, laboratory, management, and operation activities. Additional independent quality oversight of these programs was provided by DOE. The verification and assessment of the effectiveness of programs and procedures required by the RI/FS Work Plan included quality surveillances and quality audits. Quality surveillance is defined as spot checks of program implementation to determine conformance to specified requirements. These checks could be compared to EPA performance audits. Quality audit is defined as an in-depth review of an entire program, including an evaluation of the associated quality program and procedures, effectiveness of their implementation, and review of associated documentation. These evaluations could be compared to EPA system audits.

Nonconformance and corrective action reporting programs and procedures were included in the RI/FS QAPP to report identified deviations. Nonconformance reports are used by management to review the subject activities to determine technical program impacts to samples and laboratory analyses. The reports also allow senior staff and QA personnel to independently review the response. The corrective action report requires an investigation of the root cause for significant and/or reoccurring nonconformances and identifies the steps taken to identify the nonconformance and root cause, prevent recurrence, and assign resources to correct the nonconformance and provide for corrective action. These reports are reviewed by project management and final actions are approved by senior staff and QA personnel.

A field variance program was also part of the RI/FS work, recognizing that field programs could not always perform the required work as specified due to obstacles or other changed site conditions. This program provided for a one-time change to a field task or project management requirement with management approval. The approval by management was provided after technical impacts and justifications were reviewed by senior staff and QA personnel who determined that no significant impacts were identified.

There was a total of 340 project surveillances performed on the FEMP RI/FS. The surveillances covered field and sampling phases of work performed. The surveillance program required that a

check list be developed using task or project criteria. QA personnel reviewed the in-progress work during the surveillance against the respective check list. Identified program or procedural deficiencies were reported through nonconformance reports. Differences with the work requirements were identified and reported to project management for review and assessment. A review of all RI/FS QA surveillance reports written between 1986 and 1992 was performed to categorize observations and nonconformances against applicable quality program elements. Management responses for these reports were provided and determined to be adequate after review by independent quality reviewers. No open quality surveillance or nonconformance reports were issued for Operable Unit 5 tasks.

Eleven program audits were performed from 1985 through 1992 for the CIS and RI/FS programs. Audits were required to be performed annually for the RI/FS by an independent organization. The audits were performed against the 18 quality program elements identified in the work plans for all FEMP program management, field, and laboratory activities. The audits identified program strengths, deficiencies, activities the quality program element deficiencies impacted, and the effects of the impacts on the operable units. A review of FEMP audit impacts noted that there were no findings that impacted the samples or the usability of data collected for Operable Unit 5.

Project field variances generated during the RI/FS programs were issued for changes requested during the performance of field activities for work that could not be performed as specified. These variances were for one-time occurrences and provided a mechanism for review of field program variance requests.

Ninety-two DCRs had been initiated and approved through August 1992, for a permanent change to project-specific procedures included in the Work Plan (Sampling Plan and QAPP). The changes involved such actions as analysis of geotechnical, chemical, and radiological parameters; modifying sampling strategy and analytical parameters; addition of treatability studies; and modifying DQO levels on specified analyses.

A review was performed by QA personnel of all the FEMP quality reports including surveillance reports, audits and audit findings, field variance reports, and nonconformances. This review was performed to determine the total number of reports and the quality impacts of nonconformances and findings on the field-related sampling and analysis performed for the FEMP operable units. This review was also to assess quality trends and quality performance. The primary deviations reported in

the quality program (i.e., nonconformance reports and audit findings) were for RI/FS programmatic issues that did not impact specific samples collected for the Operable Unit 5 program.

2.11 DATA MANAGEMENT

As previously discussed in Section 2.1, the data set used to support the RI is a combination of several different sources and programs at the FEMP. Each individual program and data set was evaluated and prioritized to be consistent with the data requirements and objectives of the RI. The data was compiled into a central database and evaluated for completeness and accuracy. Figure 2-50 illustrates the RI data management process.

A Task Sample Inventory List (TSIL) was used to provide an index of the samples and numbers and types of analyses expected under each task. The TSIL was developed from work plans and project-specific plans for each task. Field forms such as the chain-of-custody, request for analysis and sample collection logs were used to determine sample numbers, laboratories used and sample locations as well as other specific information such as duplicate samples, QA samples, number of sample fractions being analyzed, and analytical parameters. The TSIL was used to monitor progress as data advanced along three pathways to develop the SED.

The primary sources of information are the field information (specific locations and sample types), analytical data (reported values from the contract laboratories), and validation qualifiers (confidence levels for each data point). All of this information was entered into the SED using electronic data transfer from the analytical laboratory or double-key entry from field forms and other paper records. Once entered, a verification process ensured the accuracy and completeness of the data. The product of the verification process is a final TSIL which is an index of the final database.

2.12 DATA VALIDATION

The validation process is an independent, systematic assessment of the quality of a data set. The process evaluates data, the manner in which it was collected, and the laboratory QC process used. Further, the data validation process compares the data to established criteria. The validation process reviews specific parameters associated with the data to determine whether it meets the principal DQOs of precision, accuracy, completeness, comparability, and representativeness. To support the data quality assessment process, a review and verification is also conducted to assess the adherence of field activities to established RI/FS QAPP or SCQ requirements.

To verify that these objectives are met, a data validation program was established in accordance with EPA's "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" and "National Functional Guidelines for Organic Data Review" (EPA 1988, 1991). The validation process examines laboratory analysis and reporting to determine compliance with appropriate analytical procedures. Data qualifiers are assigned to the analytical results, through the validation process, to alert the user of any deviations from the established requirements and to provide an indication of the level of confidence in the data. All laboratory data used in the development of source-term estimates for the Operable Unit 5 baseline risk assessment were subjected to data validation. The validation program is divided into two phases and has been completed for all data collected under the RI/FS or other programs used in the quantitative evaluation of risk in this RI Report.

2.12.1 Phase 1: Verification of Sample Collection Activities

Field verification consists of a review of the documentation associated with the sampling event including sampling personnel training records, sample collection logs, chain-of-custody and request-for-analysis forms, and field activity daily logs. The RI/FS data associated with Operable Unit 5 were found to be in compliance with the National Functional Guidelines for Organic Data Review (EPA 1991).

2.12.2 Phase 2: Analytical Validation

The validation of analytical data is correlated to analytical support levels (ASLs) A through E defined in the SCQ; these FEMP-specific ASLs are analogous to the EPA's Analytical Levels 1 through 5. The ASLs are assigned depending on the intended use of the data and the QC methods required. For example, data used to support the Operable Unit 5 risk assessment and nature and extent of contamination discussions are labeled ASL C, D, and E. There are validation protocols and criteria that parallel the ASLs.

ASLs A and B are assigned to screening, field analyses, and non-CLP analyses; the level of QC is less stringent for these than for others. ASLs A and B were used only to focus RI sampling efforts for higher level analyses.

ASL C includes all analyses performed in a qualified laboratory. Chemical data are generated in the EPA CLP Statement of Work (SOW). The analyses are reported under a Certificate of Analysis from

the laboratory with the associated QC information; raw data are not included in the data package. These data are evaluated based on the QC summary information presented with the Certificate.

ASL D includes all chemical data analyzed and reported by the EPA CLP routine analytical services SOW and these analyses for Operable Unit 5 were performed at an off-site laboratory. Radiological data were generated and reported employing methods in the QAPP or the performance-based requirements as presented in the SCQ. This level is characterized by rigorous QA/QC procedures and documentation and requires a presentation of QC information and raw data with the results to allow the data validator to recreate the analytical process. These analyses are validated by an extensive evaluation of the data and the data package for completeness.

ASL E includes analysis by nonstandard methods performed at an off-site laboratory. Nonstandard methods are those that have not been evaluated for suitability and published by the EPA as acceptable for the intended purpose (e.g., for radiological data). These data are subject to the same rigorous QA/QC standards as ASL D and, in addition, require the development of validation criteria for the method established by the laboratory to ensure its suitability.

The analytical results presented in the appendices to this report use nomenclature employing both EPA Analytical Levels 1 through 5 and ASLs A through E. Analytical data subjected to data validation under the terms of the RI/FS QAPP, before the issuance of the SCQ, were reported using Analytical Levels 1 through 5. Following approval of the SCQ, all data validation efforts uniformly adopted and reported results employing ASLs A through E.

2.12.2.1 Chemical Data Validation

For chemical data, RI field investigations generated by separate reviews were performed for organic and inorganic analyses performed at ASL C based on QC results reported with the data. For volatile, semivolatile, pesticide/PCB, and inorganic analyses performed as ASL D (the majority of RI/FS chemical data), each sample was reviewed and appropriate qualifiers (discussed in Section 2.12.3) were assigned. In addition, a minimum of 10 percent of the data were comprehensively reviewed with the calculations rechecked and the results recreated. These checks did not identify any significant deviations that warranted further review.

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Data validation has evolved from a tool primarily for monitoring EPA CLP laboratory performance to a requirement for all data being used in decision-making processes such as risk assessment. Improvement in the analytical capability of laboratories as well as increased scrutiny of data has introduced more rigorous QA/QC requirements from EPA for implementation in the laboratory. The guidance for data validation has changed in tandem with these changes in the laboratory requirements. Since 1985, there have been several revisions of EPA's National Functional Guidelines for Organic Data Review, the most recent being June 1991. Data validation at the FEMP must take into account the timeframe in which the samples were collected and analyzed, as well as the data requirements in place at that time.

The SCQ details DQOs required for sample data collected on site, the ASL level data must meet for each intended use, and established site-specific data validation criteria used in evaluating sample data. Samples collected as part of the RI/FS were in accordance with the RI/FS QAPP, as was validation of the data. SCQ guidance was progressively reflected in validation consistent with the incorporation of SCQ provisions in ongoing laboratory contracts. The data were evaluated for compliance with the following criteria:

- Sample holding times
- Initial instrument calibration
- Surrogate recoveries
- Blank contamination
- Linearity
- Detection limits
- Initial calibration standards
- Continuing calibration standards
- Serial dilutions
- Instrument tuning
- Continuing instrument calibrations
- Matrix spike recoveries
- Internal standard response
- Retention time shift
- Accuracy of calculations
- Method of standard addition
- Laboratory control sample

As in all data validation activities, the validator's professional judgment used in conjunction with established validation guidelines was applied in the assignment of qualifiers.

From April through June 1993, an assessment of the available validation results for Operable Unit 5 and the other FEMP operable units data sets was conducted. Minor changes in holding time criteria for semivolatiles, pesticides, and PCBs were implemented for the ongoing Operable Unit 5 validation program. This in-progress change in the application of the validation criteria resulted in a small portion (< 10 percent) of the data set having a stricter interpretation of holding time criteria for these fractions.

40 CFR 136 and EPA's National Functional Guidelines for Organic Data Review delineate technical holding times for volatiles, semivolatiles, pesticides, PCBs, and inorganics. These criteria were developed in large part to ensure reasonable turnaround in analytical data moving through a laboratory. Studies investigating effects of extended holding times on high molecular weight polynuclear aromatic hydrocarbons (PAHs), pesticides, and PCBs have determined the following:

- These compounds exhibit a low degree of solubility in aqueous solutions.
- Chemical structure and bonding characteristics of these compounds favor adsorption to solid particulate matter.
- Photochemical, microbial, and thermochemical degradation of these compounds is minimal when stored at 4^0C in tightly closed glass vessels with teflon lids in absence of light.
- When stored as described above, these compounds exhibit very low partition coefficients; therefore very little volatilization occurs.
- After extraction, stability of high molecular weight PAHs, pesticides, and PCBs has been established (EPA requires the analytical laboratory to maintain sample extracts for semi-volatiles, pesticides, and PCBs for 6 months after initial analysis).

Based on these studies, guidance developed by EPA Region III and by Hanford (in "Data Validation Procedure for Chemical Analysis") allows semivolatile, pesticide, and PCB compounds to be qualified as estimated "J" for exceeding holding time criteria, or in cases of gross violation of holding times, to be qualified based on the data validator's professional judgment (FERMCO 1993, ES&T, Carey and Sundberg 1977, Manahan 1989, and EMSL 1987). The change in holding time criteria for late eluting semivolatiles, pesticides, and PCBs provides additional data for the quantification of risk.

During the validation process of the metals analyses, it was noted that very low matrix spike recoveries occurred for the majority of the antimony analyses. Very low matrix spike recoveries indicate the inability of the sample digestion process to recover antimony from the sample matrix. Because the digestion process is demonstrated to be incapable of removing antimony from the sample, antimony results in all samples associated with very low matrix spike recoveries were rejected. Rejection of results because of poor matrix spike behavior is standard EPA validation protocol.

2.12.2.2 Radiological Data Validation

EPA-approved methods do not presently exist for radiological analyses nor does EPA have guidelines in place for its validation. The radiological analyses for the RI/FS were performed at Analytical

Level 5 under the QAPP and ASLs C and D under the SCQ according to standard operating procedures or performance-based specifications. DOE performed an evaluation and verification of those procedures/specifications and the QA plans of the contract laboratories. Finding them to be compliant with established protocols and general industry standards, DOE developed a validation program for radiological data that was subsequently reviewed by EPA. All samples used to support the Operable Unit 5 baseline risk assessment were validated accordingly.

Although precise criteria would be different for organics, inorganics, and radiological parameters, the overall logic for the evaluation of radiological data are very similar to those for chemical parameters. The radiological data were evaluated for compliance with the following criteria:

- Sample holding time
- Initial calibration verification
- Continuing calibration verification
- Traceability/verification of reference standard materials
- Blank contamination
- Result calculation verification
- Detection limits
- Associated uncertainties
- Radiometric/Gravimetric yields
- Laboratory QCs (i.e., duplicates, laboratory control samples, matrix spikes).

Due to the size of the data set for Operable Unit 5, validation of the radiological data occurred over the period of July 1992 through December 1993. During this time period radiological validation criteria were progressively refined to reflect more rigorous quality and documentation requirements being imposed upon contract laboratories and reflect new technical information or changes in site guidance (i.e., the SCQ).

Changes progressively adopted by the radiological validation process included:

- In April 1993, validation guidance was modified to discontinue qualifying data as unusable if there were three separate justifications for qualifying data as estimated. In summary, three estimated qualifiers did not automatically mandate assignment of a rejected label.

- In April 1993, validation guidance was modified to stop the qualification of radiological data as unusable if there was missing quality control data (i.e., duplicate matrix spikes, laboratory control samples), assuming initial and continuing calibration were acceptable. Missing quality control data reflects only that the accuracy/precision cannot be reliably assessed. These data were assigned a qualifier signifying the value was estimated.

- In August 1993, FEMP validation guidance was changed to reflect that use of the acceptance ranges, as specified in applicable laboratory contracts, were required to determine when no qualification of data was required. The most significant result of this direction was that a small population of data, previously not qualified, were qualified as unusable due to elevated radiometric recovery acceptance limits.

- In August 1993, validation guidance was modified to use minimum detectable concentrations as radiological detection limits to determine actuals and nondetects instead of previously used contract required detection limits (CRDLs). The primary reason for this change was that the minimum detectable concentrations provided a much better approximation to the real detection limits for the analytical methods than the CRDLs.

- In November 1993, FEMP validation guidance was modified to employ the use of relative error ratios (i.e., ratio of concentrations of duplicate analyses to their respective total propagated errors) instead of the relative percent difference technique for the evaluation of duplicate samples.

2.12.3 Data Usability

All of the laboratory analytical data used in the Operable Unit 5 baseline risk assessment has been validated and assigned qualifiers where applicable. Upon completion of the validation process much of the data was assigned a validation qualifier providing a confidence level in the data. When positive values are correct and supported by the data package, no qualifier is assigned. Flags are assigned which have no direct bearing on the usability of the data, but provide information to guide the end user in making proper and correct decisions regarding the usability of the data. The following is a brief summary for the validation qualifiers and flags used in the Operable Unit 5 data set and how data so qualified is allowed by EPA guidance to be used in baseline risk assessment.

J Qualifier: This qualifier may be assigned to individual analytical results for primarily three reasons:

1. QC information based on the ASL validation review criteria is insufficient or missing.

2. Matrix spike or duplicate analysis or chemical yield (radiological) is outside the acceptable range.

3. The analyte is detected at levels below the instrument calibration range. By definition these are estimated values.

The J qualifier, with no other laboratory qualifier, indicates that the compound or analyte is present, and the reported value may be inaccurate or imprecise. The J qualifier identifies instances where the limit of quantitation is uncertain. The Risk

Assessment Guidance for Superfund (EPA 1989b) and the Data Quality Objectives for Remedial Response Activities allow for estimated data (J) qualified as reported from the analytical laboratory to be used in risk assessments and to support definition of the nature and extent of contamination.

U Qualifier: Data that were observed at levels less than the corresponding limit of detection were qualified as U, meaning not detected above the associated value. This qualifier is assigned by the laboratory, and it was also used as a validation qualifier when common field or laboratory blank contaminants were detected in a sample less than action level as defined by the validation criteria. For nature and extent, the U qualifier establishes the lowest concentration of an analyte that can confidently be defined as nondetect. If an analyte was not detected in a certain media of a specific waste area, the calculation for concentration source terms did not include one-half the sample quantitation limits. Like the laboratory qualifier U, one-half of the sample quantitation limit has been used as a surrogate in calculating the concentration term in risk calculations.

R Qualifier: Data qualified as rejected are considered unusable for risk assessment. These data are so qualified whenever the analyses were performed grossly outside acceptance windows for the criteria established in the validation process. Data of this nature may have limited usability to support characterization of the nature and extent of contamination, but is not suitable for the requested ASLO.

C Qualifier: This represents calculated values for total uranium and total thorium.

Validation flags are informational in nature and are not validation qualifiers. These flags provide the user of the data with additional information which may be helpful in the overall evaluation of the data set.

"-" Flag: The "-" indicates that the data has been validated and that no validation qualifier is necessary. This most often occurs when the laboratory reports a positive result above

the CRDL and no other laboratory qualifier is associated with this value. The "-" flag has no impact on data usability.

NV Flag: This flag is assigned to data which is "Not Validated." The following types of data are assigned the NV Flag:

1. Analytical data that is not subject to validation such as matrix spike analysis and laboratory blank analysis.
2. Radiological data in which the contract laboratory was unable to provide a complete data package that was able to be validated.
3. Data analyzed by the FEMP on-site laboratory.
4. Geotechnical data.

Chemical data also has a laboratory qualifier assigned based on requirements of the analytical method. Laboratory qualifiers are used to evaluate the data during the validation process, while the validation qualifier is used to assess the quality of the data.

TABLE 2-1

REMEDIAL INVESTIGATION DATA EVALUATION MATRIX

Informational Need		Source of Data Used to Support RI	Section Where Discussed In Text	Data Used in RI Report: Physical Characteristics of Study Area	Nature & Extent of Contamination	Input to Develop F&T Models	Source Term for Risk Assessment
A. SURFACE SOIL							
1. Radiological Properties	1a.	CIS Surface Soil Sampling	2.5.2		●		
	1b.	RI Surface Soil Sampling	2.5.6		●		●
	1c.	Final Interim Report - Air, etc.	2.5.1		●		●
	1d.	RI Piezometer/Borings Program	2.6.3		●		●
	1e.	Removal Actions	2.5.5		●		●
	1f.	MH180 Removal Action Sampling					
	1g.	Environmental Monitoring Program	2.5.4		●		
			2.5.3		●		
2. Chemical Properties	2a.	RI Surface Soil Sampling	2.5.6		●		●
	2b.	RI Piezometer/Boring Program	2.6.3		●		●
	2c.	Removal Actions	2.5.5		●		●
3. Physical Properties	3a.	RI Well Drilling (Surface Sampling)	2.6.3	●		●	
	3b.	Soil Conservation Service	3.4.8	●		●	
	3c.	FEMP Construction Projects Geotechnical Borings	2.6.1	●		●	
4. Background Concentrations of Naturally Occurring Constituents	4a.	RCRA/CERCLA Background Study	2.5.6		●		●

TABLE 2-1 (Continued)

Informational Need		Source of Data Used to Support RI	Section Where Discussed In Text	Data Used in RI Report: Physical Characteristics of Study Area	Nature & Extent of Contamination	Input to Develop F&T Models	Source Term for Risk Assessment
B. SUBSURFACE SOIL							
1. Chemical & Radiological Characteristics	1a.	RI Well Drilling Program	2.6.3		●	●	●
	1b.	RI Piezometer/Boring Program	2.6.3		●	●	●
	1c.	RI Trenching Program	2.6.4		●	●	●
	1d.	Removal Action	2.6.2		●		●
2. Physical Characteristics - Lithology & Engineering Properties	2a.	RI Well Drilling Program	2.6.3	●		●	
	2b.	RI Piezometer/Boring Program	2.6.3	●		●	
	2c.	DOE Baseline Survey Wells	2.6.1	●			
	2d.	RCRA Well Drilling Program	2.6.1	●			
	2e.	Final Interim Report	2.6.1	●		●	
	2f.	Dames & Moore Study Well Drilling Program	2.6.1	●			
	2g.	FEMP Construction Projects Geotechnical Borings	2.6.1	●			
	2h.	Geotechnical Analysis of Pit Berms Drilling	2.6.1	●			
	2i.	NLO Monitoring Well Program	2.6.1	●			
	2j.	NLO Production Well Drilling	2.6.1	●			
	2k.	Other Off-Site Wells	2.6.1	●			
	2l.	Paddys Run Road Site RI/FS Drilling Program	2.6.1	●			
	2m.	NLO Landfill Siting Borings	2.6.1	●			
	2n.	RI Trenching	2.6.4	●			

TABLE 2-1 (Continued)

Informational Need	Source of Data Used to Support RI	Section Where Discussed In Text	Data Used in RI Report: Physical Characteristics of Study Area	Nature & Extent of Contamination	Input to Develop F&T Models	Source Term for Risk Assessment
C. GROUNDWATER						
Perched Water						
1. Radiological - Water Quality	1a. RI Well Sampling Program	2.7.1		●		●
	1b. RI Piezometer/Boring Program	2.7.1		●		●
	1c. RCRA Groundwater Program	2.7.3		●		●
2. Chemical - Water Quality	2a. RI Well Sampling Program	2.7.1		●		●
	2b. RI Piezometer/Boring Program	2.7.1		●		●
	2c. RCRA Groundwater Program	2.7.3		●		●
3. Water Levels	3a. RI Well Sampling Program	2.7.2	●		●	
	3b. RI Piezometer/Boring Program	2.7.2	●		●	
4. Hydraulic Conductivity - Yield	4a. RI Well Drilling Program	2.7.2	●		●	
	4b. RI Slug Testing	2.7.2	●		●	
	4c. RI Glacial Overburden Hydraulic Testing	2.7.2	●	●		
5. Background Water Quality	5a. Background Water Quality Report	4.0		●		●
Regional Aquifer						
1. Radiological - Water Quality	1a. RI Well Sampling Program	2.7.1		●		●
	1b. RI Boring Program	2.7.1		●		●
	1c. RCRA Groundwater Program	2.7.3		●		●
2. Chemical - Water Quality	2a. RI Well Sampling Program	2.7.1		●		●
	2b. RI Boring Program	2.7.1		●		●
	2c. RCRA Groundwater Program	2.7.3		●		●
3. Hydraulic Conductivity - Yield	3a. South Plume Removal Action Pump Testing	2.7.3	●		●	
	3b. SOWC Pump Testing	2.7.3				
	3c. FEMP Production Well Pump Testing	3.5.2.1	●		●	
	3d. A&W Alternative Water Supply Pump	3.5.2.1	●		●	
	Testing	2.7.3	●		●	
4. Water Levels	4a. RI Well Sampling Program	2.7.3	●		●	
	4b. Paddys Run Road Site RI Data		●		●	

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TABLE 2-1 (Continued)

Informational Need	Source of Data Used to Support RI	Section Where Discussed In Text	Data Used in RI Report: Physical Characteristics of Study Area	Nature & Extent of Contamination	Input to Develop F&T Models	Source Term for Risk Assessment
5. Background Water Quality	5a. Background Water Quality Report	4.0		●		●
D. SURFACE WATER						
Paddys Run						
1. Radiological Quality	1a. RI Surface Water Program	2.4.6		●		●
	1b. Environmental Monitoring Program	2.4.4		●		
2. Chemical Quality	2a. RI Surface Water Program	2.4.1.1		●		●
3. Topography of Study Area	3a. 1988/1992 Flyover Survey	2.2	●		●	
4. Rainfall Intensity	4a. Cincinnati/Northern Kentucky Airport	3.2.2	●		●	
5. Background Surface Water Quality	5a. RI Background Water Quality Report	4.0		●		●
Great Miami River						
1. Radiological Quality	1a. RI Surface Water Program	2.4.6		●		●
	1b. Environmental Monitoring Program	2.4.4		●		
2. Chemical Quality	2a. RI Surface Water Program	2.4.6		●		●
3. River Gaging	3a. Miami Conservancy District Plan	3.3	●			
4. Background Quality	4a. RI Background Water Quality Report	4.0		●		●
Site Drainage Ditches						
1. Radiological Quality	1a. RI Surface Water Program	2.4.6		●		●
	1b. Environmental Monitoring Program	2.4.5		●		
	1c. Best Management Practices Program	2.4.3		●		
2. Chemical Quality	2a. Best Management Practices Program	2.4.3		●		

TABLE 2-1 (Continued)

Informational Need		Source of Data Used to Support RI	Section Where Discussed In Text	Data Used in RI Report: Physical Characteristics of Study Area	Nature & Extent of Contamination	Input to Develop F&T Models	Source Term for Risk Assessment
E. SEDIMENT							
Paddys Run							
1. Radiological Constituents	1a.	RI Sediment Sampling Programs	2.4.6		●		●
	1b.	Environmental Monitoring Program	2.4.4		●		
	1c.	1986 Paddys Run Survey	2.4.1		●		
	1d.	1987 Characterization Investigation Study	2.4.2				
2. Chemical Constituents	2a.	RI Sediment Sampling Program	2.4.6		●		●
Great Miami River							
1. Radiological Constituents	1a.	RI Sediment Sampling Program	2.4.6		●		●
	1b.	Environmental Monitoring Program	2.4.4		●		●
2. Chemical Constituents	2a.	RI Sediment Sampling Program	2.4.6		●		●
Site Drainage Ditches							
1. Radiological Constituents	1a.	RI Sediment Sampling Program	2.4.6		●		●
	1b.	Environmental Monitoring Program	2.4.5		●		
2. Chemical Constituents	2a.	RI Sediment Sampling Program	2.4.5		●		●
F. AIR							
1. Airborne Radon Concentrations	1a.	Environmental Monitoring Terradex Cup Program	2.8.2		●		
2. Meteorological Data - Wind, Temperature	2a.	FEMP Meteorological Tower	2.3	●		●	
	2b.	Cincinnati/No. Kentucky Airport	3.2.2				
3. Direct Radiation	3a.	RI Surface Soil Sampling Program (Rad. Surveys)	4.5.6		●		
	3b.	Environmental Monitoring TLD Program	2.8.3		●		
4. Air Quality	4a.	Environmental Monitoring Program Boundary Stations	2.8.1		●		

TABLE 2-1 (Continued)

Informational Need		Source of Data Used to Support RI	Section Where Discussed In Text	Data Used in RI Report: Physical Characteristics of Study Area	Nature & Extent of Contamination	Input to Develop F&T Models	Source Term for Risk Assessment
G. BIOLOGICAL RESOURCES							
1. Description of Terrestrial Ecology	1a.	Miami University studies	2.9.2	●			
	1b.	1977 Pomeroy et al. study	1.4.5	●			
2. Description of Aquatic Ecology	2a.	RI Biological Resources Sampling Program	2.9.1	●			
	2b.	Miami University studies	2.9.2	●			
	2c.	1992 Env. Monitoring Program/Miller et al.	2.9.3	●			
	2d.	1977 Pomeroy et al. study	1.4.5	●			
	2e.	1978 Bower et al. study	1.4.5	●			
	2f.	1952 Tarzwell et al. study	1.4.5	●			
3. Wetlands/Floodplains	3a.	RI Biological Resources Sampling Program	2.9.1	●			
	3b.	1993 Ebasco Wetlands Delineation	2.9.4	●			
	3c.	1993 Parsons Floodplain Delineation	2.9.4	●			
4. Threatened and Endangered Species	4a.	RI Biological Resources Sampling Program	2.9.5	●			
	4b.	Miami University studies	2.9.5	●			
	4c.	1992 ODNR Survey of Miami Whitewater Forest	2.9.5	●			
	4d.	1993 St. John Crayfish Survey	2.9.5	●			
5. Bioaccumulation	5a.	RI Biological Resources Program	2.9.1	●			
	5b.	RI EWMF Study	2.9.1	●			
	5c.	Environmental Monitoring Program	2.9.3	●			
	5d.	Miami University studies	2.9.2	●			
6. Population Genetics	6a.	Miami University studies	2.9.2	●			

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TABLE 2-1 (Continued)

Informational Need		Source of Data Used to Support RI	Section Where Discussed In Text	Data Used in RI Report: Physical Characteristics of Study Area	Nature & Extent of Contamination	Input to Develop F&T Models	Source Term for Risk Assessment
H. ARCHAEOLOGICAL AND HISTORICAL RESOURCES							
1. Archaeological and Historical Resources	1a.	Archaeological Surveys	3.6.4	•			
	1b.	Historical/Cultural Resource Surveys	3.6.4	•			
I. MISCELLANEOUS							
1. Population and Land Use	1a.	1990 Census Data	3.6	•		•	
	1b.	RI Survey	3.6	•		•	

TABLE 2-2

FEMP RI/FS ANALYTICAL PARAMETERS

HSL Parameters

HSL Inorganics:
- Aluminum
- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Calcium
- Chromium (total)
- Cobalt
- Copper
- Cyanide
- Iron
- Lead
- Magnesium
- Manganese
- Mercury
- Molybdenum
- Nickel
- Potassium
- Selenium
- Silicon
- Silver
- Sodium
- Thallium
- Vanadium
- Zinc

HSL Volatile Organics:
- 1,1-Dichloroethane
- 1,1-Dichloroethene
- 1,1,1-Trichloroethane
- 1,1,2-Trichloroethane
- 1,1,2,2-Tetrachloroethane
- 1,2-Dichloroethane
- 1,2-Dichloroethene (total)
- 1,2-Dichloroethylene
- 1,2-Dichloropropane
- 2-Butanone
- 2-Hexanone
- 4-Methyl-2-pentanone
- Acetone
- Benzene
- Bromodichloromethane
- Bromoform
- Bromomethane
- Carbon disulfide
- Carbon tetrachloride
- Chlorobenzene
- Chloroethane
- Chloroform
- Chloromethane
- cis-1,3-Dichloropropene
- Dibromochloromethane
- Ethylbenzene
- Methylene chloride
- Styrene
- Trichloroethene
- Vinyl acetate
- Vinyl chloride

HSL Semivolatile Organics:
- 1,2-Dichlorobenzene
- 1,2,4-Trichlorobenzene
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- 2-Chloronaphthene
- 2-Chlorophenol
- 2-Methylnaphthalene
- 2-Methylphenol
- 2-Nitroaniline
- 2-Nitrophenol
- 2,4-Dichlorophenol
- 2,4-Dimethylphenol
- 2,4-Dinitrophenol
- 2,4-Dinitrotoluene
- 2,4,5-Trichlorophenol
- 2,4,6-Trichlorophenol
- 2,6-Dinitrotoluene
- 3-Nitroaniline
- 3,3'-Dichlorobenzidine
- 4-Bromophenyl phenylether
- 4-Chloro-3-methylphenol
- 4-Chloroaniline
- 4-Chlorophenyl-phenyl ether
- 4-Methylphenol
- 4-Nitroaniline
- 4-Nitrophenol
- 4,6-Dinitro-2-methylphenol
- Acenaphthene
- Acenaphthylene
- Anthracene
- Benzoic acid
- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(g,h,i)perylene
- Benzo(k)fluoranthene
- Benzyl alcohol
- bis(2-Chloroethoxy)methane
- bis(2-Choroethyl)ether
- bis(2-Chloroisopropyl)ether
- bis(2-Ethylhexyl)phthalate
- Butyl benzyl phthalate
- Carbazole
- Chrysene
- Dibenzofuran
- Dibenzo(a,h)anthracene
- Diethylphthalate
- Dimethylphthalate
- Di-n-butyl phthalate
- Di-n-octyl phthalate
- Fluoranthene
- Fluorene
- Hexachlorobenzene
- Hexachlorobutadiene
- Hexachlorocyclopentadiene
- Hexachloroethane
- Indeno(1,2,3-cd)pyrene
- Isophorone
- Naphthalene
- Nitrobenzene
- N-Nitroso-di-n-propylamine
- N-Nitrosodiphenylamine
- Pentachlorophenol
- Phenanthrene
- Phenol
- Pyrene

Full HSL Parameters

- HSL Inorganics
- HSL Volatile organics
- HSL Semivolatile organics

HSL Pesticides/PCBs:
- 4,4'-DDD
- 4,4'-DDE
- 4,4'-DDT
- Aldrin
- alpha-BHC
- alpha-Chlordane
- Aroclor 1016
- Aroclor 1221
- Aroclor 1232
- Aroclor 1242
- Aroclor 1248
- Aroclor 1254
- Aroclor 1260
- beta-BHC
- delta-BHC
- Dieldrin
- Endosulfan sulfate
- Endosulfan-I
- Endosulfan-II
- Endrin
- Endrin aldehyde
- Endrin ketone
- gamma-BHC
- gamma-Chlordane
- Heptachlor
- Heptachlor epoxide
- Methoxychlor
- Toxaphene

HSL & Parameters

- HSL Inorganics
- HSL Volatile organics
- HSL Semivolatile organics
- HSL Pesticides/PCBs
- Organophosphorus Pesticides
- Dioxins
- Furans

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TABLE 2-2 (Continued)

Full Radiological Parameters		General Groundwater Quality Parameters	
Radiological:	**Miscellaneous General Radiological:**	**General Chemistry:**	**Miscellaneous General Chemistry:**
Cesium-137	Gross alpha	Ammonia	Alkalinity
Neptunium-237	Gross beta	Chloride	
Plutonium-238		Fluoride	
Plutonium-239/240		Nitrate	
Radium-226		Phenols	
Radium-228		Phosphorus (total)	
Ruthenium-106		Sulfate	
Strontium-90		Sulfide	
Technetium-99		Total organic carbon	
Thorium-228		Total organic halogens	
Thorium-230		Total organic nitrogen	
Total thorium			
Total uranium			
Uranium-234			
Uranium-235/-236			
Uranium-238			

Note: HSL + includes Full HSL plus organophosphorus pesticides, dioxins and furans.

TABLE 2-3

ANALYTICAL PARAMETERS FOR RI/FS SAMPLING PROGRAMS

Description	Type	# of Samples	Radiological	Inorganics	Cyanide	Volatiles	Semi-volatiles	Pesticides/PCBs	OP Pesticides	Herbacides	Dioxins/Furans	General Chemistry	Geotechnical	Totals
Engineered Waste Management Facility Sampling	Soil	89	69	22	22	22	22	22				23		202
	Biological	34	34											34
Waste Pit Area Runoff Control Hand Auguring	Soil	104	20	50	44	47	47	50						258
Plant 1 Pad Post Excavation	Soil	127	108	39	20	20	20	20						227
Plant 1 Pad Hand Augering Pre-Excavation Sampling and TCLP Metals	Soil	69	22	21	21	22	26	25						137
Plant 2/3, 6, and 8 recovery wells	Groundwater	12	11	10	10	8	10	10				1		60
	Soil	8	4	4		4	4	4		4				24
Underground Storage Tanks-site Assessment	Sediment	11				11								11
	Surface water	8				8								8
FMPC Plant 8 Core Sampling	Soil	69	45	14	3	14	14	11		11		10	10	132
Operable Unit 2 Trench Support	Groundwater	8	4	4	4	4	4	4	5	4	4	4		41
4-RCRA Well Program	Groundwater	20	7	7	4	10	7	7	6	7	7	8		70
	Soil	28	28	1		1	1	1		1				33
Solid Waste Incinerator Area Sampling	Soil	443	408	34	34	34	34				34			578

TABLE 2-3 (Continued)

Description	Type	# of Samples	Radiological	Inorganics	Cyanide	Volatiles	Semi-volatiles	Pesticides/PCBs	OP Pesticides	Herbacides	Dioxins/Furans	General Chemistry	Geotechnical	Totals
Plug/Abandon Wells	Groundwater	2	2	1		1	1	1		1		1		8
	Soil	5	5	1		1	1	1		1		1		11
Additional Groundwater Sampling for HSL Analyses - Perched Groundwater Removal Action	Groundwater	17	6	9	9	9	9	9						51
South Groundwater Contamination Plume Removal Action, Part 5	Groundwater	72	40	36		25	25					36		162
RCRA Phase I Perimeter Well Installation Program	Groundwater	12	12	4	4									20
RCRA Phase II Waste Pits and Production Area Well Installation	Groundwater	7	7											7
Annual Sampling of 7 Perched Water Removal Action Extraction Wells	Groundwater	13	9	6	6	6	6	6						39
South Plume Groundwater Recovery System - Part 5, Phase II	Groundwater	56	48	8	8	5	4	6				9		88
Operable Unit 1 (Waste Pit Soil and Groundwater Samples)	Pit leachate	25	14	24	16	17	15	15	9	16	13	17		156
	Pit material	117	38	38	25	94	50	39	15	28	26	55	28	436

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TABLE 2-3 (Continued)

Description	Type	# of Samples	Radiological	Inorganics	Cyanide	Volatiles	Semi-volatiles	Pesticides/PCBs	OP Pesticides	Herbacides	Dioxins/Furans	General Chemistry	Geotechnical	Totals
Operable Unit 1 RI/FS Work Plan Addendum	Groundwater	12	12	12			12							36
	Pit leachate	21	15	15	15	15	15							75
	Soil	26	26	26	26	26	26				26			156
	Surface water	3	3	3	3	3	3							15
Additional Sampling Activities for Operable Unit 2	Groundwater	3	2	3		1		95				2	6	109
	Soil	187	60	106	63	98	91		23	53	26	43		563
Operable Unit 2 RI/FS Resampling Activities	Groundwater	1	1	1								1		3
	Soil	14	3	4	3	10	10	3	3	1	3	12		52
Sampling and Analysis Plan of Boring/Well 1433 in the South Field	Groundwater	3	3	2	2	2	2	2				2		15
	Soil	2	1	1		1	1	1		1		1		7
Sampling and Analysis Plan for RI/FS Work Plan Addendum - Operable Unit 2	Groundwater	81	339	76	60	52	51	51				53		682
	Sediment	8		7	7	7	7	7				1		36
	Soil	303		211	195	220	219	218		13		34		1110
	Surface water	13		12	12	12	12	12				12		72

5696

TABLE 2-3 (Continued)

Description	Type	# of Samples	Radiological	Inorganics	Cyanide	Volatiles	Semi-volatiles	Pesticides/PCBs	OP Pesticides	Herbacides	Dioxins/Furans	General Chemistry	Geotechnical	Totals
RI/FS Work Plan	Soil	371	350	24	1	19	12	16		16			1	439
	Groundwater	939	910	882	60	61	53	52	42		9	886		2955
	Sediment	265	68	8	8	7	8	8	4			3	5	119
	Surface water		189	54	8	9	8	8	8			53		337
	Soil	464	464											464
	Biological	296	283	2			2	2				2		291
	Soil	1	1											1
Drum Baling Area Investigation	Groundwater	19	6	13	6	6	6	8				8		53
	Soil	78	73	38	4	1	3	1						120
K-65 Silo Subsoils and Perched Groundwater Sampling and Analysis Plan	Groundwater	6	5	5	5	5	6	6				5		37
Silo Berm	Soil	42	19	13	8	13	13	13		5		10	10	104
K-65 Silo Berm Vertical Boring and Analysis Plan	Groundwater	3	3											3
	Soil	95	20	28	12	18	16					11	11	116
Additional Characterization of Vadose and Perched Water in the K-65 Area	Groundwater	20	17	6	7	5						5		40
	Soil	3	2	1										3
	Groundwater	759	397	51	49	61	67	50	11		1	381		1068
	Soil	1953	1620	453	211	320	255	207	13	55	10	99		3243

TABLE 2-3 (Continued)

Description	Type	# of Samples	Radiological	Inorganics	Cyanide	Volatiles	Semi-volatiles	Pesticides/PCBs	OP Pesticides	Herbacides	Dioxins/Furans	General Chemistry	Geotechnical	Totals
Paddy's Run South Investigation	Groundwater	485	484	133		1	2					134		754
	Surface water	12	12	1								1		14
	Soil	3	2	1		1	1	1		1				7
8 Additional Groundwater Monitoring Wells	Groundwater	8	8	8	8	8						8		40
	Soil	10	2	10		10	9	10		10				51
Operable Unit 5 (OU5) RI/FS Work Plan Addenda	Groundwater	179	107	55	32	53	36	29	1		1	73		387
	Sediment	5	5	5	5	5	5	5	4		4			38
	Soil	167	156	62	55	80	56	62	11	7	11	3		503
	Surface water	2	2	1	1	1	1	1						7
Miscellaneous Additional Wells for OU5	Groundwater	56	51	29	3	4	5	4	4		4	29		133
	Soil	13	12	2		2	2	2		2		2	1	25
Work Plan Addendum for the OU5 Outfall Line Investigation Groundwater Sampling	Groundwater	22	22	2	2	2	2	2				3		35
OU5 Work Plan Addendum for Excavation of Trenches in the Northeast Area at the FEMP	Groundwater	2	1	1	1	1	1	1	1		1	1		9
Installation of One Monitoring Well at Location 0166	Groundwater	15	13	3	3							3		22
	Soil	2	1	1		1								3

5696

TABLE 2-3 (Continued)

Description	Type	# of Samples	Radiological	Inorganics	Cyanide	Volatiles	Semi-volatiles	Pesticides/PCBs	OP Pesticides	Herbacides	Dioxins/Furans	General Chemistry	Geotechnical	Totals
FEMP Trap Range Investigation	Soil	25	9	16	9									34
Great Miami Riverbank Characterization	Soil	174	174											174
Pilot Plant Drainage Ditch Seepage and Surface Water Background Investigation	Surface water	68	50	27	27	15	14	6				14		153
CRU5 EWMF Wells	Groundwater	2	2	1	1	1	1	1				1		8
Surface and Subsurface Soil Sampling Investigation	Soil	758	406	351	335	268	267	269						1896
	Groundwater	27	14			13								27
Plugging and Abandonment of Well No. 67 in the KC-2 Warehouse	Sediment	4	2	2	2	2	2	2		2				14
	Groundwater	1	1	1		1	1	1						5
OU5 Surface Water and Sediment Sampling	surface water	2	2	1	1	1	1	1				1		8
Additional Monitoring Well Installation and Abandonment	Groundwater	133	94	36	35	23	21					22		231
	Sediment	1	1											1
	Soil	137	132	5		5								142

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TABLE 2-3 (Continued)

Description	Type	# of Samples	Radiological	Inorganics	Cyanide	Volatiles	Semi-volatiles	Pesticides/PCBs	OP Pesticides	Herbacides	Dioxins/Furans	General Chemistry	Geotechnical	Totals
Snapshot Monitor Well Sampling and Surface Water and Sediment Sampling	Groundwater	682	500	304	289	211	2	1				228		1535
	Sediment	79	58	24	23	23	21							149
	Surface water	137	92	45	45	20	17					22		241
FEMP Glacial Till/Vadose Zone Hydraulic Investigations Work Plan	Groundwater	24	9	10		2						5		26
Southwest Field Investigation	Groundwater	2	2											2
	Soil	34	34											34
	Surfacewater	6	6											6
Hydrogeologic Study of FMPC Discharge to the Great Miami River	Surface water	10	10											10
RCRA Detection Program	Groundwater	39	7	38	39	3	1	37	37	37	37	39		275
Offsite Groundwater Sampling	Groundwater	21	21											21
Outfall Pipeline Borings/ Manhole 180	Soil	271	271											271
RCRA Groundwater Sampling	Groundwater	128	92	90	18	92	19	18	15	18	12	106		480
RCRA Groundwater Quality Assessment Program	Groundwater	139	87	52		52						47		238
Manhole 180 - Offsite Soil Removed	Soil	48	48											48

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TABLE 2-3 (Continued)

Description	Type	# of Samples	Radiological	Inorganics	Cyanide	Volatiles	Semi-volatiles	Pesticides/PCBs	OP Pesticides	Herbacides	Dioxins/Furans	General Chemistry	Geotechnical	Totals
Field Support for Uranium Soils Integrated Demonstration	Soil	101	101											101
Characterization Investigation Study	Sediment	158	158											158
	Soil	1241	1196	44	41	45	46	44						1416
	Surface water	10	10	9	9	10	10	10						58
South Plume Groundwater Recovery System: Design, Monitoring Well Installation and Well Abandonment	Groundwater	60	60	20								20		100
Historical Groundwater Data	Groundwater	1008	852	527	426	836	584	55	12	9		824		4125
IT Litigation Data 1986	Soil	325	325											325
IT Litigation Data 1988	Soil	169	169											169
Plant 1 Pad Crack Sampling	Soil	44	21	24										45
EM South Field Pump Test	Groundwater	12	12											12
South Groundwater Contamination Plume	Groundwater	51	52	32	32	32	1	1				52		202
Plant 1 Pad Continuing Release	Groundwater	9	9	9	9	9						9		45
Pilot Plant Sump	Groundwater	6	6	6		6		2						20
Site RCRA Sampling	Groundwater	207	206	203	195	198	103	21				203		1129

TABLE 2-3 (Continued)

Description	Type	# of Samples	Radiological	Inorganics	Cyanide	Volatiles	Semi-volatiles	Pesticides/PCBs	OP Pesticides	Herbacides	Dioxins/Furans	General Chemistry	Geotechnical	Totals
Closure Report for Plant 6 Storage Pad, Tanks 5 and 6, and the Nitric Acid Rail Car	Groundwater	93	3	93	92	93	93	114	92			92		672
	Soil	47	21	46		45	33		22	22				189
Underground Storage Tank Removal	Soil	46		35		38	6					32		111
	Surface water	22		18		15	7					8		48
Grand totals		14899	12045	4773	2733	3564	2569	1692	338	325	229	3771	72	32111

TABLE 2-4

WELLS THAT PREDATE THE FEMP REMEDIAL INVESTIGATION/FEASIBILITY STUDY

Pre-RI/FS Designation	RI/FS Well No.	Contractor	Comments
12D	1012	Dames & Moore	
--	1013	Dames & Moore	Plugged & abandoned
--	1015	Dames & Moore	
19TP	1019	Dames & Moore	Plugged & abandoned
20TP	1020	Dames & Moore	
21TP	1021	Dames & Moore	Plugged & abandoned
22TP	1022	Dames & Moore	Plugged & abandoned
RB	1040	Unknown - private well	
Argonne A-S	1053	ERM - Midwest, Inc.	
Argonne B-S	1054	ERM - Midwest, Inc.	
Argonne C-S	1055	ERM - Midwest, Inc.	
DH	1058	Unknown - private well	
1A	1059	Unknown - private well	
OS-1A	1060	Unknown - private well	
Cone House	1124	Unknown - private well	Hand dug
PWT1	1490	Soil & Material Engineers, Inc.	
PWT2	1491	Soil & Material Engineers, Inc.	
PWT3	1564	Soil & Material Engineers, Inc.	
PWT4	1684	Soil & Material Engineers, Inc.	
PWT5	1685	Soil & Material Engineers, Inc.	
OW3, SW1	1901	National Lead of Ohio	
OW2, SW2	1902	National Lead of Ohio	
OW1, SW3	1903	National Lead of Ohio	
SW4	1904	Unknown - private well	
SW5	1905	Unknown - private well	
OW5, SW6	1906	National Lead of Ohio	
OW4, SW6	1907	National Lead of Ohio	
OW6	1908	National Lead of Ohio	
--	1913	Dames & Moore	Plugged & abandoned
4	2004	National Lead of Ohio	
11	2011	National Lead of Ohio	
13S	2013	Dames & Moore	Plugged & abandoned
14S	2014	Dames & Moore	
15S	2015	Dames & Moore	
16S	2016	Dames & Moore	
17S	2017	Dames & Moore	
18S	2018	Dames & Moore	Plugged & abandoned
19S	2019	Dames & Moore	Plugged & abandoned
20S	2020	Dames & Moore	
21S	2021	Dames & Moore	Plugged & abandoned
22S	2022	Dames & Moore	Plugged & abandoned
BU-101	2026	Unknown - private well	
12-5	2036	Unknown - private well	
Schaefer Pallet Co.	2050	Unknown - private well	

TABLE 2-4 (Continued)

Pre-RI/FS Designation	RI/FS Well No.	Contractor	Comments
State 8	2056	Unknown - private well	
State 16	2057	Unknown - private well	
OS-1	2060	Unknown - private well	
OS-2	2061	Unknown - private well	
IT-2	2067	IT Corporation	
IT-1	2068	IT Corporation	
IT-6	2069	IT Corporation	
IT-5A	2070	IT Corporation	
IT-4	2071	IT Corporation	
BPH, EM-10, EMR-10	2104	Unknown - private well	
State 10	2105	Unknown - private well	
BU-91	2121	Unknown - private well	
BU-92	2122	Unknown - private well	
12-3	2123	Unknown - private well	
OAB	--	Layne Ohio Co.	
1S	3001	National Lead of Ohio	Plugged & abandoned
3	3003	National Lead of Ohio	
5	3005	National Lead of Ohio	Plugged & abandoned
8S	3008	National Lead of Ohio	
9	3009	National Lead of Ohio	
10	3010	National Lead of Ohio	
13D	3013	Dames & Moore	Plugged & abandoned
14D	3014	Dames & Moore	
16D	3016	Dames & Moore	
17D	3017	Dames & Moore	
18D	3018	Dames & Moore	Plugged & abandoned
19D	3019	Dames & Moore	Plugged & abandoned
20D	3020	Dames & Moore	
Argonne A-D	3053	Weston	
Argonne B-D	3054	Weston	
Argonne C-D	3055	Weston	
OS-3	3062	Unknown - private well	
James Dill	3063	Unknown - private well	
Robert James	3099	Unknown - private well	
Charles Young	3100	Unknown - private well	
1D	4001	National Lead of Ohio	
8D	4008	National Lead of Ohio	
15D	4015	Dames & Moore	
BU-13	4023	Unknown - private well	
P-1	4101	FMPC Production Well	
P-2	4102	FMPC Production Well	
P-3	4103	FMPC Production Well	
--	4427	SOWC Production Well	
--	4428	SOWC Production Well	

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TABLE 2-5

MONITORING WELLS AND BORINGS THAT USED THE HYDROPUNCH II TECHNIQUE

Monitoring Well Number		Boring Number			
1892	3821	1999	11021	11093	3727
1942	3880	11000	11022	11094	3823
1954	3881	11001	11023	11095	3824
2119	3897	11002	11024	11096	3847
2166	3898	11003	11025	11097	3851
2454	3899	11004	11026	11098	
2954	3900	11005	11027	11099	
21063	4398	11006	11028	11100	
21064	4424	11007	11029	11101	
21065	4425	11008	11030	11102	
3027	4426	11009	11032	11103	
3398	4432	11010	11047	2641	
3417	4436	11011	11048	2647	
3429	4439	11012	11049	2681	
3431	4446	11013	11050	2825	
3432	4451	11014	11051	2845	
3435	4938	11015	11082	2848	
3452	41066	11016	11083	3642	
3733		11018	11084	3680	
		11019	11091	3682	
		11020	11092	3683	

TABLE 2-6
BORING PROGRAMS THAT PREDATE THE FEMP REMEDIAL INVESTIGATIONS/FEASIBILITY STUDY

Program Name	No. of Borings	Project Start Date	Contractor
NLO - UF6-UF4/Plant 5	15	Jul '84	Rust Engineering Co.
NLO - Railroad Relocation	10	Oct '84	Rust Engineering Co.
NLO - K-65 Tanks	8	Aug '85	Camargo Associates
NLO - Conceptual Design Program	28	Sep '85	Lockwood Greene Engineering
Proposed Buildings 6 and 8 Expansion	14	Apr '86	Rust Engineering Co.
Slag Leach Building/Uranium Control Pad	7	Apr '86	Rust Engineering Co.
Drum Reconditioning	7	Apr '86	Rust Engineering Co.
Existing Water Storage Tank, FMPC	1	Aug '86	Camargo Associates
Proposed In Vivo Building/Training Center	10	Nov '86	Rust Engineering Co.
Derby Breakout and Slag Milling Area	7	Jan '87	Rust Engineering Co.
Proposed Building, FMPC	2	Mar '87	William Cargile Contractors
D & D Facility/Boiler Plant Maintenance Building	12	Mar '87/Oct '85	Rust Engineering Co.
Decladding & Box Furnace/General Sump/N2 Systems	11	Apr '87	Rust Engineering Co.
Lu/Lu Project	6	Jun '87	Rust Engineering Co.
Water Treatment Plant/Nu-Sal Furnace	7	Aug '87	Rust Engineering Co.
Storm Water Retention	7	Sep '87	Lockwood Greene Engineering
RIMIA Facility	7	Feb '88	Rust Engineering Co.
Biodenitrification Facility Upgrade (Site 1)	5	Oct '88	Rust Engineering Co.
Analytical Facilities Expansion	8	Sep '88	Rust Engineering Co.
FMPC Water Pollution Control	23	Aug '82	NLO, Inc.
Supply/Service-Tank Farm/Proposed Sanitary Landfill	16	Jul '84	NLO, Inc.
Geotechnical Exploration - Coal Storage Facility	6	Jul '88	WMCO
Foundation Investigation	38	Apr '51	U.S. Army Corp. of Engineers
Total Borings	255		

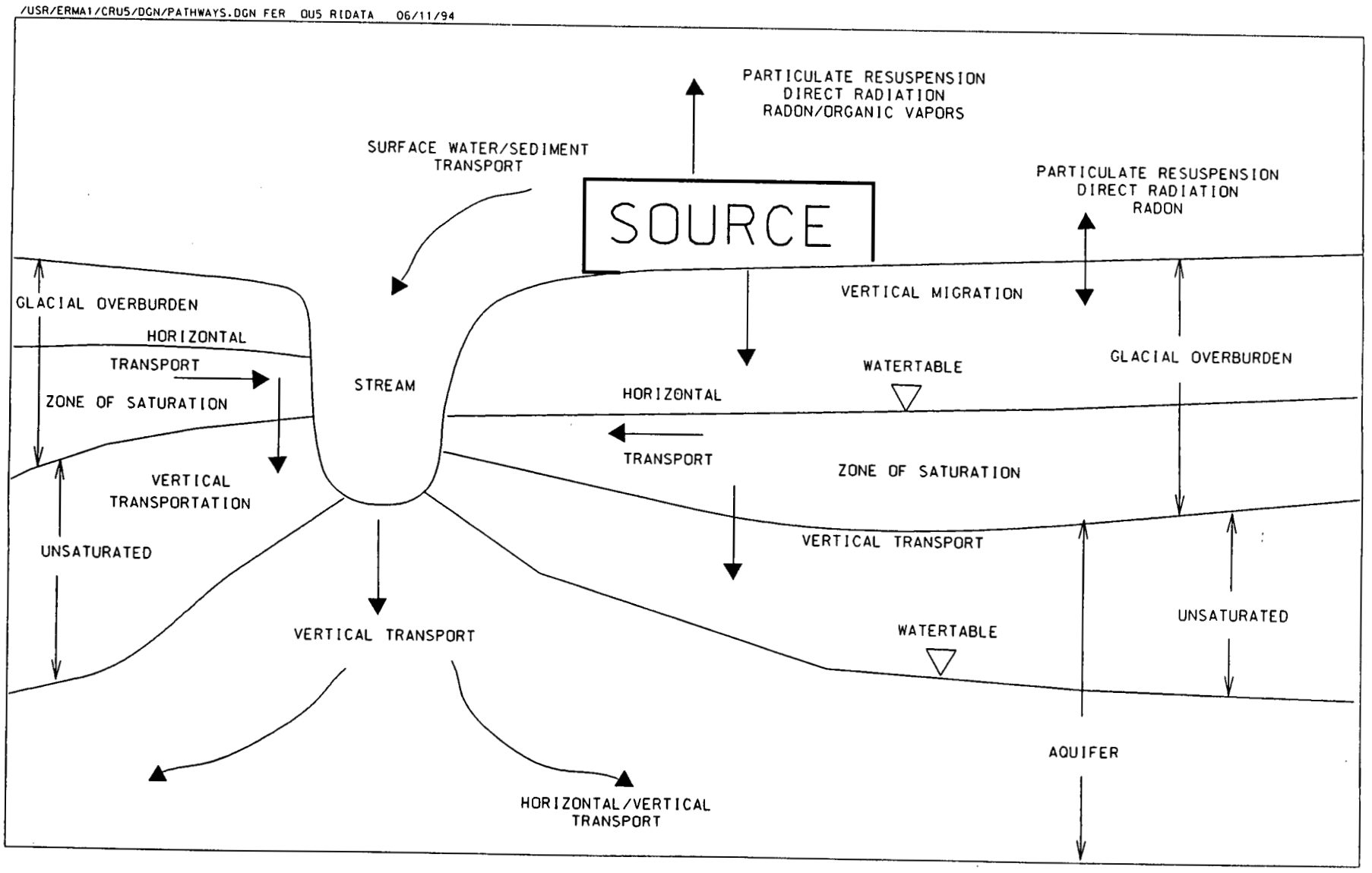

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FIGURE 2-1. CONCEPTUAL CONTAMINANT PATHWAYS

000268

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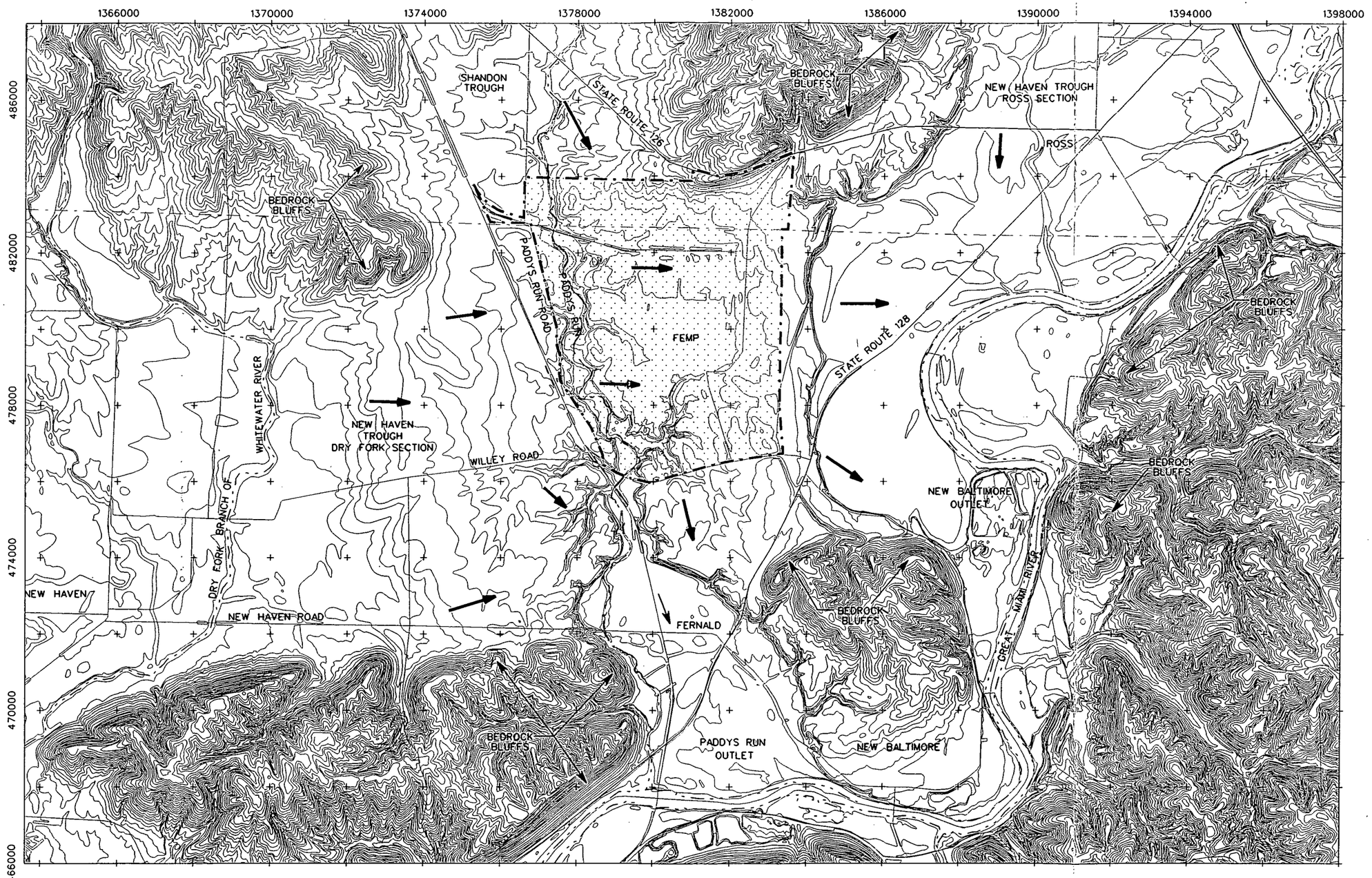

LEGEND:

FEMP BOUNDARY

GENERAL GROUNDWATER FLOW DIRECTION

000269

SCALE

2750 1375 0 2750 FEET

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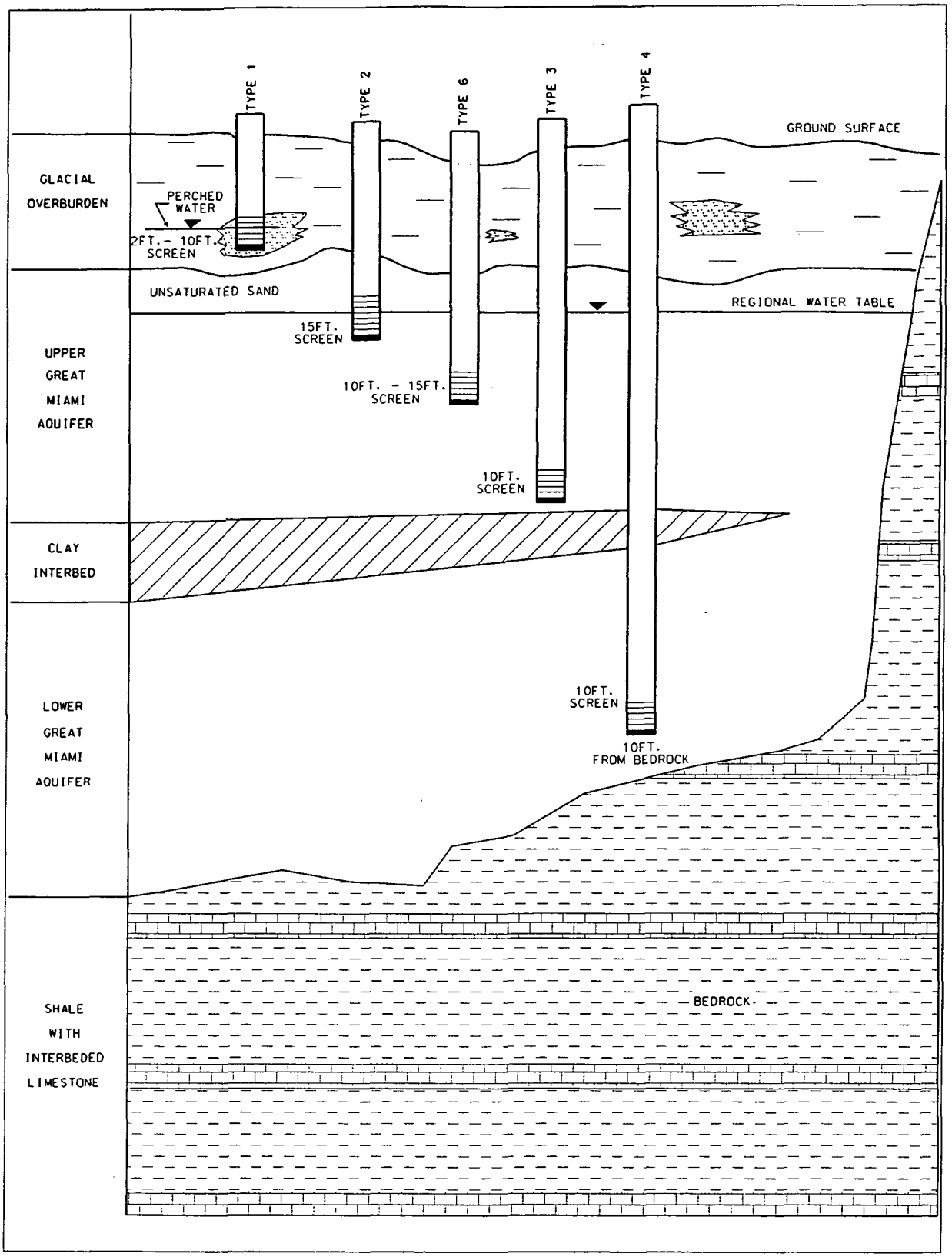
USR/ERMA3/5ARN1/DGN/MAP/HOR/DPTH/C110060.DGN
FER 005 RIDATA 5-31-94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 2-2. FEMP INVESTIGATION AREA

/USR/ERMA3/FMPC/IDX/WELLDPTH.DGN FER 005 RIDATA 06/11/94



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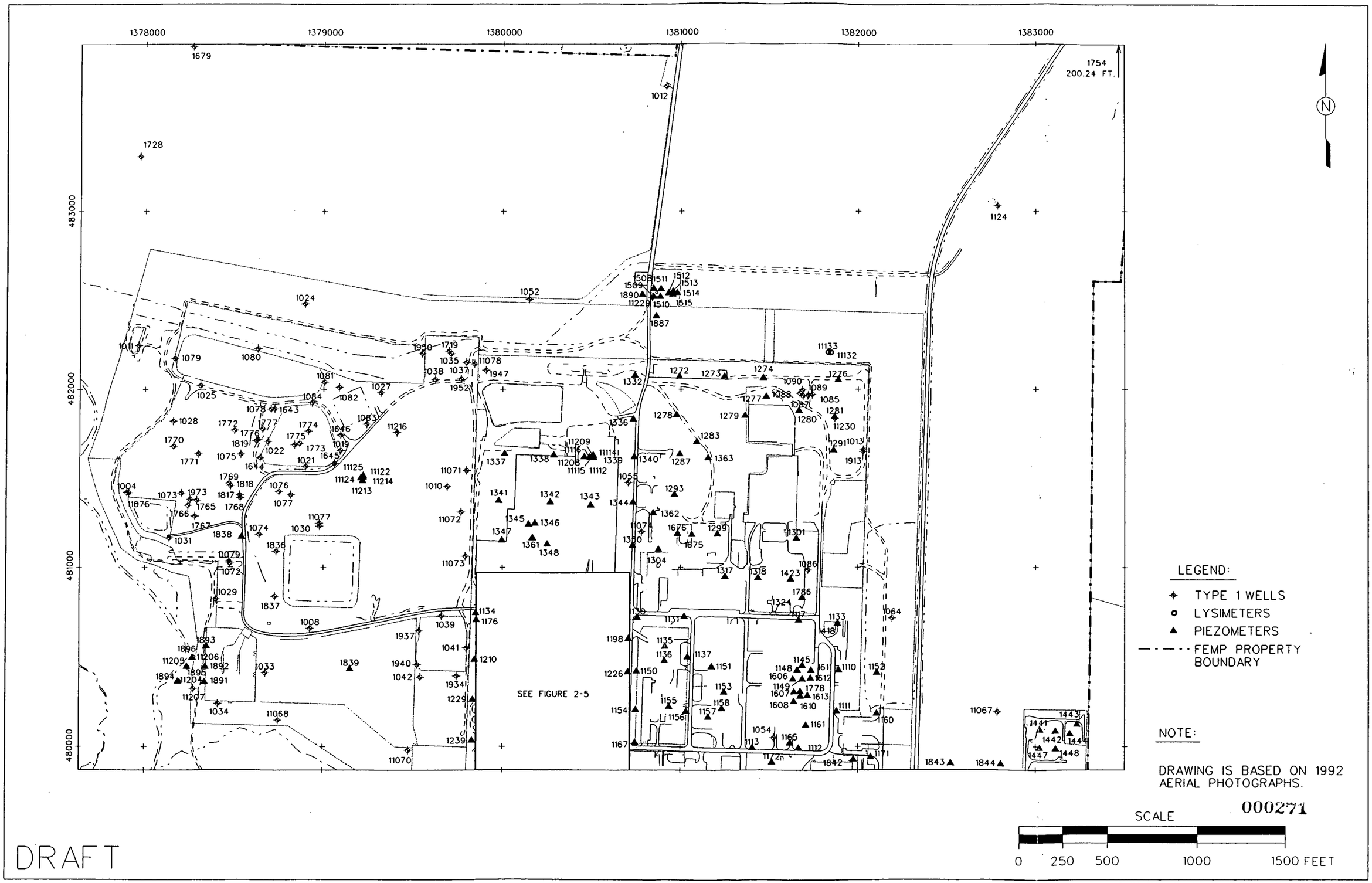
000270

FIGURE 2-3. CLASSIFICATION SCHEME FOR MONITORING WELLS



/usr/erma3/fmpc/dgn/bmp/c110027.dgn ou5 RI data 05/25/94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 2-4. TYPE 1 WELLS
NORTHERN PORTION OF THE FEMP

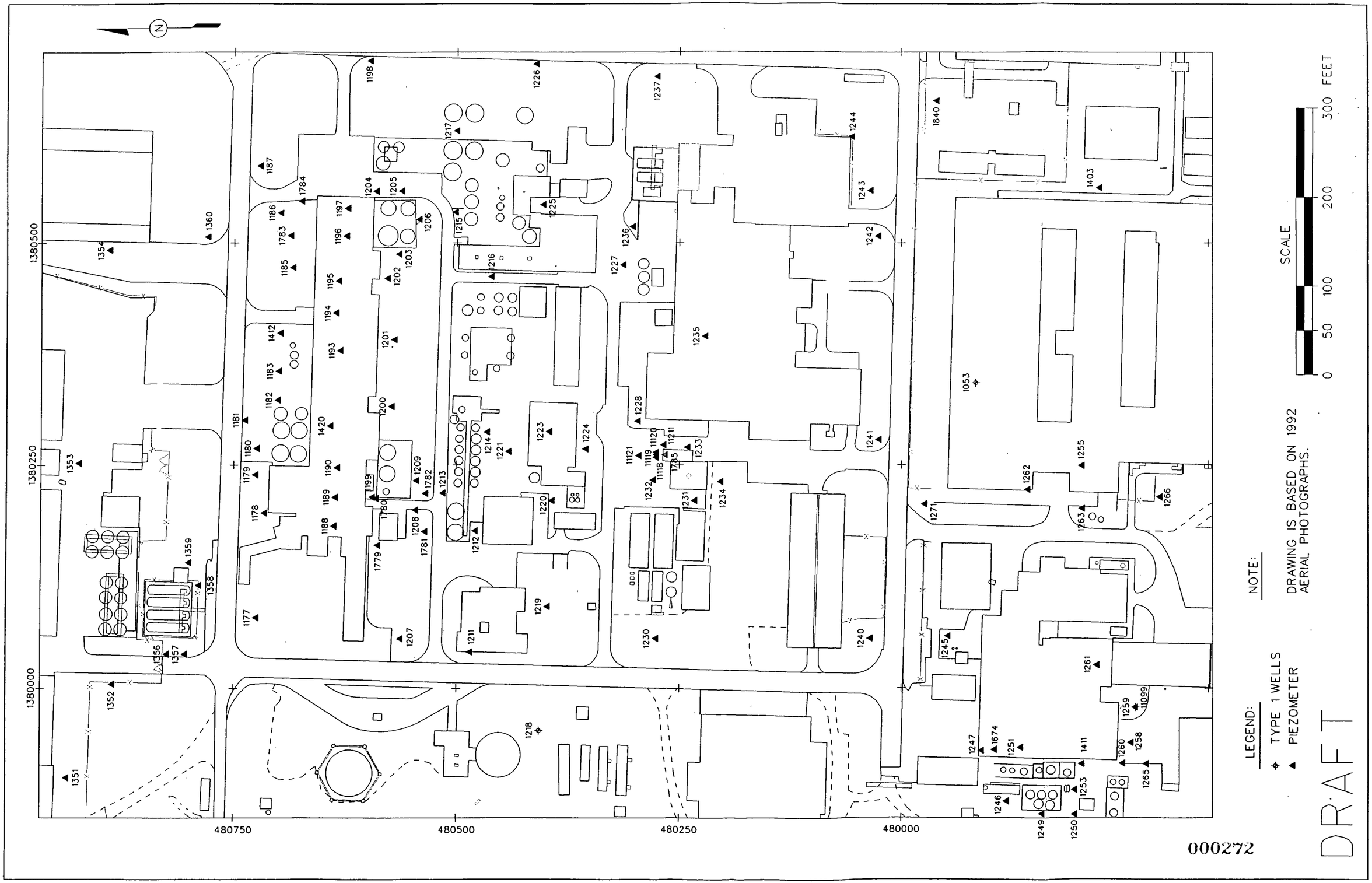


FIGURE 2-5. TYPE 1 WELLS - SOUTHWEST PRODUCTION AREA

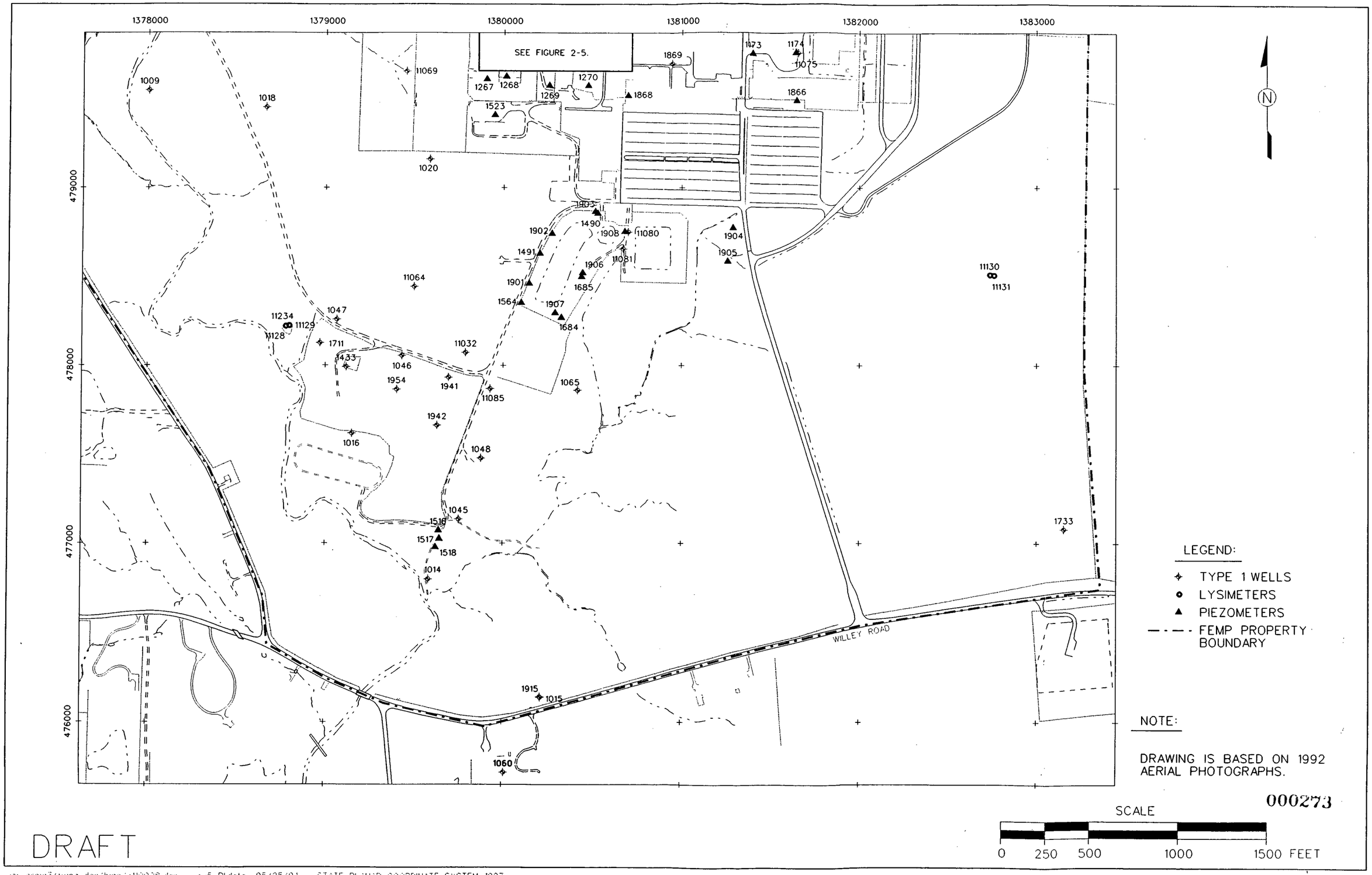


FIGURE 2-6. TYPE 1 WELLS
SOUTHERN PORTION OF THE FEMP

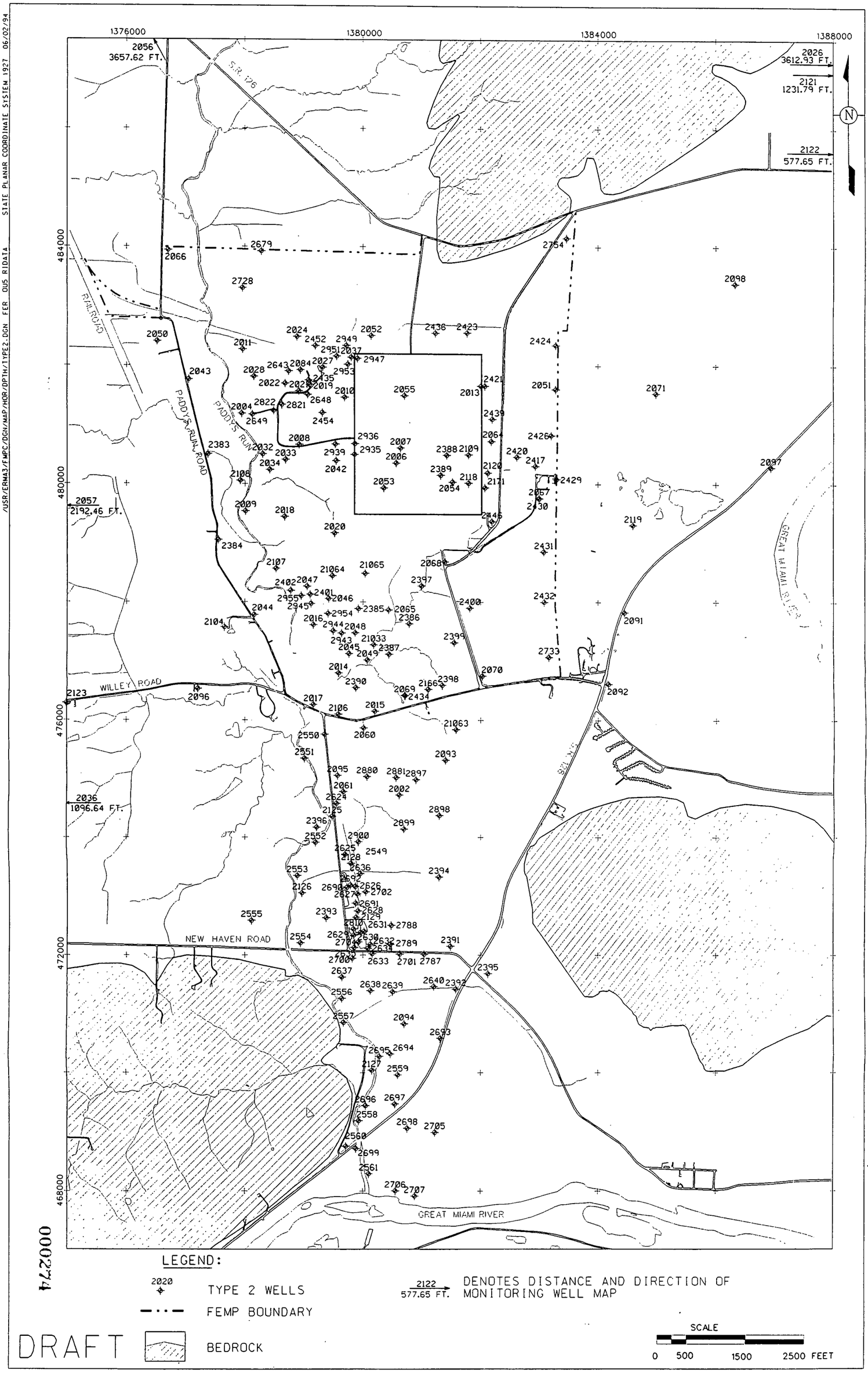


FIGURE 2-7. TYPE 2 MONITORING WELL LOCATIONS

000274

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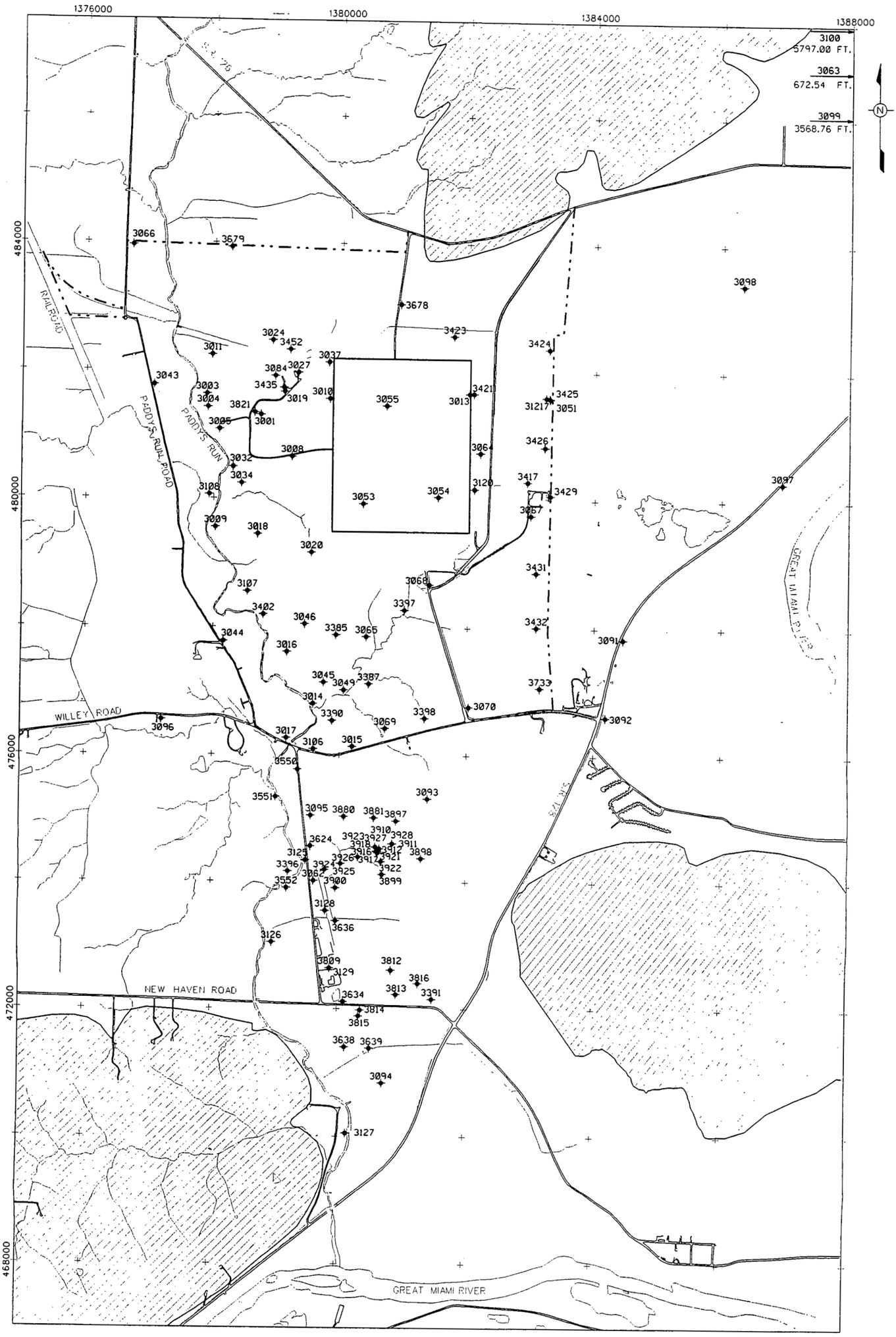

LEGEND:

3020 ✦ MONITORING WELL NUMBER

3020 → 577.65 FT. DENOTES DISTANCE AND DIRECTION MONITORING WELL OUTSIDE OF MAPPING

FEMP BOUNDARY

FEMP PRODUCTION AREA BOUNDARY

BEDROCK

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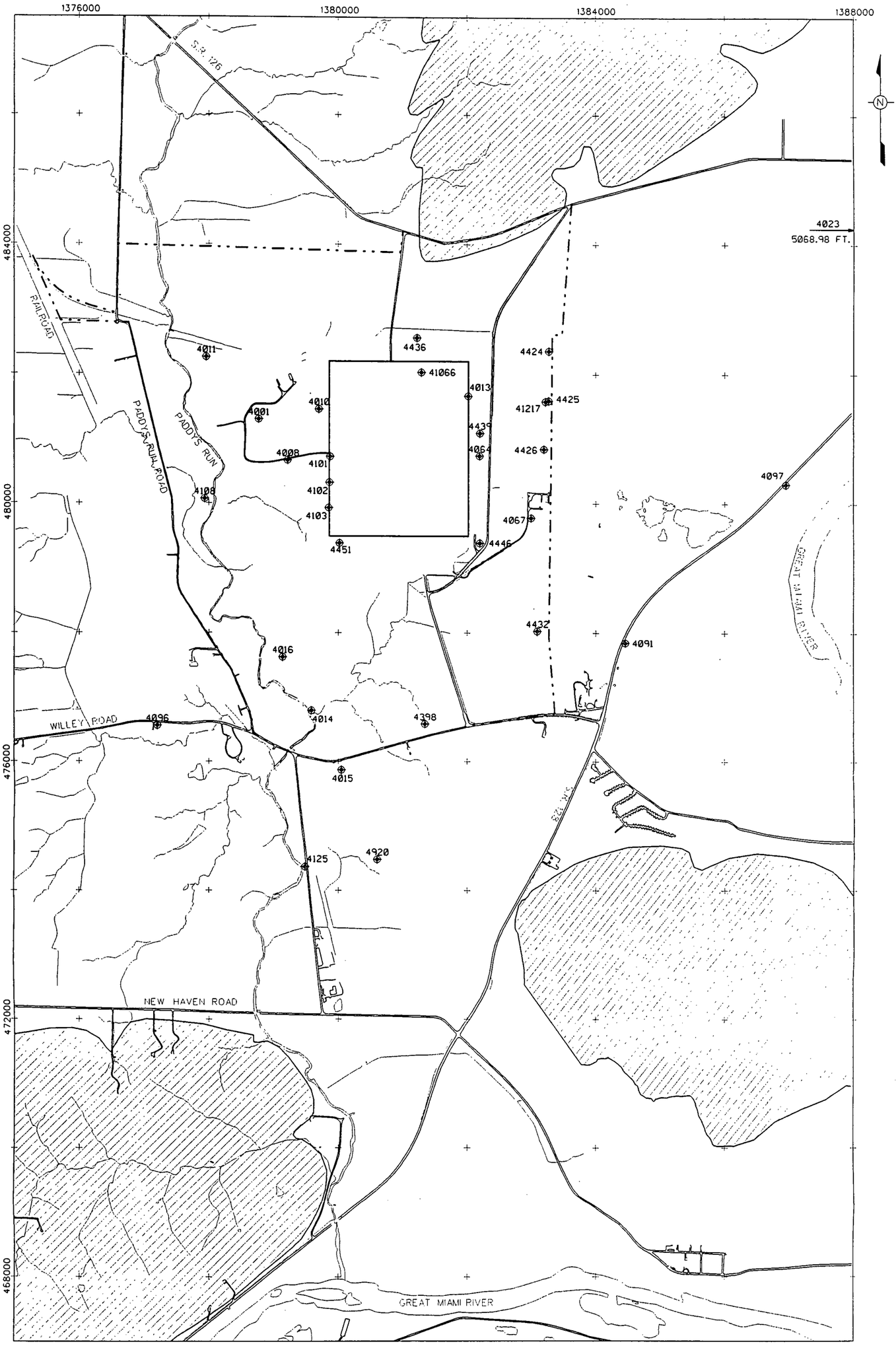
SCALE

0 500 1500 2500 FEET

FIGURE 2-8. TYPE 3 MONITORING WELL LOCATIONS

000275

6699



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LEGEND

4020 — MONITORING WELL NUMBER

4020 → 577.65 FT. — DENOTES DISTANCE AND DIRECTION MONITORING WELL OUTSIDE OF MAPPING

FEMP BOUNDARY

FEMP PRODUCTION AREA BOUNDARY

BEDROCK

SCALE

0 500 1500 2500 FEET

FIGURE 2-9. TYPE 4 MONITORING WELL LOCATIONS

STATE PLANAR COORDINATE SYSTEM 1927

000276

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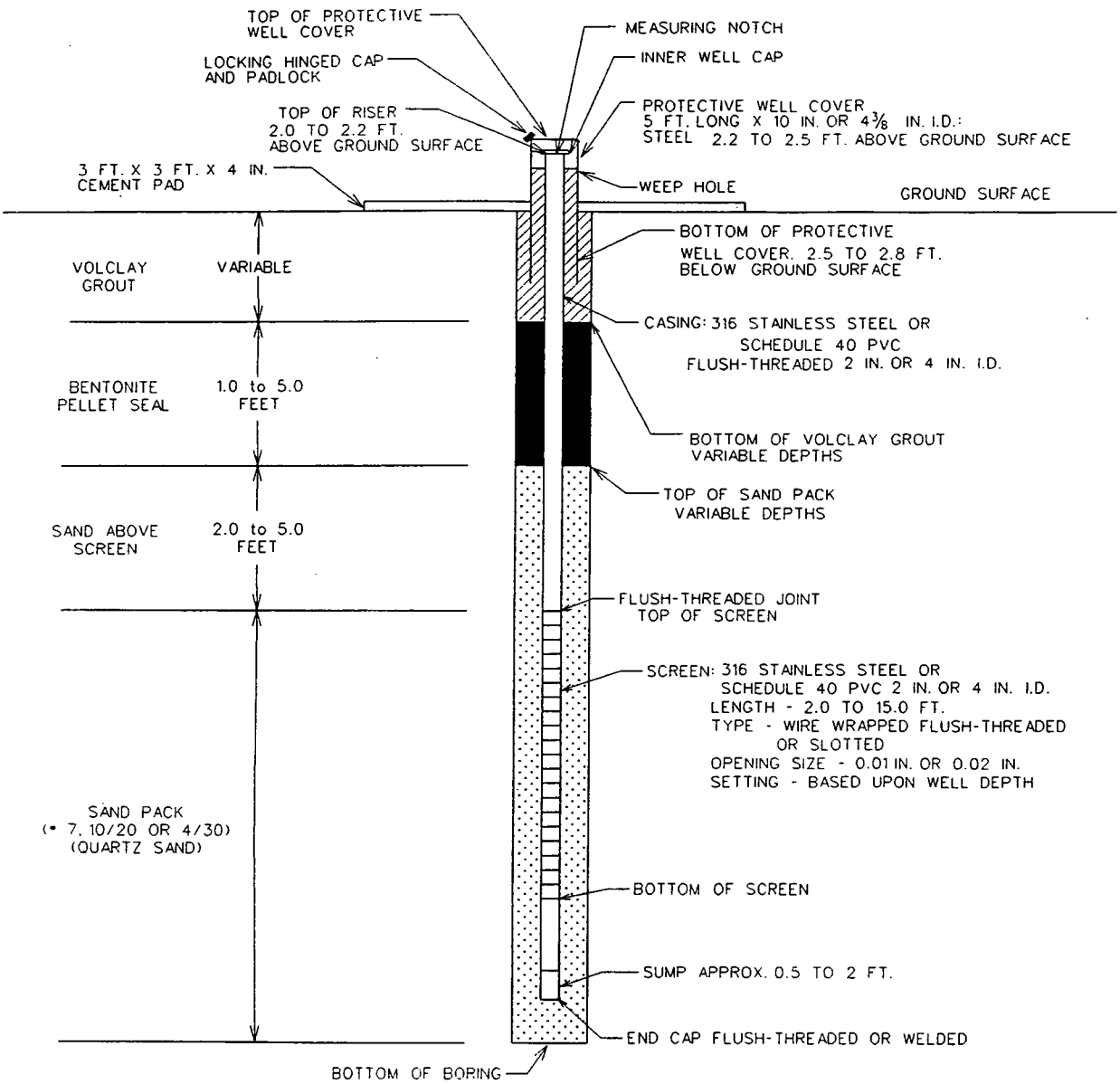

NOT TO SCALE

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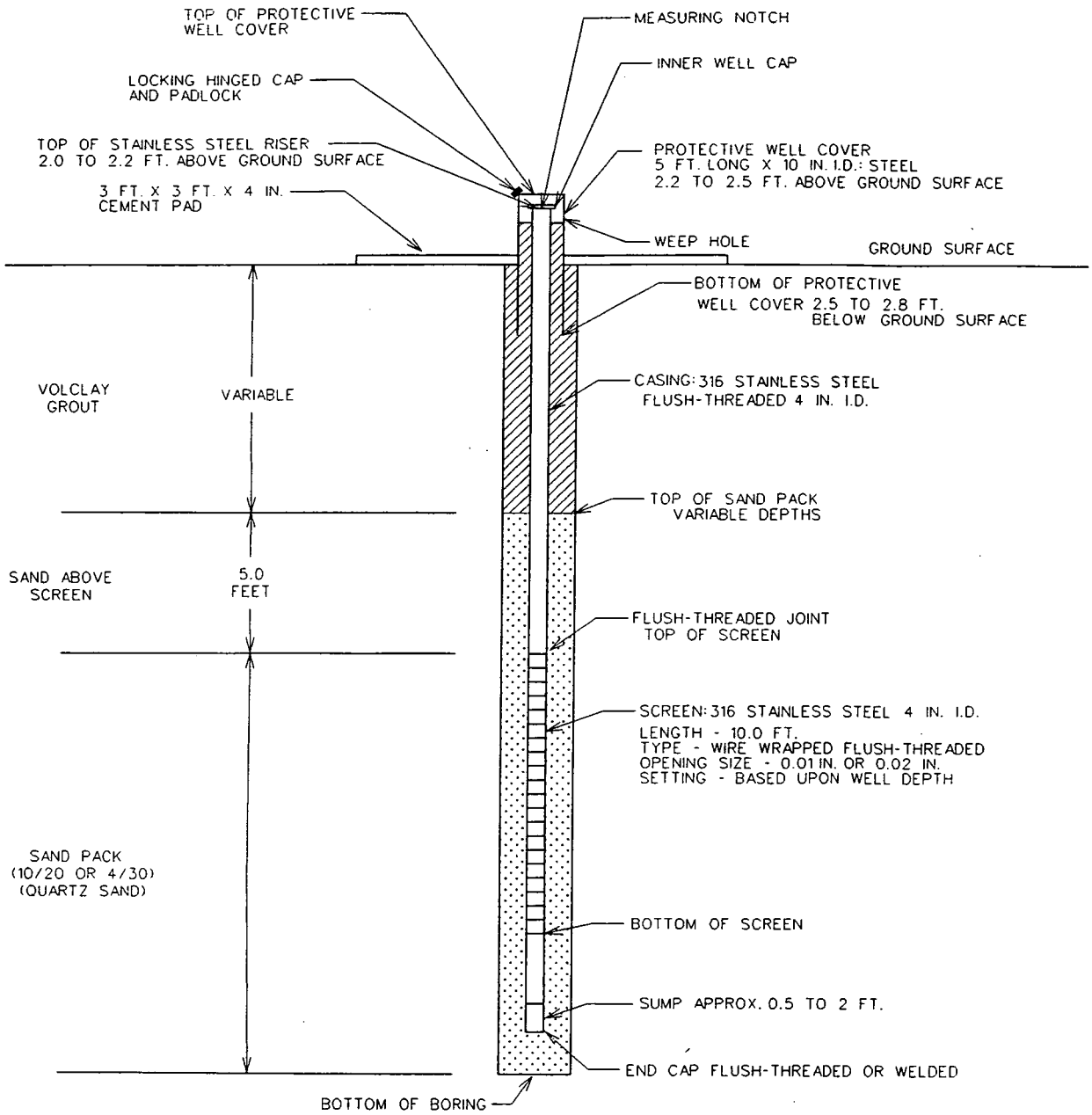
FIGURE 2-10. TYPE 1 AND TYPE 2 WELL COMPLETION SPECIFICATIONS



NOT TO SCALE

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FIGURE 2-11. TYPE 3 AND TYPE 4 WELL COMPLETION SPECIFICATIONS

/u3/fmpc/dgn/bmp/409125.dgn ou5 Ridata 05/25/94

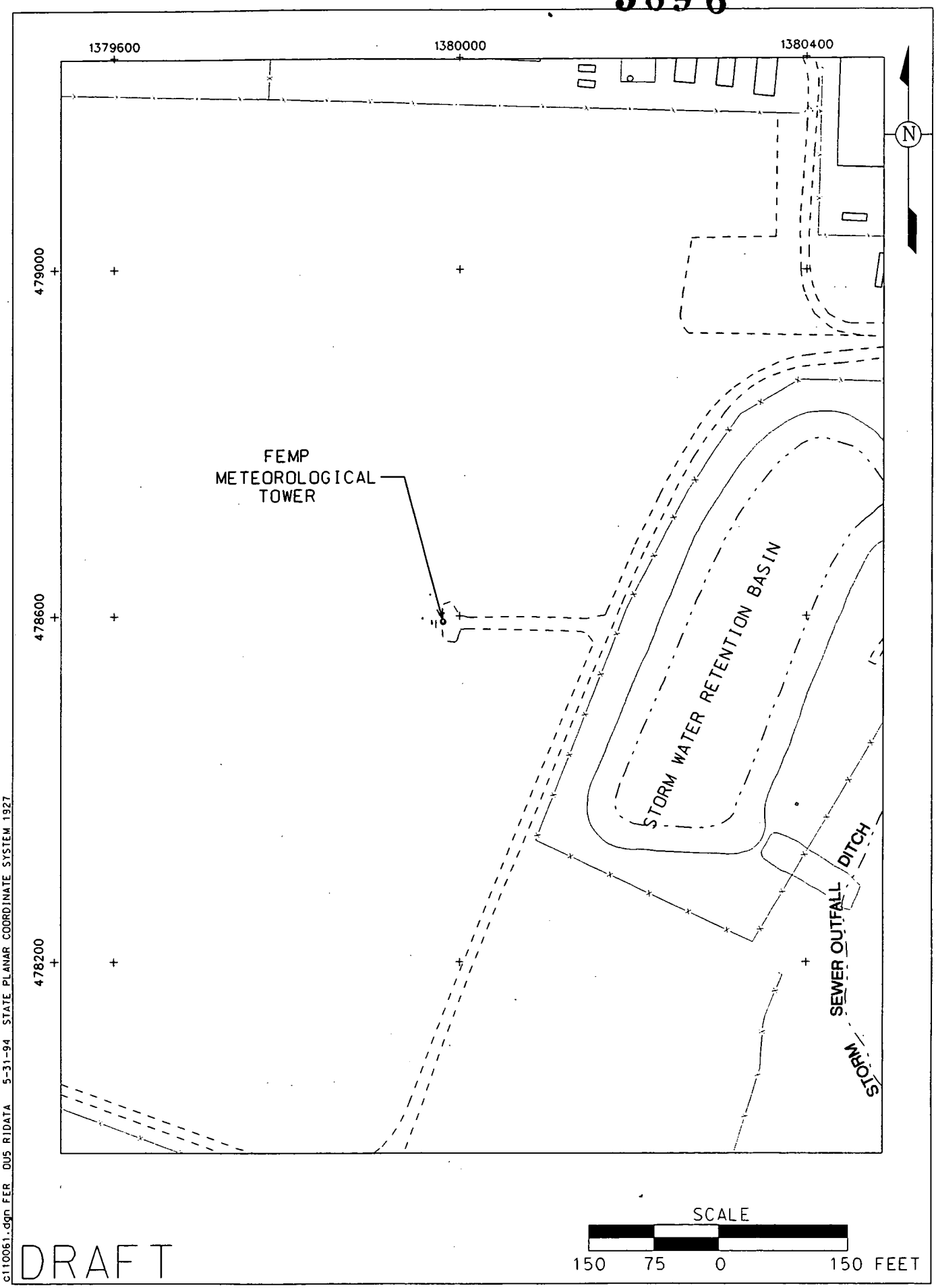


FIGURE 2-12. LOCATION OF FEMP METEOROLOGICAL TOWER

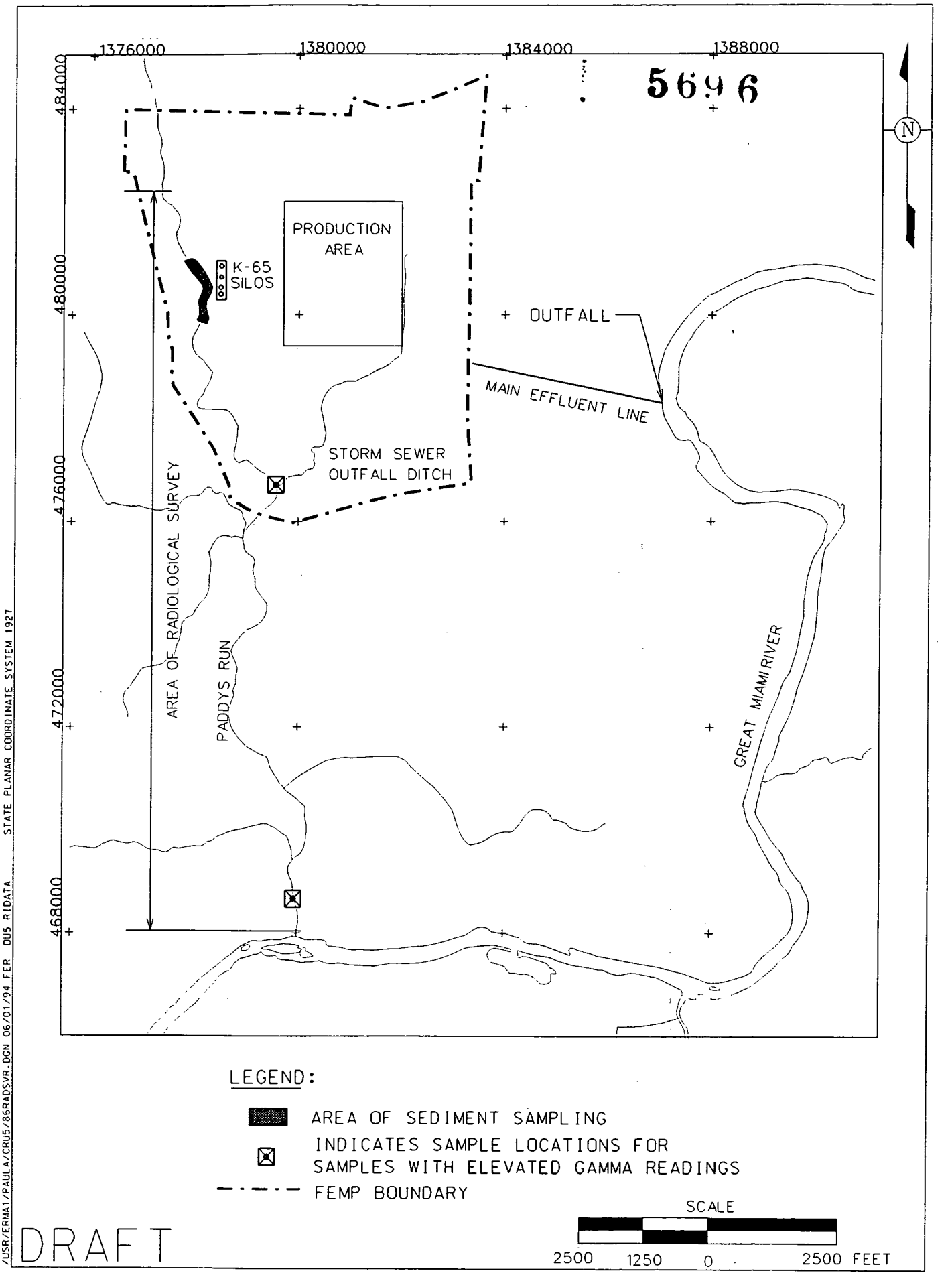
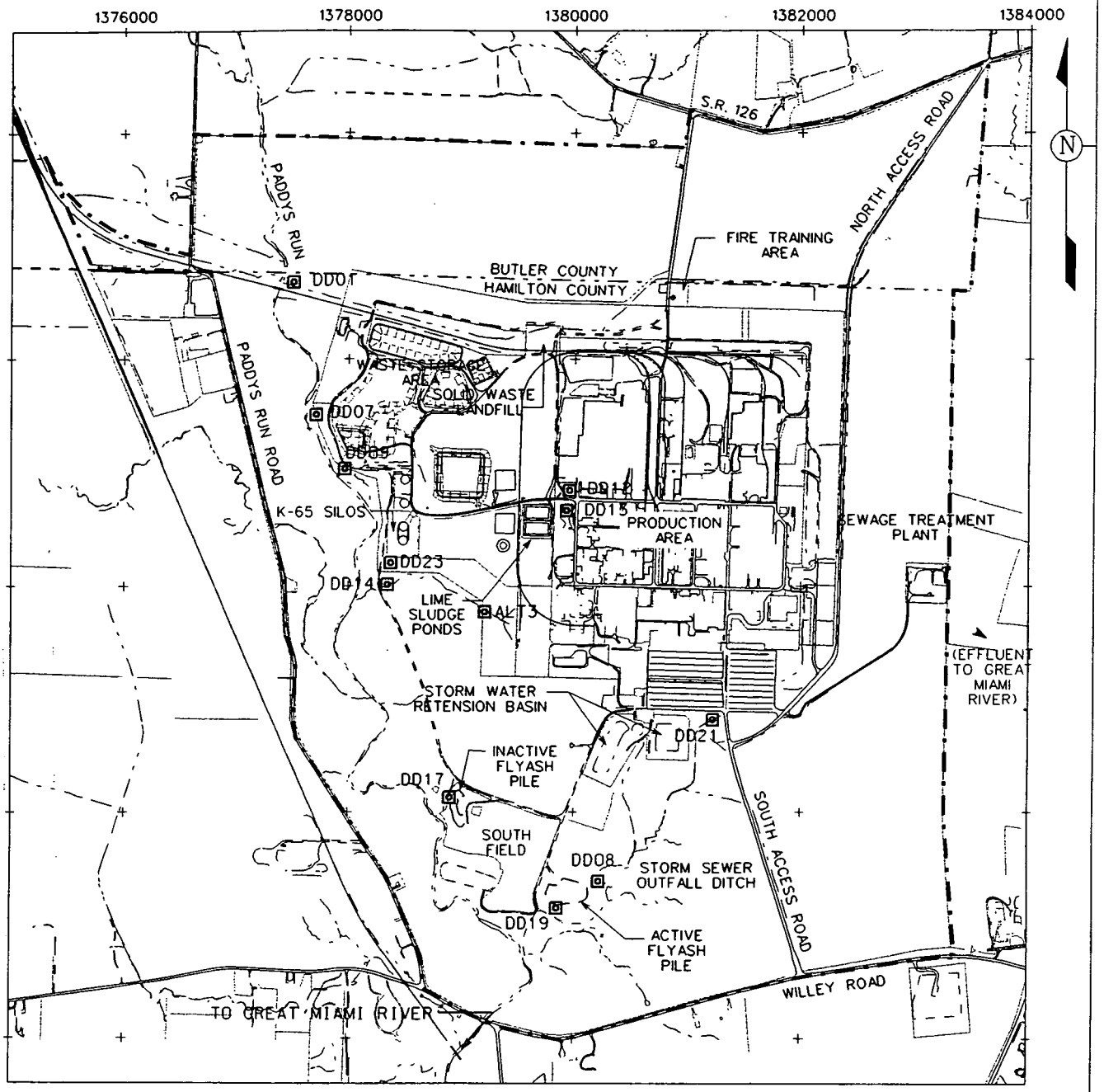


FIGURE 2-13. 1986 RADIOLOGICAL SURVEY OF PADDYS RUN



NOTE:

DATA TAKEN FROM:
WESTINGHOUSE MATERIALS COMPANY OF OHIO. 1989. "FEED MATERIALS PRODUCTION CENTER ENVIRONMENTAL MONITORING ANNUAL REPORT."

R.F. WESTON. 1988. "ADDENDUM TO BEST MANAGEMENT PRACTICES PLAN: STORM WATER SAMPLING RESULTS."

LEGEND:

- STORM WATER RUNOFF SAMPLING POINT (7/20/88)
- COUNTY LINE
- FEMP BOUNDARY

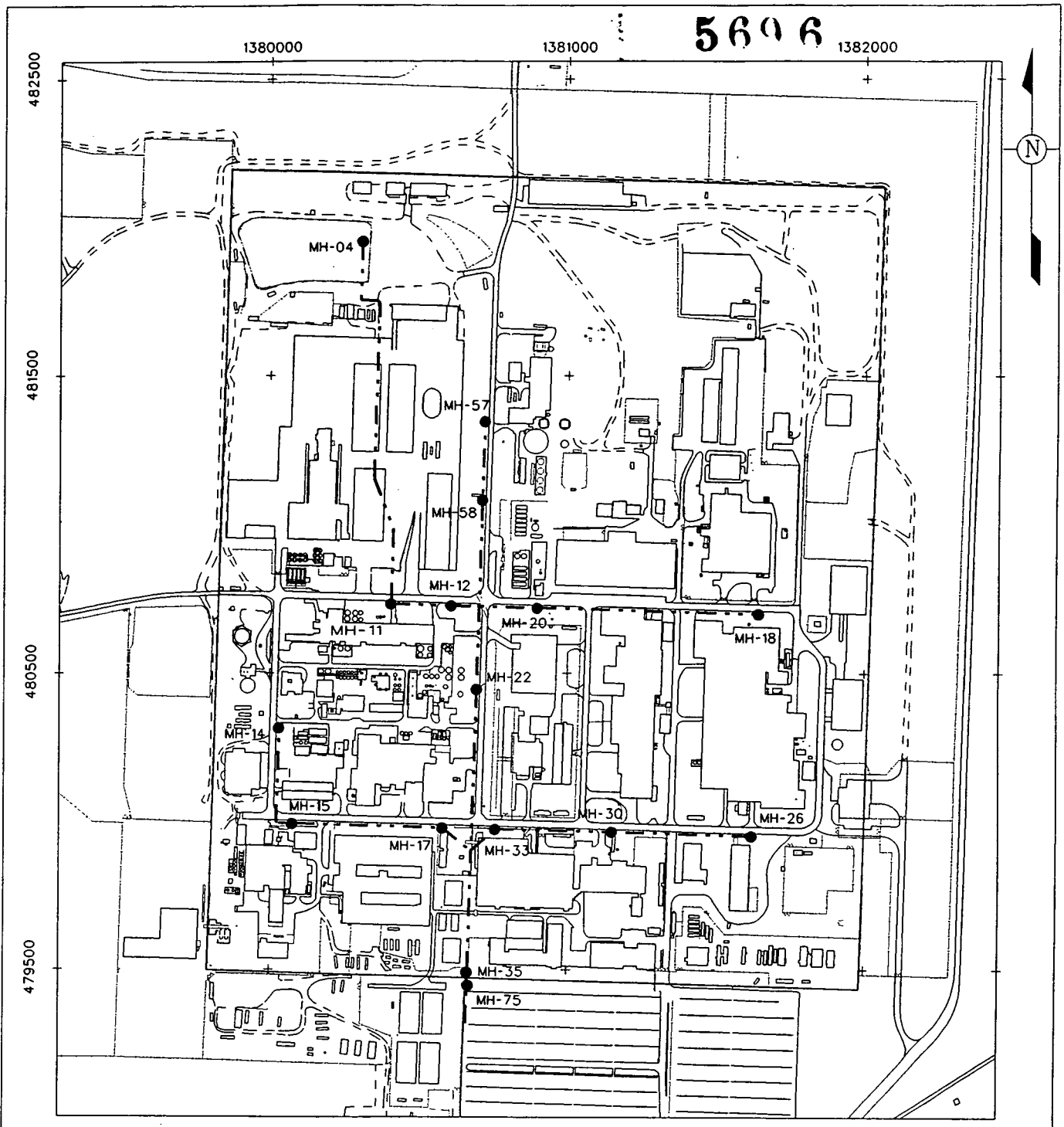
SCALE

1400 700 0 1400 FEET

DRAFT

c110076.dgn FER OU5 RIDATA 6-17-94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 2-14. STORM WATER RUNOFF SAMPLING LOCATIONS FOR THE BEST MANAGEMENT PRACTICES PLAN



NOTE:

DATA TAKEN FROM :

1. R.F.WESTON. ADDENDUM TO BEST MANAGEMENT PRACTICES PLAN: STORMWATER SAMPLING RESULTS. 1988.

LEGEND:

MH-33 ● STORM SEWER SAMPLING POINT (MANHOLE)

— · — · — STORM SEWER LOCATION

——— PRODUCTION AREA BOUNDARY

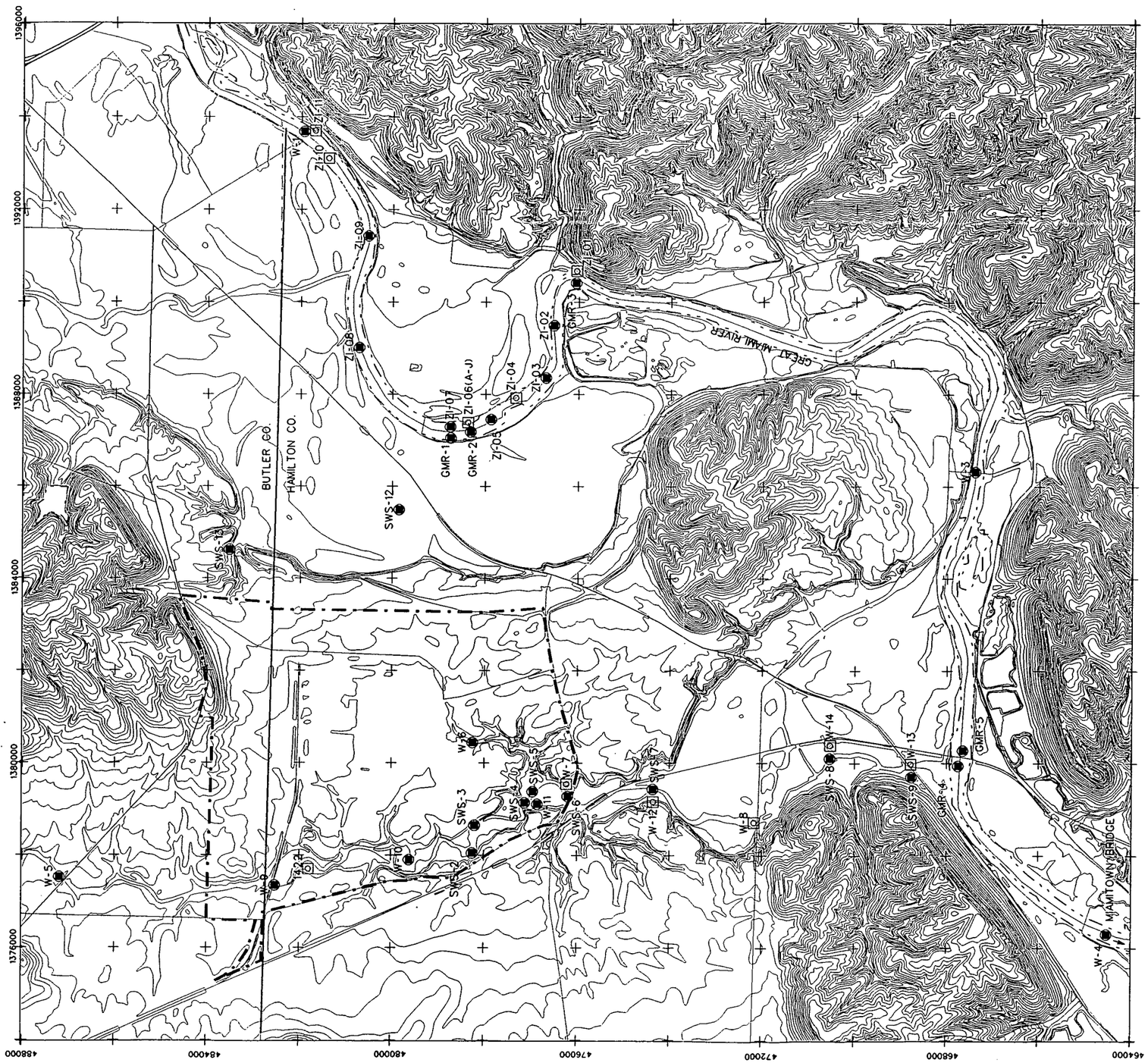
SCALE

500 250 0 500 FEET

c110075.dgn FER OU5 RIDATA 6-15-94 STATE PLANAR COORDINATE SYSTEM 1927

DRAFT

FIGURE 2-15. LOCATIONS OF STORM SEWER SAMPLES COLLECTED IN 1988 FOR BEST MANAGEMENT PRACTICES PLAN



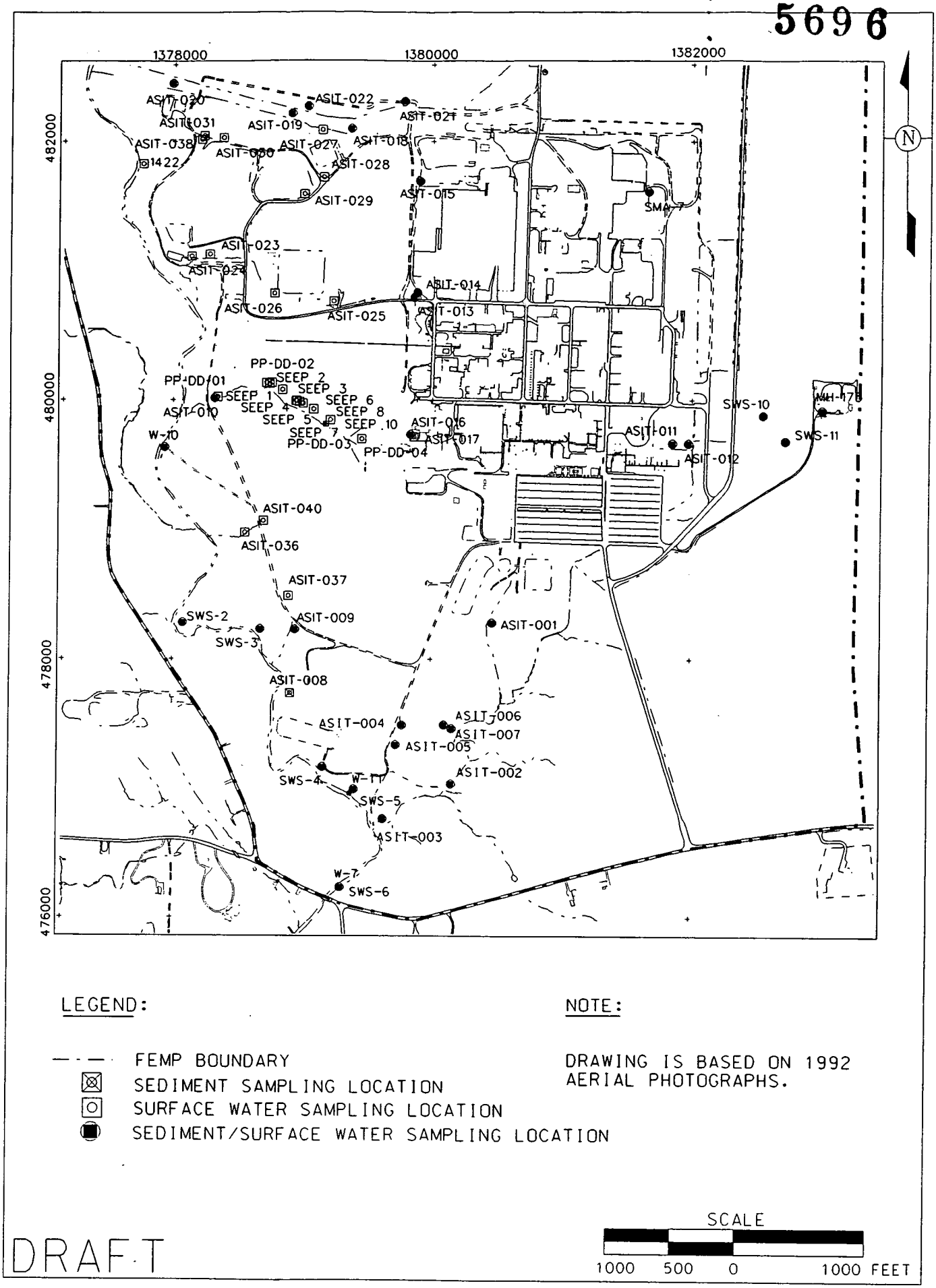
SCALE
2500 1250 0 2500 FEET

LEGEND:
- SURFACE WATER SAMPLING LOCATION
- SURFACE WATER / SEDIMENT SAMPLING LOCATION
- FEMP BOUNDARY

FIGURE 2-16. SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS

DRAFT

C110057.dgn FER DUS RIDATA 6-1-94 STATE PLANAR COORDINATE SYSTEM 1927



LEGEND:

- FEMP BOUNDARY
- SEDIMENT SAMPLING LOCATION
- SURFACE WATER SAMPLING LOCATION
- SEDIMENT/SURFACE WATER SAMPLING LOCATION

NOTE:

DRAWING IS BASED ON 1992 AERIAL PHOTOGRAPHS.

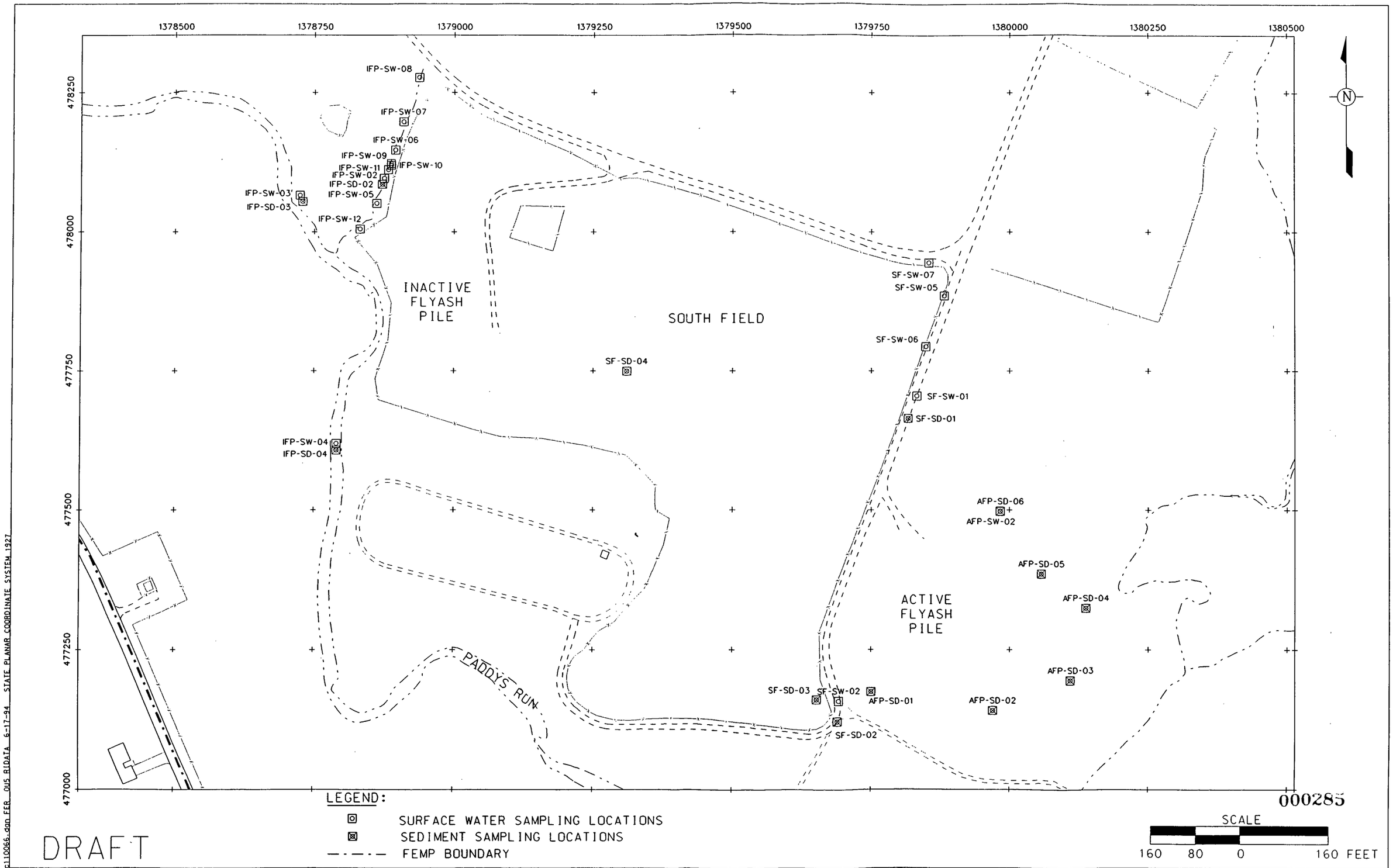
SCALE

1000 500 0 1000 FEET

DRAFT

/USR/ERMA3/FMPC/DGN/MAP/HOR/OPTH/C110077.DGN FER OU5 RIDATA 06/11/94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 2-17. SEDIMENT AND SURFACE WATER SAMPLING LOCATIONS ONSITE AT THE FEMP



000285

FIGURE 2-18. 1993 OPERABLE UNIT 2 SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS - SOUTH FIELD & FLYASH PILE AREAS

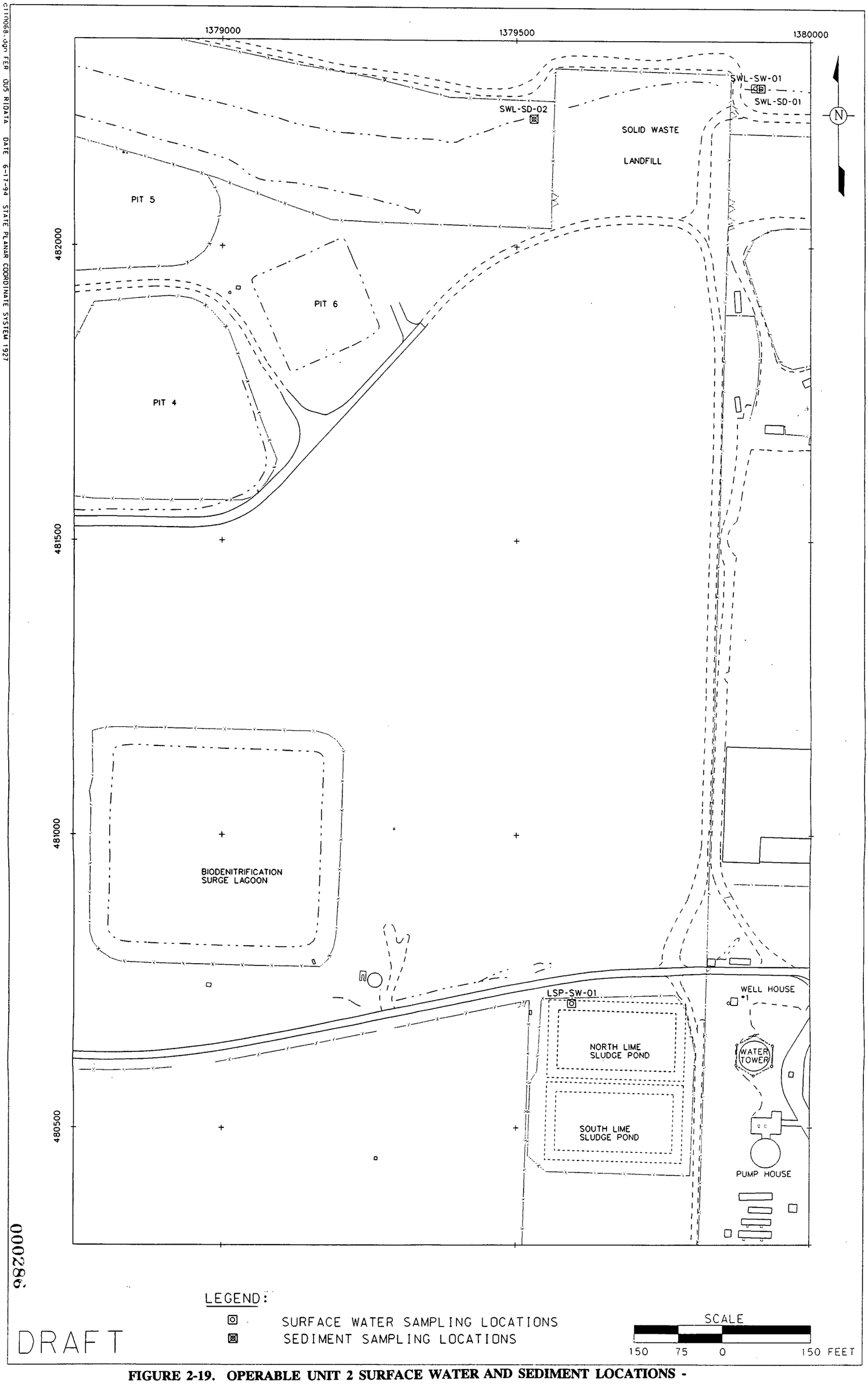
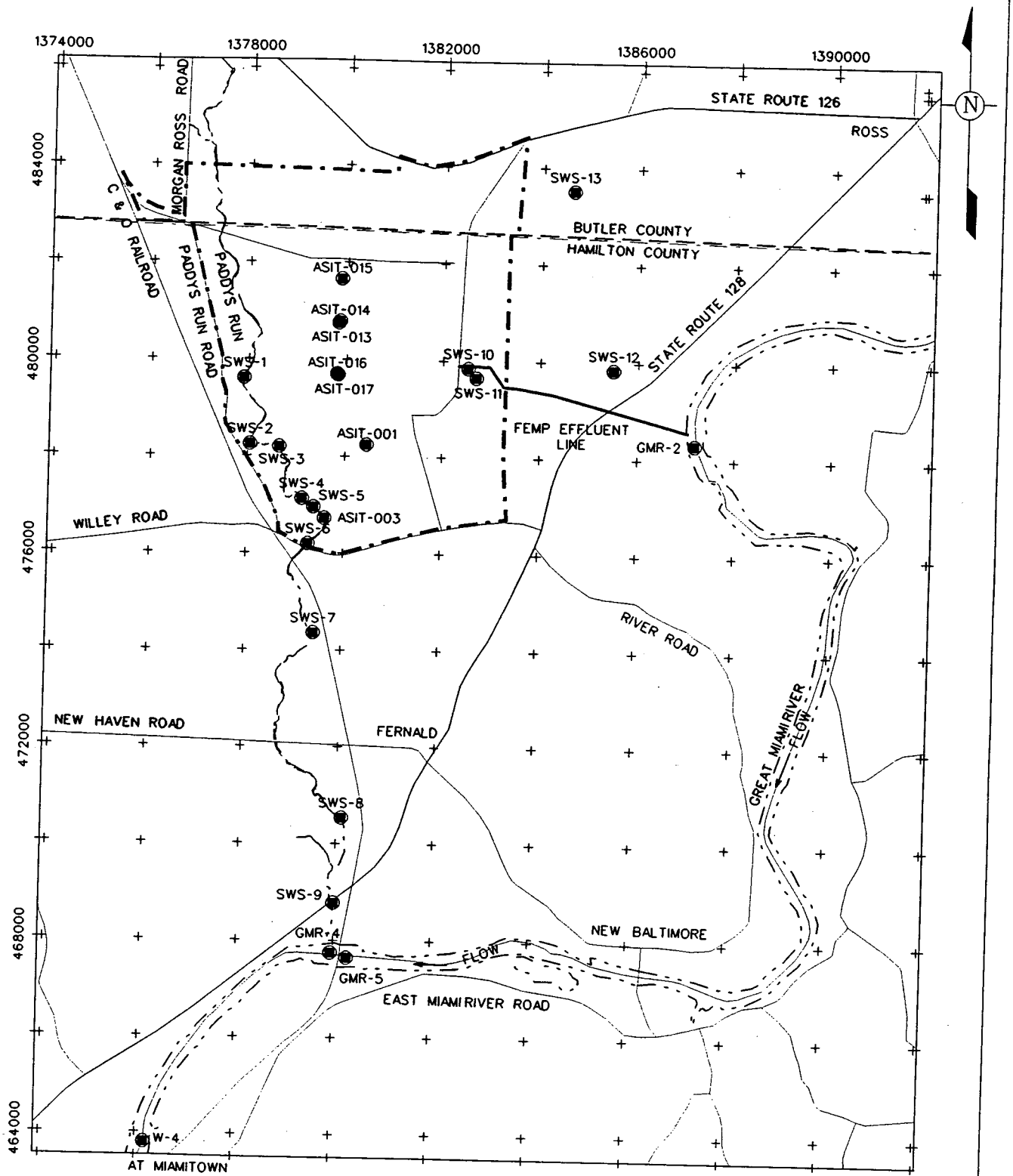


FIGURE 2-19. OPERABLE UNIT 2 SURFACE WATER AND SEDIMENT LOCATIONS - SOLID WASTE LANDFILL & LIME SLUDGE PONDS

000286

5696



LEGEND:

- SURFACE WATER AND SEDIMENT SAMPLING LOCATION
- FEMP BOUNADRY
- COUNTY LINE

NOTE:

DATA TAKEN FROM: PROJECT SPECIFIC PLAN FOR THE SNAPSHOT MONITORING WELL SAMPLING AND SURFACE WATER AND SEDIMENT SAMPLING (1993)

SCALE

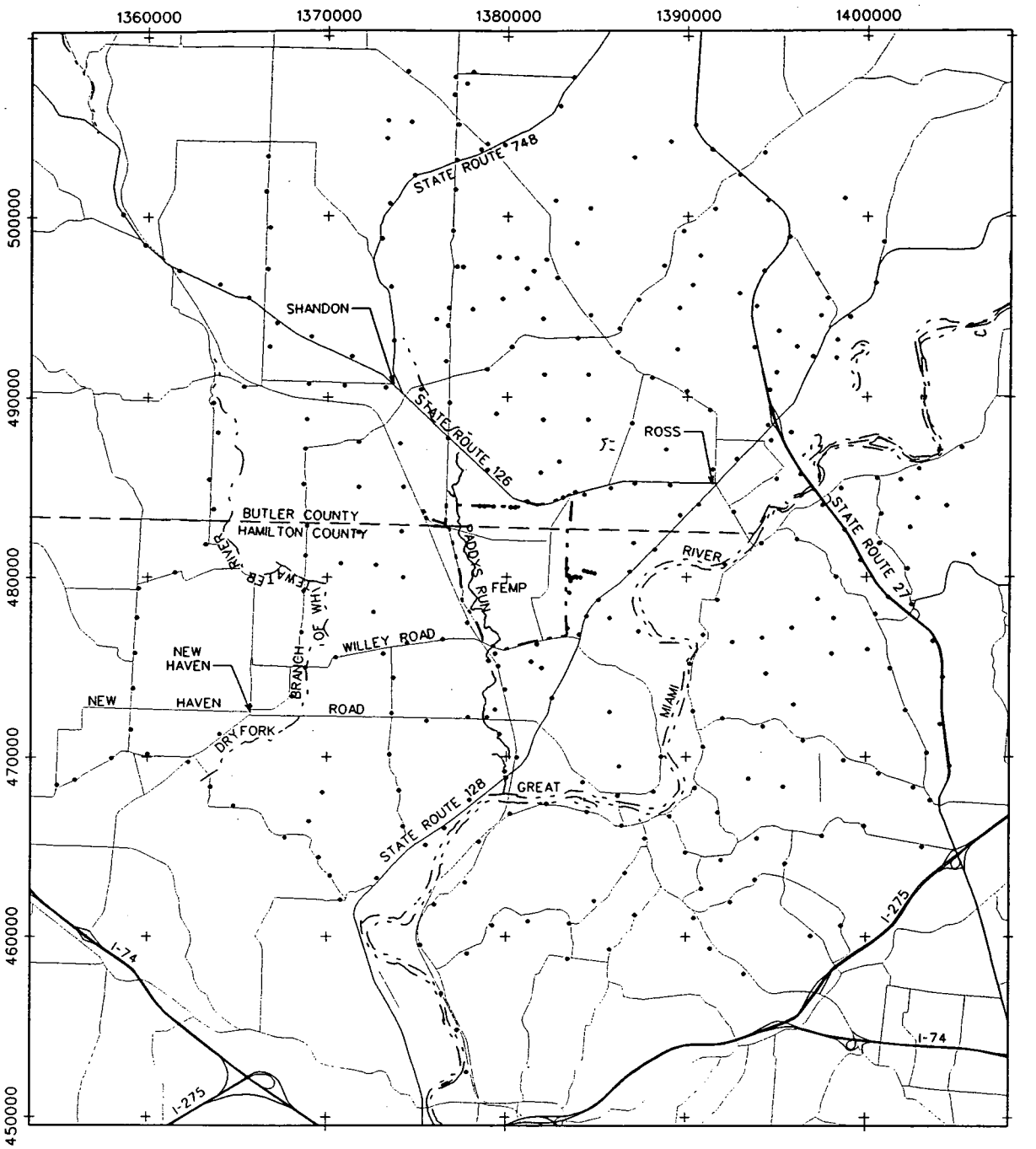
3000 1500 0 3000 FEET

000287

DRAFT

/usr/ermo3/5arn1/dgn/map/hor/dpth/c110062.dgn FER OUS RIDATA 6-8-94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 2-20. "SNAPSHOT" SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS



LEGEND:

- • APPROXIMATE SOIL SAMPLE LOCATION
- —·—·— FEMP BOUNDARY
- — — — COUNTY LINE

NOTE:

DATA TAKEN FROM:
IT, 1986, FINAL INTERIM REPORT-AIR, SOIL, WATER, AND HEALTH RISK ASSESSMENT IN THE VICINITY THE FEMP, FERNALD, OHIO.

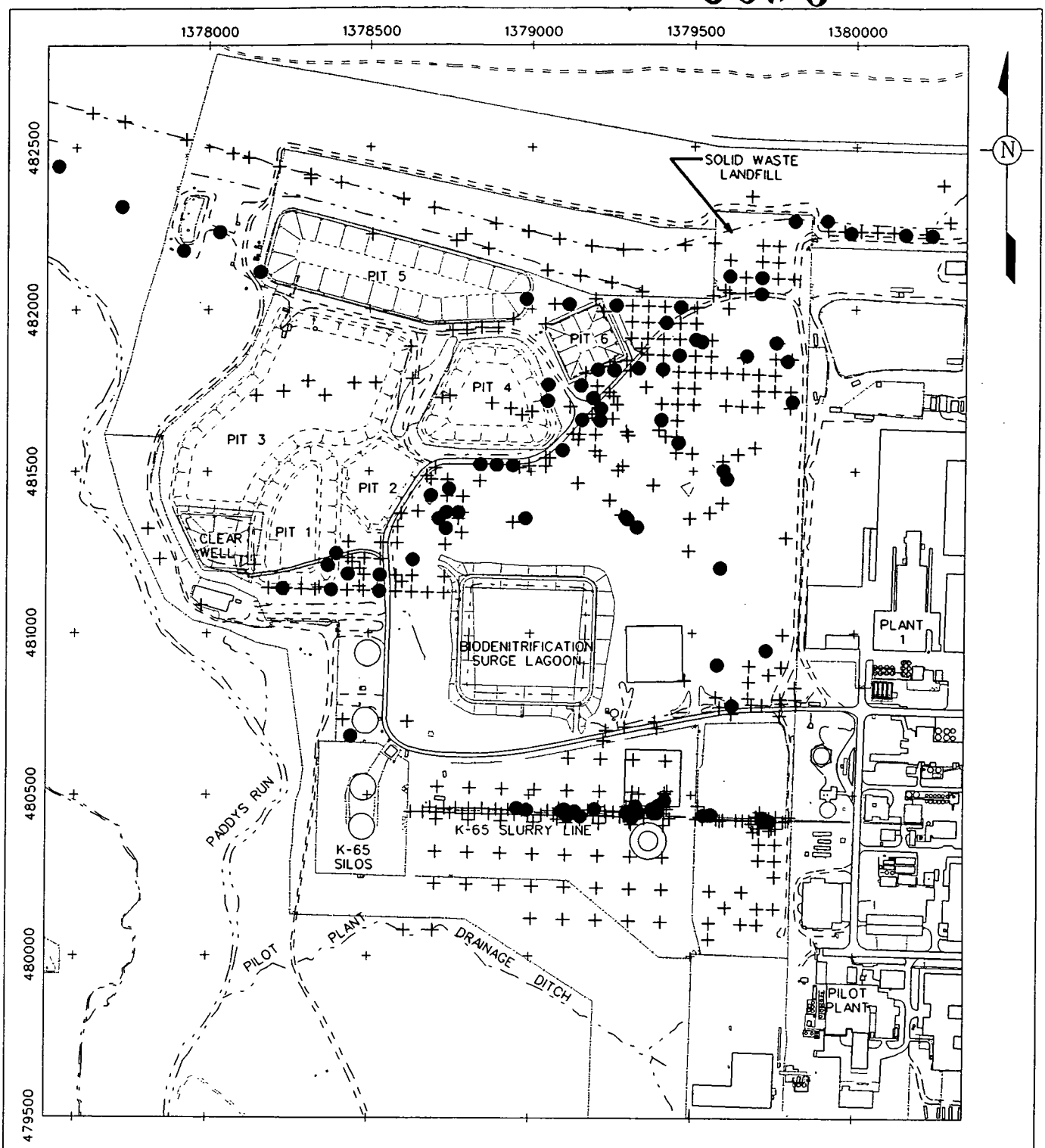
SCALE

9000 4500 0 9000 FEET

DRAFT

lit_data.dgn FER QUS RIDATA 6-17-94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 2-21. SOIL SAMPLING LOCATIONS-LITIGATION SUPPORT STUDY



LEGEND:

+ SURFACE SOIL SAMPLING LOCATION (0-6 IN.)

● SURFACE SOIL SAMPLING LOCATION (0-6 IN. & 6-18 IN.)

NOTE:

SAMPLING LOCATION AND NUMBER OF SAMPLES ARE APPROXIMATE. DATA TAKEN FROM: WESTON, 1986, SITE CHARACTERIZATION OF WASTE STORAGE AREAS.

SCALE

450 225 0 450 FEET

DRAFT

c110071.dgn FER OU5 RIDATA 6-17-94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 2-22. SURFACE SOIL SAMPLING LOCATIONS IN THE WASTE STORAGE AREA

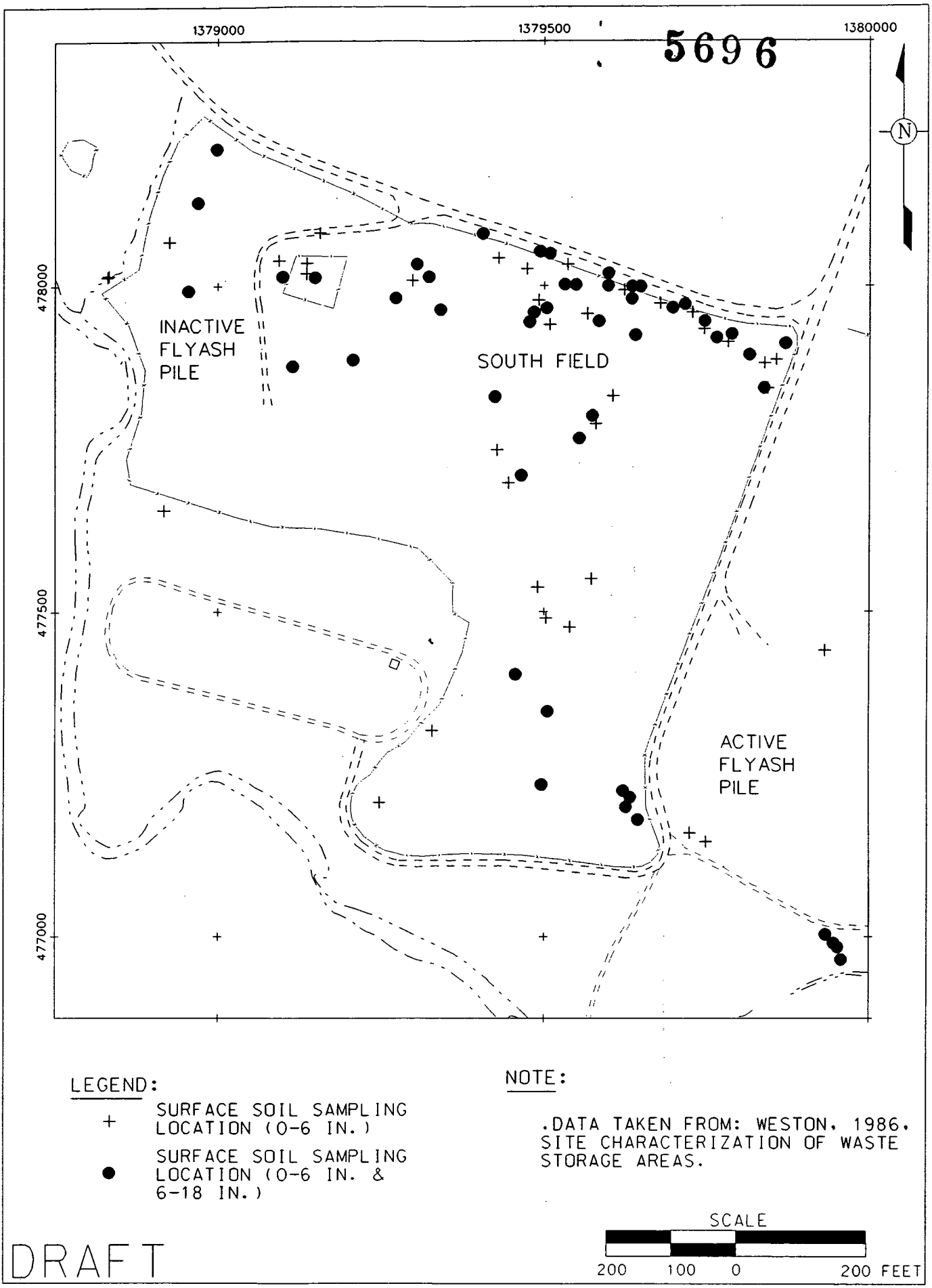
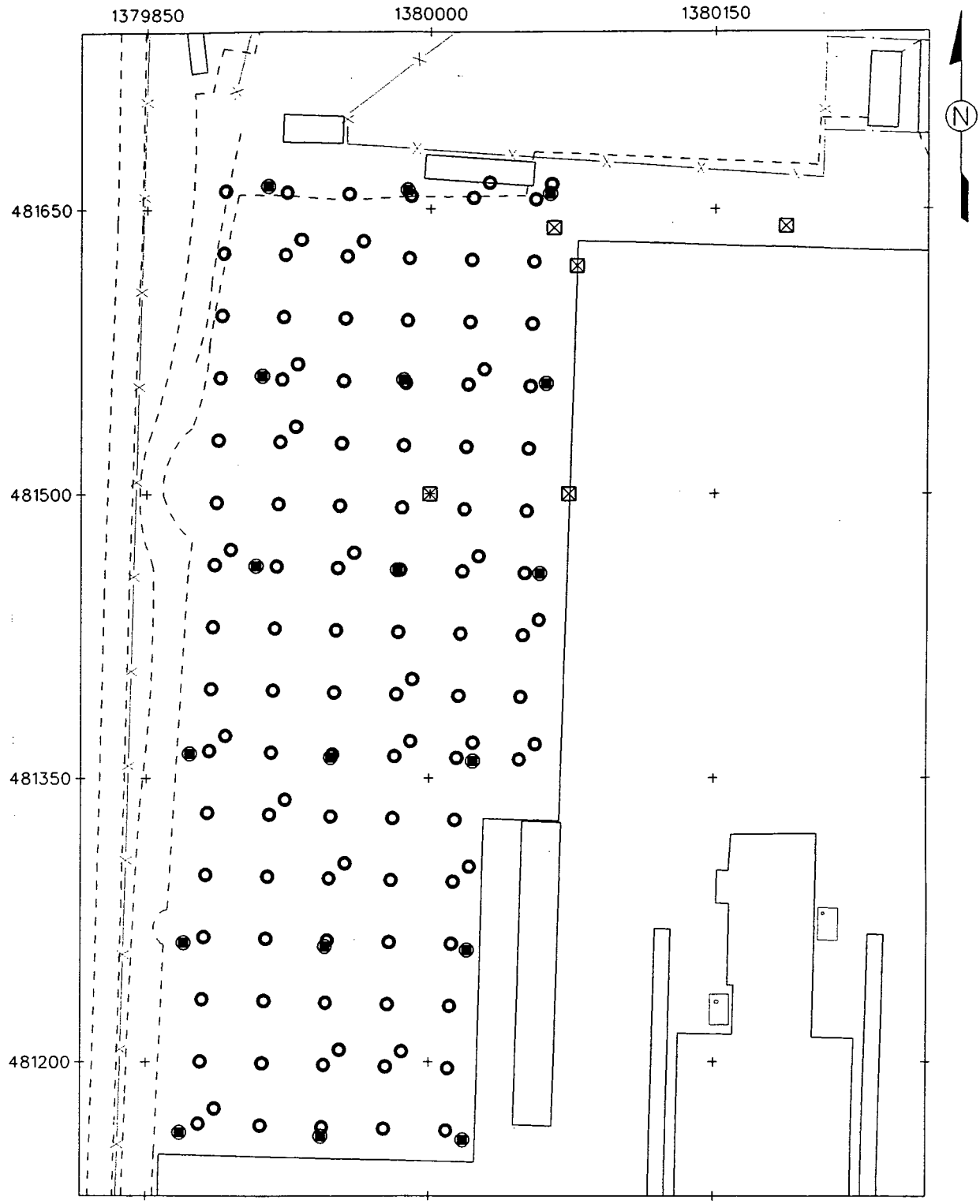


FIGURE 2-23. SURFACE SOIL SAMPLING LOCATIONS IN SOUTH FIELD AND FLYASH PILE AREAS



/usr/ermo3/fmpc/dgn/map/hor/map/c110044.dgn STATE PLANAR COORDINATE 1927

LEGEND:

- ⊠ RI/FS SURFACE SOIL SAMPLING
- ● PLANT 1 PAD HAND AUGERING PRE-EXCAVATION SAMPLING AND TCLP METALS
- ○ PLANT 1 PAD POST-EXCAVATION

NOTE:

DRAWING IS BASED ON 1992 AERIAL PHOTOGRAPHS.

SCALE

0 40 80 160 240 FEET

DRAFT

FIGURE 2-24. SURFACE SOIL SAMPLING LOCATIONS
PLANT 1 PAD

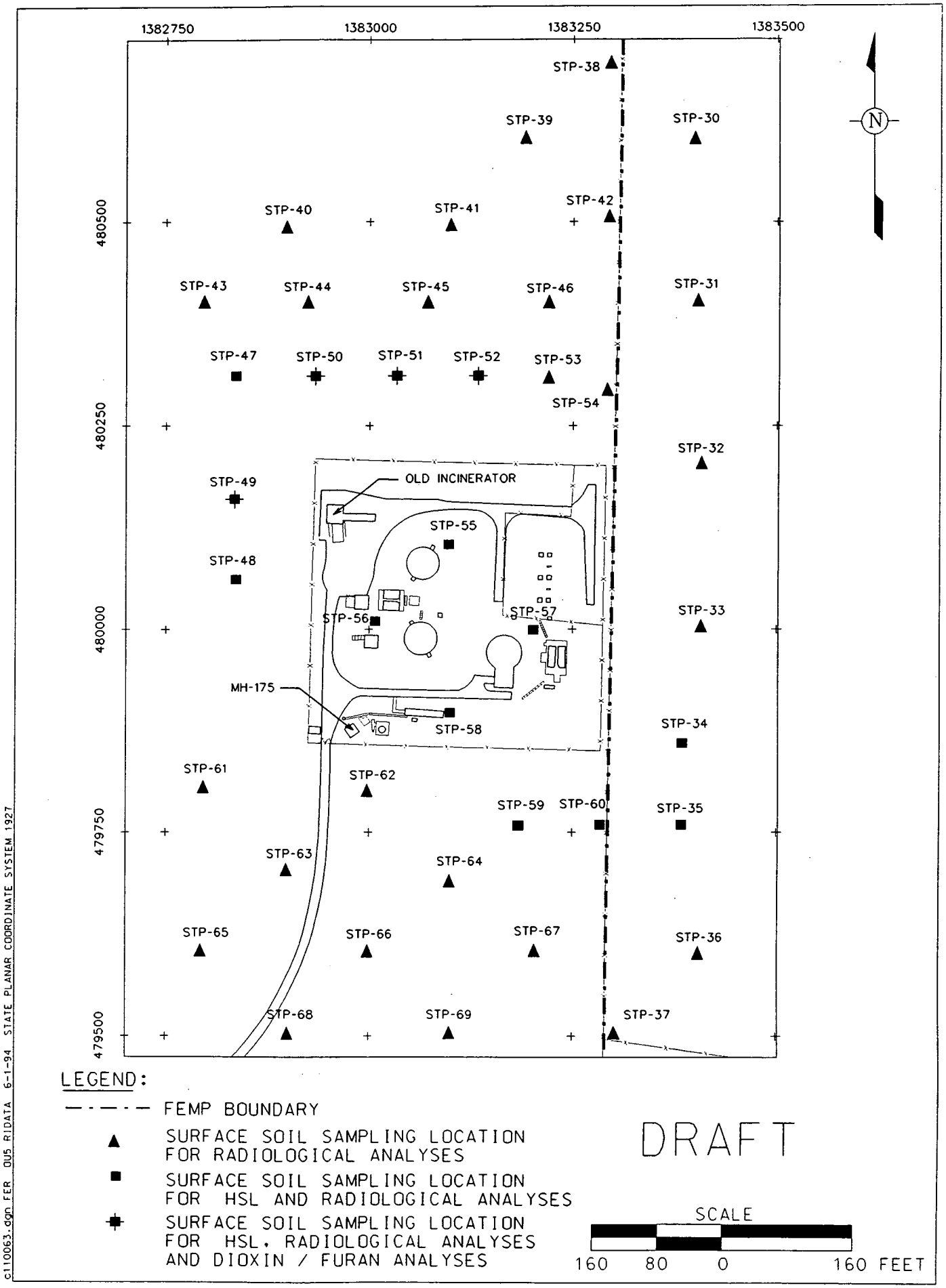


FIGURE 2-25. SURFACE SOIL SAMPLING LOCATIONS FOR SEWAGE TREATMENT PLANT INCINERATOR AREA

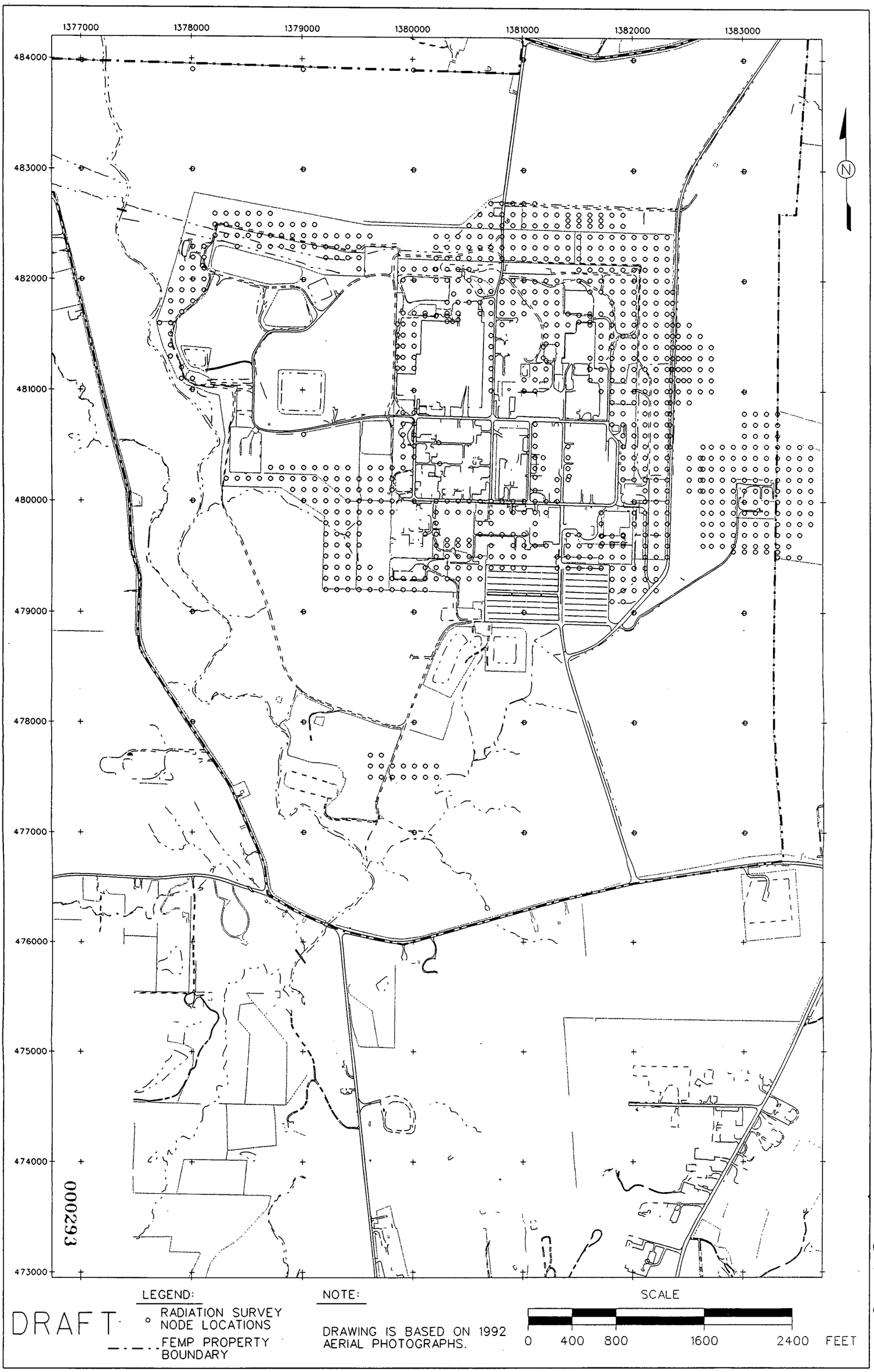


FIGURE 2-26. RADIATION MEASUREMENT SURVEY

5696

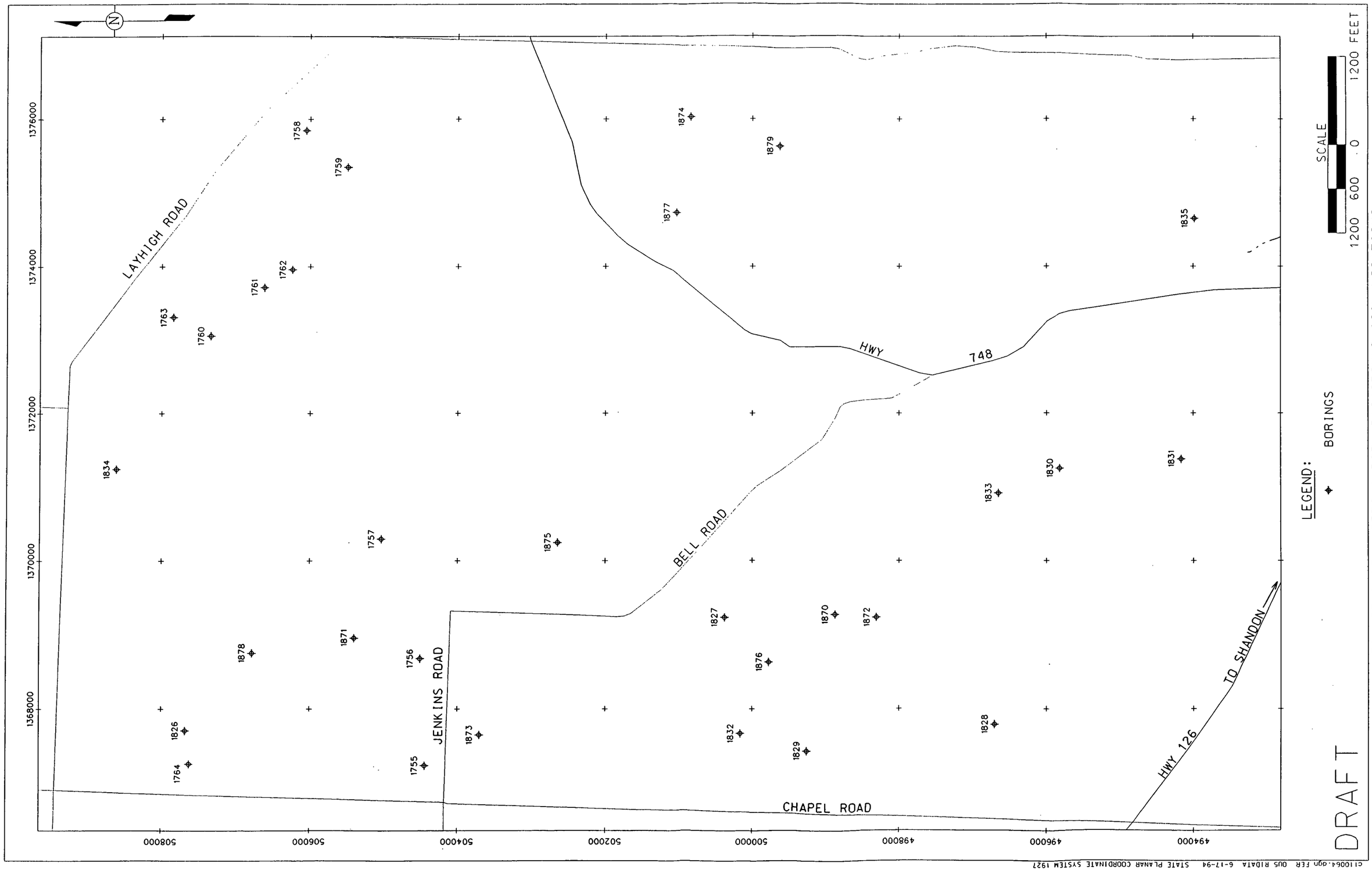
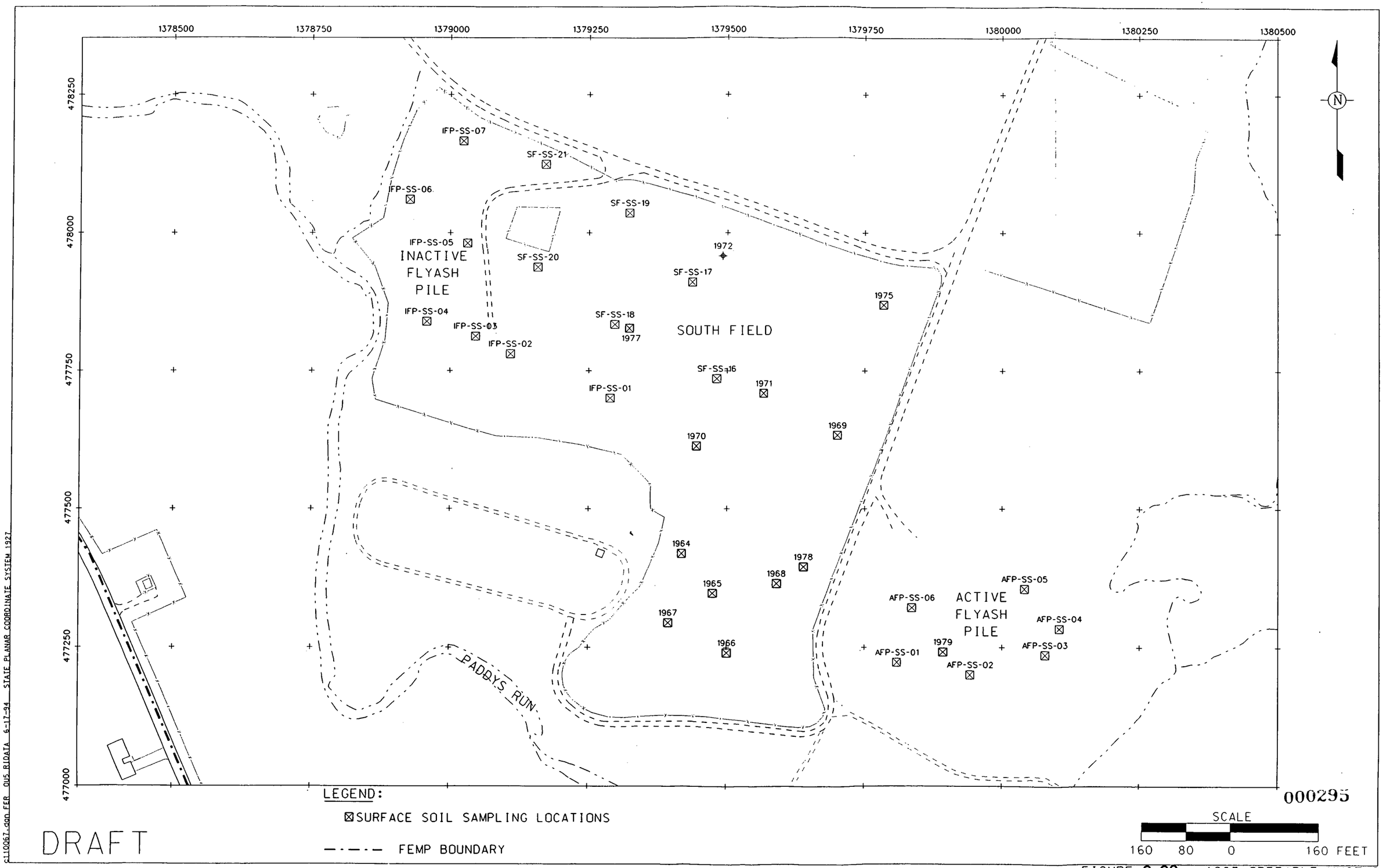


FIGURE 2-27. CERCLA/RCRA BACKGROUND SOIL LOCATIONS



000295

FIGURE 2-28. 1993 OPERABLE UNIT 2 SURFACE SOIL SAMPLING LOCATIONS - SOUTH FIELD AND FLYASH PILE AREAS

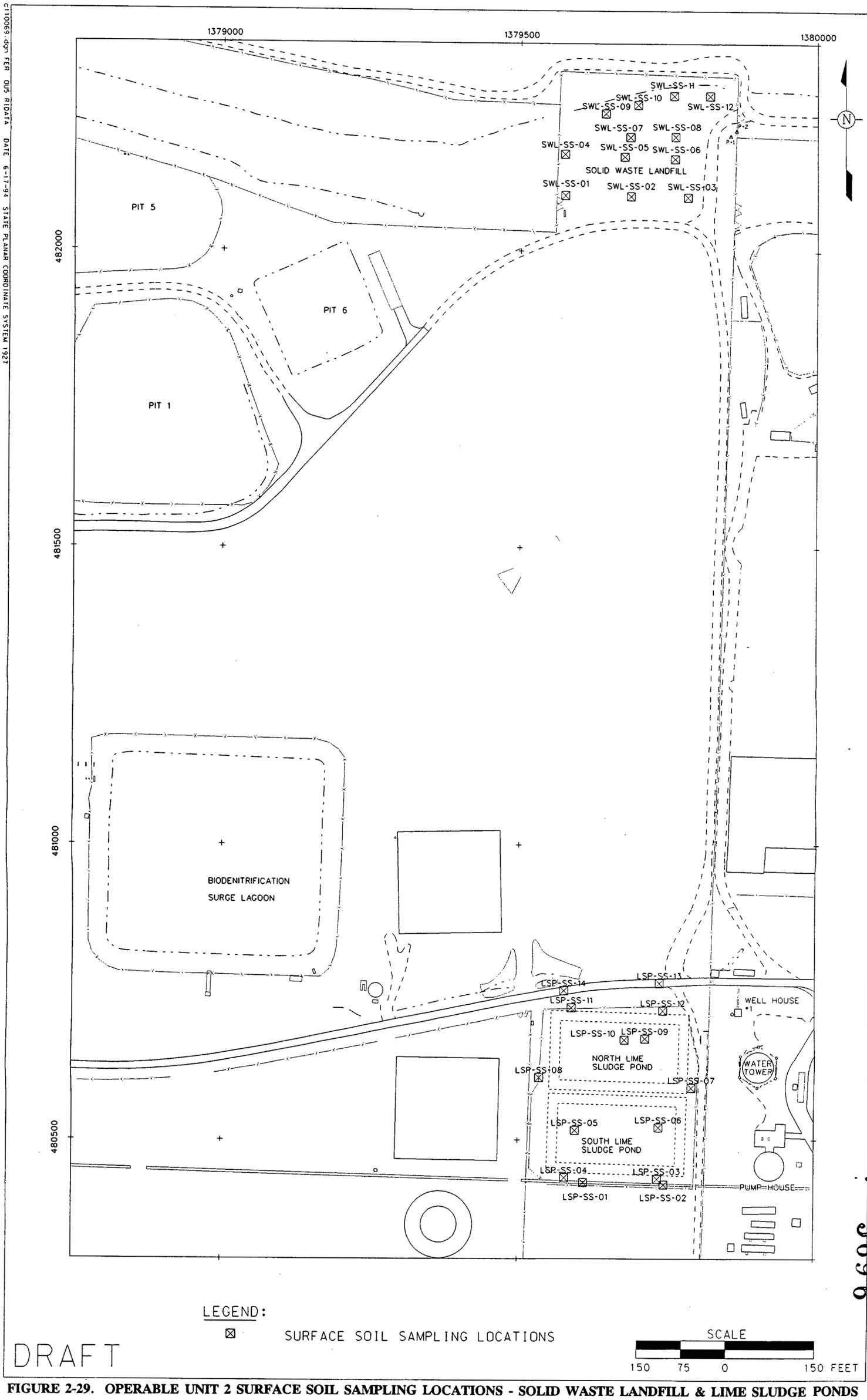
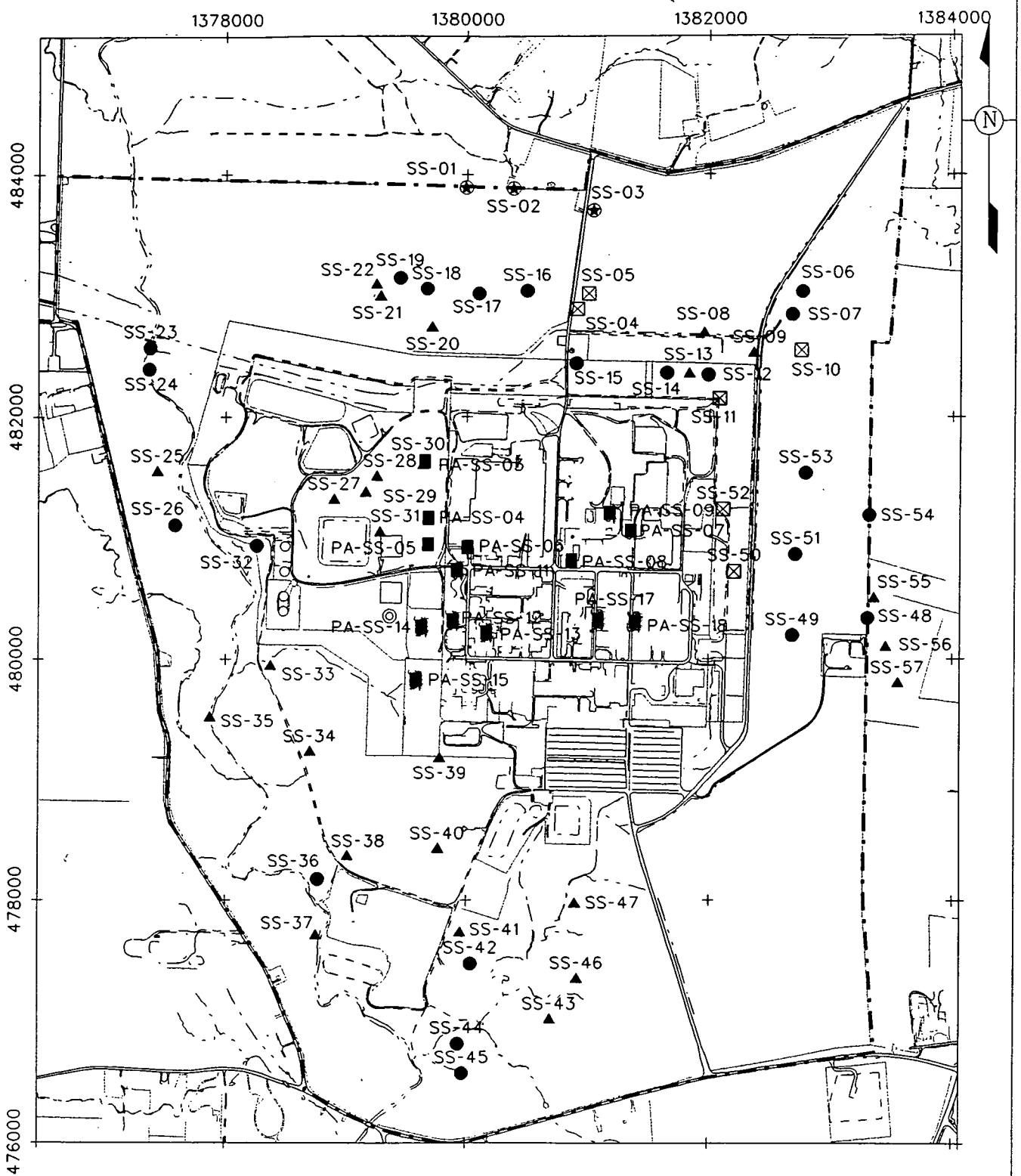


FIGURE 2-29. OPERABLE UNIT 2 SURFACE SOIL SAMPLING LOCATIONS - SOLID WASTE LANDFILL & LIME SLUDGE PONDS



LEGEND:

- ✱ SAMPLING LOCATION FOR HSL INORGANICS
- ⊡ SAMPLING LOCATION FOR FULL HSL
- ● ECOLOGICALLY SENSITIVE AREA TO BE SAMPLED FOR FULL HSL
- ▲ SAMPLING LOCATION FOR FULL HSL AND FULL RADIONUCLIDES
- ■ SAMPLING LOCATION IN FORMER PRODUCTION AREA
- —·— FEMP BOUNDARY

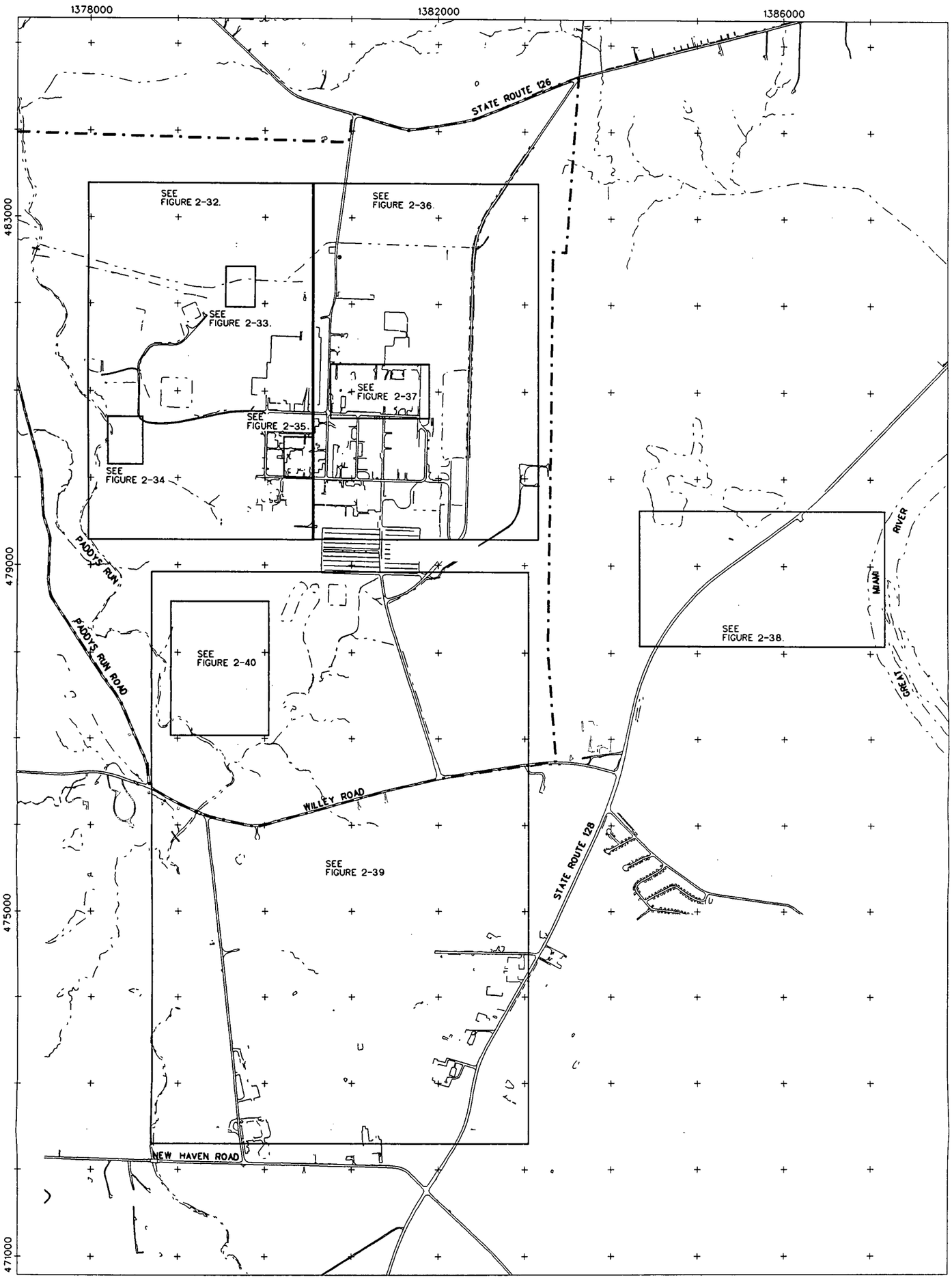
DRAFT

SCALE

1200 600 0 1200 FEET

c110065.dgn FER OU5 RIDATA 6-17-94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 2-30. 1993 SURFACE SOIL SAMPLING INVESTIGATION



LEGEND:

FIGURE AREA OUTLINE

FEMP PROPERTY BOUNDARY

NOTE:

DRAWING IS BASED ON 1992 AERIAL PHOTOGRAPHS.

SCALE

0 600 1200 2400 3600 FEET

DRAFT

000298

5696

FIGURE 2-31. BORINGS - KEY MAP

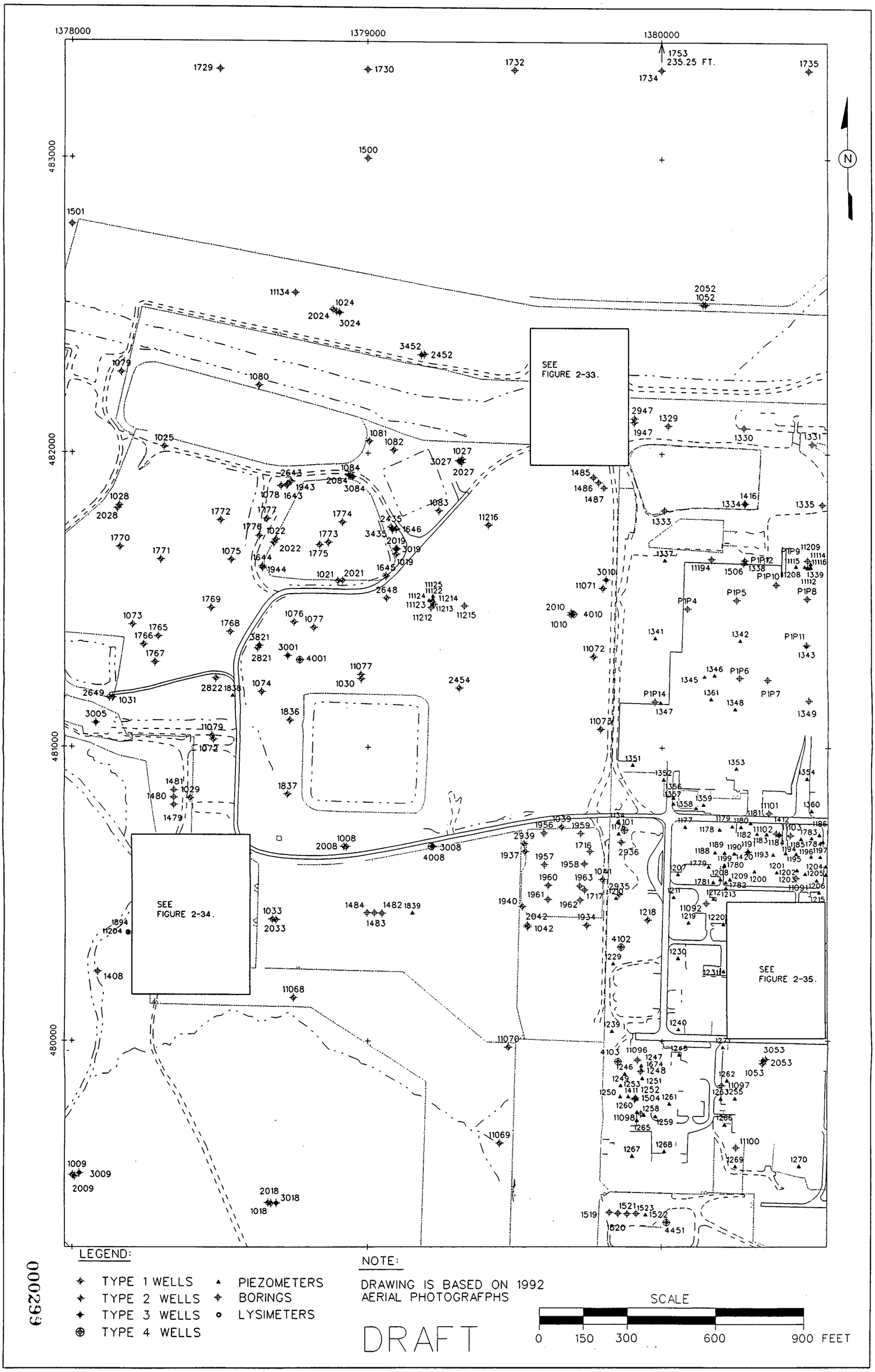
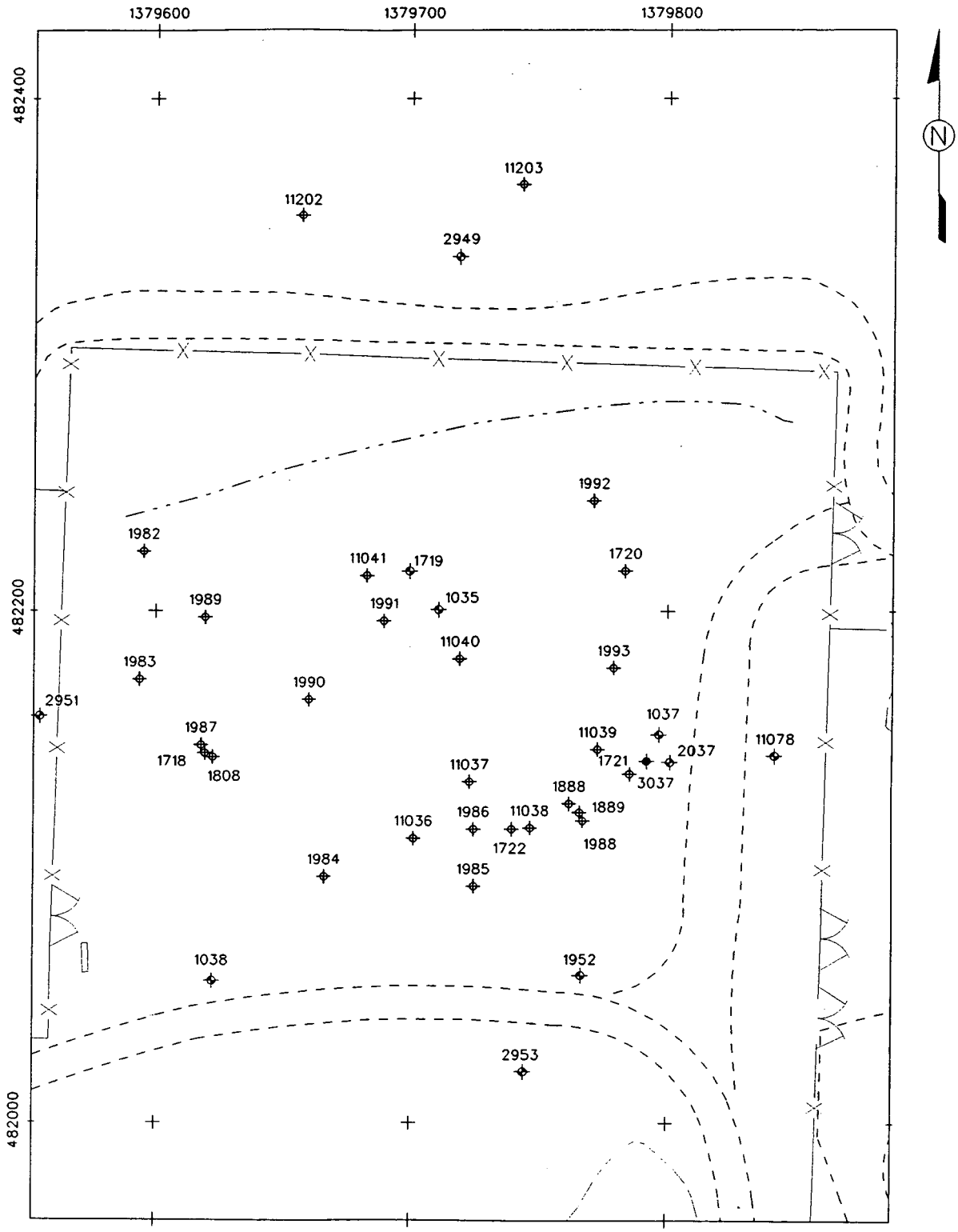


FIGURE 2-32. BORINGS - NORTHWEST AREA OF THE FEMP

/usr/ermo3/fmpc/dgn/bmp/c110030.dgn ou5 date 06/02/94 STATE PLANAR COORDINATE SYSTEM 1927

000299

5696



LEGEND:

- BORINGS
- TYPE 1 WELLS
- TYPE 2 WELLS
- TYPE 3 WELLS

NOTE:

DRAWING IS BASED ON 1992 AERIAL PHOTOGRAPHS.

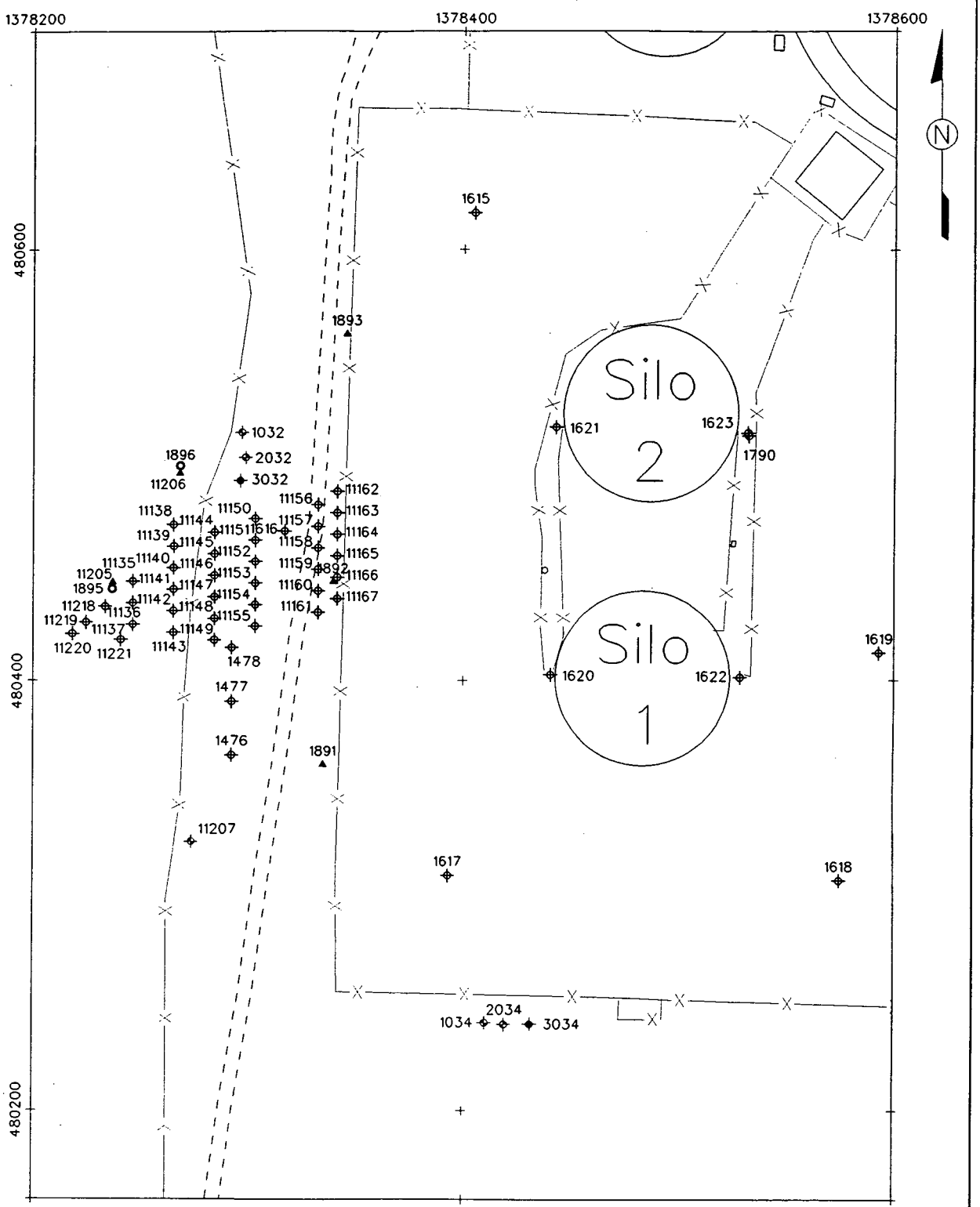
SCALE

0 30 60 120 180 FEET

DRAFT

/usr/ermo3/fmpc/dgn/bmp/c110036.dgn ou5 data 05/25/94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 2-33. BORINGS - SOLID WASTE LANDFILL AREA



LEGEND:

- BORINGS
- TYPE 1 WELLS
- TYPE 2 WELLS
- TYPE 3 WELLS
- PIEZOMETERS
- LYSIMETERS

NOTE:

DRAWING IS BASED ON 1992 AERIAL PHOTOGRAPHS.

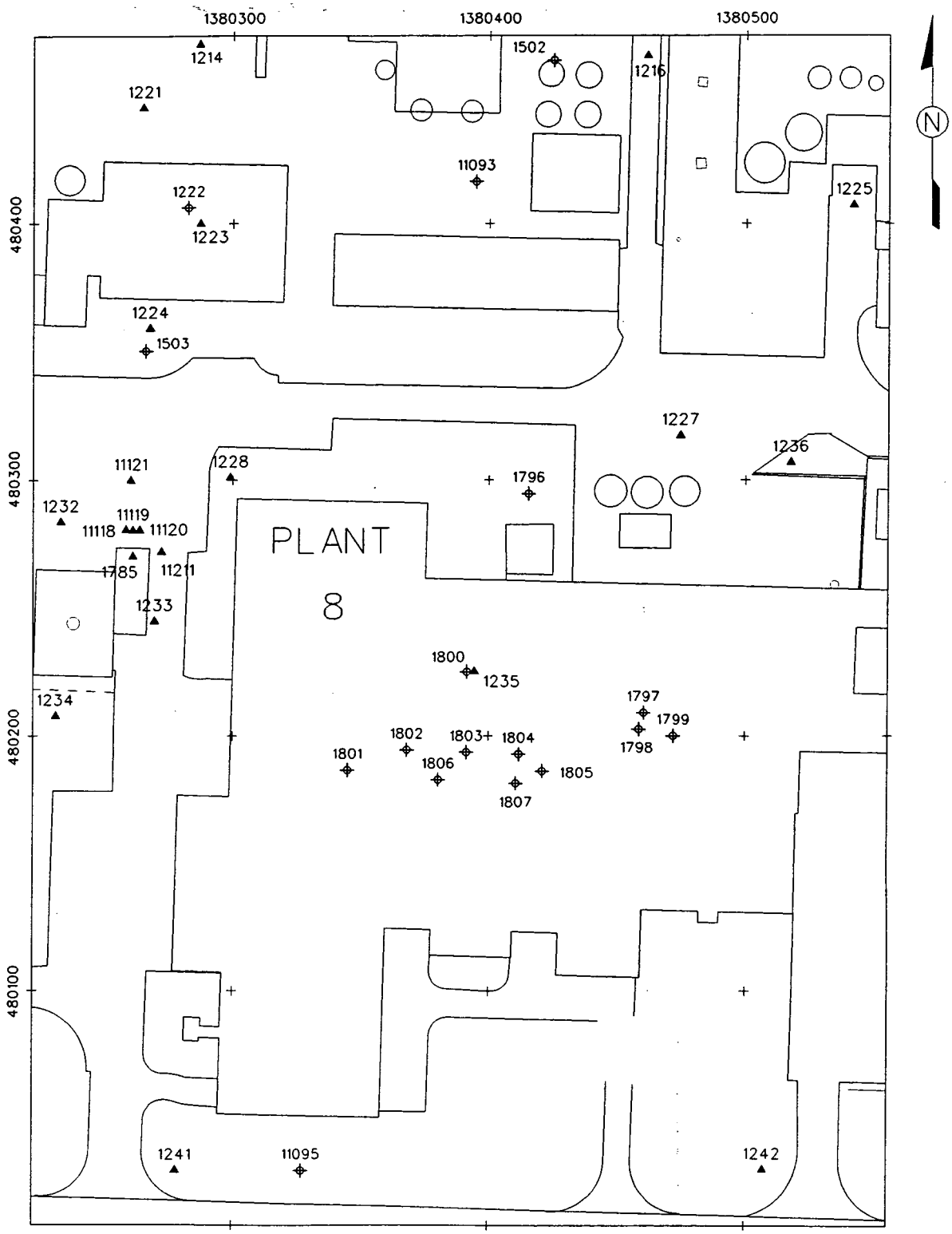
SCALE

0 35 70 140 210 FEET

DRAFT

/usr/ermd3/fmpc/dgn/bmp/c110039.dgn ou5 RI data 06/01/94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 2-34. BORINGS - K-65 SILOS AREA



LEGEND:

- ⌖ BORINGS
- ▲ PIEZOMETERS

NOTE:

DRAWING IS BASED ON 1992 AERIAL PHOTOGRAPHS.

SCALE

0 30 60 120 180 FEET

DRAFT

/usr/ermo3/fmpc/dgn/bmp/c110038.dgn STATE PLANAR COORDINATE SYSTEM 1927 06/01/94

FIGURE 2-35. BORINGS - PLANT 8 AREA

/usr/erma3/fmpc/dgn/bmp/c110031.dgn ou5 Rldata 06/02/94 STATE PLANAR COORDINATE SYSTEM 1927

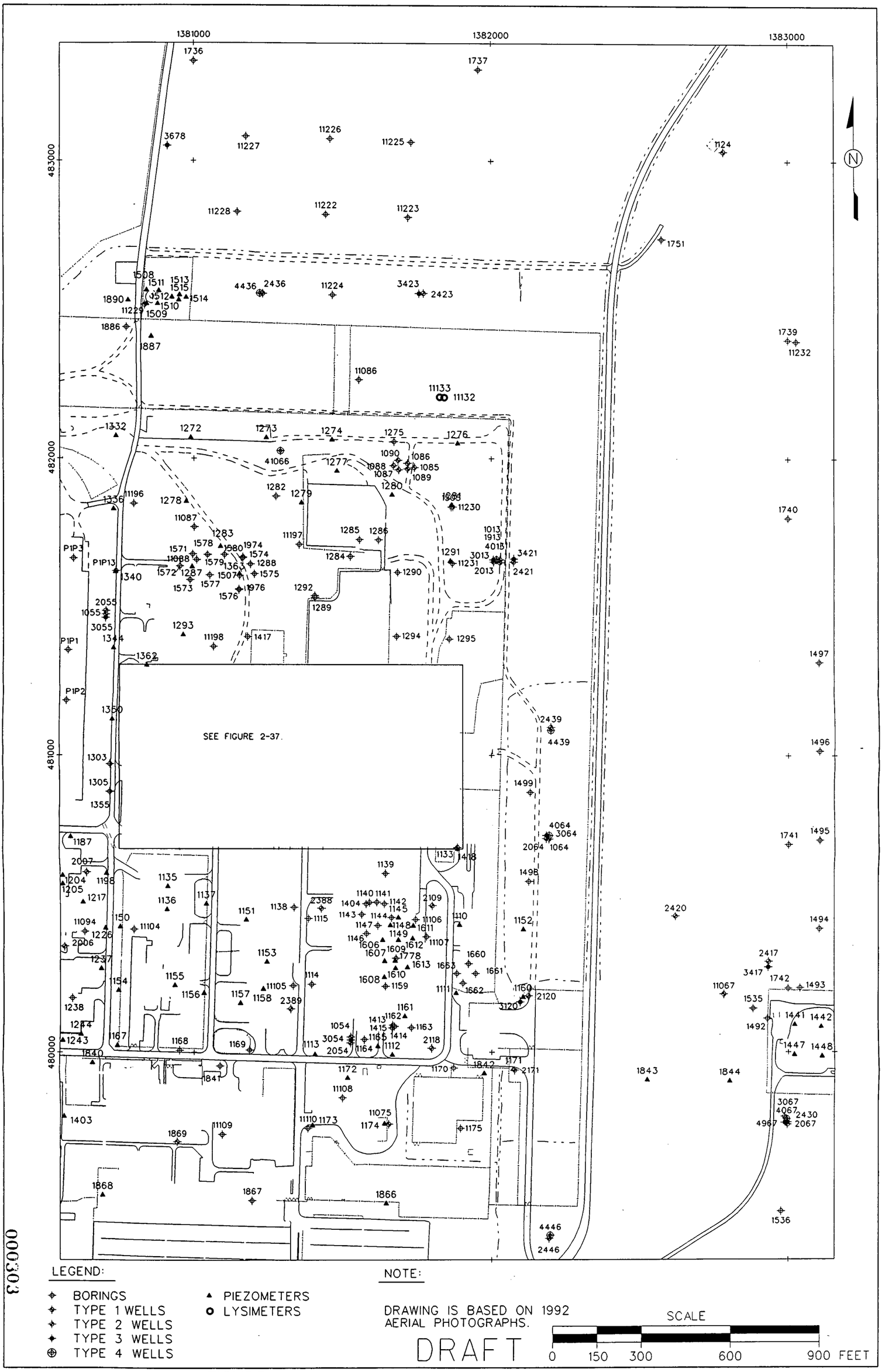
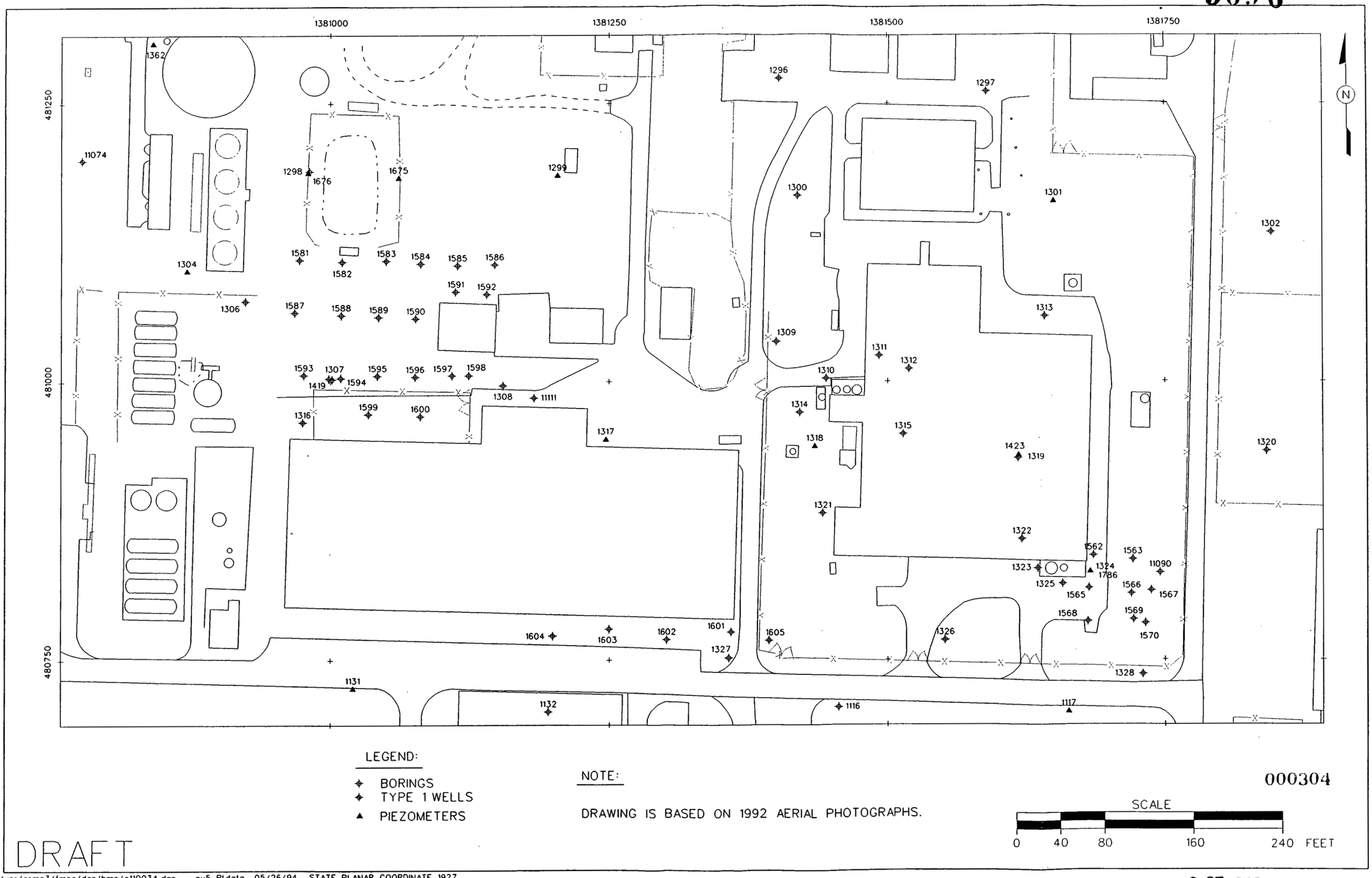


FIGURE 2-36. BORINGS - NORTHEAST AREA OF THE FEMP



LEGEND:

- BORINGS
- TYPE 1 WELLS
- PIEZOMETERS

NOTE:

DRAWING IS BASED ON 1992 AERIAL PHOTOGRAPHS.

SCALE

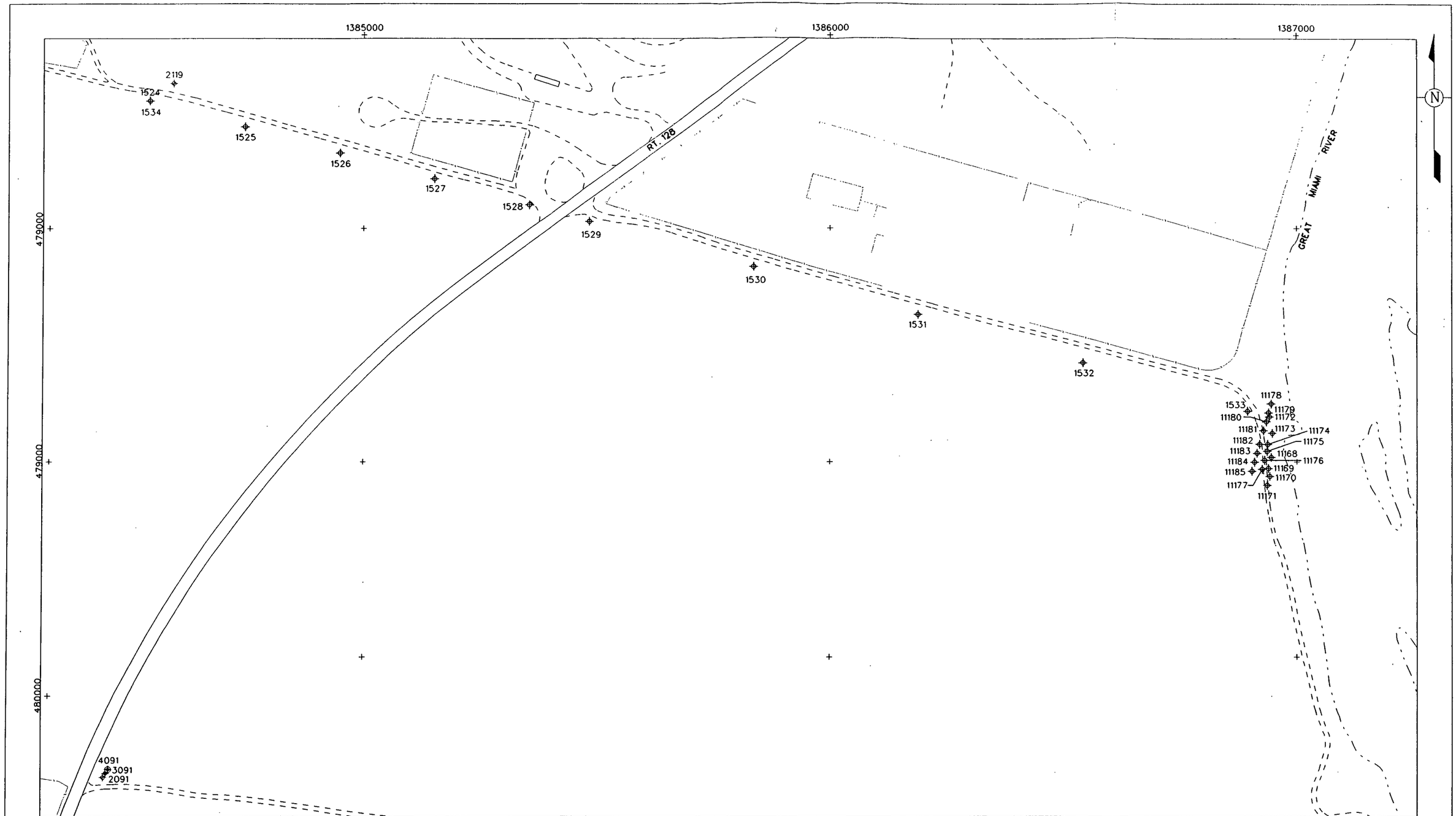
0 40 80 160 240 FEET

000304

DRAFT

/usr/erma3/fmpc/dgn/bmp/c110034.dgn ou5 RI data 05/26/94 STATE PLANAR COORDINATE 1927

FIGURE 2-37. BORINGS
PLANT 9 AND MAINTENANCE AREA



NOTE:

DRAWING IS BASED ON
1992 AERIAL PHOTOGRAPHS.

LEGEND:

- BORINGS
- TYPE 1 WELLS
- TYPE 2 WELLS
- TYPE 3 WELLS
- TYPE 4 WELLS
- FEMP BOUNDARY

SCALE 000305

200 100 0 200 FEET

DRAFT

/usr/erma3/fmpc/dgn/bmp/c110033.dgn ou5 RI data 05/26/94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 2-38. BORINGS
FEMP OUTFALL LINE AREA

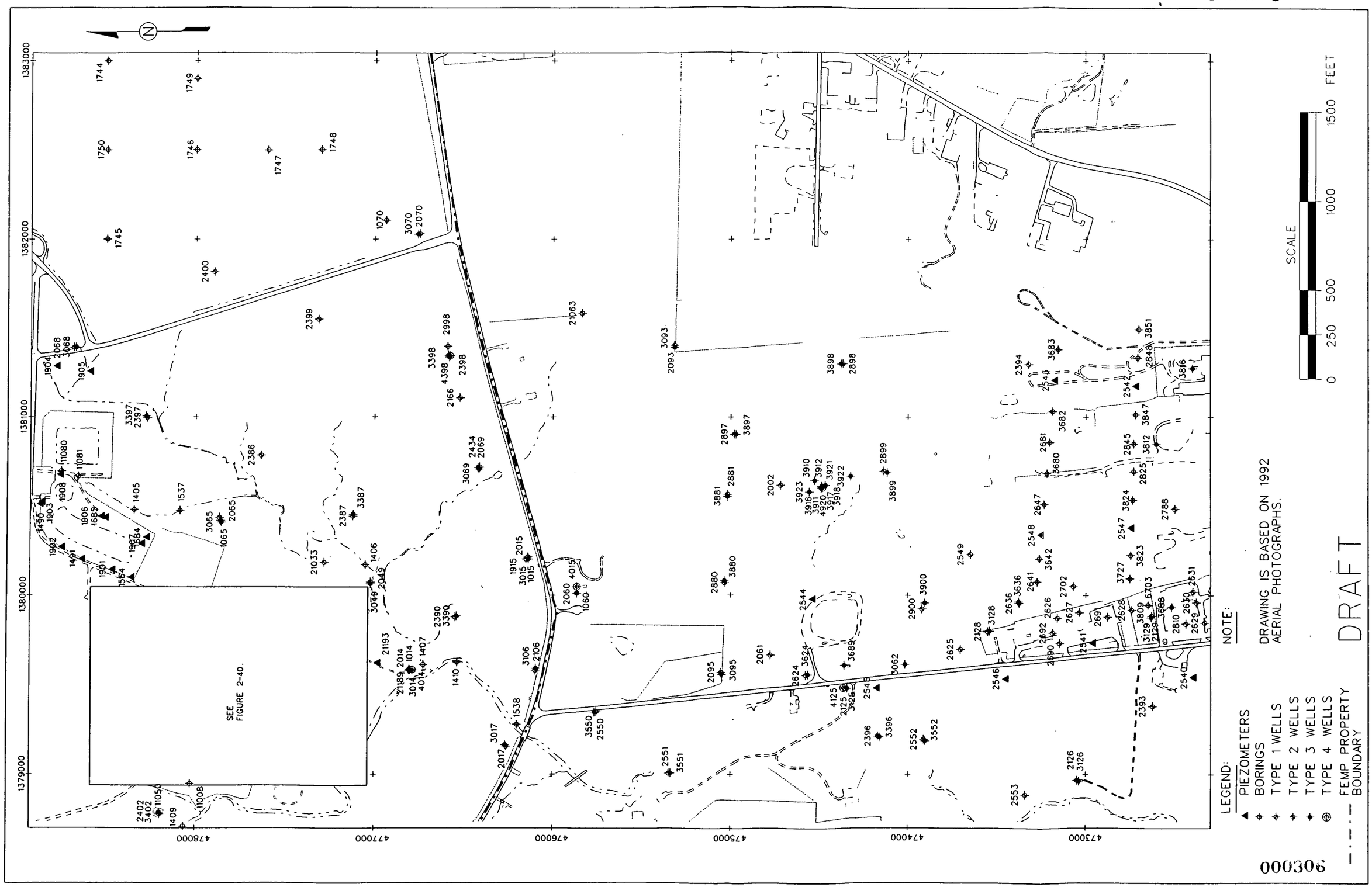
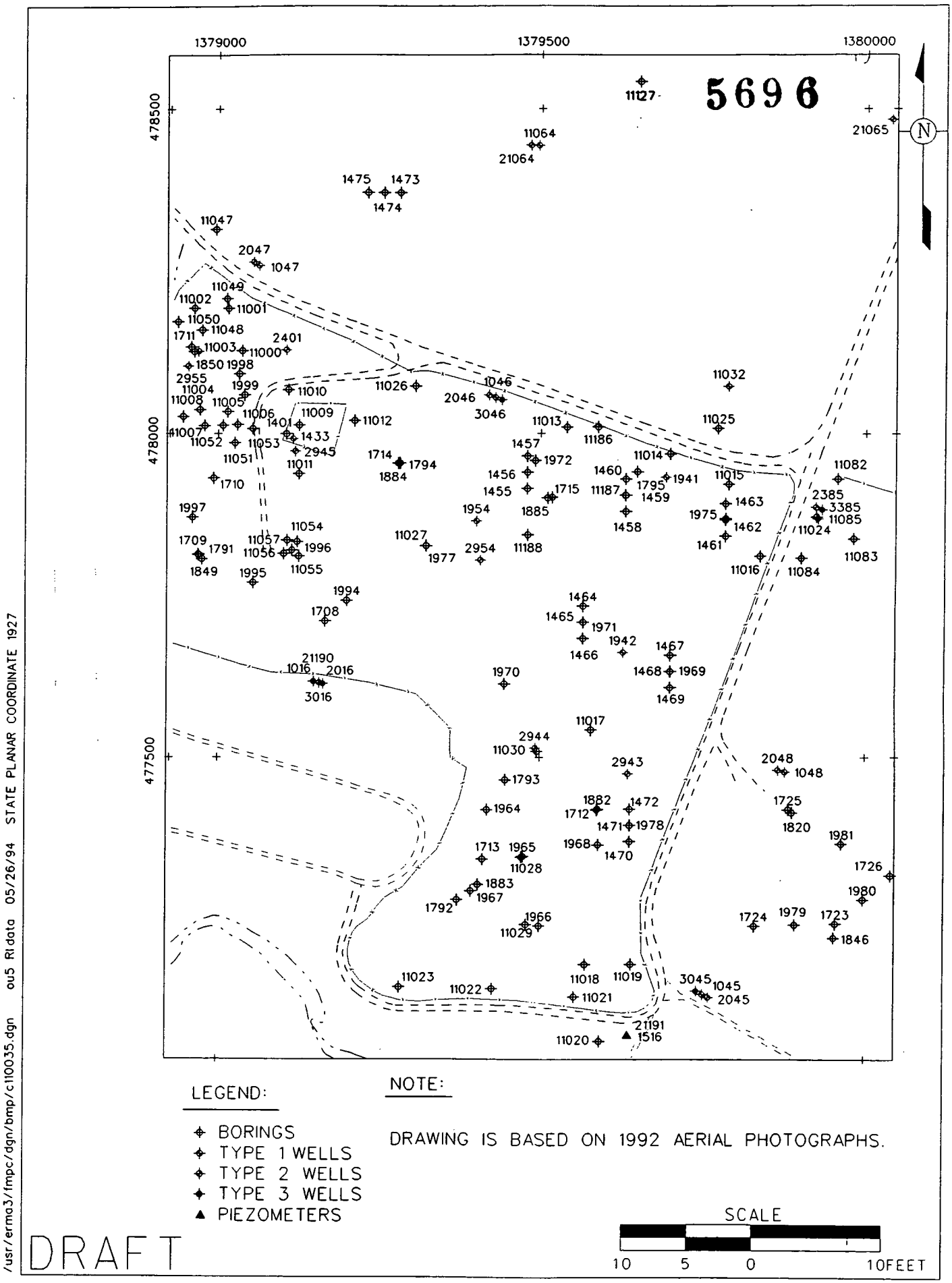


FIGURE 2-39. BORINGS - SOUTHERN PORTION OF FEMP AND SOUTH PLUME AREA

/usr/erma3/fmpc/dgn/bmp/c110032.dgn ou5 RI data 05/26/94 STATE PLANAR COORDINATE SYSTEM 1927



LEGEND:

- BORINGS
- TYPE 1 WELLS
- TYPE 2 WELLS
- TYPE 3 WELLS
- PIEZOMETERS

NOTE:

DRAWING IS BASED ON 1992 AERIAL PHOTOGRAPHS.

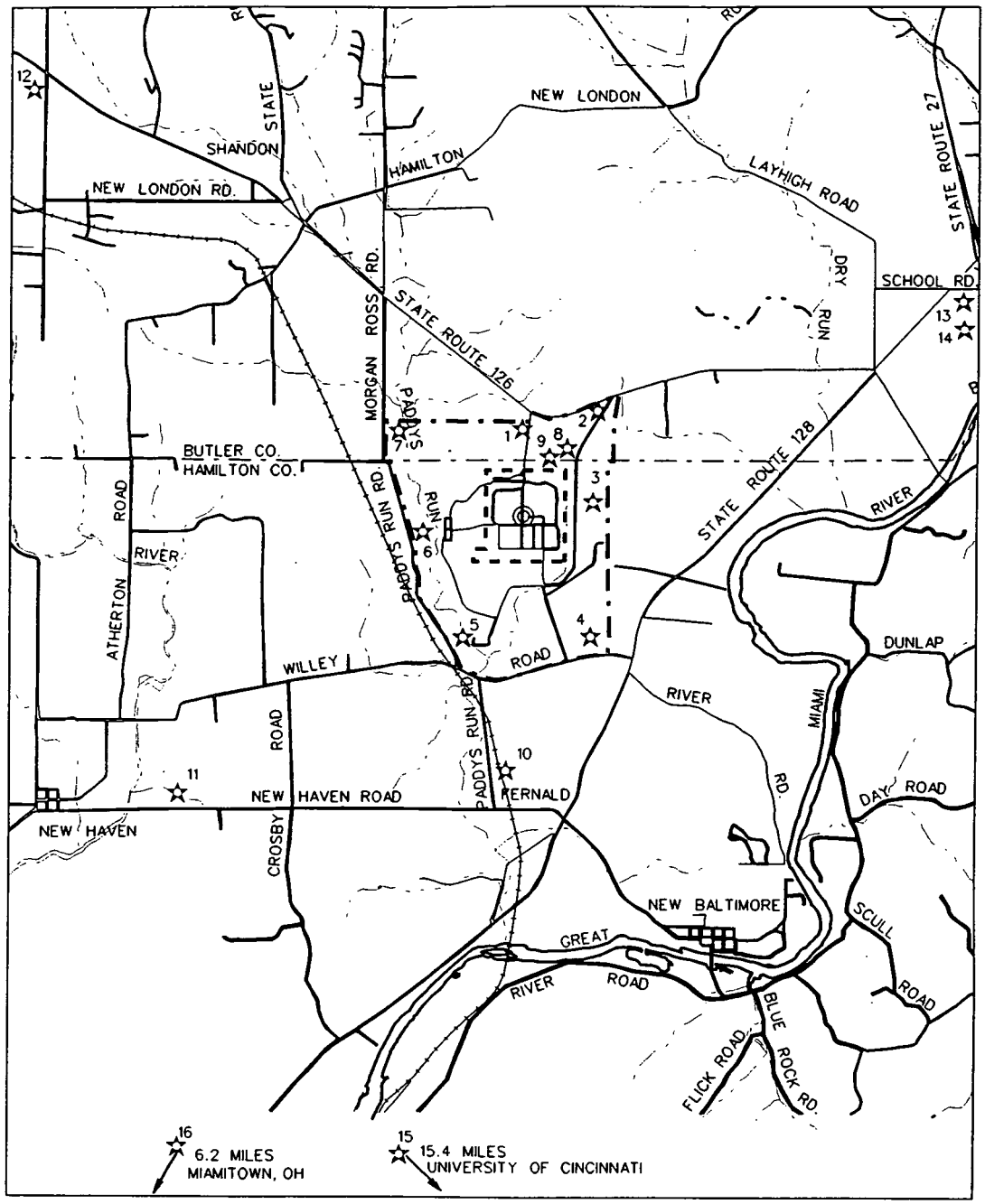
SCALE

10 5 0 10FEET

DRAFT

/usr/erma3/fmpc/dgn/bmp/c110035.dgn ou5 RI data 05/26/94 STATE PLANAR COORDINATE 1927

FIGURE 2-40. BORINGS - SOUTH FIELD AREA



LEGEND:

DISTANCE FROM CENTER OF PRODUCTION AREA TO SAMPLING LOCATIONS OFF MAP

AIR MONITORING LOCATION

FEMP BOUNDARY

PRODUCTION AREA BOUNDARY

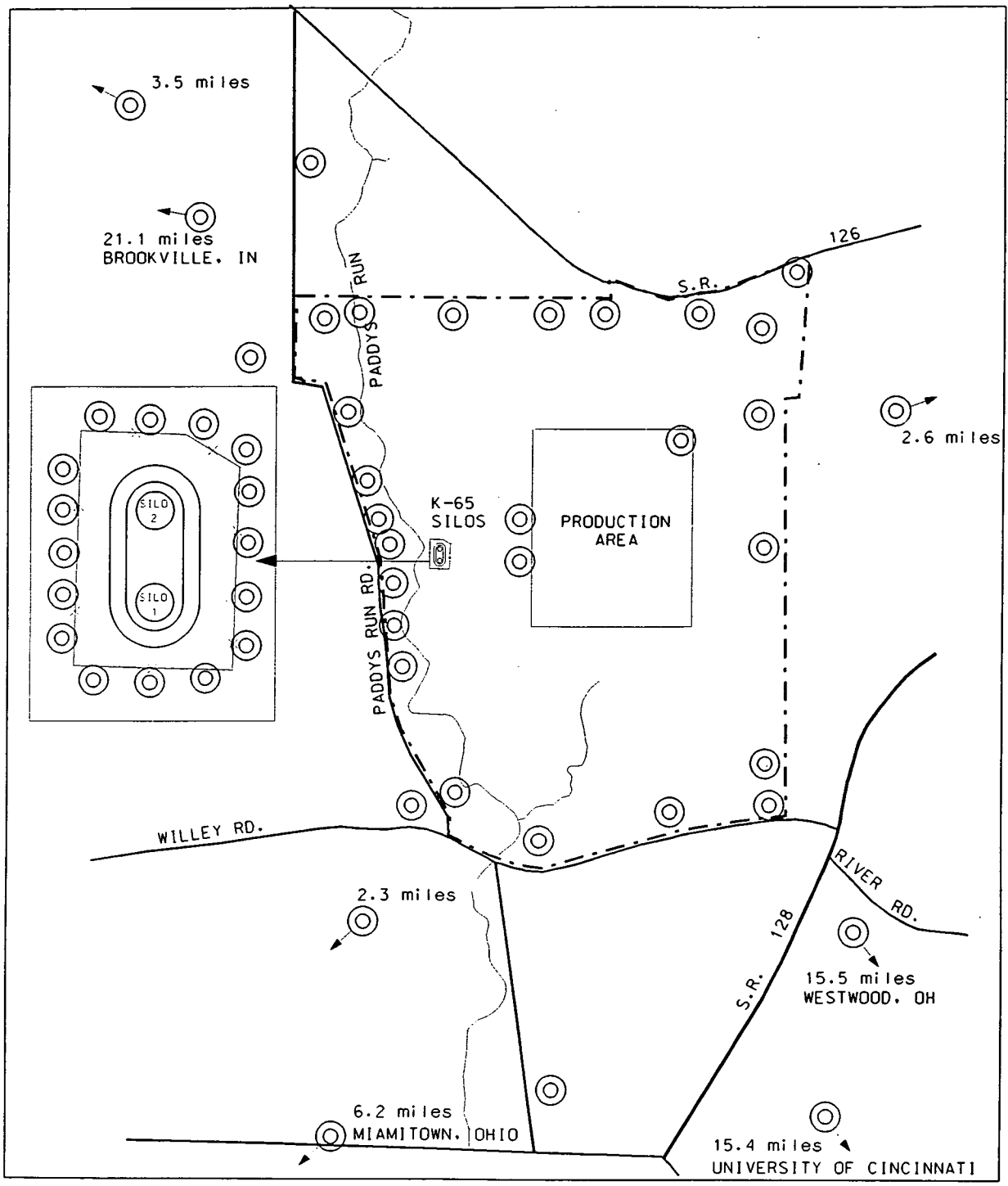
SCALE

1 ½ 0 1 MILE

DRAFT

/usr/ermal/paula/cru5/cru5 air.dgn ou5 RI data 06/13/94

FIGURE 2-41. AIR MONITORING LOCATIONS



LEGEND:

— · — · — FEMP BOUNDARY

◎ AIR MONITORING STATIONS

◎→ DISTANCE FROM CENTER OF PRODUCTION AREA TO LOCATION OFF THE MAP

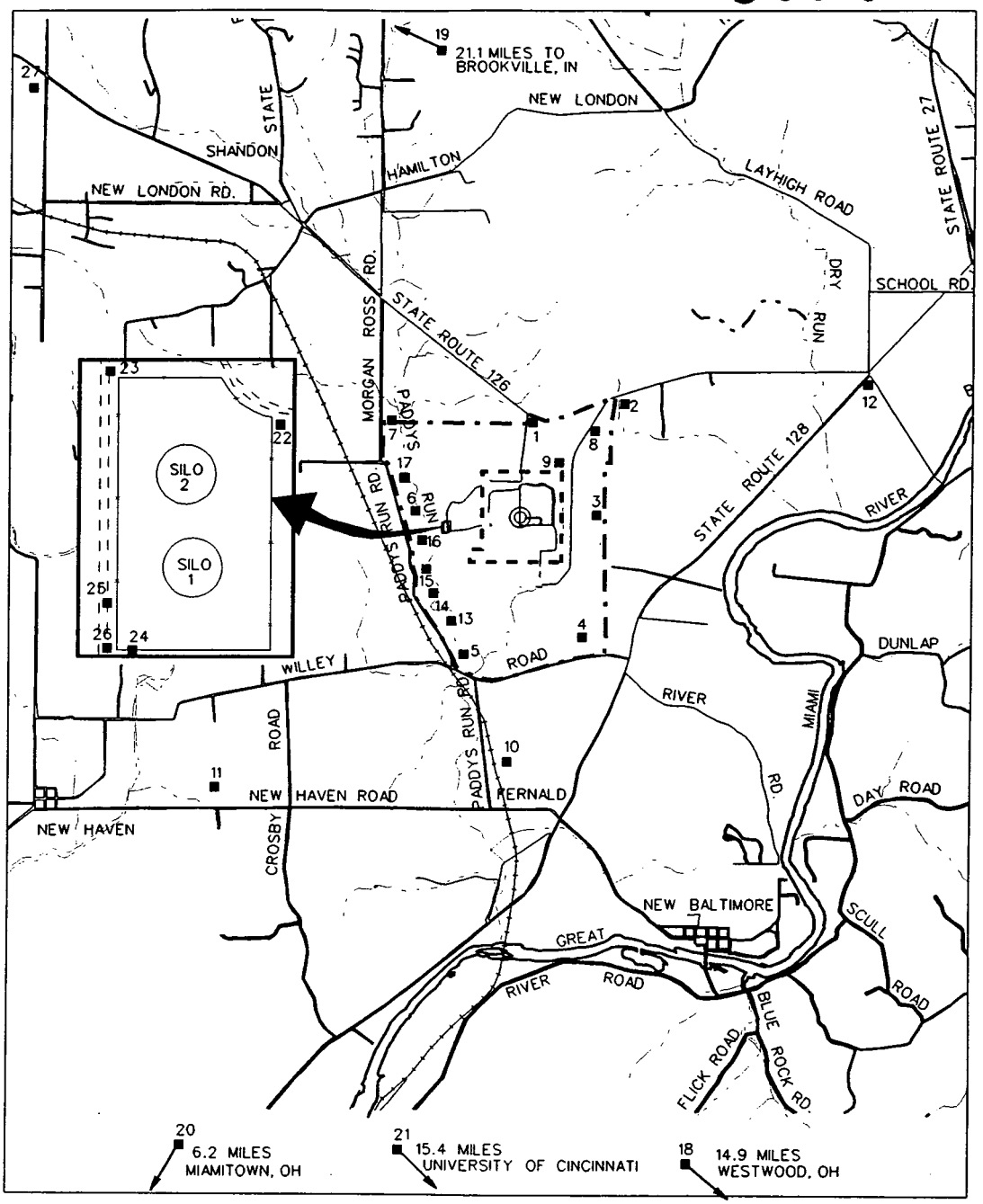
SCALE

1000 500 0 1000 FEET

DRAFT

49195A22.DGN 06/01/94 FER OU5 RIDATA

FIGURE 2-42. RADON MONITORING LOCATIONS



LEGEND:

- DISTANCE FROM CENTER OF PRODUCTION AREA TO DOSIMETER LOCATIONS OFF MAP
- DOSIMETER LOCATION
- FEMP BOUNDARY
- PRODUCTION AREA BOUNDARY

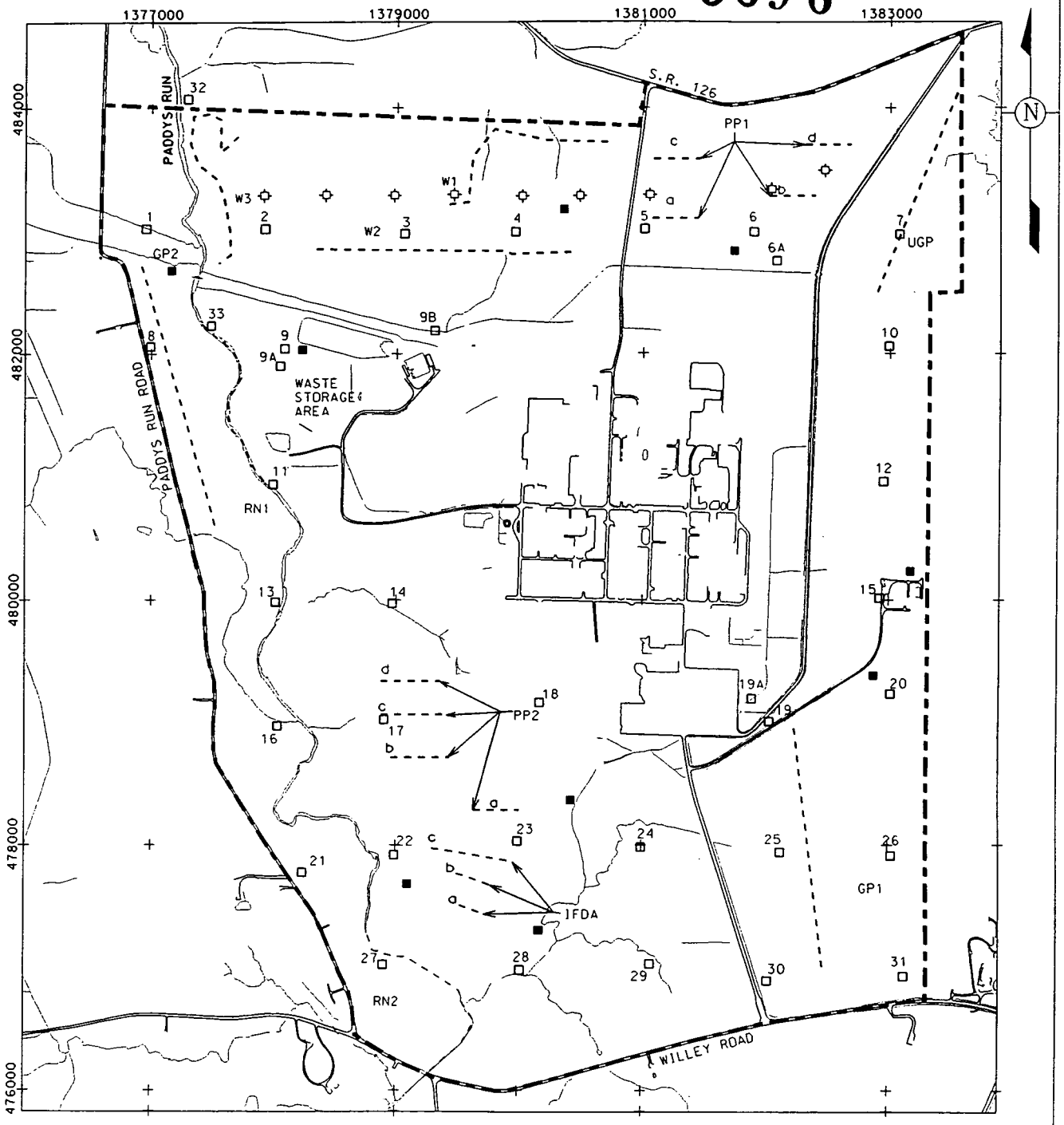
SCALE

1 ½ 0 1 MILE

DRAFT

/usr/ermal/paula/cru5/cru5 pre.dgn ou5 Rldata 05/27/94

FIGURE 2-43. DIRECT RADIATION MONITORING LOCATIONS



LEGEND:

- FEMP PROPERTY BOUNDARY
- WATERWAYS
- RI/FS VEGETATION SAMPLING SITE
- RI/FS MAMMAL TRAP SITE
- EWMF TREE TISSUE SAMPLES
- TRANSECTS: FACEMIRE ET AL. (1990)
- IFDA — INACTIVE FLYASH DISPOSAL AREA
- W — WOOD LOT
- RN — RIPARIAN
- UGP — UNGRAZED PASTURE
- GP — GRAZED PASTURE
- PP — PINE PLANTATION

NOTES:

1. 9A SEEP
2. 9B POND/DRAINAGE DITCH
3. 6A DRAINAGE DITCH
4. 19A DRAINAGE DITCH

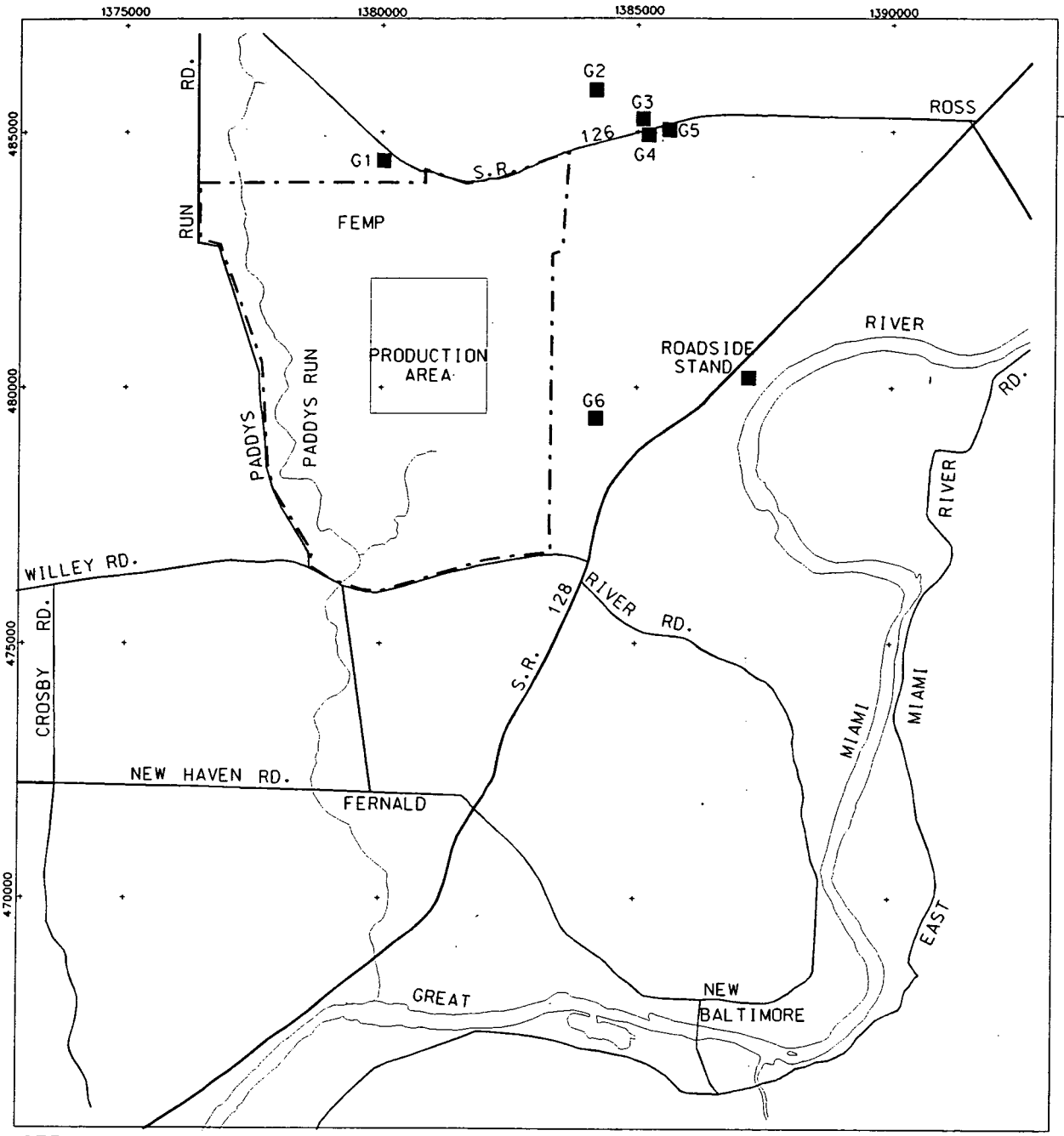
SCALE

0 1100 2200 FEET

DRAFT

/usr/ermol/paula/cru5/cru5veg.dgn ou5 RI data 06/01/94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 2-44. LOCATIONS OF FACEMIRE et al. TRANSECTS AND RI/FS MAMMAL AND VEGETATION SAMPLING SITES



NOTE:

INDIANA CONTROL AREAS
(NOT SHOWN ON MAP)

11 5041 HIGHLAND COURT ROAD, BROOKVILLE, IN N580.923 E687.671

12 SAME AS 11

13 N672.048 E687.671 (SITE COORDINATES)

14 N664.096 E689.594 (SITE COORDINATES)

LEGEND:

■ PRODUCE OR AGRICULTURAL CROP SAMPLING LOCATION

— · — · — FEMP BOUNDARY

G1	3881 CINCINNATI-BROOKVILLE RD.
G2	4033 CHRISTIAN ROAD
G3	3418 CINCINNATI-BROOKVILLE ROAD
G4	3418 CINCINNATI-BROOKVILLE ROAD
G5	3133 CINCINNATI-BROOKVILLE ROAD
G6	N479.398 E1.384.217
ROADSIDE STAND	0.8 MILES NORTH OF WILLEY ROAD ON STATE ROUTE 128, EAST SIDE

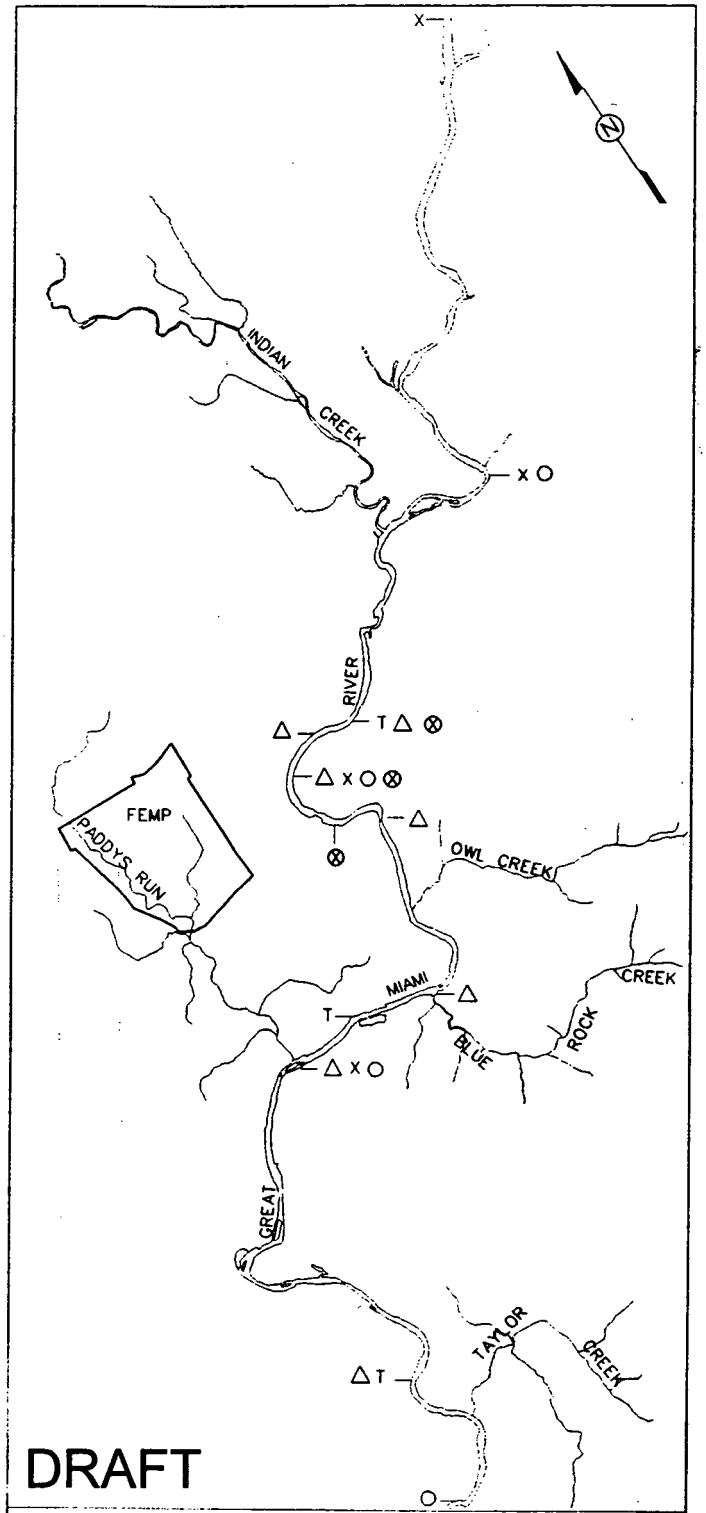
SCALE

6000 3000 0 6000 FEET

DRAFT

49195A21.DGN FER OU5 RIDATA STATE PLANAR COORDINATE SYSTEM 1927 06/01/94

FIGURE 2-45. LOCATION OF 1987/88 RI/FS SAMPLING SITES FOR GARDEN PRODUCE, AGRICULTURAL CROPS, AND SOIL IN THE FEMP VICINITY



DRAFT

LEGEND:

- T TARZWELL, 1951, FISH
- ⊗ POMEROY, 1977, FISH AND MACROINVERTEBRATES
- x ENVIRONMENTAL MONITORING/MILLER et al., 1992, FISH, (RADIOLOGICAL)
- □ FACEMIRE et al., 1986 - 1987, FISH AND MACROINVERTEBRATES
- O RI/FS, 1987, FISH AND MACROINVERTEBRATES (RADIOLOGICAL)
- △ RI/FS, 1988 - 1990, MACROINVERTEBRATES
- G FACEMIRE et al., 1986 - 1987, GENETIC/MORPHOLOGICAL

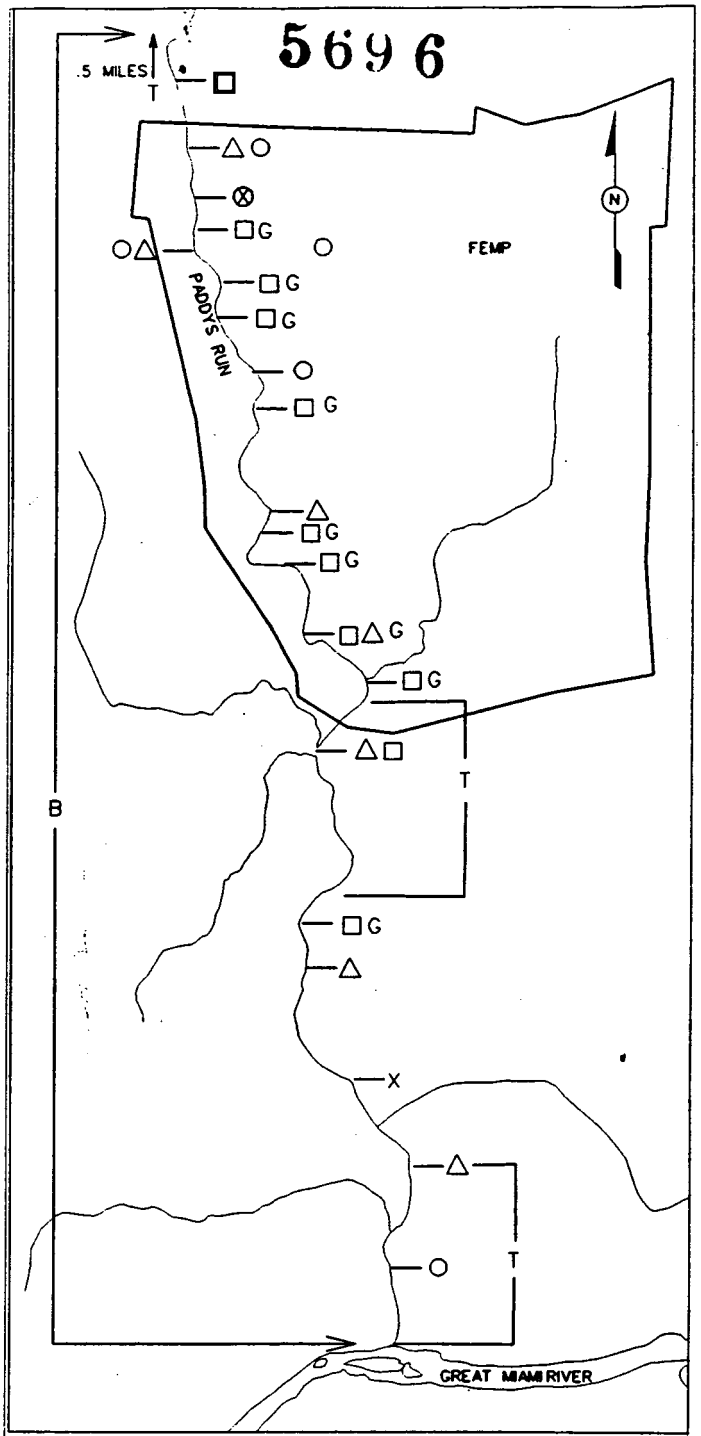
SCALE

0 1 2 3 MILES

CRU5_GMR.DGN 1-28-94

FIGURE 2-46. APPROXIMATE SPECIES SURVEY/SAMPLING LOCATIONS ON THE GREAT MIAMI RIVER

5696



/ermal/paula/cru5/cru5_pr1.dgn 1-21-94

LEGEND:

- T TARZWELL, 1951, FISH
- ⊗ POMEROY, 1977, FISH AND MACROINVERTEBRATES
- x ENVIRONMENTAL MONITORING/MILLER et al., 1992, FISH,
- □ FACEMIRE et al., 1986 - 1987, FISH AND MACROINVERTEBRATES
- O RI/FS, 1987, FISH AND MACROINVERTEBRATES (RADIOLOGICAL)
- △ RI/FS, 1988 - 1990, MACROINVERTEBRATES
- G FACEMIRE et al., 1986 - 1987, GENETIC/MORPHOLOGICAL
- B BAUER, 1972-1973, FISH

SCALE

0 2500 5000 FEET

FIGURE 2-47. APPROXIMATE SPECIES SURVEY/SAMPLING LOCATIONS ON PADDYS RUN

LEGEND:

△ POTENTIAL HABITAT
ADULT CAVE SALAMANDERS ARE NORMALLY FOUND IN LIMESTONE SEEPS, WELLS, SPRINGHOUSES, AND UNDER ROCKS IN SPRING-FED STREAMS.

● KNOWN HABITAT
ADULT CAVE SALAMANDERS HAVE BEEN OBSERVED IN THESE AREAS.

—·—·— FEMP BOUNDARY

SCALE
3250 1625 0 3250 FEET

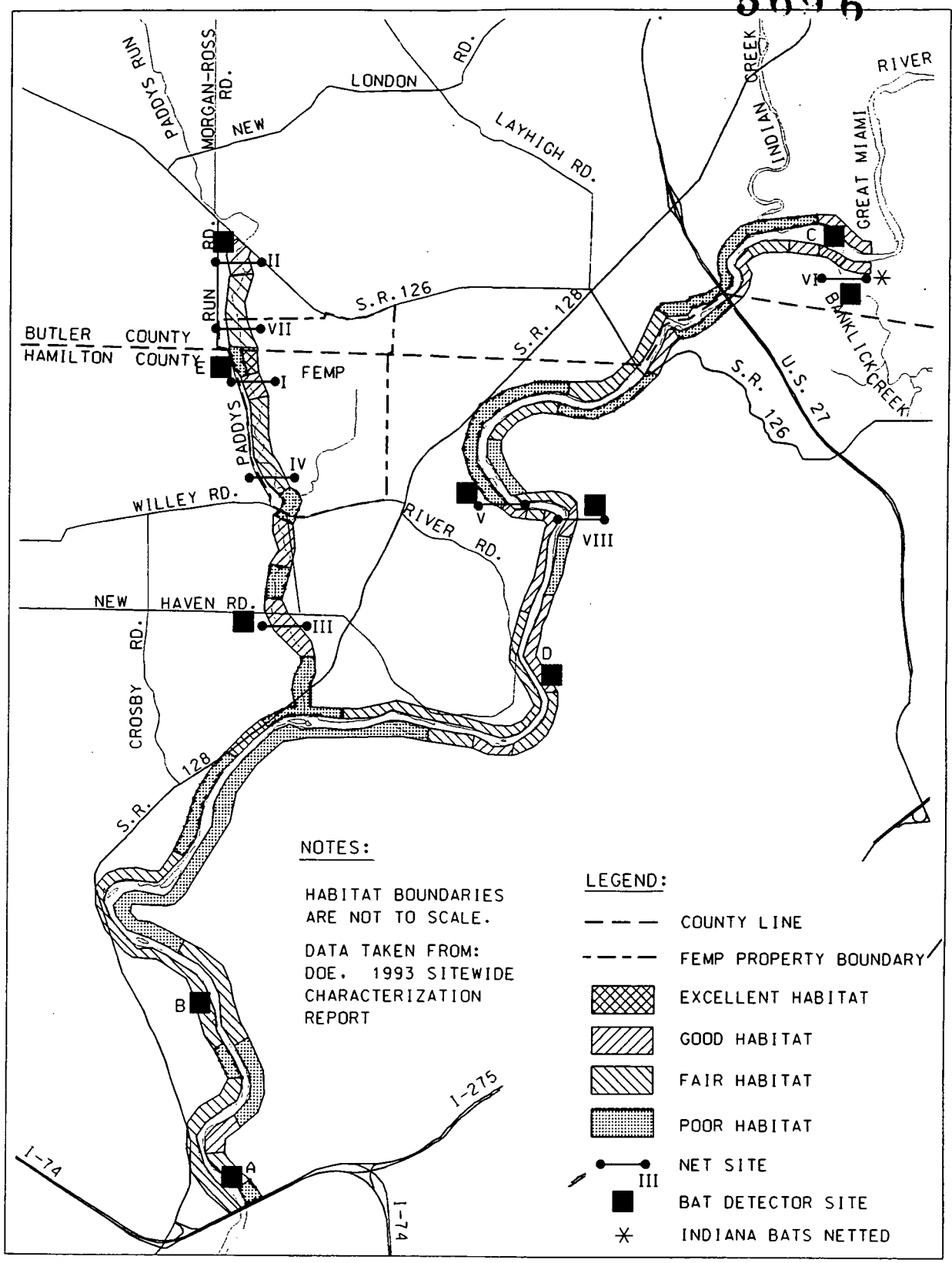
DRAFT

c110061.dgn OUS RIDATA 5-31-94 STATE PLANAR COORDINATE SYSTEM 1927

000314

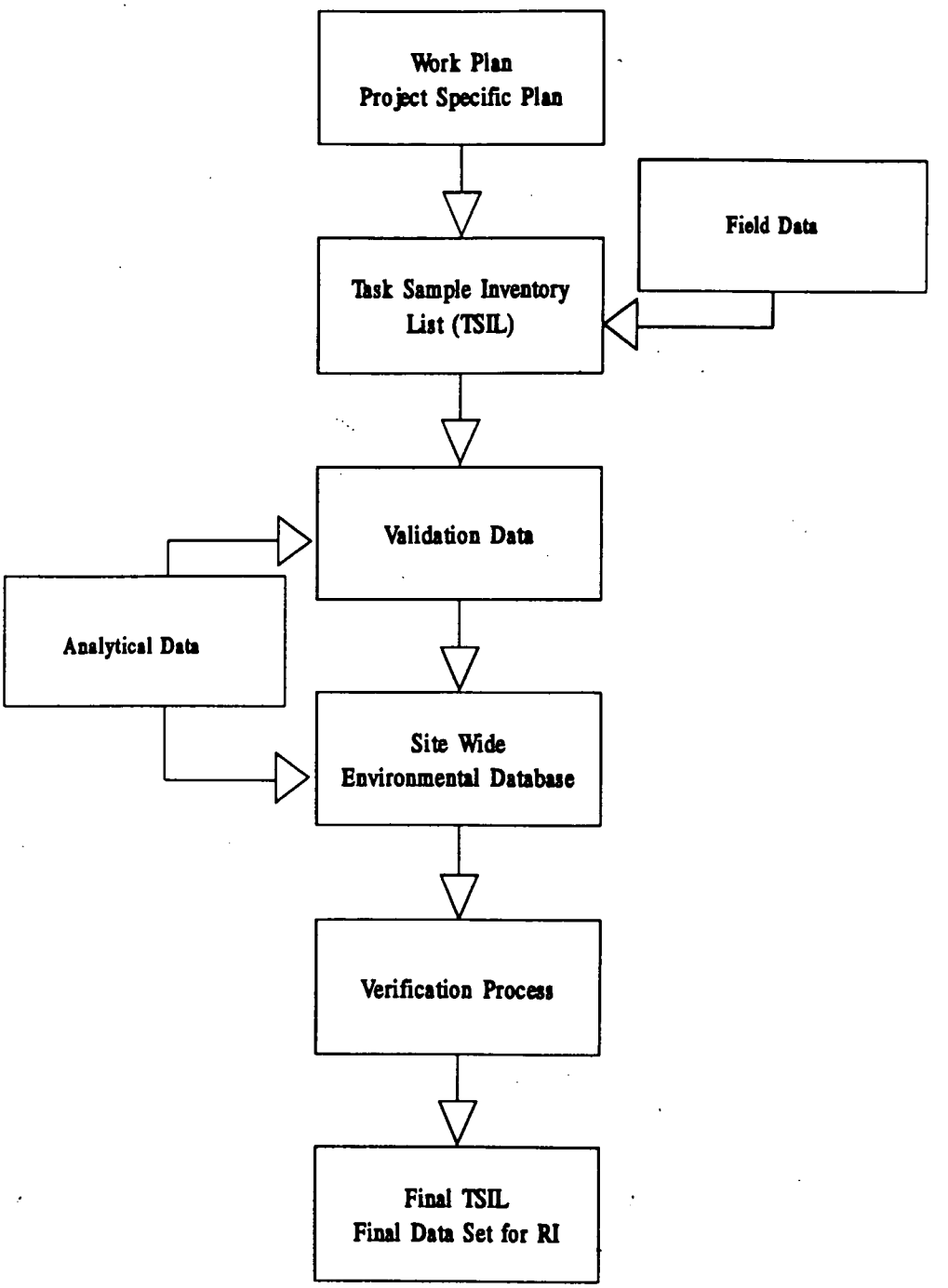
5696

FIGURE 2-48. KNOWN AND POTENTIAL HABITATS OF CAVE SALAMANDERS



DRAFT

FIGURE 2-49. INDIANA BAT SAMPLING SITES AND HABITAT EVALUATION AT THE FEMP AND VICINITY



DRAFT

FIGURE 2-50. DATA MANAGEMENT FLOW CHART

3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

The results of the remedial investigation (RI) and previous studies have been synthesized to provide an understanding of the physical characteristics of the study area and the contaminant pathways present within the study area. These physical characteristics determine how contamination, was dispersed and describe the mechanisms governing contaminant transport. These physical characteristics are also used to predict what will happen to the contamination in the future using the flow and transport modeling presented in Section 5.0. The format of Section 3.0 follows the suggested outline presented in the remedial investigation/feasibility study (RI/FS) guidance document (EPA 1988) except for a slight reordering.

Contaminant transport may occur along the following pathways:

Surface water
- Erosion of contaminated surface soil into Paddys Run and the storm sewer outfall ditch (SSOD)
- Flow of contaminated surface water runoff into Paddys Run and the SSOD
- Discharge of treated or untreated storm water and groundwater into the Great Miami River through the FEMP discharge outfall line

Groundwater
- Leaching of contaminants from contaminated soil through the vadose zone to the underlying Great Miami Aquifer
- Infiltration of contaminated perched groundwater through the vadose zone to the underlying Great Miami Aquifer
- Infiltration of contaminated surface water from Paddys Run and the SSOD to the Great Miami Aquifer
- Natural and induced flow of groundwater in the Great Miami Aquifer which can carry dissolved contaminants and, potentially, contaminants adsorbed to colloidal particles

Air
- Volatilization of organic compounds, wind erosion of contaminated particulate matter, and the direct release of radon gas.

Section 3.0 is divided into eight subsections. The first six sections characterize the physical properties associated with the contaminant pathways outlined above. An understanding of these physical properties is essential to understanding information presented in Sections 4.0 and 5.0. Sections 3.2.5, Water Budget and 3.6.3, Conceptual Model of the Hydrogeology of the Study Area provide summaries of the information presented to that point regarding contaminant pathways. The sections leading up to Section 3.6.3 all present background information as to how parameter values

were determined, or the significance of the value to contamination migration. Section 3.1 discusses topography. Section 3.2 discusses meteorology. Section 3.3 presents surface water hydrology. Section 3.4 presents the geology and soil. Section 3.5 provides basic geochemical data for background groundwater conditions and soil properties. Section 3.6 presents the hydrogeology. Section 3.7 presents demography, land use, archaeology, and historical resources and Section 3.8 presents the ecology.

The regional data are presented using the U.S. Geological Survey (USGS) Shandon 7.5 minute topographic quadrangle as a base map with 10-foot contours and a scale of 1:24,000 (USGS 1981). Data specific to the investigation area is presented on maps derived from the photogrammetric survey conducted for the Fernald Environmental Management Project (FEMP). These maps have either 5- or 1-foot contours and include locations for existing buildings and land features as of 1992. The presentation of the surface features, geology and hydrogeology is presented from a regional perspective and then focus on finer detail through each presentation.

3.1 SURFACE FEATURES

The advance and retreat of continental glaciers shaped the local topography and created the hydrogeologic setting of the RI area. The FEMP site and surrounding area lie at the southern edge of the Till Plains section of the Central Lowland physiographic province. The bedrock of the province is characterized by broad structural and sedimentary basins and domes.

3.1.1 Topography

The topography in the area of the RI includes gently rolling uplands with steep hillsides along the major streams such as the Great Miami River. The main topographic feature in the vicinity of the FEMP is the New Haven Trough, a relatively broad, flat-bottomed valley flanked on either side by bluffs that rise to a maximum of 300 feet above the general level of the valley floor, as shown in Figure 3-1.

Maximum elevation along the northern boundary of the FEMP property is a little more than 700 feet above mean sea level. The production and waste storage areas rest on a relatively level plain at about 580 feet elevation. The plain slopes from 600 feet along the eastern boundary of the FEMP to 570 feet at the K-65 silos, and then drops off towards Paddys Run at an elevation of 550 feet (Figure 3-1). All natural surface drainage on the FEMP is from east to west and south into Paddys

Run, with the exception of the extreme northeast corner where approximately 23 acres drain east toward the Great Miami River.

Construction activities altered the topography of the FEMP in the production and waste storage areas. In 1952 the production area was extensively graded to create a land surface that sloped evenly from north to south. Rough grading maps from 1952 indicate that up to 10 feet of surface material was removed from the northeast half of the production area and used to fill low areas in the south and southwest portions. During construction of the waste pits, that area was extensively regraded. On the west side of Pit 3 and the Clearwell, the top of the berm is approximately 30 feet above the original grade. Farther south, along the edge of the Paddys Run Valley, the South Field and flyash piles were emplaced partly on glacial overburden and partly on the Great Miami Aquifer where the glacial overburden had been eroded away by Paddys Run.

3.2 METEOROLOGY

Information on the local climate was obtained from the on-property meteorological system installed at the FEMP in 1986 and the National Weather Service (NWS) office at the Greater Cincinnati/Northern Kentucky International Airport. Rainfall records that supplement the NWS data were obtained from the Miami Conservancy District, whose staff collect data along the Great Miami River.

3.2.1 Prevailing Winds

The FEMP meteorological system became operational in the mid-1980s and collects site-specific data for wind speed and direction, lapse rate, dew point, temperature, relative humidity, barometric pressure, and precipitation. The FEMP meteorological system was used by the National Oceanic and Atmospheric Administration (NOAA) to examine the complexity of the local wind field at the Fernald site (U.S. Dept. of Commerce 1989). The NOAA study showed that two major features affect the site: the Great Miami River Valley and the ridges surrounding the site. A study by International Technology Corporation (IT) (1986) showed that the wind flow data from the Greater Cincinnati/Northern Kentucky International Airport were sufficiently representative of local conditions to serve as a database for the years before the installation of the on-property meteorological system.

On-site wind data is available for 1988, 1989, and 1991 through 1993; records are not available for 1990 due to equipment problems. Figure 3-2 shows the wind patterns at the FEMP recorded from the 33-foot sampling station and is a composite of data from 1988 and 1989, 1991 and 1992.

Figure 3-2 represents typical conditions and clearly shows that prevailing winds are generally from the southwest and west-southwest. Figure 3-3 is the wind rose for the FEMP with 1993 data only. The patterns in Figures 3-2 and 3-3 indicate that local wind patterns are consistent year to year at the FEMP.

The most frequent adverse weather conditions in the region occur from severe thunderstorms and tornados. As part of the probabilistic risk assessment performed for the FEMP (DOE 1990), an annual probability was assessed for a tornado occurring per square mile within Ohio. Based on accumulated data for Ohio during the years 1978 through 1990, the annual probability was calculated to be 1.25 in 10,000.

3.2.2 Precipitation

The average annual precipitation for the Greater Cincinnati area for the 30-year period from 1963 through 1992 was 40.86 inches and ranged from 27.99 inches in 1963 to 57.58 inches in 1990. The highest precipitation occurs during the spring and early summer. The maximum 24-hour rainfall event on record occurred in March 1964 when 5.21 inches fell. Precipitation is typically lowest in late summer and fall.

A histogram (Figure 3-4) summarizes precipitation recorded at the Greater Cincinnati/Northern Kentucky International Airport by the NWS from 1988 to 1993. Also shown are data from FEMP on-property precipitation measurements taken during 1993 and data available from New Baltimore and the Southwestern Ohio Water Company's (SOWC) collector well, Hamilton (8 miles north) and Fairfield (3 miles northeast). Figure 3-4 shows that the pattern of rainfall is similar at all stations although the monthly totals vary slightly. Therefore, historic data from the NWS station at the airport represents conditions in the immediate area of the FEMP and can be used in models that estimate rainfall and surface runoff.

The average annual snowfall for the 1963-64 to 1991-92 30-year period was 22.9 inches, with the heaviest snowfall usually occurring in January. The maximum monthly snowfall of 31.5 inches occurred in January 1978. The maximum recorded snowfall over a 24-hour period occurred in March 1968 when 9.8 inches were recorded at the Greater Cincinnati/Northern Kentucky International Airport.

3.2.3 Temperature

The regional climate is defined as continental, with temperatures ranging from a monthly average of 29.2°F in January to 75.7°F in July. The highest temperature recorded from 1963 through 1992 was 103°F in July 1988, and the lowest was -25°F in January 1977. Average ambient air temperatures measured by the FEMP meteorological system for 1987 through 1993 are shown in Table 3-1. The average number of days per year with a minimum temperature of 32°F or less is 109 days, and the average number of days per year with a maximum temperature of 90°F or greater is 20 days. Maximum frost depth ranges from 30 to 36 inches.

3.2.4 Evapotranspiration

Evapotranspiration is the amount of water present in the soil that is lost to the atmosphere by either evaporation from the soil or transpiration by plants. Evapotranspiration depends on a number of factors including temperature, relative humidity, solar radiation, and wind speed. Evapotranspiration is also dependent on the soil moisture content, soil type, and the type and maturity of vegetative cover. Moisture levels in the soil fluctuate seasonally. The moisture content is generally lowest in late summer and is replenished during the late fall, winter, and spring. Moisture needs of most crops are greatest in July and August when rainfall is generally insufficient to meet the needs of the vegetation; therefore, the soil progressively dries out during summer.

Table 3-2 presents the average daily evapotranspiration in Ohio with typical agricultural crop ground cover between April and September (USDA et al. 1970). The majority of water loss by evapotranspiration occurs during these months in Ohio. The total evapotranspiration during this period under cloudy, normal, and bright conditions is 17.4, 22.4 and 28 inches, respectively. These seasonal totals indicate that deviations from the norm (22.4 inches) are approximately ±25 percent.

The Ohio Department of Natural Resources (ODNR) has prepared water loss estimates for Ohio (Harstine 1991). Water loss is defined as the difference between the 50-year average annual precipitation and stream flow. With the assumption that other water losses due to seepage to deep semiconfined aquifers are negligible, water loss should equal evapotranspiration. For the FEMP area, the 50-year average annual water loss is 26 inches. With the assumption that average annual water loss may vary by ±25 percent as is the case for evapotranspiration, the expected range is 19.5 to 32.5 inches per year (in./yr), which is consistent with the range given in Table 3-2.

Potential evapotranspiration (PET) is defined as the evapotranspiration which would occur if there was always an adequate water supply available to a fully vegetated surface. This term implies an ideal water supply to the plants. If the water supply available to the plants is less than the PET, the deficit will be drawn from soil moisture storage until about 50 percent of the available supply is used. As soil moisture is removed, the actual evapotranspiration will decrease below the PET until the wilting point is reached and evapotranspiration ceases (Schultz 1980).

Table 3-3 indicates the total annual PET is 26.73 inches. This estimate is essentially identical with the Harstine (1991) estimate of 26 inches. Table 3-3 also lists the range of PET, assuming ±25 percent variation due to cloudy and bright conditions, to be 20.05 to 33.42 inches/year for the FEMP area. On an annual basis, precipitation exceeds PET by about 5 to 9 inches. This excess water takes the form of surface runoff and aquifer recharge, which will be discussed in Sections 3.3 and 5.3.

Table 3-3 also gives the monthly precipitation gain/deficit (rainfall minus PET). The average PET exceeds precipitation in June, July, and August by 2.1, 3.5 and 3.3 inches, respectively. This estimate of evapotranspiration is consistent with field observations during the RI and indicates that evapotranspiration has an impact on the potential migration of contaminants in the perched groundwater system by removing water from the glacial overburden in the summer months. Many shallow drainages and seeps, as well as portions of Paddys Run, dry up in late May or June and remain dry until late in the fall. Therefore, during the summer, perched groundwater is removed by evapotranspiration rather than migrating laterally to drainages. This means that the surface water pathway modeling is conservative in that it assumes steady-state conditions and does not take credit for the reduced potential for groundwater to migrate during the summer months.

3.2.5 Water Budget

Figure 3-5 illustrates the general water budget for the FEMP area. The annual average precipitation is 40.86 inches, or approximately 41 inches, Section 3.2.2. The 50-year annual average water loss due to evapotranspiration is approximately 26 inches (Section 3.2.4). Based on these two values approximately 15 inches of the annual precipitation is available for surface water runoff and aquifer recharge. Of this 15 inches, it is estimated that where glacial overburden is present that approximately 6 inches recharges the Great Miami Aquifer and 9 inches becomes surface water runoff. Surface water runoff is to the west-southwest, following surface topography (Section 3.1.1).

These estimates for recharge and surface water runoff are consistent with previous studies and calibration results of the SWIFT Great Miami Aquifer Model-Summary of Improvements Report (DOE 1994j). Spieker (1968a) estimated that the annual rainfall recharge rate to the Great Miami Aquifer in the Fairfield-New Baltimore area ranges from 6-21 inches. This area of coverage is much larger than the RI study area and extends far to the north where hydrogeologic conditions are different than those found at the FEMP. Walton and Schaefer (1956) estimated Great Miami Aquifer recharge for an area just east of the FEMP property. They estimated that recharge in the area of the SOWC pumping wells was 8.5 inches/year. This estimate was made for a year of near-average precipitation. Glacial overburden does not overlie the Great Miami Aquifer in the area of the SOWC wells. Glacial overburden does overlie the Great Miami Aquifer beneath the FEMP property. As is further explained in Sections 3.4 and 3.6, the glacial overburden serves to restrict infiltration; therefore, recharge over the FEMP site should be lower than recharge at the SOWC wells.

Calibration of the SWIFT Great Miami Aquifer flow and transport model and hydraulic conductivities of glacial overburden sediment also support a recharge to the Great Miami Aquifer in the lower end of the 6-15 inches per year range. As is presented in Section 3.6.1.1, the geometric mean of the horizontal hydraulic conductivity for the gray clay is in the glacial overburden, calculated from slug tests, is 1.87×10^{-6} cm/s. Vertical hydraulic conductivity is usually smaller than horizontal hydraulic conductivity due to bedding planes and depositional features which impede the downward movement of groundwater. A one order of magnitude difference is realistic, which indicates the vertical hydraulic conductivity of the gray clay in the 10^{-7} cm/s range. A recharge value of 6 inches/year implies a vertical hydraulic conductivity in the 10^{-7} cm/s range, under a unit hydraulic gradient (DOE 1993c). This leaves approximately nine inches of precipitation each year available for the surface water runoff pathway.

3.3 SURFACE WATER HYDROLOGY

The FEMP is located within the Great Miami River Basin drainage (Figure 3-6). The Great Miami River is the receiving stream for the FEMP waste water effluent discharge and represents the main surface water feature in the vicinity of the FEMP. The river flows generally to the southwest and has a drainage area of approximately 3360 square miles (mi^2) at the Hamilton gauge, which is located about 10 miles upstream from the FEMP discharge outfall.

The river exhibits meandering patterns that result in sharp directional changes over distances of less than 3000 feet. Directly east of the FEMP and within the RI/FS study area, the river passes through a 180-degree curve known as the "Big Bend" (Figure 3-7). A 90-degree bend in the river also occurs near New Baltimore, approximately two miles downstream from the FEMP point of discharge (Figure 3-1).

The average discharge of the Great Miami River at Hamilton, based on 55 years of records, is 3305 cubic feet/second (ft^3/s) (Miami Conservancy District 1993). Using drainage area scaling, the corresponding average flow at the FEMP point of discharge has been estimated to be 3460 ft^3/s. The maximum discharge ever recorded for the Great Miami River at Hamilton occurred on March 26, 1913 and was estimated to be 352,000 ft^3/s. The maximum discharge since the construction in 1922 of five retaining basins, located approximately seven miles upstream of Hamilton, was 108,000 ft^3/s and occurred on January 21, 1959. The 100-year-flood discharge has been calculated to be 81,455 ft^3/s for the site reach. The minimum daily discharge of 155 ft^3/s was recorded on September 27, 1941. This value is approximately half of the 7-day, 10-year low flow value (Q_{7-10}) of 267 ft^3/s, as computed by the USGS for the Hamilton gauge. This translates to 280 ft^3/s at the site reach for a 7-day, 10-year low flow.

3.3.1 Surface Drainage on the FEMP

Natural surface drainage from the FEMP is primarily to Paddys Run. Paddys Run originates north of the site, drains southward along the west side of the FEMP, and enters the Great Miami River approximately 1.5 miles south of the FEMP (Figure 3-7). Paddys Run is an ungauged, intermittent stream that flows primarily between January and May, with an estimated discharge for this period ranging between 0.2 and 4.0 ft^3/s (Dames & Moore 1985). Peak flows have not been measured. Paddys Run loses flow to the underlying aquifer along much of its course on and south of the FEMP due to its highly permeable channel bottom which is eroded into the Great Miami Aquifer. Infiltration modeling discussed in Section 5.3.2 indicates that recharge through the Paddys Run channel to the Great Miami Aquifer occurs at a rate of approximately 14 inches per year. The surface water model development and results are contained in DOE 1994i.

The course of Paddys Run has been artificially modified by FEMP construction activities at least twice. Part of Paddys Run previously flowed close to the waste storage area, but in 1961 it was diverted to the west, away from the waste pits to assure that Paddys Run would not erode the west

berm of Pit 3. A basin was left between the waste pits and the new channel of Paddys Run. A second modification occurred in 1970, downstream of the K-65 silos (Figure 3-8 shows the location of the waste pits and silos). In this case, Paddys Run was straightened to prevent erosion of Paddys Run Road. Sand and gravel were removed from the bed of Paddys Run, just south of the K-65 silos, between 1952 and 1985 (WMCO 1987) for FEMP construction activities. Neither of these modifications changed the potential migration pathway because they did not cut into the glacial overburden on the east side of Paddys Run where all the FEMP contaminant source areas are located.

A principal drainage feature of the FEMP is a tributary to Paddys Run known as the SSOD. This drainage course originates east of the former production area, flows southwest across the southern portion of the site, and enters Paddys Run near the southwest corner of the property (Figure 3-9). The stream bottom in the southern portion of this drainage course is composed of sand and gravel which is part of the Great Miami Aquifer. Given the geologic similarity, the vertical seepage rates through the stream bottom are similar to Paddys Run. Like Paddys Run, the SSOD drainage courses are generally dry in the summer and fall, with flows occurring during and immediately after precipitation.

The SSOD historically conveyed surface water runoff from the production area directly to Paddys Run when the capacity of the storm sewer lift station (Figure 3-7), which diverts low-flow storm water to Manhole 175, was exceeded. A storm water retention basin (SWRB) was constructed in October 1986 and expanded with construction of a second chamber in December 1988. After at least a 24-hour retention period to allow for settling of suspended solids, the water is pumped out of the basin to the Great Miami River via the FEMP's effluent line. The basin is designed to retain the runoff from a 10-year, 24-hour rainfall event; only in the event of an overflow would storm water from the production area now enter the SSOD.

Table 3-4 lists the overflow events and the estimated volume of water that has been discharged to the SSOD during each event. Since the last overflow on May 17 and 18, 1990 the pumpout capacity of the basin has been increased as part of Removal Action 3. Construction of the east chamber of the SWRB necessitated relocation of a portion of the drainageway upstream of the storm sewer discharge point and the SWRB spillway. Since 1988 the flow from the headwater area on the eastern side of the production area has been directed around the east and southern sides of the east chamber of the

SWRB. The storm sewer discharge point and the SWRB overflow are now on a short tributary to the main water course that makes up the SSOD drainage.

The completion of Removal Action 16 in August 1993 improved the collection of surface water runoff along the perimeter of the production area. Figure 3-7 shows the area where runoff is controlled and directed to the SWRB. Before Removal Action 16, surface water exited the west side of the production area into the waste storage area and the pilot plant drainage ditch on the west and exited the southeast corner of the production area, near the electrical substation, into the upper portion of the SSOD. As will be discussed in Appendix C, these drainages carried contaminated surface water.

3.3.1.1 Controlled Drainage

Surface water has always been collected in the production area and discharged to the Great Miami River or the SSOD. With the installation of the SWRB the discharge to the SSOD has virtually been eliminated. The improvements in operation of the basin and the impact of Removal Action 16 have culminated in a reduction of contaminants being released from the FEMP. Discharge from the basin occurs after particulate matter has settled out of the water, thus reducing the amount of contamination being discharged to the Great Miami River.

Waste pit surface runoff for Pits 1, 2 and 3 has been diverted to the Clearwell since they were capped. Surface water runoff from the perimeter area of the waste storage area previously entered Paddys Run via three tributaries. The southernmost of the three entered Paddys Run just south of the Clearwell and north of the silo area. Before the construction of storm water runoff controls of Removal Action 2 in 1992, this stream drained the area northeast of the biodenitrification surge lagoon including the northwest corner of the former production area and the Plant 1 Pad. The northern tributary drained along the north side of Pit 5 and entered Paddys Run immediately south of the railroad tracks. The smallest of the drainages was between Pits 3 and 5 and discharged into the basin area between Pit 3 and Paddys Run. Figure 3-7 shows the former discharge points. The 1992 implementation of Removal Action 2 diverted the flow of these three streams into a collection sump (Figure 3-8) that allows for treatment of the water before discharge through Manhole 175 to the Great Miami River. The removal action also diverted the surface runoff from the area east and south of the biodenitrification surge lagoon to the pilot plant drainage ditch via a culvert.

The surface water runoff controls depicted in Figure 3-8 prevent the migration of contaminated surface water from the waste storage and production areas to Paddys Run and the SSOD and subsequent infiltration to the Great Miami Aquifer or surface flow to the Great Miami River.

3.3.1.2 Uncontrolled Drainage

Several drainageways on the FEMP property are not controlled and thus are potential pathways for surface contaminants to reach Paddys Run, the Great Miami Aquifer, or the Great Miami River. Figure 3-9 is a topographic map using 5-foot contours developed from the 1992 flyover survey that shows the location of the uncontrolled drainages for comparison to the controlled area in Figure 3-8. Section 1.3 describes the potential source areas and Section 4.5 discusses the nature of contamination in these drainageways. Beginning on the north side of the FEMP and moving counter clockwise around the FEMP the uncontrolled drainages shown in Figure 3-8 are:

North side drainage ditch
Pilot plant drainage ditch
Southwest drainage ditch
South drainage ditches
Storm sewer outfall ditch
Southeast drainage ditches
East side drainages ditch
Northeast drainage ditch

The area north of the waste storage and production areas drains into the north side drainage ditch which flows to Paddys Run along the north side of the railroad tracks. As indicated in the wind rose in Figures 3-2 and 3-3, prevailing winds are to the northeast so this drainage area could contain contamination from air releases. The fire training area and the solid waste landfill, north of the production area, are also in this drainage basin.

Located to the south of the waste storage area and west of the production area, the pilot plant drainage ditch receives storm water from the area south of the pilot plant (discussed in Section 1.3.4.10). As shown in Figures 3-8 and 3-9, the pilot plant drainage ditch currently receives surface water from the area between the biodenitrification surge lagoon and the production area. During the winter and early spring this ditch has a number of springs along both banks that drain the glacial overburden.

Between the pilot plant drainage ditch and the SSOD is a large relatively flat area. Surface water drains to Paddys Run from this flat area as indicated in Figure 3-9. The southwest drainage ditch has eroded a gully approximately half way between the pilot plant drainage ditch and the inactive fly ash pile.

The three south drainage ditches flow from the area north of the South Field to Paddys Run or the SSOD through or adjacent to the Operable Unit 2 investigation areas. One stream has eroded a gully adjacent to the west side of the inactive flyash pile and flows directly into Paddys Run. The second drainage consists of ditches on each side of the road that separate the South Field from the active flyash pile. These ditches carry water into the Paddys Run alluvium which lies directly on the Great Miami Aquifer, resulting in a combination of infiltration into the aquifer and flow to Paddys Run. The third stream has eroded a shallow gully on the north side of the active flyash pile and flows into the SSOD in an area where infiltration to the Great Miami Aquifer occurs (Figure 3-10).

The SSOD receives the bulk of the remainder of the uncontrolled runoff from the FEMP property. The southeast drainages bring surface water from predominantly agricultural land south of the FEMP and east from pastures in the southeast corner of the FEMP. As shown in Figure 3-9, the east side drainage collects water from the area east of the production area including the area surrounding the sewage treatment plant and inactive incinerator.

The northeast drainage, in the very northeastern corner of the FEMP, is the only drainage that flows east off the FEMP to the Great Miami River (Figure 3-1). As shown in Figure 3-9, this stream has cut a deep gully and has eroded to the level of the floodplain of the Great Miami River where it flows on alluvium and infiltrates into the Great Miami Aquifer or reaches the Great Miami River.

3.3.2 Aquifer Recharge from Surface Streams

In the area of the FEMP there is only minor recharge to the Great Miami Aquifer in areas where streams and wetlands occur on the glacial overburden due to the very low hydraulic conductivity of the glacial overburden (discussed further in Section 3.6.1.1). In areas where streams have cut through the glacial overburden, there is a much greater potential for infiltration due to the high hydraulic conductivity of the Great Miami Aquifer (discussed further Section 3.6.2.1). Infiltration modeling (discussed in Section 5.3.2) indicates that recharge through the Paddys Run channel to the

Great Miami Aquifer occurs at a rate of approximately 14 inches per year. The surface water model development and results are contained in DOE 1994i.

Figure 3-10 shows the areas where infiltration is most likely to occur because the stream has eroded through the glacial overburden and illustrates the gaining and losing stretches of Paddys Run and the SSOD. These stretches are determined by comparing elevations of monthly water table maps from 1990 and the streambed elevations. Between the waste pit area and a point just south of the SSOD, Paddys Run is losing water to the aquifer. The elevation of the streambed is above the water table in the aquifer and the stream thus loses water through its bed to the aquifer. The water table elevation and the streambed elevations are very close in the area labeled Zone B in Figure 3-10. In the half-mile stream interval south of the SSOD, Paddys Run may be losing to or receiving water from the aquifer depending on the season. Even in dry weather Paddys Run is always receiving water from the aquifer in the half-mile stretch of stream north of New Haven Road. From approximately New Haven Road to the Great Miami River, Paddys Run is again a losing or gaining stream depending on the season.

Figures 3-11 and 3-12 show that a high degree of correlation exists between the Paddys Run hydrograph and the regional aquifer hydrographs. These hydrographs are based on data collected at 60-minute intervals using pressure transducers and a data logger at a well cluster (Location 014) on Paddys Run above the confluence with the SSOD (Figure 3-10). The data were collected from a stilling well constructed in the bed of Paddys Run and from Well 2014 located approximately 10 feet from the bank of Paddys Run. As the Paddys Run hydrograph peaks during a storm event, the groundwater hydrograph shows a peak a very short time later, indicating a very strong hydraulic connection between the stream and the regional aquifer.

As a result of infiltration to the aquifer, sections of Paddys Run are dry much of the summer. Surface flow and aquifer recharge are greatest between late fall and early spring when storms are frequent and soil moisture levels are sufficient to provide a base flow between storm events. Because Paddys Run and the SSOD lose water to the underlying aquifer, these streams are a significant pathway to the aquifer for contaminant transport. Surface water discharges from the former production area to the SSOD and from the waste storage area to these losing surface streams are the major direct pathway by which contaminants reached the aquifer.

3.4 GEOLOGY AND SOIL

Published investigations of the geology in the FEMP area include Fenneman (1916), Durrell (1961), and Spieker (1968b), Soil Conservation Service (SCS) mapping (USDA et al. 1980, 1982), and Brockman (1988). A comprehensive geologic history has been developed for the FEMP and surrounding area based on these published studies, with modifications and extensions resulting from data collected during the RI/FS.

The Illinoian age outwash deposits in the buried valleys and the Wisconsin age glacial overburden are of primary concern in the RI because they both contain groundwater. Groundwater is the pathway most likely to transport contaminants to off-property receptors. The valley fill has regional significance and the glacial overburden, due to its limited lateral extent, has local significance under the FEMP property itself.

Sections 3.4 and 3.6 present the physical setting that limits the occurrence of groundwater and the factors that control the direction and rate of groundwater movement. Section 4.7 and 4.8 will present the nature and extent of contamination within both the local and regional groundwater systems. Section 5.0 presents predictions of the future migration of contaminants via the groundwater pathway using computer models calibrated against the information presented here and in Section 4.0.

3.4.1 Geologic History

The geologic history of the FEMP is based upon Fenneman (1916), Brockman (1988), and the FEMP RI/FS investigations. In summary, the FEMP overlies a 2- to 3-mile-wide buried Pleistocene valley known as the New Haven Trough. This valley was eroded by the ancestral Ohio River during the Pleistocene and was subsequently filled with glacial outwash sands and gravel that were in turn covered by glacial overburden as a younger glacier advanced across the area. The outwash deposits under the FEMP are a part of the Great Miami Aquifer, which is a widely distributed buried valley aquifer. The valley fill aquifer system is a major source of drinking water and industrial water in southwestern Ohio. Much of the buried valley aquifer in the Great Miami River Basin has been designated a "Sole Source Aquifer" by the U.S. Environmental Protection Agency (EPA). This designation is given to aquifers that, if contaminated, would pose a significant risk to public health.

In Late Ordovician time (approximately 450 million years ago), sediment that would become a predominantly flat-lying shale with thin interbedded limestone as deposited in a shallow sea. This

shale comprises the relatively impermeable bedrock which underlies the FEMP area and forms the highlands surrounding the Great Miami River and its tributaries.

Before the Pleistocene glaciation (approximately 2 million years ago), the area was relatively flat, sloped to the north and contained a northward flowing drainage system. This system was referred to as the Teays River System and consisted of two major streams with many tributaries. At some time during the Early Pleistocene epoch, this north-flowing river system was disrupted by the advance of Nebraskan and Kansan continental glaciation. Today the remnants of the Teays drainage system can be found in the Cincinnati area on bedrock highs well above the elevation of the Great Miami Aquifer.

During the mid- to late-Pleistocene period, three major continental glaciers advanced to the north of the Cincinnati area. These were the Kansan (more than 1.2 million years ago), Illinoian (approximately 125,000 to 400,000 years ago), and Wisconsin (approximately 11,000 to 70,000 years ago) glacial episodes (Durrell 1982). The drainage system that developed south of the advancing ice sheets was known as the Deep Stage Drainage System. In the Cincinnati area the Deep Stage Drainage System was composed of the ancestral Ohio River and three major tributaries: the Miami River, the East Fork of the Little Miami River, and the Licking River (Figure 3-13A). The Miami River followed much the same channel as the present-day Great Miami River from Middletown to Ross. The East Fork of the Little Miami River entered the Cincinnati area from the northeast. The Licking River came in from the south in its present-day channel, but continued to the north of the present-day Ohio River.

These three rivers combined to form what is known as the ancestral Ohio River (Figure 3-13A) which entered the Cincinnati area from the east along the present-day channel of the Ohio River, then turned northeast through the valley now occupied by the Little Miami River. There it was joined by the East Fork and flowed west through the Norwood Trough to the Mill Creek Valley, where it joined the Licking River. The ancestral Ohio River then flowed north through the Mill Creek Valley and west where the Miami River joined it south of Hamilton. It continued to the southwest through the New Haven Trough which underlies the FEMP to near Harrison, where it turned and flowed south through what is now the Whitewater River Valley.

Several tributary streams of later importance entered the main stream in the vicinity of the FEMP. Two streams originated near Miamitown. One flowed north to join the ancestral Ohio River between Shandon and Fernald and the other flowed south following the course of the present-day Great Miami River. Two other small streams originated near New Baltimore and flowed north to the main stream. The Dry Fork of the Whitewater River, which now lies to the west of the area, formerly flowed east to Shandon and then south through what is now the Paddys Run Valley (Figure 3-13A) to the ancestral Ohio River.

During the time of Deep Stage Drainage and the early stages of Illinoian Glaciation, the river valleys cut deeply into the shale bedrock to depths up to 200 feet below current valley floor elevations. As the Illinoian ice sheet advanced into the area, ice began to block the Miami River and its confluence with the ancestral Ohio River. This caused water to pond in the Mill Creek Valley. For a time, water still flowed to the west along the front of the advancing ice sheet and carved the present-day Great Miami River Valley along what had been the tributary system near Miamitown (Figure 3-13A) and New Baltimore.

When the confluence of the Miami River and the ancestral Ohio River was completely blocked, the ponded water in the Mill Creek Valley rose until it overflowed low divides and carved outlets at Anderson's Ferry and at what is now downtown Cincinnati. This created the present-day channel of the Ohio River (Figure 3-13B). As the ice retreated, the valleys of the Deep Stage Drainage were filled with well-sorted sand and gravel outwash deposits forming the Great Miami Aquifer system, and the Great Miami and Ohio rivers were established in their present-day channels.

The last stage of glaciation, the Wisconsin, was much less disruptive to the drainage in the area. The ice sheet advanced only as far as the south side of the FEMP. The main effect of this glacial advance in the area of the FEMP was the displacement of the Dry Fork of the Whitewater River from its historic channel into its present-day channel. As it retreated, the ice deposited a moraine which formed a dam and lake over much of what is now the FEMP. The dam was breached, draining the lake permanently. The lake basin is now part of the Paddys Run drainage basin. The impact of the Wisconsin glacial advance will be discussed in greater detail in Section 3.4.3.

Since the last retreat of continental glaciers, the streams in the area have removed portions of the glacial overburden. The Great Miami River has eroded laterally to remove glacial overburden east of

the FEMP and has exposed a wide floodplain on the glacial outwash deposits that comprise the buried valley aquifer. Paddys Run and its tributaries are also in contact with these deposits in the stream's lower reaches.

3.4.2 Ordovician Bedrock Geology and Seismology

Published investigations of the bedrock geology in the FEMP area that were reviewed include Fenneman (1916), Scotford (1965), Spieker (1968b), Bassarab and Huff (1969), Booth and Osborne (1971), Watkins and Spieker (1971), Butler and Scotford (1973), Swinford (1990), and Schumacher et al. (1991).

Bedrock in the area is shale and fossiliferous limestone of Middle and Late Ordovician age approximately 450 million years old (Fenneman 1916). It outcrops on steep valley walls and in numerous interstate highway road cuts in southwestern Ohio. In the area included in the RI at the FEMP the bedrock layers are essentially horizontal, contain little or no usable groundwater and are not a part of any significant contaminant pathway. Bedrock in southwestern Ohio is generally covered with a thin layer of glacial deposits that ranges in thickness from a few feet at higher elevations to as much as 400 feet where buried valleys exist. These glacial deposits contain groundwater and are the focus of the RI at the FEMP.

The shale and thin fossiliferous limestone beds that comprise the bedrock units found in the FEMP area formed in a shallow sea that existed during Ordovician time. Figure 3-14 provides a stratigraphic column for the bedrock in the Cincinnati area. The oldest formation is at the bottom of the column; subdivisions of the formations, lithologic description, and a range of thicknesses for the formations are also included. In general, shale predominates the bedrock until the latest time. Thus the steeper bluffs along the New Haven Trough contain more limestone than the bedrock in the bottom of the buried valleys.

Regionally, the FEMP lies in the Central Lowland physiographic province, which is characterized by broad structural basins and domes. Among these features is the Cincinnati Geoanticline, or "Cincinnati Arch," a broad, gently sloping structural ridge. The FEMP is located near the axis of this structural arch which exposes some of the oldest bedrock in the state of Ohio. Within the RI area the bedrock layers are essentially horizontal.

Watkins and Spieker (1971) performed extensive seismic refraction surveys to determine the thickness and extent of the sand and gravel deposits filling the bedrock valley. Test drilling was used in conjunction with the refraction surveys to verify the accuracy of the seismic determination of the depth of the valley floor. A map of the top of bedrock has been compiled from the bedrock map produced by Watkins and Spieker (1971), with additional information provided by Leow (1985), Vormelker (1985), and wells constructed for the RI. Top of bedrock elevation contours are shown in Figure 3-15. The bedrock valley system in the vicinity of the FEMP consists of the New Haven Trough and its tributaries and is depicted in Figure 3-16.

Based on published regional geological maps of southwestern Ohio, there are no major faults, active or inactive, in the vicinity of the FEMP. However, the presence of minor faults cannot be completely dismissed, since Paleozoic rocks are largely covered by Pleistocene sediment and fault traces older than the Pleistocene could be obscured.

The historical record of seismicity and the absence of post-Wisconsin faults show that significant damage from local earthquakes at the FEMP is unlikely. Throughout the 19th and 20th centuries, no damaging earthquakes have been recorded within 71 miles of the FEMP. Nine earthquakes caused minor damage at a distance of between 71 and 199 miles from the FEMP, and one earthquake caused localized damage at Anna, Ohio, about 75 miles north of the FEMP.

Three earthquakes that occurred at New Madrid, Missouri, in 1811-1812 resulted in ground motions equivalent to intensity levels of VI and VII on the Modified Mercalli Intensity (MMI) which are the highest recorded accelerations for the Cincinnati area. The closest reported earthquakes to the FEMP occurred near Maysville, Kentucky, approximately 63 miles southeast of Cincinnati: two with an intensity of V MMI in 1928, one with an intensity of V MMI in 1933, and one with an intensity of III in 1937.

There were approximately 37 earthquakes from 1928 through 1939 in the Anna, Ohio area, 75 miles north of the FEMP. Two of these events had an intensity level of VII MMI, one an intensity of VII-VIII MMI, one an intensity of VI+ MMI, and one an intensity of VI MMI (DOE 1990).

The Uniform Building Code's (International Conference of Building Officials 1988) indicates the seismic risk zone for the Cincinnati area is one on a scale of zero to four. This indicates that a slight earthquake could occur in the region of the FEMP.

3.4.3 Glacial Geomorphology

The glacial history of the RI area is in part reflected in the shape of current land forms. It is important to know this history of ice movement across the FEMP area because it is the geologic deposits resulting from the advance and retreat of the ice that now control the migration of contaminants at the FEMP.

Continental glaciers move because they are fluid and as snowfall increases their thickness in northern regions, the downward pressure causes the edges of the ice to flow outward. As the ice advances it shears off topographic highs and fills low areas in its path with till composed of ground rock and soil. The ice also carries rock and debris on its surface. Ice continues to advance as long as the flow of ice outward exceeds the rate at which the leading edge of the ice is melting. Thus, even if the leading edge of the ice seems to be stationary, rock and till continue to be brought into the area. The edge of the maximum ice advance is therefore marked by a ridge composed of till pushed up by the advancing ice and deposits of debris carried by the flowing ice. The deposits at the edge of the ice are referred to as a terminal moraine.

Although glaciers are said to "retreat," there is no physical movement back to the area from which the ice advanced. Instead, the rate of flow of the ice from the source area is less than the rate at which the leading edge of the ice is melting back towards the source area. Thus, debris carried forward on or within the flowing ice is deposited on the ground as the leading edge of the ice retreats. If the rate of melting occasionally is less than the rate of ice flow, a new moraine will develop; because it develops at a line where the retreat of the ice pauses, it is called a recessional moraine. Because the leading edge of the ice is always melting there is an abundance of water at the leading edge. During ice advance this water carries sand, silt, and clay into lakes which form behind the moraines.

Figure 3-17 is a portion of the Shandon topographic quadrangle map (USGS 1965). Arrows have been added to show the probable movement of the ice sheet that moved down what is now Paddys Run Valley. This small ice lobe deposited the clay-rich glacial overburden on top of the valley fill

outwash deposits at the FEMP. North of the New Haven Trough the ice was confined laterally by the steep bluffs on either side of the valley. When the ice reached the New Haven Trough it was no longer confined and spread laterally as it crossed the trough. As the ice moved forward it deposited a layer of till and pushed up a low ridge at its leading edge. The low ridge west of Paddys Run is the topographic expression of the terminal moraine from this ice advance. The farthest advance of the southern edge was at least to the bedrock bluffs on the south side of the New Haven Trough (Figure 3-18) and may have been as far as the Great Miami River south of Fernald. The rising topography on the east side of the FEMP suggests that the crest of the terminal moraine was slightly east of the eastern boundary of the FEMP. Lateral erosion by the Great Miami River has removed the moraine east of the FEMP.

As the ice retreated a lake formed behind the terminal moraine (probably located in the vicinity of Fernald). The shores of the lake reached a maximum elevation of approximately 580 to 585 feet. Eventually, probably due to a combination of erosion at the outlet of the lake and lateral erosion by the Great Miami River, the moraine dam failed and the lake drained. Ultimately, a large meander of the Great Miami River cut laterally north of New Haven Road and completely removed the terminal moraine. Paddys Run has since eroded its valley down into and through the glacial overburden into the aquifer. Paddys Run flows on the aquifer from just south of where the K-65 silos were built to the Great Miami River.

As the ice retreated it left a small recessional moraine located in the northwestern portion of the FEMP east of Paddys Run. During the formation of this moraine, sand and silt were washed into the lake that formed on the FEMP. As will be discussed more fully in Section 3.4.5, the till deposited by the advancing ice, the lake fill that was deposited behind the terminal moraine, and gravel and silt from the recessional moraine make up the glacial overburden.

The postglacial topography of the FEMP has remained the same since the Wisconsin age glacier retreated except for erosion along Paddys Run and the SSOD. The topography of areas where little or no erosion has occurred can be used to infer glacial depositional features left by the ice. Figure 3-18 is a geologic map showing the till uplands, lake basin and Paddys Run channel. The till uplands are areas with elevations above approximately 580 feet where the topography reflects a combination of processes, where glaciers deposit sediment at their front as they retreat or melt in place.

The surface geology map (Figure 3-18) also portrays the surface extent of the lacustrine deposits that filled the basin north of the terminal moraine. The mapped edge is approximately coincident with the present 580- to 590-foot elevation interval on the topographic map. The Soil Conservation Service (SCS) mapped lacustrine deposits as present only at elevations below 580 to 590 feet, indicating that the former outlet and the shoreline of the lake are at an elevation of approximately 585 feet; data from RI borings confirm this interpretation. The extremely flat topography west of the SWRB is typical of a filled lake basin.

3.4.4 Great Miami Aquifer Outwash Deposits

During the Illinoian glacial retreat about 125,000 years ago, the Deep Stage Valley, including the New Haven Trough, was filled with about 200 feet of glacial outwash sediment deposited by water running from the margins of the glaciers. The sediment consisted mainly of well-sorted sand and gravel distributed by braided streams that crisscrossed the valley floor. The thick sand and gravel deposits in the bedrock troughs formed the present-day Great Miami Aquifer. A blanket of poorly sorted clay-rich glacial overburden was deposited on top of the outwash sediment during the Wisconsin ice advance, about 20,000 years ago. Since the retreat of the Wisconsin continental glacier, the streams in the FEMP area have removed part of the glacial overburden left by the ice sheet. Postglacial erosion by Paddys Run and the Dry Fork of the Whitewater River has exposed the Great Miami Aquifer along their beds where they cross the New Haven Trough. Postglacial erosion by the Great Miami River has removed portions of the glacial overburden that covered the Aquifer and terrace remnants that stand topographically higher than surrounding bottom lands.

In the study area, the thickness of the Great Miami Aquifer varies from 120 to 200 feet thick in the center of the valley and tributary valleys to only a few feet along the valley walls. Regionally the glacial deposits are homogeneous and are typically described as well-sorted sand and gravel with only minor amounts of silt and clay. As will be discussed in Section 3.6.2.1, silts and clays exist locally which make the aquifer heterogeneous.

Within the coarse-grained sediment of the Great Miami Aquifer, a clay interbed underlies most of the FEMP and parts of the area to the west. Figure 3-19 is an isopach map showing the thickness of the clay interbed. The clay interbed layer is uniform in texture and contains only a small amount of silt and sand. It was deposited in a lake or low-energy stream environment and in some samples displays thin light and dark layers called varves. The interbed pinches out to the south and east, extends an

unknown distance to the west, and grades into glacial till deposits to the north in the Shandon Tributary.

The clay interbed lies about 100 to 125 feet below the land surface and generally about 60 to 80 feet below the water table. Figure 3-20 is the topographic surface of the top of the interbed. Because of this interbed, which acts as an aquitard, the aquifer beneath the FEMP is divided into upper and lower halves.

3.4.4.1 Regional Geologic Model

A regional geologic model has been created using a series of surfaces maps and three dimensional geographical information system (GIS) computer programs. The surface layers used to construct the model are derived from published maps and data from the RI and pre-RI borings and wells. Plate 3-1 shows the area covered in the geologic model which extends from the west side of the Dry Fork of the Whitewater River to east of the Great Miami River Valley and from south of the Great Miami River north to include the village of Shandon.

The surface layers from the bottom up are:

- Bedrock topography from Watkins (1971) and RI well records
- Lower and upper surfaces of the clay interbed from RI and pre-RI well logs
- Top of the Great Miami Aquifer from RI and pre-RI well logs
- Average water table surface from wells with 30 or more readings
- Land surface topography from the USGS Shandon Topographic Quadrangle (1965).

The bedrock topography includes digitizing the topographic surface from seismic data presented in Watkins (1971) and adding depth to bedrock data from RI wells that encountered bedrock. The well and literature data were recontoured using 10-foot contours and a standard triangulation routine that uses data points and contours. The model grid uses 100-foot squares; therefore the line marking the edge of bedrock on Plate 3-1 has a stepped pattern. The bedrock boundary shown is at an elevation of 540 feet slightly above the average water table in the aquifer which fluctuates between 507 and 530 feet elevation over the investigation area.

Digitized 10-foot interval topographic contours from the Shandon Quadrangle are used for the land surface in this model. The elevations of the Great Miami River and the Dry Fork of the Whitewater River are taken from the Shandon Quadrangle and used in the interpretation of the water table. The

topographic surface is also used where data from borings are not available to distinguish the glacial overburden/Great Miami Aquifer boundary.

The lower and upper surfaces of the clay interbed were developed from the visual classification of soil records (Appendix P) from the RI and well logs from pre-RI wells from state records. A zero thickness boundary was established on the east, south and west side of the clay interbed where boring records indicate the clay interbed is missing. On the north the clay interbed was assumed to extend to the bedrock wall of the buried valley. The surfaces were contoured and show the top of the clay interbed (Figure 3-20) and an isopach map depicts the thickness of the clay interbed (Figure 3-19).

Although the water table in the aquifer will be discussed fully in Section 3.6.2.2. the average water table surface has been added to this model to show the relation of the water table to recharge and discharge points on a regional scale.. The average water table data is from Type 2 wells with 30 or more monthly readings that are located in the immediate vicinity of the FEMP and the area between the FEMP and the Great Miami River on the east and south. For the model, the surface elevation of the Great Miami River, as shown on the Shandon Topographic Quadrangle (USGS 1965) is used on the east and south. On the west the elevation of the bed of the Dry Fork of the Whitewater River was used to estimate the elevation of the recharge from the stream. There are no data points on the north with which to estimate the water table beyond the FEMP boundary so a flat surface was assumed. The model surface is the result of triangulation contouring of the data points at the wells and the selected elevations from the topographic maps.

The base of the glacial overburden is interpreted from RI and pre-RI well data, the elevation of the base of Paddys Run and geomorphological interpretation of the land surface south of the FEMP. On the east side of the FEMP the base of the glacial overburden is projected from the well data to the east where it is cut by the topographic surface. On the west it is assumed that the base of the glacial overburden is the same as the bottom elevation of the Dry Fork of the Whitewater River although the contact could be further to the east. The base of the glacial overburden is the result of triangulation contouring of the well data set and the elevations selected from the topographic map.

3.4.4.2 Regional Cross Sections

As shown on Plate 3-1 (see Plates) five regional cross sections have been generated using the regional geologic model. The cross sections are generated by slicing through the layers of the model. All

wells and borings greater than 30 feet deep and within 200 feet of either side of the cross sections have been projected to the plane of the section to give a relative indication of the density of data available along the plane of the section.

Cross section I-I' is located along the northern edge of the production area. The cross section (Figure 3-21) extends from the bedrock bluff on the west across the FEMP to the Great Miami River Valley to the bedrock bluff on the east. The clay interbed extends from the bedrock on the west to approximately the eastern edge of the FEMP. A remanent of the clay interbed is also located under the Great Miami River Valley. The clay interbed is thought to have been deposited during a period when the ancestral Ohio River was temporarily blocked. Subsequent erosion as the continental glaciers advanced and retreated has removed the clay interbed in many areas of the Great Miami Aquifer.

On the FEMP cross-section I-I' shows that Paddys Run has eroded almost all the way through the glacial overburden and the artificially flattened production area is clearly defined by the topography. The glacial overburden thickens to the east and the contact between the glacial overburden and the aquifer also rises slightly to the east. A steep bluff truncates the glacial overburden east of the FEMP where meanders of the Great Miami River have carved a wide and almost flat valley bounded on the east by the bedrock bluff.

The water table in the aquifer shown in cross section I-I' (Figure 3-21) is highest in the west and slopes toward the Great Miami River. Under the River there is a mound on the water table since the water table is depressed by the pumping of the SOWC collector wells and the Great Miami River is recharging the aquifer (Spieker 1968a). As will be discussed in Section 5.3.3, groundwater leaving the eastern side of the FEMP eventually would pass under the Great Miami River and be drawn to the SOWC collector wells.

Cross section II-II' is south of cross section I-I' and rotated slightly further south on the eastern end (Plate 3-1). The cross section (Figure 3-22) shows that the deepest part of the bedrock valley is under the central part of the FEMP. The clay interbed extends across much of the FEMP; however, as is shown in Figure 3-19 the clay interbed has been eroded and the eastern boundary is irregular. On the FEMP Paddys Run has not eroded through the glacial overburden, glacial overburden is thinner than in cross section I-I' and the base of the glacial overburden is at a higher elevation. The

bluff that forms the west side of the Great Miami River Valley includes a gently sloping river terrace. At the base of the bluff is a deep meander scar. The Great Miami River is located approximately in the middle of its valley in this cross section which is the closest the river approaches the FEMP. The water table under the FEMP slopes to the river and there is a subdued mounding effect on the water table visible under the river.

Cross section III-III' (Plate 3-1) extends from the Dry Fork of the Whitewater River to the east side of the Great Miami River Valley and passes along the southern end of the FEMP (Figure 3-23). The bedrock valley gets deeper to the west as this cross section is almost exactly along the axis of the New Haven Trough. A small remnant of the clay interbed is shown in the section but it is not present under the FEMP this far south.

The entire width of the glacial overburden is shown in cross section III-III'. The crest of the terminal moraine is clearly evident as is the basin-like upper surface of the glacial overburden. The broad basin shape is because the ice in the advancing glacier was thickest in the middle and spread outward as it crossed the New Haven Trough. Paddys Run has eroded through the glacial overburden at this location. The river terrace east of the FEMP is wider than in cross section II-II' and the Great Miami River Valley is lower than in the previous sections.

Cross section III-III' illustrates the general groundwater flow under the FEMP. Recharge occurs at the Dry Fork of the Whitewater River and flows to the east under the FEMP. Cross section III-III' is south of the influence of the pumping of the SOWC wells, the River is no longer recharging the aquifer, and groundwater discharges to the Great Miami River. The eastern end of cross section III-III' is south of the zone of influence from the pumping of the SOWC collector wells (IT 1988).

Cross section IV-IV' (Plate 3-1) is oriented north to south and located along the eastern edge of the FEMP. This section (Figure 3-24) shows both the New Haven Trough and the buried valley under the Great Miami River where it passes south of New Baltimore (Plate 3-1). The bedrock rises between the two deep stage valleys. The apparent thick glacial overburden over the bedrock high is caused by the cross section cutting close to the rounded end of the bedrock "island" that is located between the FEMP and New Baltimore. Bedrock rises to the same height as the glacial overburden just behind the plane of the cross section. In the south under the Great Miami River the Deep Stage

Valley was not cut as deeply as under the New Haven Trough because it was only the Great Miami River, not the ancestral Ohio River, that carved this valley (Watkins 1971).

The bedrock bluffs are shown on the north of the cross section where the highest elevations on the FEMP are located. The glacial overburden has an irregular upper surface across the FEMP and a very flat upper surface south of the FEMP. This flat surface may be the top of the terminal moraine on the east side of the ice lobe. The glacial overburden is thinnest near the southern edge of the FEMP and thickens as the ice moved down the valley between the bedrock highs toward the village of Fernald (Figure 3-17).

The water table under the FEMP is flat in cross section IV-IV' because flow is to the east into the plane of the section. South of the FEMP the water table slopes to the south down the Paddys Run outlet (Figure 3-16) and discharges into the Great Miami River.

Cross section V-V' (Figure 3-25) is oriented north to south and is aligned along the Paddys Run valley. As shown in Figure 3-25 the bedrock surface is lowest just south of the FEMP and appears to rise to the south because the section is cut along the western edge of the Paddys Run Outlet in the Deep Stage Drainage system (Figure 3-16). Like cross section IV-IV' the depth of the deep stage valley under the Great Miami River is less than the depth of the New Haven Trough. The clay interbed is interpreted to extend north of the FEMP into the Shandon Tributary and is present under all of the FEMP in this cross section.

The actual bed of Paddys Run crosses back and forth in and out of the plane of the section as it flows from north to south. Under the FEMP (Figure 3-25) where Sections I-I' and II-II' are shown, Paddys Run has removed most of the glacial overburden. As the contact between the glacial overburden rises and Paddys Run erodes downward the stream comes in contact with the Great Miami Aquifer and loses water to the aquifer. Near the southern end of the FEMP in cross section V-V' it is clear that the glacial overburden has been eroded away and Paddys Run is flowing on the aquifer. Further south, half way between the FEMP and the Great Miami River, Paddys Run has eroded through the glacial overburden and the water table intercepts the surface. This is the area in Figure 3-10 where Paddys Run is always receiving water from the aquifer. To the south the land surface does not slope downward as fast as the water table descends to the level of the Great Miami River. Therefore,

whether Paddys Run is losing water to the aquifer or receiving water from the aquifer is dependent on the level of the Great Miami River.

3.4.5 Geology of the Glacial Overburden

The FEMP is built upon a sequence of Wisconsin Age till, lake basin, and loess deposits that overlie the outwash deposits in the buried valley aquifer. To distinguish the Wisconsin Age deposits from the Illinoian outwash deposits, the former is collectively referred to as glacial overburden. The glacial overburden beneath the FEMP is predominantly clay-rich till that contains lenses of coarser-grained sediment. The glacial overburden is saturated beginning approximately 3 to 5 feet below the ground surface. The dominance of fine-grained particles in the till at the base of the glacial overburden restricts the vertical migration of contaminants to the underlying Great Miami Aquifer. The following is a detailed description of the stratigraphy of the glacial overburden presented in the order of deposition.

The oldest to youngest units are glacial till, lake basin fill, and aeolian loess. The till was spread by the advancing ice, is predominantly clay and is pervasive across the FEMP, except in areas where it has been removed by erosion or excavation activities. The lacustrine deposits overlie the till, are composed of predominantly clay and silt with scattered sand lenses, and are restricted to a former lake basin along the western margin of the FEMP. The basin fill, collectively referred to as lacustrine deposits, was probably deposited contemporaneously with the melting of the glacial ice. Both the till and lacustrine deposits contain interbeds of silt, sand, and gravel. The aeolian loess is very fine-grain, wind blown particles removed from the till and lacustrine deposits and redeposited in a blanket over the area by the wind.

All of the soil and sediment within the glacial overburden contain a similar assemblage of minerals (Table 3-5). Approximately 50 percent of the glacial overburden is comprised of carbonate minerals that exert a strong influence on the chemistry of perched groundwater (Section 3.5), due to their greater solubility relative to the remaining silicate minerals.

Plate 3-2 (see Plates) is a surface contour map of the bottom of the glacial overburden and the top of the sand and gravel in the Great Miami Aquifer. The map is based on stratigraphic data from the 198 borings that penetrate through the glacial overburden into the Great Miami Aquifer in the FEMP area. The elevation of the surface shows small-scale local variation that regionally varies from 545 feet in

the northwest corner of the site to 565 feet in the southeast corner of the FEMP. The base of the glacial overburden dips down to an elevation of approximately 538 feet along the west side of the production area. Well 2754 in the northeast corner of the FEMP does not intersect the aquifer but instead passes from glacial overburden into bedrock on the wall of the buried valley. In general the glacial overburden over the aquifer is thickest in the waste pit area and thins to the southeast. This is consistent with the movement of the ice across the area from northwest to southeast.

Plate 3-3 (see Plates) is an isopach map of the thickness of the glacial overburden before construction of the FEMP and is based on the difference between the preconstruction topographic surface and the elevation of the bottom of the glacial overburden shown in Plate 3-2. Therefore, only glacial materials deposited by natural processes are shown. The thickness of the glacial overburden has been diminished under the northeast quarter of the production area and almost completely removed under portions of Plant 6, the SWRB, and Waste Pit 3. Thus the thickness of the clay-rich glacial overburden has been reduced to a few feet in thickness under portions of Plant 6, the SWRB, and Waste Pit 3. The fill in the Operable Unit 2 South Field and flyash areas laps over the edge of the glacial overburden onto the floodplain alluvium of Paddys Run, where the glacial overburden has been eroded away. Figure 3-26 summarizes the areas where the glacial overburden has been most severely thinned by construction or removed by erosion.

Below are stratigraphic descriptions of the three basic units that comprise the glacial overburden. The text refers to cross sections A-A' through J-J'. Figure 3-27 is an index map showing the locations of these eight cross sections as well as more detailed cross sections under the Operable Units 1, 2, and 3 investigation areas. The cross sections were constructed by selecting lines of borings and interpreting the correlation of till, silt and sand between the borings. Borings within 100 feet of either side of the line of the cross section are projected to the plane of the section to increase the data available for interpretation. This interpretive tool leaves out borings that do not lie near the plane of the cross sections. However, the sections do provide a reasonable representation of the general distribution of subsurface material.

Cross sections A-A' through J-J' are presented as a fence diagram in Plate 3-4 and show the general geology of the glacial overburden. The detailed cross sections shown in Figure 3-17 are described in Appendix Q as individual sections.

3.4.5.1 Till

Till is an unsorted, heterogeneous mixture of clay, silt, sand, and angular pebble- to cobble-size rock fragments. Typically, approximately 70 percent of the material in till is clay and silt forming the matrix in which the sand and angular rock fragments are suspended. Till, in the Fernald area, is predominantly reworked local shale and limestone that was transported southward and deposited in front of or beneath the advancing glacier. Lodgement till is till that was overridden by the advancing glacier and is a compact and tight material. Ablation till is till that was deposited as the glacier receded or melted in place. It is less compact than lodgement till, because it was not compacted by the weight of an advancing ice mass. It is assumed that, site wide, an indeterminant thickness of till at the base of the glacial overburden is lodgement till. There is no readily available method for distinguishing lodgement from ablation till.

The till beneath the FEMP contains lenses of coarser-grained silt, sand, and gravel (described as SM, SC, GC, GM, and ML in the visual classification of soil records [see Appendix P] that were made during drilling operations). This coarse sediment could have been deposited by subglacial or proglacial streams; however, some portion of the sediment could have been deposited as crevasse fills. Due to the variety of possible depositional environments the sand, silt, and gravel units can rarely be correlated over distances greater than a few hundred feet in cross sections. Cross sections A-A' and C-C' along the east and north sides of the FEMP (Plate 3-4) illustrate the sparse distribution of sand lenses within the till. Cross sections A-A' and B-B' show how the till thins to the south as the top of the underlying aquifer is present at higher elevations in the southeast part of the FEMP. Similarly cross section J-J' along the south edge of the FEMP shows how the till thins to the east.

3.4.5.2 Lacustrine

The first workers to map the extent of the lacustrine deposits in the FEMP area were the SCS (USDA et al. 1980, 1982). The mapped extent of lacustrine deposits presented in Figure 3-18 is based on USDA mapping, Brockman's (1988) mapping, and more detailed RI/FS data. In cross sections B-B' and D-D' through F-F' (Plate 3-4) the lacustrine deposits are labeled as undifferentiated glacial outwash because at this scale it is not possible to draw lines depicting all the small clay, silt, and sand lenses. The shape of the undifferentiated glacial outwash body depicts the area where the lacustrine deposits are present at the FEMP. Cross section G-G' is roughly along the southern boundary of the lacustrine deposits on the FEMP and shows the distribution of larger silt and sand lenses.

The lacustrine deposits consist of distinct thin layers of clay and silt with some sand and gravel in less distinctive lenses. Lake clay, in field descriptions, is distinguished from till clay by the lack of sand and gravel within the clay layer. Till clay is typically described as having a minor component of sand-size and coarser rock fragments within the clay matrix. Within the lake basin, clay layers are rarely described as having a component of sand-size or greater material.

3.4.5.3 Loess

Loess is a deposit of windblown silt from denuded plains, outwash fans, and river valleys. Loess deposited after the Wisconsin Glaciation is regionally pervasive in southwest Ohio and the Fernald area. Loess is identifiable today in areas not modified by construction excavations and grading.

Loess is present in the area north of the former production area and along the eastern margin of the FEMP. In these areas, loess is noted in field descriptions as CL or ML. Refer to Table 3-6 for Unified Soil Classification System [USCS] definitions of soil descriptors. Field descriptions are interpreted as loess when the sample was collected outside the lake basin and the description does not include the presence of minor quantities of material coarser than silt. Loess is typically about 3 feet thick, but may locally be as thick as 8 feet.

Loess has been stripped or regraded throughout much of the former production area and is therefore absent or difficult to differentiate if present. In field descriptions, loess cannot be distinguished from lacustrine silt and clay; therefore the interpretation of the depositional environment is dependent on the location of the sample site. Since the loess is a near-surface deposit generally found above the water table it is not significant to the migration of contaminants or the movement of groundwater within the glacial overburden.

In summary, the glacial overburden is predominantly composed of clay-rich till. Glacial tills do not characteristically contain laterally extensive deposits of well-sorted coarse-grained sediment. The till typically contains a heterogeneous mix of sand, gravel, and small cobble-size rock fragments within a clay-rich matrix. This is the case beneath the eastern and northern portions of the FEMP where small discontinuous units of silt, sand, and gravel are present within the till clay. The vertical lithologic profile found beneath the eastern portion of the FEMP is different from the profile found beneath the FEMP's western portion. Under the western portion, a basin that formed on the till filled with lacustrine deposits consisting predominantly of clay and silt with some sand and gravel. The

depositional environment within the basin is that of a series of deltas formed by muddy steams flowing into the lake that filled the basin behind a dam formed by the terminal moraine. These deposits were partially reworked into sand bars and beach-type deposits by wave action along the margins of the lake. The shoreline of the lake probably rose and fell seasonally and during warmer and colder decades.

The lacustrine deposits were deposited by processes that could yield laterally extensive systems of coarse-grained sediments. Conversely, the glacial till was deposited by processes that normally do not produce laterally extensive systems of coarse-grained sediment. The depth of brown oxidation shown in the cross sections (Appendix Q) in the till generally mimics topography; however, within the lacustrine deposits, the depth of brown oxidation is variable and in many cases coincident to the contact between lacustrine deposit and till. This color change provides indirect evidence that the movement of groundwater is more prevalent in the coarse-grained sediment than in the clay-rich till. This discussion is expanded in Section 3.6.1.

3.4.6 Detailed Cross Sections for Glacial Overburden

The cross sections are interpreted from the qualitative field descriptions of field geologists contained in the visual classification of soil forms (Appendix P). The cross sections described in Appendix Q portray the subsurface geology of the waste storage area (Figures Q-1 through Q-10), former production area (Figures Q-11 through Q-29), fire training area (Figures Q-30 and Q-31), sewage treatment plant area (Figures Q-32 through Q-34), and the SWRB area (Figures Q-35 through Q-38). Each cross section includes the preconstruction land surface as well as the existing topography, above-grade additions such as buildings or fill, and below-grade modifications such as pits or structural foundations. Lateral correlations of color and grain size were made only for undisturbed strata.

3.4.7 Geotechnical Data

Extensive geotechnical data were collected in the glacial overburden for construction projects at the FEMP. Data for 107 borings were obtained from searches of construction files. The majority of the samples collected during these studies were split-spoon samples, which limited the tests to those that could be performed on disturbed samples; e.g., grain size, Atterburg limits, and moisture content. Approximately 27 borings had undisturbed samples collected by Shelby tubes or Dennison samplers. Most of these samples were analyzed for parameters requiring undisturbed samples, such as core

permeability or consolidation. Table 3-7 presents a summary of the geotechnical data available. The following is a summary of grain-size analyses. Interpretation of the hydrogeological data is discussed in Section 3.6. Appendix N includes summaries of all geotechnical data for the glacial overburden and the physical and chemical properties of soil in Hamilton and Butler counties (USDA et al. 1980 and 1982).

Grain-size analyses were conducted on one or more samples from 71 borings in the glacial overburden. Grain-size analytical results are grouped according to depositional unit and the determination of depositional unit is based on cross sections and surface geology maps. Results of the tests are summarized as percentages of gravel, sand, silt, and clay, based on American Society for Testing Materials (ASTM) grain-size divisions. Tests performed by the U.S. Army Corps of Engineers in 1951-1952 used the Wentworth Scale which defines a No. 10 sieve rather than a No. 4 sieve as the division between fine gravel and coarse sand. These results have been converted to the ASTM system to allow comparison here.

It is assumed that the grain-size analyses represent a semirandom selection of till and lacustrine samples. Tables 3-8 and 3-9 present analytical results for soil classified as CL using USCS guidelines for samples that were collected from till and lacustrine deposits, respectively. Samples from till that are classified as CL have an average gravel/sand/silt/clay percent ratio of 8/25/43/24, and samples from the lacustrine deposits classified as CL have an average percent ratio of 1/10/63/26. The percentages agree well with the differences noted from the field descriptions; till CL contains higher quantities of sand and gravel than lacustrine CL; however, both are dominantly silt with approximately 25 percent clay.

Similarly, Tables 3-10 and 3-11 present a comparison of coarse-grained materials (SM, SC, GC) collected from sand within till and lacustrine deposits, respectively. Samples from the sand within the till have an average gravel/sand/silt/clay percent ratio of 11/66/20/3 and samples from the lacustrine deposits have a percent ratio of 14/61/20/5. These two categories of coarse-grained materials are nearly equivalent in terms of their grain-size distribution.

A number of soil borings have recently been completed at the FEMP for various construction and field investigations in the glacial overburden. As part of the characterization process for these borings, soil samples were collected and sieved to determine the percentage of gravel, sand, silt and

clay as defined by the ASTM scale. During the installation of monitoring wells in the glacial overburden in 1993, soil samples were collected from the screened interval by split-spoon sampler at all of the well locations for sieve analyses. Soil samples were dry sieved and the cumulative percent by weight retained and recorded for the No. 10, 20, 40, 60, 100 and 200 sieve and the pan. This information was then used to generate a semilogarithmic plot of the grain-size distribution curves with the arithmetic Y-axis represented as percent finer by weight and the logarithmic X-axis presented as grain size in millimeters. An example of this plot is contained in Appendix N. From these distribution curves the percentage gravel, sand, silt, and clay were derived using ASTM guidelines.

The textural triangle in Figure 3-28 is divided into specific subdivisions representing the various USCS soil types. The subdivisions for the textural triangle were determined by reviewing the USCS definitions of the various soil types and comparing these definitions with definitions prepared by R. L. Folk (1980) for a textural triangle that classified soil using a sand, gravel, and mud description process, with mud representing the silt and clay fraction of a sieve analysis. Using the direct comparisons of the two classification systems, it is possible to use the boundaries defined by Folk (1980) to derive the boundaries for the USCS in the textural triangle in Figure 3-28. The three axes of the triangle are percent silt and clay, sand, and gravel.

The USCS is divided into two general categories. These categories are coarse-grained soil and fine-grained/highly organic soil. Because the textural triangle does not have a means of distinguishing the plasticity index of the sample or the silt and clay fractions, several of the classifications had to be grouped together into subdivisions presented in the textural triangle. The significance of this plot is that it allows a field description of a sample to be confirmed by sieve analysis in the laboratory and it assists in determining the homogeneity or heterogeneity of the unit from which the sample was collected.

Using the grain distribution curve for each sample or reported distribution, the percent gravel, sand, silt and clay was determined for all available samples from the glacial overburden including the Corp of Engineers data. A summary of these values is presented in Appendix N. The percentages of gravel, sand, silt and clay are plotted on the textural triangle in Figure 3-29. The distribution of points in the textural triangle clearly indicate that even in the intervals where well screens are placed for monitoring wells in the glacial overburden, the composition of the glacial overburden is dominated by silt and clay.

3.4.8 Soil

Soil characteristics affect the suitability of a site for agriculture or construction; the likelihood of erosion during remedial actions; and the kinds of habitats, such as wetlands, that can develop on a site. Three major soil groups occur in the vicinity of the FEMP: Russell-Xenia-Wynn, Fincastle-Xenia-Wynn, and Fox-Genesee (USDA et al. 1980, 1982). The soil is moderately high in productivity and frequently used for growing cash crops and producing livestock. Appendix N contains tables that provide the physical, chemical, and engineering properties for the soil types found in the region of the FEMP.

The Butler and Hamilton county soil surveys show 15 specific soil series or types mapped within FEMP boundaries, as shown in Figure 3-30 (USDA et al. 1980, 1982). Table 3-12 lists the symbol, name, slope, and drainage classification for specific soil units mapped within the FEMP boundaries. The major series are Fincastle and Xenia silt loams, which also cover large areas west of the FEMP. These soils are light colored, medium acidic, and moderately high in productivity when properly managed. Moisture-supplying capacity is moderate, as is fertility and organic content.

The Fincastle series consists of deep, nearly level, somewhat poorly drained soil on broad flats. Permeability is low, and the available water capacity is high. The seasonal high water table is commonly found between 1 and 3 feet below the ground surface from January to April. In areas where this soil is predominant, artificial drainage is required for moderate crop productivity. This soil is associated with the production area at the FEMP and the pastures to the east and west.

The Xenia soil series is a deep, nearly level, moderately well-drained soil located on till plains. Permeability is moderately low, available water capacity is high, and the runoff hazard is low. The seasonal high water table is usually within 2 to 6 feet of the surface from March to April. This soil is located within the northern part of the FEMP.

The Ragsdale soil series is nearly level, deep, and very poorly drained. It is considered hydric; that is, periodically depleted of oxygen due to water saturation (USDA 1987a,b). This very poorly drained Ragsdale silty clay loam is mapped for approximately 53 acres (5 percent of the area of the FEMP) in the northern portion of the FEMP. It is usually located in long, narrow depressions or in shallow basins. The permeation rate is slow, available water capacity high, and the seasonal high

water table is near the surface from December through May. This soil is associated with a jurisdictional wetland in the northern end of the FEMP (see Section 3.8.3).

Three soil series at the FEMP, represented by four map units, are classified as somewhat poorly drained soil. These include the Fincastle series described above, the Henshaw series, and the Raub series. Somewhat poorly drained soil occupies approximately 364 acres (35 percent) at the FEMP, excluding the 120 acres of highly developed portions of the Fincastle-Urban land complex under the production area. The Henshaw series is deep, nearly level, somewhat poorly drained soil on flats and low stream terraces and in basins. The Henshaw series underlies the flyash piles and South Field areas included in Operable Unit 2. Permeability is moderately low, available water capacity is high, and runoff is slow. The seasonal high water table is usually within 2 feet of the ground surface between November and March. This soil exists along the western property line adjacent to Paddys Run Road and south of the former production area.

The Raub series is deep, nearly level, somewhat poorly drained, dark soil located on glacial till plains. This soil has slow permeation rates and high available water capacity. The seasonal high water table is between 1 and 3 feet during January through April. This soil is located on upland terraces in the southeast portion of the FEMP and immediately north of the former production area.

The remaining 10 soil series mapped within FEMP boundaries are moderately well-drained and well-drained upland soils. The Dana series consists of deep, gently sloping, moderately well-drained soil on slopes or in gently sloping basins on till plains and moraines. This series has moderate permeability and the available water capacity is high. The water table is usually perched at a depth of 3 to 6 feet between March and April. This soil occupies the upper third of the northern pine plantation.

3.5 GROUNDWATER GEOCHEMISTRY

The principal geochemical processes that control groundwater chemistry are dissolution of minerals and solids in the soil by rainwater and adsorption/ion exchange reactions between the groundwater and soil particles, and oxidation/reduction (redox) reactions (these processes are discussed in detail in Appendix F). As groundwater chemistry will reflect the solids it is in contact with, it is important to establish the mineralogical composition of the soil in the vadose and saturated zones so that the origin of dissolved solids (i.e., solute) in the groundwater can be evaluated. Additionally, the aqueous form

(i.e., speciation) of the solute in the groundwater provides important information for assessing the nature and extent of groundwater contamination, as presented in Sections 4.7 and 4.8. This section of the RI Report summarizes the composition, speciation, and origin of groundwater present in both the glacial overburden and Great Miami Aquifer.

3.5.1 Rainwater/Glacial Overburden Chemistry

Rainwater falling on the glacial overburden will react with minerals/solids and organic material to form porewater that ultimately becomes groundwater. The composition of groundwater solute is controlled primarily by the solubility of various minerals or leaching of solids in the soil. In any given mixture of minerals or solids, the most soluble or leachable phases will have the greatest influence on the solute composition. The mineralogical summary of glacial overburden provided in Table 3-5 indicates that carbonate minerals play the most important role in establishing the composition of groundwater solute.

At the FEMP site, the moderately low pH of the rainwater (about 5) is raised by dissolution reactions with carbonate mineral fragments (dolomite and calcite) present in the soil. Rainwater dissolution reactions are most likely to occur in the upper few feet of the unsaturated glacial overburden. The pH of the groundwater/glacial overburden system will be buffered in the range of 7 to 8 by carbonate mineral (e.g., $CaCO_3$) dissolution, CO_2 dissolution, and carbonic acid (H_2CO_3) dissociation. Important reactions in this system are:

(1) $CaCO_3 + H_2O <-> Ca^{+2} + HCO_3^- + OH^-$

(2) $CO_2 + H_2O <-> H_2CO_3$

(3) $H_2CO_3 <-> H^+ + HCO_3^-$

The dissolution of $CaCO_3$ in water (Reaction 1) contacting air containing about 0.03 percent CO_2 results in an equilibrium pH of about 8. Lower pH values are generally observed in FEMP soil because the activity of CO_2 (i.e., partial pressure of CO_2) in the soil is greater than in the air, due to decomposition of organic debris and respiration of microorganisms. The higher CO_2 activity in soil drives Reaction 2 to the right to produce more H_2CO_3, which dissociates immediately (Reaction 3) to release H^+ and lower the pH. The large reservoir of carbonate minerals (30 to 50 percent of the glacial overburden) and biogenic sources of CO_2 allow the water/soil system to be buffered between 7 and 8 by the interplay of the above three reactions.

Silicate minerals present in the glacial overburden (e.g., quartz, feldspar, and clay minerals (see Table 3-12) have less influence on the chemistry of the groundwater due to their low solubilities (relative to carbonate minerals) at near neutral pH values. These minerals provide silica, potassium, sodium, aluminum, and various trace metals to the groundwater via dissolution and ion exchange reactions. The weathered surface area of these minerals will play an important part in the adsorption of ions from the groundwater.

Cation exchange capacity of glacial overburden, as measured by exchangeable sodium ion, varies from 1 to 13 milliequivalents per 100 grams (meq/100 g). A comparison of these values to the 1.7 to 6 meq/100 g observed for river clays (Tables 9-3, 9-4, and 9-5 in Berner, 1971), indicates the glacial overburden has moderate to good capacity for cation exchange and adsorption. However, the cation exchange capacity measurement does not provide information on the exchange and adsorption of anions (e.g., $UO_2(CO_3)_2^{-2}$).

Redox reactions may also influence the mobility of ions in perched groundwater. Platinum-electrode measurements of Eh vary from 71 to 221 millivolts (mV) over the pH range of 7.0 to 7.6 (Issue 3 and 5 Report, Appendix A in Groundwater Modeling Report; DOE, September 1993) indicating perched groundwaters are transitional between an oxidizing and reducing environment. For the elements iron and chromium, these Eh values correspond to the immobile iron (III) and chromium (III) oxidation states. However, the Eh range also corresponds to the uranium (VI) oxidation state, indicating uranium will be mobile in these waters. Uranium will be reduced to the relatively immobile uranium (IV) oxidation state of the Eh if the groundwater drops below about 25 mV.

3.5.2 Groundwater Composition

The composition of groundwater in the glacial overburden and Great Miami Aquifer is summarized in Figures 3-31 and 3-32. These figures were derived from the Characterization of Background Water Quality for Streams and Groundwater (DOE1994a). Groundwater chemistry depicted on both of these trilinear diagrams is dominated by calcium and magnesium cations and the bicarbonate anion. The trilinear diagrams are constructed using charge equivalent values, which are derived by multiplying the ion concentration expressed as molarity (moles/L) by its charge. Based on charge equivalent units, calcium constitutes approximately 60 percent, magnesium about 30 percent, and sodium plus potassium about 10 percent of the total cations. Bicarbonate plus carbonate constitutes about 80

percent of the anions, followed by sulfate and chloride. The charge equivalent percent for calcium plus magnesium is approximately equal to bicarbonate, indicating the groundwater compositions reflect dissolution of calcite and dolomite. Appendix F.3.I contains the data used to plot the Piper Nets in Figures 3-31 and 3-32.

Groundwater compositions were entered into the EQ3NR geochemical code (Version 7.1; Wolery 1992) to evaluate mineral saturation indicies and ion speciation. The saturation index is defined as the logarithm of the ion activity product minus the logarithm of the solubility product (i.e., log[iap/sp]). Using this convention, minerals having a saturation index equal to or greater than zero are saturated, while values less than zero indicate undersaturation. Mineral saturation indicies reported in Table 3-13 indicate the groundwaters are saturated with the minerals listed in Table 3-5, implying that groundwater has equilibrated with the soil and sediment in the glacial overburden and Great Miami Aquifer.

Table 3-14 summarizes the aqueous species for the common ions in glacial overburden and Great Miami Aquifer groundwater. In addition to the major cations Ca^{+2}, Mg^{+2}, Na^{+}, and K^{+}, bicarbonate species are important for calcium, magnesium, and sodium, and sulfate species are important for calcium and magnesium. Other dominant species include Cl^{-}, HCO_3^{-}, $H_2CO_3^{o}$, and SO_4^{-2}. The formation of carbonate complexes in these groundwaters (e.g., $CaHCO_3^{-}$, $MgHCO_3^{-}$, $NaHCO_3^{o}$) is an important observation that will be discussed when uranium contamination is addressed in Section 4.0. Additionally, Appendix F.3.I provides a detailed discussion on the mobilization of uranium by carbonate-rich groundwater.

3.6 HYDROGEOLOGIC SETTING OF THE STUDY AREA

Figure 3-22 is the geologic cross section through the buried valley that exists beneath the FEMP site. Groundwater is present in both the glacial overburden and within the sand and gravel of the Great Miami Aquifer. A generalized stratigraphic column for the study area is presented in Figure 3-33. The Great Miami Aquifer water table system is contained within the 120- to 200-foot-thick deposit of glacial outwash (sand and gravel). The outwash deposits are sometimes divided by a clay interbed up to 20 feet thick which serves as an aquitard. Figure 3-19 illustrates the areal extent of the clay interbed.

The glacial overburden is saturated from approximately 3 to 5 feet below the ground surface down to the base of the glacial overburden. Unsaturated conditions exist just beneath the base of the glacial overburden. Saturated conditions are again present at the Great Miami Aquifer water table. Approximately 3 to 45 feet of unsaturated sand and gravel exist between the base of the glacial overburden and the water table of the Great Miami Aquifer.

Because of the unsaturated sediment below the glacial overburden, groundwater within the glacial overburden is "perched" above the water table of the Great Miami Aquifer. Figure 3-34 illustrates how fluid pressures change with depth due to the presence of saturated sediments within and unsaturated sediments beneath the glacial overburden. Fluid pressure is zero at the water table where it is in equilibrium with the atmospheric pressure, greater than atmospheric pressure in saturated conditions, and less than atmospheric pressure in unsaturated conditions.

Outwash deposits in the Great Miami Aquifer are capable of sustaining yields of hundreds of gallons of water per minute, with exceptional wells reaching the thousands of gallon per minute range. In general the glacial overburden deposit does not supply groundwater in quantities sufficient for public water supplies. On the FEMP, a localized area of sand and gravel within the glacial overburden are capable of supplying a sustainable yield of approximately 1.0 gpm. A small channel in the waste pit area is also capable of supplying a sustainable yield of 1 gpm. This will be discussed further in Section 3.6.1.1. Recharge to the Great Miami Aquifer occurs through subcrops of bedrock that bound the valley walls, through induced infiltration of surface water and through percolation of precipitation.

Water moving from the surface down to the Great Miami Aquifer must either move through or over the glacial overburden. The perched water table in the glacial overburden follows topography and slopes to the west-southwest. Beneath the former production area the average gradient ranges between .008 and .015. The overall vertical hydraulic gradient through the glacial overburden is 1, because unsaturated conditions are present at the base of the overburden. The water table of the Great Miami Aquifer slopes to the east, southeast and south towards the Great Miami River. The average gradient is approximately 0.008 in the northwest by the Shandon Tributary, 0.0008 in the middle of the New Haven Trough, and 0.002 in the Paddys Run Outlet area. The potential for fluid movement in the glacial overburden is low compared to the potential for movement in the Great Miami Aquifer.

3.6.1 Hydrogeology of the Glacial Overburden

The glacial overburden underlies the former production area and all of the waste storage areas on the FEMP Plate 3-3. The glacial overburden is composed principally of clay-rich till, lacustrine silt and clay lenses, and minor outwash silt and sand lenses. The glacial overburden also contains a perched groundwater system. The glacial overburden is critical to the contaminant migration pathway analysis because its low hydraulic conductivity has limited infiltration down to the underlying Great Miami Aquifer, and because the glacial overburden is the point at which many contaminants first enter the environment.

While the glacial overburden consists predominately of clay and silt, with minor amounts of sand and gravel. As was presented in Section 3.4, most of the sand and gravel is located beneath the western portion of the FEMP in a basin where lacustrine sediment was deposited. The distribution of sand and gravel beneath the eastern portion of the FEMP appears to be more random, and less dense. This variation in sediment type, along with the lack of readily recognizable depositional features under much of the FEMP site, makes the determination of hydraulic properties and flow pathways difficult. For the purpose of the RI, the objective was to bracket this uncertainty so that the conceptualized pathway is conservative, meaning that the greatest amount of contamination is carried to a potential receptor in the shortest period of time.

A yellow-brown to gray color change is present in the glacial overburden. No lithologic or depositional differences are evident in sediment above the color change front compared to sediment below the color change. The gray color is due to trace amounts of iron in the soil that are in the ferrous (Fe^{+2}) oxidation state which colors the soil blue gray. As weathering takes place, the ferrous iron is converted to ferric iron (Fe^{+3}), a hydrous oxide of iron that colors the soil brown. The conversion of the iron is probably assisted by bacteria in the soil, although it could be due to a simple chemical reaction. Regardless of the process, the presence of brown coloration is evidence that oxygenated groundwater is actively circulating to that depth. Circulation deeper is not as active because it has not caused additional iron oxidation.

The bottom of the yellow-brown oxidation front is typically defined by a 1- to 2-foot-thick transition zone in which gray clay material exhibits mottled brown stringers in the clay-rich material. Brown staining also diffuses outward from the stringers a short distance. The fact that the brown coloration is strongest along stringers is an indication that secondary permeability enhances groundwater

circulation in the upper clay-rich portions of the glacial overburden and facilitates infiltration of surface water into the glacial overburden. Secondary permeability is created by such elements as desiccation cracks, animal burrows, root tubes, insect burrows and fractures. The effect of secondary permeability decreases with depth, as evidenced by the patterns of brown and gray coloration in the transition zone. Figure 3-35 illustrates the eight different sediment types within the glacial overburden based on grain size and color.

Figure 3-36 is a map which illustrated where most of the coarser sand and gravel sediment within the glacial overburden is located. The map is useful for determining trends and selecting areas for hydraulic testing. The highlighted areas do not represent contiguous interconnected units of sediment but simply indicate where most of the coarser grained material is located. The heavy dashed line outlines the eastern extent of the basin deposit. The map indicates that most of the coarser grained material is present within the basin or trends to the basin from the north. Within the basin itself, coarser grained sediment is located along the northern rim. During the time that the glacial overburden was being deposited, sediment would have entered the area from the north.

Groundwater will preferentially move through and migrate toward material that is more permeable and offers the least resistance to flow. Sand and gravel are much more permeable than clay and silt. At the FEMP, most of the sand and gravel within the glacial overburden is surrounded by clay and silt as illustrated in Figure 3-36. The low-permeability clay and silt keeps the water from migrating any great distance quickly. The possibility exists though, that sand and gravel could communicate hydraulically and create a "stair step" pathway down through the underlying low-permeablity clay and silt. Fractures and other secondary porosity features could also "short circuit" the clay and silt. Data is presented in the hydraulic conductivity section to quantify the magnitude of these possibilities. To be conservative, both primary and secondary "short circuit" pathways were considered in the conceptual model presented in Section 3.6.3 which is used to model flow and transport.

The low-permeability clay in the glacial overburden limits infiltration of both water and contamination into the underlying Great Miami Aquifer. The presence of a perched groundwater system is the first line of evidence that the till at the base of the glacial overburden retards the downward movement of groundwater. The fact that the glacial overburden provides a true perched groundwater condition is demonstrated by the presence of approximately 3 to 45 feet of unsaturated sand and gravel between the base of the saturated glacial overburden and the water table in the Great Miami Aquifer. The

thinner sections of unsaturated Great Miami Aquifer exist beneath surface streams such as Paddys Run.

Several approaches have been taken to quantify the restrictive properties of the gray clay, for it is the gray clay that is found at the base of the overburden. The gray clay has the lowest permeability of all the sediments in the glacial overburden as is discussed in Section 3.6.1.1. The gray clay does not prohibit all movement of groundwater. In reality, groundwater has the ability to move through most geologic materials, given time, and the same holds true for the gray clays found at the base of the glacial overburden. A good analogy is that the glacial overburden deposits are like a large sponge which is situated on top of the Great Miami Aquifer. How much water slowly drips from this sponge down into the aquifer is in large part dependent upon its hydraulic properties.

3.6.1.1 Hydraulic Properties

Extensive field testing has been conducted to determine the hydraulic conductivity of the glacial overburden sediment (DOE 1994e) and the restrictive properties of the gray clay. The field testing included slug tests, yield tests and pumping tests. Cores of gray clay collected in the field have been measured for bulk density, moisture content (by weight), permeability and specific gravity. Sediment samples have undergone partical size analysis for textural identifications.

An examination of the textural triangle (Figure 3-29) presented in Section 3.4.7 shows the grain-size distribution of the soil in the glacial overburden. It is apparent that data points are densely concentrated in a relatively small area of the textural triangle. The majority of the data fall within the "60 to 80 percent silt and clay" and the "20 to 40 percent sand" zone of the textural triangle, which corresponds to the USCS groupings ML/MH and CL/CH. These soils are described generally as silty or clayey fine sands, sandy clays, sandy silts, silty clays, silts, or clays.

Both Freeze and Cherry (1979) and Fetter (1980) have developed tables that correlate soil type to hydraulic conductivity. Based on the Freeze and Cherry table, the area with the greatest density of points in the textural triangle correlates to material with hydraulic conductivities of from 10^{-5} to 10^{-10} cm/s. Using the Fetter table to convert the same data, a range of hydraulic conductivities from 10^{-4} to 10^{-6} cm/s would be expected. These geotechnical data indicate that the glacial overburden is predominantly composed of sediment with a low hydraulic conductivity.

Figure 3-35 illustrates the eight different sediment types (grouped by grain size and color) that were considered in the interpretation of hydraulic properties. Gradations between the eight sediment types also exist. Slug testing was conducted to determine hydraulic conductivities for all eight sediment types. Additional lab testing was done to further quantify the restrictive properties of the gray clay which is the sediment type with the lowest hydraulic conductivity.

Hydraulic Conductivities

Hydraulic conductivity is a measure of the rate at which water could potentially move through porous sediment. It is expressed as a distance divided by time; for this report, as centimeters per second (cm/s) or feet per day (ft/d). The pathway of least resistance for the migration of water and contaminants will be the pathway that exhibits the greatest hydraulic conductivity. Hydraulic conductivity values can vary through space within a geologic formation making the formation heterogeneitic and they can vary according to the direction in which they are being measured making the formation anisotropic.

Because the glacial overburden is both heterogeneous and anisotropic, the "true" hydraulic conductivity is difficult to determine. The hydraulic conductivity of the glacial overburden cannot be expressed in terms of one value. The scale at which the hydraulic conductivity is measured effects the measurement (Bradbury and Muldoon 1990). Physical characteristics of geologic materials such as particle size, roundness, and degree of sorting, which determine the hydraulic conductivity of a volume of sediment, vary spatially. This spatial variation is large in the glacial overburden. As the volume of sediment being tested changes, the number of heterogeneities included in the sample changes. These heterogeneities may be either conductive or restrictive. Thus, hydraulic conductivity calculations must be evaluated in regard to the type of sediment tested, the volume of sediment tested and the method used for the measurement.

The hydraulic conductivity of the glacial overburden at the FEMP has been calculated using core permeability tests, slug tests, and pumping tests. The volume of material tested in each of these methods increases respectively. It is common for hydraulic conductivities calculated from small volumes of material, such as core samples, to be lower than those calculated with tests that incorporate larger volumes of material, such as slug tests. It is also common for slug test results to be lower than pumping test results.

For the purposes of calculating hydraulic conductivity, the glacial overburden sediment was divided into gray or brown clay, silt, sand, and gravel (Figure 3-35). Core permeability tests were performed on 41 core samples collected from borings drilled for the following investigations described in Section 2.6 and Appendix S:

- Engineering Evaluation for the Engineered Waste Management Facility
- Waste Pits 3 and 5 and Clearwell Dikes Stability Analysis
- Geotechnical Exploration of Coal Storage Facility
- Proposed Sanitary Landfill
- FEMP Glacial Till/Vadose Zone Hydraulic Investigation.

All of the materials in these cores were clay-rich till and lacustrine deposits collected from depths of 1.0 to 23.0 feet, except for one sample collected between a depth of 31.0 and 33.0 feet (Table 3-15).

The hydraulic conductivities measured for the 41 core samples ranged from 3.9×10^{-9} to 1.0×10^{-6} cm/s. These values are extremely low but they are laboratory measurements made on small volumes of samples. Twelve of the core samples were taken from the gray clay as part of the FEMP Glacial Till/Vadose Zone Hydraulics Investigation. The geometric mean for these 12 samples is 2.25×10^{-8} cm/s.

Slug tests have been performed in the glacial overburden at the FEMP (Figure 3-37). Data from 70 of these tests have been grouped according to the sediment types and increasing hydraulic conductivity, Table 3-16. The geometric means for the sediment groupings are as follows:

HYDRAULIC CONDUCTIVITY GEOMETRIC MEAN BY SEDIMENT GROUP

	Hydraulic conductivity	
Group	ft/d	cm/s
Brown clay	1.0×10^{-1}	3.59×10^{-5}
Gray clay	5.30×10^{-3}	1.87×10^{-6}
Brown silt	2.8×10^{-1}	9.88×10^{-5}
Gray silt	2.5×10^{-1}	8.83×10^{-5}
Brown sand	5.0	1.75×10^{-3}
Gray sand	2.3	8.04×10^{-4}
Brown gravel	8.7×10^{1}	3.07×10^{-2}
Gray gravel	1.1×10^{1}	4.03×10^{-3}

The hydraulic conductivity of gray clay calculated from slug tests (1.87 x 10^{-6} cm/s) is greater than the hydraulic conductivity of gray clay calculated from core samples (2.25 x 10^{-8} cm/s). This probably results from a larger volume of sediment being tested by a slug test, resulting in a larger degree of heterogeneity in the sample.

During the calculation and interpretation of slug test data, the location of the well screen relative to the sediment type and water level in the well was compared to determine whether the well exhibited confined or unconfined conditions (Figure 3-38). It was noted that wells completed in clay sediment exhibited unconfined conditions. Wells completed in silt, sand, or gravel, with a few exceptions, exhibited "apparent" confined conditions. The term "apparent" is used because the glacial overburden sediment becomes saturated approximately 3 to 5 feet below the ground surface. The appearance of confined conditions occurs when the coarser grained sand and gravel yields water more readily to a well than the surrounding clay and silts do. The water level in wells completed in sand and gravel equilibrate to the surrounding water table of the overall perched groundwater system.

Seven yield tests and three constant-rate pumping tests were conducted in the glacial overburden in 1993. The seven yield tests were conducted in areas of the glacial overburden where a larger amount of sand and gravel is present (Figure 3-36 and 3-37). The purpose of the yield tests was to select the three most promising areas for conducting constant-rate pumping tests. The pumping tests were conducted to determine the hydraulic conductivity of the sediment that is capable of yielding sufficient water to perform a week long pumping test.

Yield tests were conducted to gain a better understanding of the yield capabilities of the glacial overburden perched groundwater system by determining how much water sediment would yield before going dry. A large, interconnected flow system should be able to yield water to a well faster and longer than a small, discontinuous system. The glacial overburden consists mostly of clay and silt. Slug test calculations indicate that the geometric mean of hydraulic conductivity ranges from 1.87 x 10^{-6} cm/s (gray clay) to 3.59 x 10^{-5} cm/s (brown clay). Hydraulic conductivities calculated from cores were even lower. Sediment with hydraulic conductivities this low does not readily supply groundwater to wells. Any appreciable yield would have to come from coarser grained sand and gravel that has a higher hydraulic conductivity. Therefore areas which have a higher amount of sand and gravel were selected for yield testing (Figure 3-36 and 3-37).

The results of the yield tests (Table 3-17) indicate that a calculated one week sustainable discharge from the glacial overburden ranges from less than 1 to 2.5 gpm, and only three areas are capable of supporting a one week constant-rate test of approximately 2-2.5 gpm. The three areas are a channel in the waste pit area (Well 11214), Plant 1 area C (Well 1339), and Plant 8 (Well 1785). The two yield test locations in opposite corners of the production area (south of the pilot plant [Well 1259] and the northeast corner of the production area [Well 1274] went dry before a sustainable yield could be calculated (Figure 3-37). Although the test wells were screened in sand and gravel, the results indicate that a sustainable yield is dependent upon the migration of groundwater from the surrounding clay and silt into the sand and gravel. The surrounding clay and silt could not recharge the sand or gravel fast enough to keep up with the pumping, causing the wells to go dry. The yield test results support the observation that the low hydraulic conductivity of the clay and silt controls the movement of groundwater in the glacial overburden beneath the FEMP.

Three constant-rate pumping tests were conducted in the glacial overburden for the purpose of determining a hydraulic conductivity for the areas capable of providing a 2-2.5 gpm yield to support a week long pumping test. The tests were conducted in areas of the FEMP that appeared to contain large interconnected deposits of saturated sand and gravel in the waste pit area, Plant 1 pad, and at Plant 8. The locations of the three pumping test wells (11214, 1785, and 1339) are identified in Figure 3-37 and were selected based upon the results of yield tests. Figure 3-39 illustrates the general layout of each of the pumping tests. Up to six observation wells were installed for each test at distances from the pumping well ranging from 10 to 100 feet.

Hydraulic conductivity and storativity, by area, are as follows:

HYDRAULIC CONDUCTIVITY OF COARSE-GRAINED SEDIMENT

	Hydraulic Conductivity		
Area	(ft/d)	(cm/s)	Storativity
Plant 1 pad	15.1	5.3×10^{-3}	0.006
Plant 8	23.8	8.4×10^{-3}	0.005
Waste pit area (channel)	4.3	1.5×10^{-3}	0.004

In the Plant 1 pad area, the drawdown trended northeast-southwest (Figure 3-40). In the Plant 8 area, drawdown trended north-south (Figure 3-41). These drawdown trends shed light on the possibility

that preferential pathways of groundwater flow exist within the glacial overburden. As was discussed earlier, the low permeability of the clay and silt within the glacial overburden makes the glacial overburden an effective barrier to the movement of groundwater. The possibility exists though that groundwater could "short circuit" the low permeability clay and silt and migrate through sand and gravel sediment that interconnect through the clay and silt. Finding these pathways would be virtually impossible without full excavation. Predictions as to where there is a greater potential for these pathways to exist can be made by correlating the drawdown trends from the pumping tests with the distribution of coarser grained sediment and stratigraphic interpretations.

Figures 3-36 and 37 illustrates where the pumping tests were conducted and the distribution of sand and gravel. Again, it should be noted that the coarser grained sediment does not represent one continuous unit. Based upon the interpretation of cross sections this is the area where most of the sand and gravel is present and the greatest possibility of a "short circuit" pathway through the clay and silt exists. The drawdown under Plant 8 (Well 1785) trended north-south within the basin feature correlating with the trend of coarser grained sediment. Drawdown under Plant 1 (Well 1339) trended in a northeast-southwest direction, again correlating with the trend of coarser grained material leading into the basin feature from the northeast. If sediment was being deposit into the basin from the north, coarser material would be deposited along the northern rim of the basin, with finer material farther out away from the rim. This appears to be the case. The coarser grained material has a hydraulic conductivity greater than 10^{-4} cm/s.

The pumping test conducted in the waste pit area (Well 11214) reveals that channel features as small as 20 feet wide also exist and may provide "short circuit" pathways through the clay and silt of the glacial till. Figure 3-42 illustrates the nature of the channel feature. Drawdown in observation wells illustrates the trend of the channel (Figure 3-43). This small 20-foot-wide channel was pumped at 2 gpm for 8740 minutes, yielding approximately 17,480 gallons of water. Hydraulic conductivity of the sand in the channel was calculated as 1.5×10^{-3} cm/s, much higher than the clay which surrounds the channel, approximately 1.87×10^{-6} cm/s. The channel tested is oriented roughly in a north-south direction. During the Pleistocene, sediment would have moved into the FEMP area from the north out of the Shandon Tributary (Figure 3-17). Perhaps this channel is a remnant of that depositional system. If other channels are present, their orientation should also correlate to past depositional environments. Since the sediment source during the Pleistocene was to the north and flow was to the south, the Shandon Tributary appears to be the area where most of these channel features should be

located. Areas away from depositional influence of the Shandon Tributary should have a lower potential for channel features, but channels could still exist.

The results from all the hydraulic conductivity tests in the glacial overburden at the FEMP indicate that:

- Clay and silt with low permeability control the migration and yield of water and therefore the movement of contaminants within the glacial overburden.
- Groundwater yields from the glacial overburden are negligible compared to the hundreds of gpm yields which are obtainable from the Great Miami Aquifer.
- Only three areas were capable of yielding 2-2.5 gpm to support a one-week constant-rate pumping test. These areas are beneath Plant 8, Plant 1, and in a channel located in the waste pit area.
- Drawdown trends observed in the Plant 8 and Plant 1 areas indicate that hydraulic communication is enhanced by the distribution of sand and gravel within the clay and silt.
- The areas capable of supporting a week-long constant-rate test at a pumping rate of 2-2.5 gpm have hydraulic conductivities that range from 1.5×10^{-3} cm/s to 8.4×10^{-3} cm/s, and are associated with the lake basin feature described in Section 3.4.5.
- The only large system of interconnected yield appears to be located beneath Plant 8 and Plant 1. The system is limited by the surrounding silt and clay which have hydraulic conductivity values of 10^{-4} cm/s or less. The data indicate that this area could sustain a yield of approximately 1 gpm for longer than a week.
- A channel located in the waste pit area indicates that smaller systems of interconnected yield also exist. The data indicate that the channel in the waste pit area could also sustain a yield of approximately 1 gpm for longer than a week. Most of these channel features are probably located south of the Shandon Tributary as this was the source of sediment during the time that the glacial till was being deposited. The possibility of other similar channel features located elsewhere on the FEMP property cannot be ruled out.

Physical Properties of the Gray Clay

The gray clay located at the base of the glacial overburden has the lowest hydraulic conductivity of the glacial overburden material. Of all of the sediment types illustrated in Figure 3-35, it is the gray clay that is most restrictive to groundwater movement and therefore exerts the most influence on contaminant migration. Core samples were collected to quantify the restrictive properties of this sediment type (DOE 1994e). Cores were collected from six different locations (Figure 3-37) and measured for bulk density, specific gravity, moisture content, and tested for the coefficient of permeability (Table 3-18).

Porosity

The porosity of the gray clay has been determined from density measurements performed on core samples collected with Shelby tubes (Table 3-18). Shelby tube sample locations are shown in Figure 3-37. The samples collected were analyzed in a laboratory for both bulk density and particle mass density according to the Corps of Engineers laboratory soil testing method EM1110-2-1906, Appendix II. The following relationship was used to calculate porosity (Freeze and Cherry 1979):

$$n = 1 - (\text{bulk density} / \text{particle mass density})$$

Porosity calculations ranged from 23 to 30 percent with an average porosity of 26 percent.

Moisture Content

The moisture content of the gray clay located beneath the FEMP (Table 3-18) has been determined using core samples collected with Shelby tubes at sampling locations shown in Figure 3-37. The analyses were conducted according to ASTM D2216. Moisture content measurements ranged from 10.3 to 25.4 percent (by weight) with an average moisture content of 14.3 percent.

Degree of Saturation

The degree of saturation of the gray clay located beneath the FEMP (Table 3-15) has been determined using data obtained from core samples collected with Shelby tubes at the locations shown in Figure 3-37. The following relationship was used to calculate the degree of saturation.

$$S = \frac{W_m}{\gamma_w (Ve)} \times 100$$

S = *degree of saturation*
W_m = *weight of moisture in soil*
γ_w = *unit weight of water* = 62.4 *lbs./ft*^{3}
V_e = *volume of void spaces*

$$W_m = W_w - W_d$$

W_w = *wet weight of soil*
W_d = *dry wieght of soil*

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$$V_e = 1 - V_s$$

$$V_s = \textit{volume of solid particles}$$

$$V_s = \frac{W_d}{\gamma_w G}$$

$$G = \textit{true specific gravity}$$

Results indicate that the degree of saturation ranges from 76 percent to 108.4 percent, ± approximately 8 percent. The ± 8 percent brings the upper end of the range back down to approximately 100 percent. The results indicate that the gray clay is saturated.

Lysimeter Sampling

Lysimeters were installed in the base of the glacial overburden, in the gray clay, at three different locations (Figure 3-37) to determine if the gray clay at the base of the overburden is saturated and the water quality. The intent was to set one lysimeter (11234) in a fairly thin section of gray clay (approximately 10 feet thick), one lysimeter (11132) in a fairly thick section of gray clay (approximately 30 feet thick), and one lysimeter (11130) in an intermediate thickness of approximately 20 feet. All three of the lysimeters indicate that the gray clay at the base of the glacial overburden is saturated. Sampling results for the lysimeters are presented in Table 3-19; results are also discussed in Section 4.7. Uranium is present in low μg/L concentrations in the gray clay at the base of the glacial overburden. The presence of uranium indicates that even though the gray clay has a low hydraulic conductivity and restricts the flow of groundwater, uranium contamination has been able to migrate into and through the gray clay down to the base of the overburden within the past 40 years.

3.6.1.2 Recharge, Movement, and Discharge in the Glacial Overburden

The interpretation of groundwater movement in the glacial overburden is complicated by the heterogenous nature of the deposit. In general, the water table in the glacial overburden follows surface topography and slopes to the west-southwest towards Paddys Run. One area of recharge exists just north of the South Field, to the west of the SWRB (Plate 3-5) where the water table mounds. Another area of recharge exists northeast of the waste pit area where wetlands (Section 3.8.3) exist.

The average groundwater elevation for the perched groundwater is presented in Plate 3-5 (see Plates). Average conditions were selected to enter into the flow and transport model because average conditions should be more representative of long-term flow patterns. The map is based on water-level measurements collected from Type 1 wells and piezometers. Averages were calculated for wells with 20 or more monthly readings in the period from January 1988 to July 1992. Water levels in the glacial overburden at many locations show seasonal cycles, with the highest water levels in the late winter or early spring and the lowest water levels in late autumn after evapotranspiration has reduced the soil moisture. Plates 3-6 and 3-7 present the groundwater elevations for the low season in October 1991 and the high season in March 1992.

The average, low, and high perched groundwater elevation maps (Plates 3-5, 3-6, and 3-7) show similar patterns; i.e., that the highest elevations are in the northeastern part of the FEMP and the lowest elevations are on the west and southwest sides of the property. Overall the contours show that the potential flow is from northeast to southwest, following topography. Since Paddys Run and the SSOD have eroded completely through the glacial overburden, it is not possible for perched groundwater to travel laterally beyond either surface feature. Thus, the perched groundwater system under the former production and waste storage areas is restricted to that portion of the glacial overburden east of Paddys Run and north of the SSOD.

It is important to note that there are no groundwater depressions in the areas where the glacial overburden has been thinned by construction activities, indicating that it still restricts vertical groundwater flow.

The larger tributaries to Paddys Run and the SSOD that may receive perched groundwater flow (Figure 3-9) are:

- The north side drainage ditch on the north side of the railroad tracks that extends into the area of the solid waste landfill
- The pilot plant drainage ditch that flows to the west and joins Paddys Run south of the K-65 silos
- The south side drainage ditches and the former drainage channels in the glacial overburden that have been filled by the active and inactive flyash piles
- The east side drainages of the SSOD that collect water from the area east of the former production area

- The northeast drainage in the very northeastern corner of the FEMP property that flows to the east off the FEMP
- The southeast drainage ditch that enters the SSOD from the east and southeast.

Local perturbations in the perched groundwater flow are due to localized drains. All three water table maps show a distinct elongated north-south depression in the water table in the center of the former production area. This depression is due to the presence of the storm water sewer and a drainage tile installed during the construction of the FEMP that extends from the northeast corner of Plant 8 south to the SWRB and from the southwest corner of Plant 6 to the SWRB. The storm water sewer system and the drain are collecting a significant amount of infiltration and shallow groundwater in the central portion of the former production area. Analyses of water samples from the storm sewer system (Weston 1988) confirm that uranium-contaminated perched groundwater is entering the storm sewer.

Hydrographs showing the water elevation versus time for all the Type 1 wells are contained in Appendix L. The hydrographs for the Type 1 monitoring wells show that a large percentage of the wells respond to precipitation. A comparison of the hydrograph for Well 1012 with Figure 3-4, depicting the monthly precipitation for the region during the same period, shows a correlation between precipitation fluctuation and groundwater elevation fluctuations.

The hydrographs also show that the water table in the glacial overburden is generally above an elevation of 550 feet, well above the water table in the Great Miami Aquifer which generally lies between 518 to 530 feet under the FEMP.

Plate 3-8 shows the standard deviation values from the calculation of average water table elevations shown in Plate 3-5. The magnitude of the standard deviation indicates the degree to which the water table rises and falls in a given well. Plate 3-8 shows that wells with similar standard deviation values are clustered, indicating the presence of a common control over the infiltration of precipitation in that area.

The overall pattern shown in Plate 3-8 is that low standard deviations are most prevalent in the production area and the highest are along Paddys Run. Scattered occurrences of high standard deviations occur in the waste storage area and north of the waste storage and production areas. Within the production area a single well between Plant 6 and Plant 9 and one well west of the boiler plant have standard deviations greater than 2.0. One well east of the production area also has a

standard deviation greater than 2.0. These scattered occurrences of wells with high standard deviations is consistent with the scattered pattern of coarse-grained sediment bodies shown in Figure 3-36.

Wells with a standard deviation of 0.5 feet or less are clustered in the western part of the production area near Plant 2/3 and Plant 8. This is an area where paving or buildings prevent infiltration and the storm sewer collects both surface water and groundwater. The area with wells that have a standard deviation between 0.5 and 1.0 define an area that covers most of the production area and the sewage treatment plant area. Again this is the area where much of the surface is paved. Within the north central part of the production area, north of the boiler plant, the surface is covered in grass; however, the standard deviations for the wells in this area is still low. This is an area where the glacial overburden is predominantly till and infiltration is limited by the low hydraulic conductivity of the clay rich material.

The area where high standard deviations occur along Paddys Run is also the area where the water table gradient is the steepest Plate 3-5. It is reasonable to attribute the high standard deviations to the fact that these wells are near Paddys Run where, due to the elevation change, weathering is the deepest. Water infiltrates the area easily and also drains laterally to Paddys Run due to lateral weathering along the stream bank. The depth of the brown to gray color transition displayed on the cross sections in Appendix Q that cross Paddys Run also indicates deep weathering along Paddys Run.

Seepage Velocities and Travel Times

Horizontal and vertical seepage velocities through the glacial overburden were determined according to Darcy's Law. Seepage velocities are faster than Darcy's velocity because flow pathways are smaller. The relationship is as follows:

$$V = KI/N$$

where

V = seepage velocity
K = velocity hydraulic conductivity
I = gradient
N = effective porosity

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As described in Section 3.4.5, the gray clay varies in thickness across the site. Based upon examination of the numerous cross sections presented in Section 3.4.5 and Appendix Q, the site was divided into four zones based upon the minimum representative thickness of gray clay and the presence of sand and gravel (Figure 3-44). This zonation simplifies for the uncertainty that the heterogeneity of the overburden creates in making hydrogeologic interpretations. This same zonation scheme was used to model infiltration. Modeling used five zones instead of four, using the fifth zone to account for degraded soil located around Plant 6. The modeling zonation refinement is further explained in Section 5.

Profiles of each zone and hydraulic properties for each zone profile are presented in Figure 3-44. Zone I roughly correlates to the lake basin described in Section 3.4.5 where a larger amount of coarser grained material is present. Even though field evidence indicates that the coarser grained material present in Zone I is not contiguous, it is represented in the zonation scheme as a continuous sand layer. This assumption addresses the possibility that a short circuit pathway of sand and gravel exists between the former production area and Paddys Run. Hydraulic testing results presented in Section 3.6.1.1 indicate that the basin sediment is very heterogeneous and the possibility of such a large direct pathway is doubtful.

For each zone, a representative minimum thickness of gray clay was projected across the zone as the representative thickness of gray clay for the zone. For instance, Zone III has a gray clay thickness of 10 feet, the minimum representative thickness of gray clay judged to be there. The thickness of the gray clay in Zone III actually increases to the east to approximately 25 feet including a few small areas exist where the gray clay is thinner than 10 feet. This conceptualization results in vertical time of travel calculations which on an average are shorter than actual field conditions suggest. This zonation is generalized and vertical volocities and travel times vary.

In calculating horizontal seepage velocities it was assumed that most of the horizontal flow occurred above the gray clay in either brown clay, brown/gray sand, or brown clay/sand (Figure 3-45). The gradient varies depending upon when and where it is calculated. An average of the groundwater elevations observed in the glacial overburden was used to determine a gradient at two locations in the former production area and one location just north of the former production area (Plate 3-5). A range of .008 to .015 was determined. The average porosity of 26 percent was used for the clay and 30 percent for the sand. The resulting horizontal seepage velocities are presented in Table 3-20.

Seepage velocities for a gradient of .015 range from 3.138×10^{-3} ft/day (brown clay) to .08 ft/day (brown/gray sand). Seepage velocities for a gradient of .008 range from 5.885×10^{-3} ft/day (brown clay) to .16 ft/day (brown/gray sand). Advective time of travel calculations, using calculated seepage velocities and assuming a travel distance of 2000 feet (roughly the distance from Plant 8 due west to Paddys Run) range from 931 years (brown clay) to 34 years (brown/gray sand) using a gradient of .015.

Equivalent vertical hydraulic conductivities were used to determine vertical seepage velocities and advective travel times for each generalized section (Figure 3-45). Because a small area exists within Zone 1, near the pilot plant, where the gray clay thins to approximately 10 feet, vertical seepage velocities and advective travel times for Zone 1 are presented for both 10 and 20 feet of gray clay. The transport model (Section 5.0) uses actual gray clay thicknesses therefore, thickness variations within these generalized zones are accounted for in the solute modeling presented in that section. The equivalent vertical hydraulic conductivity for the glacial overburden was determined using the following relationship (Freeze and Cherry 1979):

$$K_z = d \,/\, \text{summation from i to n of } (d_i/K_i)$$

where

K_z = equivalent vertical hydraulic conductivity
d = overall thickness of all of the layers
d_i = thickness of a unique layer
K_i = hydraulic conductivity of an individual layer

The calculated K_z was then substituted for K in the seepage velocity formula to determine vertical seepage velocity. The average porosity of 26 percent was used as this is the calculated porosity for the gray clay (see Section 3.6.1.1). The lower the porosity used, the faster the calculated seepage velocity. Therefore, using this porosity for the other sediment types should result in higher seepage velocity results. A gradient of 1 was used for the vertical gradient. This represents the change in head from the water table down to the base of the glacial overburden sediment where unsaturated conditions are again encountered and the fluid pressure equals 0. Therefore, the head is equal to the height of the water column making the gradient equal to 1. The thickness of the upper-most layer was decreased by 5 feet because the water table of the perched water is located 3 to 5 feet beneath the ground surface. Results of the calculations are presented in Table 3-21. K_v is assumed to equal K_h

divided by 10. The K_v is usually smaller than K_h due to bedding planes and depositional features which impede the downward movement of groundwater.

Vertical seepage velocities range from 0.846 ft/yr (Zone II, 30 feet of gray clay) to 2.15 ft/yr (Zone 1, 10 feet of glay clay). Vertical advective travel times (using calculated seepage velocities) ranged from 41.4 years (Zone II, 30 feet of gray clay) to 13.5 years (Zone III, 10 feet of gray clay). Calculated results indicate that the thickness of the gray clay controls the vertical travel time.

3.6.2 Hydrogeology of the Great Miami Aquifer

The sand and gravel water table system of the Great Miami Aquifer is described in Section 3.4.4 and shown in Figure 2-2. The Great Miami Aquifer has been divided into hydrogeologic environments (Spieker 1968b). A hydrogeologic environment describes a portion of an aquifer possessing hydrologic and geologic properties that differ from the properties of the aquifer in adjacent areas. Four major hydrogeologic environments have been identified and mapped for the Great Miami Aquifer in the vicinity of the FEMP (Figure 3-46).

Two characteristics of aquifers are used to define these environments: transmissivity and specific yield. Transmissivity is a measure of the ability of water to move through an aquifer. Specific yield is a measure of the quantity of water an aquifer will yield from storage when the hydraulic head declines. Specific yield is related to porosity and grain size. The smaller the grain size, the more water will be retained in the aquifer and not be available to a pumping well. Conversely, coarser sediment will retain less water and have a larger specific yield.

The Type I hydrogeologic environment describes the Great Miami Aquifer along the Great Miami River floodplain. Aquifer sediment exists at land surface; thus, stream infiltration is possible. The aquifer consists primarily of well-sorted sand with gravel, although scattered lenses of clay or fine-grained material are also present. These lenses are not of sufficient thickness or areal extent to act as semiconfining layers or to significantly affect groundwater movement. Aquifer transmissivity generally ranges from 40,000 to 67,000 square feet per day (ft^2/day), with a specific yield of about 0.2. Individual wells can provide as much as 3,000 gpm. As shown in Figure 3-46, the Type I environment is further divided depending on the presence or absence of clay layers.

The Type II hydrogeologic environment is characterized by having less than 150 feet of sand and gravel with no really extensive interstratified clay layers present. Recharge by stream infiltration is not available. The specific yield for the aquifer is about 0.2. Large groundwater supplies are not generally available; Type II environments are generally located close to bedrock valley walls.

The Type III hydrogeologic environment is characterized by clayey glacial overburden overlying the Great Miami Aquifer. In the region directly beneath the FEMP, the aquifer is divided into upper and lower parts by a clay interbed approximately 10 to 20 feet thick occurring approximately 140 feet below land surface. Hence, the lower aquifer is classified as a semiconfined or leaky confined aquifer.

The coefficient of storage for the Great Miami Aquifer beneath the FEMP site has been presented in three studies. Spieker and Norris (1962) estimated a storage coefficient of .001 for the lower sand and gravel aquifer. Spieker (1968b) estimated that where groundwater occurs under unconfined conditions, the coefficient of storage is estimated to be 0.2. But the report goes on to state that in areas where the semiconfining clay interbed is present, the coefficient of storage is slightly reduced to approximately 0.1. Estimations made from the South Plume pumping test indicate that the storage coefficient ranges from .001 to .01, the smaller value being deeper than the larger value. Spieker (1968a) reports a range of hydraulic conductivity of 370,000 gpd/ft to 300,000 gpd/ft; 370,000 gpd/ft was calculated from a pumping test conducted on the SOWC Collector Well 2 (Dove 1961). Because no semiconfining clay interbed is present at this location, a saturated thickness of 125 feet was used for the calculation. From a pumping test conducted at the FEMP production wells (Spieker and Norris 1962), 300,000 gpd/ft was calculated. The semiconfining clay interbed is present at this location. Spieker and Norris report a transmissivity for the lower Great Miami Aquifer of 140,000 gpd/ft using a saturated thickness of 70 feet. Adding in the thickness of the upper portion of the aquifer (80 feet) results in a transmissivity calculation of 300,000 gpd/ft. Where the glacial overburden is present, the FEMP is over the Type III environment. Paddys Run, where it has eroded through the glacial overburden, represents a combination Type III/I environments.

The Type V hydrogeologic environment includes all of the areas outside of the buried valley of the Great Miami Aquifer. These areas are bedrock uplands consisting of shale with interbedded limestone overlain by 50 feet or less of clay-rich glacial overburden. Large quantities of groundwater are not generally transported through this material. Well yields vary widely, generally ranging from

zero to 10 gpm. However, sand and gravel lenses are erratically distributed throughout this glacial overburden and, in some cases, wells completed in these units may yield up to 50 gpm.

3.6.2.1 Hydraulic Properties

Since 1948, 11 aquifer tests have been conducted near the FEMP for the purpose of determining horizontal hydraulic conductivity (K_h). Table 3-22 shows values of K_h calculated from these 11 tests. The average K_h is 386 ft/day with a minimum of 120 ft/day and a maximum of 774 ft/day. Two of the aquifer tests were actually conducted for the FEMP. In 1962 the USGS conducted a pumping test using wells located in the former production area. The test resulted in a calculated K_h of 267 ft/day. As part of Removal Action 3, a pumping test was conducted just south of the FEMP property line in 1993 which resulted in a calculated K_h of 413 ft/day. As the tests indicate, the value of K_h varies between and within hydrogeologic environments, but the variation does not appear to be large and probably reflects textural changes resulting from slightly varying depositional conditions. The hydraulic conductivity of the clay interbed found within the Great Miami Aquifer ranges between 0.3342 to 0.4278 ft/day (1×10^{-4} to 2×10^{-4} cm/s) (Spieker and Norris 1962).

Typically, horizontal hydraulic conductivity of unconsolidated materials is greater than vertical hydraulic conductivity due to the anisotropic effects caused by horizontal bedding planes. Higher ratios will occur with greater stratification, especially with the presence of finer grained layers. Typical horizontal to vertical ratios reported for glacial outwash range from 5 to 200. A ratio of approximately 5 to 15 was calculated from the Removal Action 3 pumping test.

Storage Coefficient

Four previous studies calculated that the storage coefficient for the Great Miami Aquifer is 0.2 (Dove 1961, Spieker and Norris 1962, Spieker 1968a, and Spieker 1968b). Smith (1962) estimated that the storage coefficient was 0.23.

3.6.2.2 Recharge, Movement, and Discharge in the Great Miami Aquifer

Groundwater enters the general FEMP area from three directions (Figure 2-2). The water levels and pattern of seasonal change clearly indicate that the Great Miami Aquifer and the perched groundwater in the glacial overburden are two distinct groundwater systems. In the northeast, groundwater moves southwest from the Ross area into the portion of the New Haven Trough now occupied by the Great Miami River.

The majority of this flow is captured by the SOWC colleciton wells. The second source of groundwater is the Shandon Tributary to the north of the FEMP, which contains a tributary of the New Haven Trough that extends under the town of Shandon (Figure 3-16). The groundwater from the Shandon Tributary flows under the waste storage and former production areas and exits along the eastern boundary of the FEMP to discharge into the Great Miami River. This flow also is influenced by the pumping of the SOWC collector wells. The groundwater and the Great Miami River exit this area through the New Baltimore outlet.

The recharge from the Dry Fork of the Whitewater River, located about 2 miles west of the FEMP, causes groundwater to move to the east toward the FEMP. This flow splits with a portion going east under the FEMP to the SOWC collector wells and a portion that turns southward under the southern part of the FEMP and flows south through the Paddys Run Outlet. Although these general flow patterns dominate the regional flow system, local and short-term variations do occur within it.

Regional groundwater maps constructed from comprehensive water elevation surveys in August 1982, April 1986, and May 1988 are presented in Figures 3-47, 3-48, and 3-49, respectively. Beginning in January 1988, monthly water-level readings were collected in all RI wells in the aquifer and glacial overburden. Appendix K contains monthly groundwater elevation maps for all Type 2 and Type 3 wells.

Figure 3-50 is a groundwater elevation map of average water-level elevations collected monthly at the FEMP in Type 2 wells between January 1988 and September 1993. The average water table is presented here to show the conditions used in the groundwater model (Section 5) and to provide a comparison against monthly water table maps in Appendix K. Only wells with 30 or more monthly readings were used to calculate average conditions.

Figure 3-50 shows that the water table conditions, on the average, are similar to the conditions depicted in the regional water table maps (Figures 3-47 through 3-49). The exception is the small, 524-foot closed contour southwest of the K-65 silo area. This contour indicates that recharge from Paddys Run to the Great Miami Aquifer occurs even under average conditions. Figure 3-51 is the water table elevation for June 1990, the highest water table condition measured during the RI, and shows the pronounced mounding in the aquifer when recharge is at its maximum. Figure 3-52 is the water elevation contours for November 1988, the lowest water-table condition recorded during the RI,

and shows that during the dry late summer and early fall, there is no recharge from Paddys Run. These months correspond to the maximum and minimum data in the hydrographs in Appendix L.

Figures 3-53 through 3-56 show the water table data for Type 2 wells for 1993 at quarterly intervals to illustrate the annual recharge cycle from Paddys Run. Well 2066, located in the northwest corner of the FEMP, is in a slightly different geologic environment where the aquifer contains a great deal of silt and clay. As a result, Well 2066 always has a water level roughly 15 to 20 feet higher than the rest of the Type 2 wells. Water levels in Well 2066 always create a steep gradient from the northwest. This local sediment will not be included in the narrative for the seasonal recharge because of its unique geologic setting and the fact that it is north of the area influenced by recharge from Paddys Run.

As shown in the precipitation comparison in Figure 3-4, December 1992 was a very dry month; however, rainfall increased in late December and remained at about the same level in January 1993. The typical hydrograph shown in Figure 3-57 indicates that water levels peaked in late spring in 1993. It is the rate of rainfall that controls the recharge and the rise and fall of the groundwater table under the FEMP.

While it is true that rainfall controls the recharge of the aquifer, it is not so much the magnitude of monthly rainfall as the frequency and duration of storms that controls sustained recharge. The monthly rainfall line in Figure 3-57 shows that in some years the maximum rainfall occurs in the summer months. With the exception of 1990 which was the wettest year on record for the Cincinnati area, recharge consistently begins in the last month or two of the year. Several factors combine to cause this and the length of the rainfall event is one of the more significant factors. Summer rain occurs as sudden, often severe, short thunderstorms which dump large amounts of water for an hour or less. The low hydraulic conductivity of the clay-rich soil in the glacial overburden retards infiltration and most of the rainfall from summer storms runs off in flash floods. The hydrograph in Figure 3-11 shows the dramatic rise and fall of Paddys Run in response to the storms. In the summer the short duration storms with rapid runoff do not recharge the perched groundwater system and provide only a short duration recharge to the Aquifer (Figure 3-11). There is no sustaining flow from seeps between storms because the perched groundwater system is depleted due the lack of recharge and the effects of evapotranspiration which are at their maximum in the summer months Table 3-3.

In contrast rainfall in the late fall and winter occurs in the form of steady showers that extend for periods of several hours to several days. The lower precipitation rate and longer duration allows surface water to saturate the soil and recharge the perched groundwater system. The runoff from these rainfall events also occurs over a longer duration and there is a longer period of recharge while the rain is falling. Between rainfall events in the winter and spring the perched groundwater in the glacial overburden north of the FEMP discharges to the upper reaches of Paddys Run through seeps and provides a base flow between storms. This base flow moves down stream to the FEMP and infiltrates the Great Miami Aquifer through the bed of Paddys Run (Figure 3-10), sustaining recharge between storm events. Thus the longer duration of the rainfall events, the sustained flow from seeps upstream, and the reduced impact of evapotranspiration combine to sustain recharge to the aquifer during the winter and spring.

In January 1993 (Figure 3-53), the highest water level contour along the west side of the FEMP is 522 feet elevation and the contour pattern is open to the west. Regional groundwater flow is from the west due to normal recharge from the Dry Fork of the Whitewater River (Figure 2-2) and there is some recharge along Paddys Run due to runoff from the north. Water levels in the southern two wells along Paddys Run Road are higher than the northern two wells due to recharge from Paddys Run.

In April 1993 (Figure 3-54), the highest water level contour along the west side of the FEMP is 524 feet and the contour is closed, indicating that recharge from Paddys Run causes a "mound" on the water table that has a significant impact on water levels under the FEMP. All four wells along Paddys Run Road show water levels below 524 feet, indicating that the recharge is indeed from Paddys Run rather than due to increased recharge from farther west.

In July 1933 (Figure 3-55), the highest water level contour on the west side of the FEMP is 523 feet and the contour is again open to the west, indicating that the recharge rate from Paddys Run has diminished; however, there are still residual effects that cause the curvature to the contour. Figure 3-56 shows the October 1993 water levels and the highest contour along the west side of the FEMP is 521 feet. The 521 foot contour is almost straight under the FEMP, indicating that the residual effects of recharge from Paddys Run have dissipated. All groundwater is either flowing into the area from the north or from the west.

Figure 3-56 also shows the impact of the operation of the South Plume removal action wells on the water table in the area between Willey and New Haven roads. The recovery wells began pumping groundwater on August 27, 1993 at a rate of 400 gpm from each well for a total discharge from the system of 2000 gpm. On December 3, 1993 the pumping rate from each well was reduced to 300 gpm for a total of 1500 gpm. Hydrographs which show the impact of the pumping on water levels in individual wells are contained in Appendix L.

In conjunction with the mounding, the location of the water table divide also shifts between groundwater flow to the east and flow to the south. A groundwater divide is a high point in the water table. Water flows downward away from the divide. The divide depicted in Figure 3-50 for average and Figure 3-51 for highest water table conditions is similar in shape and location. The only difference is a slight shift to the south in the area of the inactive flyash pile and South Field during maximum recharge (Figure 3-51).

During average conditions, groundwater flows east under the waste storage and former production areas and as far south as the SWRB. Infiltration along the upper portion of the SSOD also flows to the east. Gradients to the east, however, are gentle at about 1 foot per thousand. During high recharge conditions (Figure 3-51), the divide shifts slightly to the south and conforms with the channel of Paddys Run. Groundwater gradients are still predominantly east to slightly northeast under the waste storage and production areas; however, the gradient is steeper near Paddys Run. Between the southwest corner of the production area and the confluence of the SSOD and Paddys Run, the gradients have shifted to the northeast from east under average conditions. In the area of the SWRB, the gradient is slightly more northeast than under average conditions.

The contours in the southern part of the FEMP are parallel to the alignment of Paddys Run and the lower part of the SSOD. This pattern indicates that groundwater is infiltrating along an approximate 2000-foot-long, roughly linear segment of the two streams. Groundwater is moving from the recharge area to the southeast. Under average conditions, flow is more southerly south of the divide and easterly north of the divide.

Figure 3-52 shows the location of the divide during very low water table conditions. Virtually all flow is to the east under the FEMP. Only under the southwestern corner of the FEMP property is the

gradient to the south. Under all seasonal conditions the groundwater south of the divide will flow to the south between the bedrock highs.

Appendix L contains hydrographs with the Type 2, Type 3 and Type 4 wells for each well cluster. Figure 3-57 is a typical hydrograph for a location with a well cluster. The hydrographs for the Type 2, Type 3, Type 4 monitoring wells and the hydrographs prepared for well clusters show that the wells in the Great Miami Aquifer respond to precipitation in the late fall and early winter and that the water table elevations are generally between 518 and 530 feet under the FEMP.

Figure 3-57 includes the monthly precipitation from the NWS during the same time period to show the correlation between monthly precipitation and monthly water levels in the Great Miami Aquifer at Well Cluster 009 located adjacent to Paddys Run south of the K-65 silos. From 1988 to 1993, precipitation in the region has fluctuated by 4 to 8 inches each year. The hydrographs (Appendix L) for the monitoring wells show fluctuations in the water table from 8 feet per year in wells around the FEMP to as much as 11 feet per year in wells near the Great Miami River (Cluster 097). A few erratic data points are present on some of the hydrographs and are attributable to measurement errors. The hydrograph for Well 2097, located close to the Great Miami River, shows a greater response to precipitation than do hydrographs for wells that are located farther from the river. This is due to recharge from the Great Miami River during near-flood conditions. The hydrograph for Well 2558 near the confluence of Paddys Run with the Great Miami River also exhibits some more random spikes that could be attributable to stream infiltration.

One other pattern that is present in several of the hydrographs is a drop-off in water elevations during the second half of 1993. The cluster hydrograph for Wells 2125, 3125 and 4125, located on the east side of Paddys Run half way between Willey and New Haven roads, shows this change in normal patterns. This sharp decline is due to pumping of Recovery Wells 3924 through 3928 south of Willey Road in support of Removal Action 3. This decline is present to various degrees in hydrographs within the pumping influence of the five recovery wells.

Some of the monitoring well cluster hydrographs show vertical gradients. Cluster 2108, 3108 and 4108 shows an example where there is no appreciable vertical gradient between the Type 2 and Type 3 wells but a well-defined downward vertical gradient exists between the Type 3 and Type 4 wells. This well cluster is located west of the production area on the west side of Paddys Run. The

hydrograph for Cluster 2065 and 3065 shows a slight downward vertical gradient between the Type 2 and the Type 3 monitoring wells. This well cluster is located south of the SWRB. Hydrographs for other well clusters in the vicinity exhibit slight downward vertical gradients between the Type 2 and Type 3 monitoring wells.

Figure 3-58 is a histogram showing the frequency and magnitude of the vertical gradients from all the monthly water level measurements in the Great Miami Aquifer. The distribution is essentially a bell-shaped curve. Over 1400 of the measurements (44 percent) show no gradient at all and approximately 2400 measurements (86 percent) fall within a span of 0.05 to -0.05 feet and 90 percent of the measurements are within the span of 0.35 to -0.35. As discussed in Section 3.6.2.1, the ratio of horizontal to vertical hydraulic conductivity in the Great Miami Aquifer ranges from 5 to 15 based on pumping test data; therefore, the gradients shown in Figure 3-58 are not significant to the movement of groundwater under the FEMP.

The hydrograph for Cluster 2066 and 3066 shows that there is a large vertical difference in groundwater elevations between Wells 2066 and 3066. The boring logs show that the Type 2 well is screened in a low-yielding sandy clay while the Type 3 well is screened in a coarse sand. The sediment encountered at this location in the Shandon Tributary is different from that in the main channel of the New Haven Trough and may include some till between Wells 2066 and 3066. The difference in geology between the two wells would suggest that the vertical difference of 15 to 20 feet in groundwater elevations between them is related to the clay that dominates the lithology in the upper part of the aquifer in this location in the Shandon Tributary.

Seepage Velocities and Travel Times

Horizontal seepage velocities through the Great Miami Aquifer were determined using the same equation presented in Section 3.6.1.2. The average gradient was calculated at three different locations using the average of water level elevations collected from 1988 through 1993. The traces used to calculate the average gradients are illustrated in Figure 3-50. The average gradient ranges from .0008 in the New Haven Trough (Trace B) to .002 in Paddys Run Outlet (Trace C). Using these two gradients, a horizontal hydraulic conductivity of 413 ft/day (result of the South Plume pumping test) and an average porosity of 30 percent, seepage velocity ranges from 1.1 ft/day in the New Haven Trough (Trace B) to 2.75 ft/day in Paddys Run Outlet (Trace C). Given a travel distance of 2000 feet, the time of travel ranges from 5 to 2 years.

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Paddys Run/Groundwater Interaction

Paddys Run interacts with the Great Miami Aquifer in several different ways that affect groundwater flow and discharge. The stream has eroded through the glacial overburden and into the top of the Great Miami Aquifer from about the position of the K-65 silos (Figure 3-10) to its confluence with the Great Miami River. It is directly connected with the Great Miami Aquifer in that reach. South of the FEMP, the elevation of Paddys Run is close to or above the Great Miami Aquifer water table and Paddys Run loses water to the regional aquifer. It is generally dry except during runoff periods following rainfall and snow-melt events. Sustained flow has been reported in Paddys Run during the winter and spring by Dames and Moore (1985) and recorded by stilling wells monitored during the RI. Relatively little recharge of the Great Miami Aquifer occurs where Paddys Run is on clayey till north of the K-65 silos.

Groundwater elevation contour maps for Type 2 wells (Appendix K) show that the regional water table fluctuated, based on monthly readings, as much as 8 feet during the period of January 1988 to June 1989. This water table fluctuation may be considered extreme because the FEMP experienced drought conditions from spring 1988 to early winter 1989, followed by an extended period of higher-than-average precipitation from late winter to early summer 1989.

As shown in Figures 3-11 and 3-12, there is a high degree of correlation between the Paddys Run hydrograph and the regional aquifer hydrographs. These figures are based on readings taken at 60-minute intervals using pressure transducers and a data logger. As the Paddys Run hydrograph peaks, the groundwater hydrograph shows a peak a very short time later, indicating the rapid hydraulic connection between the stream and the regional aquifer.

The effect of the recharge mound on groundwater and contaminant movement is analyzed by calculating the position of a particle of groundwater on a monthly basis. The position is determined by starting at an arbitrary point and calculating the movement for monthly intervals of a particle from that point using the slope and direction of the groundwater gradient at that point. The new gradient and slope for each particle each month is taken from the monthly water table maps in Appendix K. The particle tracks for groundwater movement are shown in Plate 3-14 for 14 locations along Paddys Run and the SSOD.

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Particle tracks for hypothetical contaminants are also shown in Plate 3-9. There is no relation between these tracks and any actual contamination in the aquifer other than a prediction of movement if contamination was present. The contaminant tracks are based on contaminants moving at one-twelfth of the velocity of groundwater because a contaminant retardation factor of 12 for uranium is currently being used in the groundwater modeling.

Plate 3-9 shows the particle tracks for 14 locations for the period beginning September 1988 through April 1990. This period represents both the time when the well network was sufficiently dense to provide good water-table data and the period of transition from unusually dry to unusually wet conditions. The points for January 1989 and 1990 are labeled on each groundwater particle track so the movement over a one-year time period is easily comparable from location to location.

The hydrographs in Appendix L show that from September through December 1988 the water table was generally at its lowest level as a result of a dry year in 1987 followed by a drought in 1988. The particle tracks for September through December therefore indicate the groundwater flow direction if there is no recharge from Paddys Run. Recharge from Paddys Run began in January 1989 and peaked in June and July of 1989. Water levels fell until December 1989 but not to the low levels of 1988. Water levels rose again from January through April 1990 to levels equal to the highest levels in 1989.

Plate 3-14 shows the particle tracks for locations A through E in the northwest corner of the FEMP. Locations A, B, and D lie along Paddys Run. Particles A and B are started in locations where Paddys Run is flowing on glacial overburden north of the point where recharge from Paddys Run to the aquifer occurs. The northernmost point where recharge begins appears to be about 300 to 500 feet north of location D. The particle tracks from locations A through E were influenced by the recharge. The degree of the influence is in part a function of the distance of the starting location from Paddys Run.

For the particle at location A the normal gradient is to the south-southeast parallel to Paddys Run, as shown by the September through December 1988 points. The track is deflected to the east slightly during the January to April 1989 period indicating that perhaps there is some leakage from Paddys Run through the glacial overburden. The track takes an abrupt turn to the northeast in October 1989 and continues on an erratic path to the northeast through April 1990. This erratic movement appears

to be in response to a reversal of gradient that results from the recharge from the south moving to the north. The net movement from January 1989 to January 1990 is a path to the southeast rather than to the south-southeast. The particle track for a contaminant starting at location A would still have been to the south during the year because it stayed well north of the main influence of recharge from Paddys Run.

For particles at locations B and C in Plate 3-14 the normal gradient is to the east. Both particle tracks show a slight shift to the north but the net movement from January 1989 to January 1990 is to the east-northeast. The contaminant track for both of these points is short and to the east, indicating that contamination in the aquifer from the waste pits will likely be migrating directly to the east.

Particles at location D (300- to 500-feet downgradient from the area where recharge appears to take place) and location E (just east of the K-65 silos) show a different pattern. The September through December 1988 period indicates that flow without recharge from Paddys Run is to the east or slightly southeast. The net movement from January 1989 to January 1990 is to the northeast. The net distance traveled is also greater than for the particles from locations A, B, or C in the same time period. This appears to be because of the steep gradients developed by the mound during the time when Paddys Run recharge was at its greatest, from January through May 1989. The contaminant particle tracks also have a path distinctly different from the water particles from locations D and E. Due to retardation the contaminants stay under the influence of the steep recharge gradients for a longer period of time and the net movement is to the east-northeast.

The groundwater track for location F shows that the highest groundwater velocities under the FEMP occur where recharge from Paddys Run simply reenforces the normal gradient. As the track shows, normal flow is slightly south of east. Paddys Run is almost perpendicular to the groundwater flow lines so the recharge increases the gradient without changing the gradient direction. The result is the longest flow path for the January 1989 to January 1990 period. The net flow direction is also essentially east as is the contaminant track.

For particles at locations H and I the normal groundwater flow direction is to the east. The impact of recharge from Paddys Run has resulted in a net flow from January 1989 to January 1990 to be to the northeast. This is where groundwater flow without recharge would turn to the southeast. Particle tracks for contaminants are essentially to the east in these two locations.

Particles at locations K and N have a slightly different path because these locations are on the upgradient side of Paddys Run. The normal gradient from September through December 1988 is to the southeast. Flow is diverted to the southwest at both locations although at slightly different times. Location N is farther north so it is impacted earlier than location K. The recharge front is moving south along the length of Paddys Run as the saturated portion of the aquifer forces water in the stream to move farther and farther south before infiltrating.

At location N the regional gradient caused movement to the east-southeast from September 1988 through January 1989 and from July through December in 1989. Recharge from Paddys Run diverts this flow to almost directly south from February through June 1989 and again from January through April 1990. The net movement for the January 1989 through January 1990 period is only slightly east of south rather than to the east-southeast. The short contaminant path is also considerably more to the south than the normal groundwater gradient indicates it should be.

At location K the flow is diverted to the southwest in May of 1989, an approximate 90 degree change in direction. The flow returns to a southeasterly direction by July 1989. The net movement from January 1989 to January 1990 is to the southeast rather than the east-southeast. The contaminant track is also diverted from an easterly to a southerly path.

Locations L and M show particle tracks that are strongly influenced by the steep groundwater gradient to the south out of the Fernald Outlet. The normal flow line approximated by the September through December 1988 period indicates that flow should be to the southeast. Only a slight increase in the spacing between the points in early 1989 indicates an increase in velocity due to recharge. The track for location L turns almost south in May 1989 after the main recharge period. The net direction of flow for the L track is more than for the M track. Both tracks appear to be converging on the location of Well 2060 where off-property contamination was first discovered. These two tracks appear to show how contamination transported by Paddys Run could have traveled off the FEMP.

The particle track for location J is different from the others because this is an area where the regional gradient is not very steep and it is influenced by recharge from the SSOD and its tributaries. The close spacing of the points indicates that the gradient is relatively flat; therefore, even though there are a number of abrupt changes in direction the net distance is relatively short. It appears that the

normal gradient is to the east and recharge causes a displacement to the south. The net movement from January 1989 through January 1990 is to the southeast.

Location G is in the vicinity of Plant 6 in the southeast corner of the production area. The particle path is very short again due to the very flat groundwater gradient under the production area. Although there is a slight deflection of the particle track to the north in the middle of the track, the net movement from January 1989 through 1990 is to the east-northeast. This location is within the area of influence of the collector wells located along the Great Miami River to the east-northeast. The distance traveled by this particle is the shortest of all the tracks calculated because of the low gradient. Contaminant transport is also in a north-northeast direction for this area.

The following conclusions are based on an analysis of the water table maps and hydrographs:

- Groundwater enters the FEMP property from the north, west, and northwest and exits toward the Great Miami River Valley to the east and south.

- The large SOWC pumping wells, located in the "big bend" meander on the Great Miami River east of the FEMP, produce a persistent cone of depression. This cone of depression creates an induced eastward flow of groundwater in the northern and central portions of the FEMP, accentuating a natural groundwater divide trending northwest to southeast across the south-central portion of the FEMP.

- Paddys Run affects local groundwater flow along the western boundary and in the area south of the FEMP. During dry seasons when there is little recharge to the regional aquifer, groundwater flows southeastward. During periods of high flow in Paddys Run, stream water infiltrates the Great Miami Aquifer and creates a groundwater mound and strong southward gradients. In the northern portion of the FEMP, the mound creates a local gradient shift and causes a northward component of flow.

- Bedrock highs south of the FEMP on the east and west also control groundwater flow direction. The combination of the eastern and western bedrock highs forces groundwater to flow due south toward the Great Miami River. The groundwater gradient steepens in the narrow bedrock channel.

- Monthly groundwater elevations show annual fluctuation, as seen in hydrographs of the FEMP monitoring wells. The short-term fluctuations are due to short duration surface water/groundwater interaction.

- Peak groundwater levels generally occur during the spring and early summer months, which are also the major groundwater recharge months. For the period of record, the highest groundwater contours occurred during the month of May 1990, when unusually large amounts of rainfall resulted in an extended period of recharge.

- Minimum groundwater levels generally occur during the late fall and early winter months of the year. This corresponds with the dry season for southern Ohio. During the RI, minimum groundwater levels occurred during the months of November 1988 through January 1989. Levels during this time were unusually low due to drought conditions that occurred from spring through fall of 1988.

- Recharge events occur along Paddys Run in late winter and early spring. Leakage from Paddys Run causes a mound in the groundwater as it infiltrates through the stream bed and enters the groundwater system.

The hydrograph of Well 02E, located at the Hamilton/Butler county line at Highway 128 in the floodplain of the Great Miami River, is shown in Figure 3-59. This monitoring well exhibits behavior identical to trends in the FEMP monitoring wells and has the largest database of any monitoring well within the regional area. As previously discussed, the water-level readings show a broad cyclic trend on a yearly basis. For most years, the groundwater experiences a fluctuation on the order of approximately 4 to 6 feet, with increases occurring faster than decreases. The average recharge period is four to five months, whereas the average discharge period lasts seven to eight months.

The drought experienced by the Cincinnati area from 1987 to 1988 is visible on the hydrograph (Figure 3-59) as the two lowest points on its curve. Although recharge did occur during the spring of 1988, it was not enough to counteract the water lost by the groundwater system during 1987. Thus, the peak groundwater level in 1988 was approximately the same as the minimum groundwater levels from previous years. The regional groundwater map for May 1988 (Figure 3-49) was developed from data collected during this drought period. Two other maps, one for August 1982 (Figure 3-47) and the other for April 1986 (Figure 3-48), show similar water-level conditions. The August 1982 levels were measured approximately midway through the dry season, whereas the April 1986 levels were measured just after the peak groundwater season. These two data sets represent very similar types of flow regime. Primary influences on hydraulic head in the Great Miami Aquifer during these periods were the pumping rates of the collector wells, precipitation recharge, recharge from Paddys Run, and the stage of the Great Miami River.

Great Miami River/Groundwater Interaction

The Great Miami River bed is in contact with the sand and gravel deposits of the Great Miami Aquifer. Because the Great Miami River partially penetrates the water table, a portion of its flow originates from surface water while a portion comes from the aquifer beneath the river. The natural

groundwater flow is generally from the aquifer to the river; that is, groundwater discharges into the river. However, pumping of the SWOC wells, which are located close to the river, induces recharge to the aquifer by stream infiltration by creating a local hydraulic gradient which causes flow from the river to the aquifer. This induced infiltration allows the collector wells to maintain a higher yield from the aquifer than could be achieved if the river was not present.

The river bed infiltration rate was investigated during the summer of 1956 near Ross (Dove 1961) and in Fairfield Township in the summer of 1962 (Spieker 1968b). Infiltration rates were calculated to be 240,000 and 492,000 gpd (3200 and 6600 inches/year) per acre of streambed, respectively. Both tests were performed in similar terrains, under low-stream flow conditions, at water temperatures of approximately 80°F.

The effects of the FEMP effluent discharge on groundwater quality due to the induced infiltration of Great Miami River water has been evaluated in a separate report (IT 1988). This study concluded that the FEMP discharge did not have a quantifiable effect on the groundwater system due to the high degree of induced infiltration that occurred upstream from the discharge point.

3.6.3 Conceptual Model of the Hydrogeology of the Study Area

Figure 3-60 illustrates the major features of the conceptual model of the hydrogeology of the FEMP study area. The groundwater pathway includes both the glacial overburden and the Great Miami Aquifer. Contamination must either move through or around the glacial overburden in order to get into the Great Miami Aquifer.

Groundwater is present in the glacial overburden and is perched above the water table of the Great Miami Aquifer. The water table in the glacial overburden is situated approximately 3 to 5 feet beneath the ground surface and generally lies within the elevation range of 560 to 602 feet under the FEMP (Plate 3-5). The slope of the water table follows surface topography and dips to the west and southwest. The gradient varies, but beneath the production area it generally ranges between 0.008 and 0.015 (see Section 3.6.1.2). The vertical gradient through the glacial overburden is 1, as unsaturated conditions exist beneath the deposit. Figure 3-34 illustrates how fluid pressures change with depth due to the presence of saturated sediment within and unsaturated sediment beneath the glacial overburden. Fluid pressure is zero at the water table where it is in equilibrium with the atmospheric pressure, greater than atmospheric pressure in saturated conditions, and less than

atmospheric pressure in unsaturated conditions. The water table in the Great Miami Aquifer slopes to the east and south, towards the Great Miami River, and generally lies at an elevation between 518 to 530 feet under the FEMP. The gradient ranges from 0.0008 in the New Haven Trough to 0.002 in the Paddys Run Outlet (see Section 3.6.2.2).

The glacial overburden is both heterogeneous and anisotropic which complicates hydrogeologic interpretations. It consists of clay, silt, sand and gravel (see Section 3.4.5) with 60 to 80 percent consisting of silt and clay. The upper portion of the glacial overburden sediment is oxidized (yellow-brown in color) the lower portion is not (gray in color) (see Section 3.6.1). Most of the sand and gravel is situated beneath the western portion of the FEMP in lacustrine deposits. The distribution of sand and gravel beneath the eastern portion of the FEMP is more random and less dense.

Variations in sediment type and the lack of readily identifiable depositional features complicates the characterization of flow pathways within the glacial overburden. Drilling data and cross section interpretations were used to simplify the heterogeneity of the glacial overburden and divide it into four zones (Figure 3-44). The zonation is based upon the geologic profile and thickness of gray clay (Figure 3-45). The sediment within the glacial overburden is grouped into eight categories based upon grain size and decree of oxidization (Figure 3-35). A representative minimum thickness for each zone is projected across the zone. The zonation is a generalization and actual vertical velocities and travel times will vary across a zone depending upon the actual thickness of gray clay present at a particular location.

Drilling data and cross section interpretations were used to conceptually simplify the heterogeneity of the glacial overburden by dividing the deposit into four different zones (Figure 3-44) and the sediment into eight different categories based upon grain size and whether or not they are oxidized (Figure 3-35). The zonation is based upon the geologic profile and the thickness of the gray clay (Figure 3-45, Section 3.6.1.1). This zonation is conservatively based upon the minimum thickness of gray clay found within a particular zone. A short circuit flow pathway between the former production area and Paddys Run was conceptualized for Zone 1 (brown/gray sand).

Hydraulic conductivities in the glacial overburden calculated from slug test results range from 1.87 x 10^{-6} cm/s (gray clay) to 3.07 x 10^{-2} cm/s (brown gravel). The gray clay found at the base of the glacial overburden is the least permeable sediment type and dominates the transportation capability of

the vertical pathway. Core permeability measurements for the gray clay yield a hydraulic conductivity of 2.25 x 10^{-8} cm/s. Slug test results yield a hydraulic conductivity of 1.87 x 10^{-6} cm/s. The porosity of the gray clay is approximately 26 percent, the moisture content (by weight) is approximately 14.3 percent, and the gray clay is saturated.

Horizontal seepage velocities in the glacial overburden, for a gradient of 0.008, range from 3.138 x 10^{-3} ft/day (brown clay) to 0.08 ft/day (brown/gray sand). Horizontal seepage velocities in the glacial overburden, for a gradient of 0.015, range from 5.885 x 10^{-3} ft/day (brown clay) to 0.16 ft/day (brown/gray sand). Horizontal advective time of travel, using seepage velocities and assuming a time of travel distance of 2000 feet (roughly the distance from Plant 8 to Paddys Run) ranges from 931 years (brown clay) to 34 years (brown/gray sand) using a gradient of .015.

Vertical seepage velocities through the gray clay range from 0.846 ft/yr (Zone II, 30 feet of gray clay) to 2.15 ft/yr (Zone I, 10 feet of gray clay). Vertical advective travel times through the gray clay (using calculated seepage velocities) range from 41.4 years (Zone II, 30 feet of gray clay) to 13.5 years (Zone III, 10 feet of gray clay).

The Great Miami Aquifer lies beneath the glacial overburden, consists of sand and gravel outwash, and occupies a buried valley that roughly follows the Great Miami River channel (Section 3.4.4). Overall the aquifer is not as heterogeneous or anisotropic as the glacial overburden deposit, which simplifies hydrogeologic interpretations. Hydraulic conductivity in the Great Miami Aquifer, in the FEMP area, is approximately 300 to 500 ft/day. The horizontal to vertical ratio of hydraulic conductivity ranges from 5 to 15. Porosity is approximately 30 percent and the storage coefficient is 0.2.

Horizontal seepage velocities through the Great Miami Aquifer range from 1.1 ft/day (in the New Haven Trough) to 2.75 ft/day (in the Paddys Run Outlet). Given a travel distance of 2000 feet, the advective time of travel ranges from 5 years to 2 years.

Outwash deposits in the Great Miami Aquifer are capable of sustaining yields in the hundreds of gallons of water per minute range. The glacial overburden at the FEMP is only capable of sustaining a yield of approximately 1 gpm for periods longer than a week, and this yield is limited to a small

area located beneath Plant 8 and Plant 1 (where the hydraulic conductivity ranges between 1.5×10^{-3} cm/s to 8.4×10^{-3} cm/s) and to a small channel located in the waste pit area.

Contamination must either move through or around the glacial overburden to reach the Great Miami Aquifer. The low hydraulic conductivity of the gray clay, 1.87×10^{-6} cm/s (slug tests), appears to control the movement of fluids. The base of the glacial overburden is saturated, but directly beneath the glacial overburden, unsaturated conditions are present. The glacial overburden appears to be acting like a sponge, which is very slowly dripping into the unsaturated sediment which lie above the water table of the Great Miami Aquifer.

3.7 DEMOGRAPHY, LAND USE, AND ARCHAEOLOGICAL AND HISTORICAL RESOURCES

This section provides a summary of population data, information on land use, and a brief summary of available archaeological and historical resources for the FEMP regional area.

3.7.1 Demographics

The FEMP is located approximately 18 miles northwest of Cincinnati, the focal point of a regional market encompassing eight counties in Ohio, Kentucky, and Indiana. These eight counties also define the Cincinnati Consolidated Metropolitan Statistical Area which has a 1990 population of more than 1.7 million; within a 5-mile radius of the FEMP site are an estimated 22,927 residents. The labor force stood at more than 920,000 with unemployment in March 1994 at approximately 5.3 percent.

There are no residences on the FEMP property. Employees of the U.S. Department of Energy and their contractors comprise the working population whose activities take place in structures that occupy approximately 203 acres near the center of the property.

Scattered residences and several villages are located near the FEMP property. Some of the nearest residences are along the western side of Paddys Run Road, a road that closely parallels the western property boundary. A dairy farm is located on Willey Road just outside the southeast corner of the boundary; leased grazing areas include acres inside the FEMP boundary. Several residences located south of the FEMP property boundary are located over the South Plume, that portion of the Great Miami Aquifer along Paddys Run contaminated by uranium that extends approximately one-half mile south of the FEMP boundary.

Certain subpopulations of potential concern within 5 miles of the FEMP are listed below according to categories suggested by the EPA (1989a). This information on sensitive subpopulations, based on 1990 census data, covers an area extending between 3 and 4 miles beyond the leading edge of the South Plume.

- Schools: no schools are located within 1 mile of the FEMP property; within 5 miles, six schools enroll 3316 students.

- Day care centers: none operate within 1 mile of the FEMP property; within 5 miles, two centers enroll a daily average of 160 children.

- Hospitals, nursing homes, retirement communities: none of these facilities operate within 5 miles of the FEMP.

- Residences with children: approximately 58 adults and 29 children resided within 1 mile of the FEMP property in 1988; an estimated 8140 children lived within 5 miles.

- Commercial and recreational fisheries: none operate within 1 mile of the center of the FEMP property; within 5 miles, recreational fishing occurs on a lake in the Miami Whitewater Forest, a county park. The Great Miami River supports no commercial fisheries in the FEMP's vicinity. A recreational fishing advisory for polychlorinated biphenyls (PCBs) in bottom-feeding fish was issued in 1989 based on data collected by the Ohio Environmental Protection Agency (OEPA).

- Industries using chemicals: none are located within 1 mile of the center of the FEMP site; two companies within 2 miles, Ruetgers-Nease Chemical Company and Albright & Wilson Company, store and handle chemicals. Known as the Paddys Run Road Site, these facilities are undergoing a state-led RI/FS; are classified as CERCLA sites; and are listed in the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS). A Proctor & Gamble research facility located approximately 2 miles from FEMP property has undergone a Screening Site Inspection by the U.S. Environmental Protection Agency (EPA) and is also listed in CERCLIS. Employees at these facilities are considered a sensitive subpopulation only if they reside within 5 miles of the FEMP property.

3.7.2 Land Use

The land adjacent to the FEMP site is primarily devoted to open land use, such as agriculture and recreation (Figure 3-61). Commercial activity is generally restricted to the village of Ross, approximately 3 miles northeast of the facility, and along S.R. 128 just south of the village. Industrial use is concentrated in the areas south of the FEMP property, along Paddys Run Road, in the village of Fernald, and in a small industrial park on S.R. 128 between Willey and New Haven roads. Concentrations of residential units are situated immediately north of the FEMP site in Ross, directly east in a trailer park adjacent to the intersection of Willey Road and S.R. 128, and southeast

in New Baltimore. Other residences are scattered around the area, generally associated with farmsteads. The Camp Ross Trails site, formerly owned by the Great Rivers Girl Scout Council, is located within 1 mile to the northeast of the FEMP property.

Because the area had been intensively used for agricultural purposes before the establishment of the FEMP, there is no land on or in the vicinity of the FEMP property where a natural environment remains intact. The land closest to this description would be recreated prairie in the Miami Whitewater Forest.

3.7.3 Groundwater Use

The buried valley aquifer of the Great Miami River Basin has been designated as a sole-source aquifer by the EPA under Section 1424(e) of the Safe Drinking Water Act (FR 1988). The buried aquifer is considered to be the sole source of drinking water for more than 600,000 people in southwestern Ohio.

Groundwater is the major source of water for industrial and domestic use in the area. The water is provided to consumers by commercial and municipal well fields and by private groundwater wells. Pumping centers downgradient of the FEMP are shown in Figure 3-62. The estimated total pumping from the major well fields averages more than 18 Mgd (Miami Conservancy District 1993). Within the greater Hamilton-New Baltimore area, there are seven major groundwater users who pump more than 100,000 gpd from the buried valley aquifer of the Great Miami River Basin. Table 3-23 lists the seven major water users, the type of water supply, and the number of people serviced by their water system. Table 3-24 lists the annual pumping rates and totals of the seven major water users. Additionally, there are many smaller industrial, commercial, agricultural, and private groundwater users in the area.

Based on data compiled by the Miami Conservancy District, groundwater use has steadily increased in the Hamilton-New Baltimore area since 1952. Nonpotable industrial use has increased 47 percent (approximately 1.1 percent per year) and potable use 175 percent (five percent per year) since 1956. The increases in groundwater usage reflect only municipal, commercial, and industrial use and do not include private residential wells, smaller industrial wells, or agricultural groundwater usage.

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3.7.3.1 Industrial Water Use

In 1952, the SOWC installed a large-diameter radial collector well in the sand and gravel glacial outwash deposits east of the Great Miami River near Ross, Ohio. The collector well was pumped for industrial water supply purposes at an average rate of 10 Mgd from 1952 to 1955. Its effective radius of influence is 200 feet. In 1955, a second collector well was installed with an effective radius of 212 feet to establish an adequate water supply for 13 industries in the Mill Creek Valley area. Historical data from the 1950s indicate that the average pumping rate from the collector wells was approximately 14 Mgd after completion of the second well. From 1980 to 1992, this pumping rate increased to 18.4 Mgd (Miami Conservancy District 1993). Spieker (1968b) and Dove (1961) concluded that from 60 to 76 percent of the total flow from the collector wells comes from induced recharge from the Great Miami River. In 1986, a third collector well was installed for emergency use only. Total flow of the three wells is not expected to exceed the 18.4 Mgd level. This level is expected to be maintained into the near future.

Other industrial groundwater users within a 5-mile radius of the FEMP include the FEMP itself, Delta Steel, Albright & Wilson Company, and Ruetgers-Nease, which are all located along Paddys Run Road southwest of the FEMP (Figure 3-63). The latter two firms are small chemical companies and Delta Steel fabricates rebar for concrete work.

Albright & Wilson used water from two wells located approximately 2000 feet south of the FEMP. The combined flow from these two wells was approximately 225 gpm. Uranium contamination in the southern Albright & Wilson well has been documented since 1981. Operation of these two wells ceased in 1992 when the FEMP provided replacement wells located west of Paddys Run upgradient of any possible contamination from the FEMP. Ruetgers-Nease operates a production well downgradient from the FEMP, pumping at a rate of 10 gpm. Delta Steel also operated a production well downgradient of the FEMP at an undetermined pumping rate. In 1992 the FEMP began operation of a replacement water supply well located upgradient of the FEMP to supply all of the water needs of Albright & Wilson. This well has an average daily flow of 290 gpm.

3.7.3.2 Potable Water Use

The water supply distributed by public water systems within the two counties surrounding the FEMP is primarily derived from the buried valley aquifer system of the Great Miami River Basin. Water supply calculations performed by the Ohio-Kentucky-Indiana Regional Council of Governments in

1988 indicated that the Great Miami Aquifer provides all of the potable water for Butler County and 48 percent of the potable water for Hamilton County. Locations of water wells downgradient of the FEMP and water service areas within a 5-mile radius of the FEMP are shown in Figures 3-62 and 3-63, respectively. The Cincinnati-Bolton water plant and the Southwest Regional Water District (formerly the Water Association) maintain well fields east and northeast of the FEMP to supply domestic users. Figure 3-63 also shows the area where DOE is partially funding the installation of a public water supply in the vicinity of the FEMP; i.e., the area without water service. The Hamilton County Department of Public Works is responsible for the design and construction of this new service and the Cincinnati Water Works will own, maintain, and operate the system after completion. Construction of the public water supply is divided into four phases with anticipated start of construction of Phase I in August of 1994. The scheduled completion of Phase IV is during the first quarter of 1995. The FEMP will cease pumping groundwater and become a major user of the new public system.

The Southwest Regional Water District and the Harrison Township Water Company provide water to residents within a 5-mile radius of the FEMP. The Southwest District provides service to the majority of Morgan and Ross Townships. Its treatment plant, located 1.5 miles northeast of the intersection of S.R. 128 and U.S. 27, has a peak capacity of 3.7 Mgd and an average flow of approximately 2.0 Mgd. Improvements to the facility and system are currently under way, pending approval of federal funding. Harrison Township operates a plant with a designed capacity of 2.4 Mgd, an operating peak capacity of 1.4 Mgd, and an average flow of 1.0 Mgd.

As shown in Figure 3-63, some residents within a five-mile radius of the FEMP are not served by a water district and must rely on private wells for the provision of potable water. Some residences use bottled water or cisterns for water storage in areas having either poor water quality or a lack of available groundwater in the shallow subsurface. Cisterns are most prevalent in the uplands area, where bedrock is overlain by a thin veneer of glacial till.

3.7.3.3 Agricultural Water Use

There are several large farms in the vicinity of the FEMP. Two known irrigation wells on farms east of the site and northwest of S.R. 128 are currently being used to irrigate fields. One farm on New Haven Road south of the site, between S.R. 128 and the village of New Baltimore, also irrigates from

a well located on the property. Farmers east and south of the FEMP, who are in proximity to the Great Miami River, irrigate their fields with water from the river (Plummer 1990).

3.7.4 Archaeological and Historical Resources

The area surrounding the FEMP site has a large and diverse archaeological and historical resource base. According to records kept by the Miami Purchase Association for Historic Preservation, an unusually high percentage of the existing 19th-century buildings in the area are historically important. Within a 2-mile radius of the FEMP boundary, there are three properties listed in the National Register of Historic Places (NRHP) and a number of additional structures that have been judged eligible for inclusion in the listing. Six major archaeological sites lie within 5 miles of the FEMP site, five of which are included in the NRHP.

There are three Indian mounds located within 3 miles of the boundary of the FEMP. The Adena Circle on the grounds of former Camp Ross Trails in Ross Township is .75 mile from the northeastern corner of the FEMP. The Demoret Mound is 1 mile directly north of the FEMP boundary and the Hogen-Borger Mound Archeological District is approximately 2.5 miles northeast. All three mounds are included on the NRHP, as are the Colerain Works and the Dunlap Archaeological Districts, which lie along the Great Miami River just east of the FEMP. Additionally, a known site of the Fort Ancient people is a few miles east-northeast of the FEMP, adjacent to the Great Miami River. These are the known significant archaeological sites near the FEMP. A number of additional studies have been carried out in the vicinity, all of which indicate that there are even more potentially significant sites that remain undiscovered.

Historic resources in the area are equally abundant. The records of the Miami Purchase Association indicate that a very large number of early settlement farmsteads have remained well-preserved. Within a 2-mile radius of the FEMP boundary there are three properties listed in the NRHP and 12 more have been inventoried and deemed eligible for inclusion.

3.8 ECOLOGY

The following sections present the results and findings of the ecological investigations described in Section 2.9.

3.8.1 Terrestrial Ecology

Facemire et al. (1990) described six distinct terrestrial habitats during their ecological baseline characterization. These habitat types and the percentage of the total FEMP area represented by each are shown in Figures 3-64 and 3-65 and Table 3-25. The following sections describe the vegetation and wildlife characteristic of these habitats.

Facemire et al. (1990) estimated that the FEMP's grazed and ungrazed pastures, pine plantations, deciduous and riparian woodlands, and inactive flyash area contain 47 species of trees and shrubs, 190 species of herbaceous plants, 20 mammal species, 98 bird species, 10 species of amphibians and reptiles, 21 species of fish, 47 families of benthic macroinvertebrates, and 132 families of terrestrial invertebrates. Appendix J.1 lists all plant and animal species identified at the FEMP according to abundance, habitats, and seasons in which they were observed.

Current FEMP land management practices directly impact the structure and composition of on-property terrestrial communities and result in a relatively high biotic diversity. Most of the FEMP is maintained in early stages of succession by mowing and grazing. Additional land use practices include bush hogging and bulldozing. These practices cause habitat fragmentation and heterogeneity, as well as the reduction of corridors important in the stabilization of many plant and animal communities. The most severely disturbed terrestrial habitat is the inactive flyash area. Relatively undisturbed habitats are restricted to the narrow riparian community along Paddys Run (ranking highest in diversity for any particular biota group) and several small woodlots. The undisturbed riparian habitat is the community most similar to mature woodlands in southwestern Ohio (Facemire et al. 1990).

3.8.1.1 Flora

Plant communities within the boundaries of the FEMP have been extensively surveyed by Facemire et al. 1990, who provides detailed data on species abundance (Appendix J, Table J.1-1. The described habitats are grazed and ungrazed pastures, pine plantations, deciduous woodlands, riparian woodlands, and an area that overlaps the inactive flyash pile and the South Field (Figure 3-65). Facemire considered these to be distinct habitats because they have distinct flora and fauna as compared to other areas of the FEMP.

Approximately 425 acres of grassland are used as pasture for dairy cattle. An additional area of mown grass is maintained between the woodland adjacent to Paddys Run and among the planted pines to reduce the fire hazard (Figure 3-65). The inactive flyash pile (Figure 3-66) was least similar to the other FEMP terrestrial habitats in terms of floral species diversity. As a mid-successional habitat, it is dominated by eastern cottonwoods, black locust, and American elm saplings. The pine plantations (Figure 3-66) were planted in 1972 with white pine, Austrian pine, and Norway spruce. White pine and Austrian pine are now the two dominant species, while Norway spruce occurs only occasionally (Facemire et al. 1990).

The native deciduous woodlands (Figure 3-65) in the northern portion of the FEMP are in various successional stages, have high shrub and tree densities, and lack the large dominant species typical of mature woodlots (Facemire et al. 1990). This may be related to the intensity and frequency of disturbance which has occurred in these areas. Understory forest layers are disturbed by cattle grazing and brush clearing that inhibits the regeneration of native forest species. Woodlots at the FEMP can be roughly classified into early and mid-stages of maturity based upon species composition, dominance, canopy cover, and canopy height.

The early successional woodlands are dominated by white ash and American elm and have low diversity and richness (Facemire et al. 1990). Two areas of woodland near the northern property boundary are considered to be in a mid-successional stage.

Tree species common to both the early and mid-successional woodlands are American elm, hackberry, wild black cherry, box elder, and white ash. These species typify disturbed areas where gaps occur in the forest canopy. Differences in species composition between the woodlands most likely reflect varying degrees of disturbance, grazing, and understory removal.

The riparian woodland bordering Paddys Run resembles a maple-cottonwood-sycamore floodplain forest (Anderson 1982) based on the dominant species present: eastern cottonwood, hackberry, American elm, and boxelder. Due to streambed alterations made to reduce bank erosion, other species have colonized the Paddys Run floodplain resulting in noticeably different species composition between the northern and southern portions of riparian woodland.

Several plant species commonly found on comparable sites in southwestern Ohio were either absent or present in very low numbers on the FEMP. These include two fern genera, an orchid, tick trefoil, and bedstraw. More significant was the rarity or absence of several taxa normally common to disturbed or successional communities including honeysuckle, dogbane, asters, and fleabanes. Several absent tree and shrub species include American beech, ailanthus (tree of heaven), American hornbeam, hop hornbeam, mulberry, tulip tree, pawpaw, and spicebush. Several trees, including the eastern red cedar, honey locust, black locust and sugar maple, were found in fewer numbers than expected. Furthermore, trees seldom averaged over 66 feet in height (Facemire et al. 1990).

Facemire et al. (1990) attributed these absences or reductions to the presence of smaller fragmented habitats on FEMP property, and to present and historic land management practices at the FEMP (e.g., grazing and bush hogging in the woodlots). The latter conclusion is further supported by the observation that all of the FEMP woodlots were noted to be in various successional stages with high shrub and tree densities. Large dominant species typical of mature woodlots in southwestern Ohio (e.g., American beech) were not recorded.

3.8.1.2 Fauna

This section includes a discussion of mammals, birds, amphibians, reptiles, and terrestrial arthropods from Facemire et al. (1990). Appendix J contains a list of the mammals (Table J.1-2), birds (Table J.1-3), amphibians and reptiles (Table J.1-4), and insects (Table J.1-5) observed or expected on the property.

The pine plantations are preferred habitat for white-tailed deer, which are the only large ungulates observed on the property. Deer densities were three times greater in the pine plantations than in the other habitats studied (Facemire et al. 1990). The combination of dense cover, mowed strips between tree rows, and the buffered thermal environment of the pines is attractive to the deer. A population of 15 to 18 deer was estimated for the FEMP by Facemire et al. 1990. Other habitats heavily used by resident and visiting deer include the riparian and deciduous forest areas.

The pine plantations are also a preferred habitat for the eastern cottontail rabbit; the woodlots, inactive flyash pile, and riparian habitats support low to moderate numbers. Density estimates range from 0.65 to 1.84 rabbits per acre in the pine plantation areas. A total of 140 eastern cottontails were estimated to be present within FEMP boundaries. Facemire considered this estimate low compared to

similar off-property habitats. The difference may be related to high predation and/or FEMP land management practices of brush clearing, grazing, and mowing.

The white-footed mouse was the most abundant of the small mammal species recorded by Facemire et al. (1990), comprising over 60 percent of the total number of animals trapped, while the short-tailed shrew occurred in the widest variety of habitats. Short-tailed shrews were three to 10 times more common in the inactive flyash pile area than in any other habitats, probably due to the dense grass cover in this area.

Various species of birds were identified at the FEMP (Table J.1-3), including breeding birds, wintering birds, and spring migrants. The high overall diversity of birds is attributed to habitat heterogeneity and to the availability of many small discontinuous patches of habitat (Facemire et al. 1990). Numerous species of birds were observed wintering at the FEMP with all habitats showing reduced species richness of wintering birds compared with breeding birds. The most common permanent resident species were the song sparrow, Carolina chickadee, and mourning dove. Twelve spring migrant species were observed on the FEMP, with riparian and woodlot habitats having the highest species richness. Low numbers of spring migrants were recorded at the FEMP and throughout the greater Cincinnati area during the study period (spring 1987), due largely to unseasonably warm and dry spring weather (Facemire et al. 1990).

Raptor species which have been observed at the FEMP include the northern harrier, red-shouldered hawk, Cooper's hawk, red-tailed hawk, and American kestrel. In addition, census studies for three owl species, including the eastern screech owl, barred owls, and the great horned owl, were conducted. These studies resulted in the identification of 15 screech owl territories and 29 territorial pairs of screech owls, computed to population densities of 14 pairs/100 acres in the riparian areas and 6 pairs/100 acres in the pine plantations. There were also two pairs of great horned owls, estimated at 1 pair/0.7 mi^2 of usable habitat. Absent from the surveys were barred owls, short-eared owls, common barn owls, and snowy owls because of unsuitable habitat (Facemire et al. 1990).

Amphibians and reptiles occupying favored habitats within the FEMP are expected to be similar in species composition to similar habitats in the region. Documentation of amphibians and reptiles was limited to incidental sightings in ephemeral breeding ponds, upland habitats, Paddys Run and the adjacent woodlands at the FEMP (Table J.1-4).

Terrestrial arthropods collected at the FEMP included insects, insect larvae, spiders, mites, ticks, and snails. Approximately 130 insect families from 15 orders were represented (Table J.1-5). The grasslands had the highest number of insect species, and the riparian woodlands the lowest, primarily because of the lack of understory vegetation in the latter. Orb-weaving spiders were abundant in stream areas and within the inactive flyash pile. Other spiders, particularly ground dwellers, are quite common within FEMP habitats but cannot be fully sampled using the netting method. Mites and ticks were also common but not fully surveyed.

3.8.2 Aquatic Ecology

Aquatic environments on and adjacent to the FEMP include the Great Miami River, Paddys Run, and wetlands. The following sections describe the plants, fish, and macroinvertebrates found in these habitats.

3.8.2.1 Great Miami River Flora

Eighty genera of phytoplankton have been recorded by the USGS in samples taken at New Baltimore from 1974 to 1982. The genera include a wide variety of green algae, diatoms and blue-green algae, the taxa recorded in the greatest numbers during this period (USGS 1992). Although aquatic plants and algae adjacent to the FEMP have not been specifically characterized, filamentous green algae was observed and several aquatic vascular plants were observed at sites above and below the FEMP outfall line discharge point (Miller et al. 1988).

3.8.2.2 Great Miami River Fish

With the Environmental Monitoring (EM) program, researchers from the University of Cincinnati have surveyed the Great Miami River from 1984 to 1994 as part of a routine sampling for species diversity and community composition (Miller et al. 1984-1993). Radiological Environmental Monitoring contracts an independent laboratory for radionuclide analysis on both whole and filleted fish from these surveys. Miller et al. (1993) report that the fishery of the Great Miami River has been stable over the last nine years (1984-1992), although fish diversity has decreased in recent years (Miller et al. 1993). In 1992, 23 species of fish were collected from four sites along the Great Miami River (see Figure 2-46) compared to 33 species of fish in 1991. Gizzard shad populations have continued to influence the fish diversity and evenness of the sites sampled. There was no indication that the FEMP had any discernible effects on the abundance, condition, or species richness of the fish

communities in the Great Miami River (Miller et al. 1993). Changes in diversity were attributed to non-point-source eutrophication or an unrelated toxin.

3.8.2.3 Great Miami River Benthic Macroinvertebrates

The Great Miami River also supports a diverse benthic macroinvertebrate community, with approximately 60 different taxa identified in samples taken from the river in the vicinity of the FEMP during RI/FS studies (Table J.1-9). Benthic macroinvertebrates are aquatic organisms, including insects, insect larvae, annelid worms and snails that are generally found in bottom substrates such as sediment, muck, and cobbles. A comprehensive discussion of the benthic macroinvertebrate study for the Great Miami River and Paddys Run is presented in the Site-Wide Characterization Report (DOE 1993).

3.8.2.4 Paddys Run Flora

Sedges and cattails were observed along Paddys Run and adjacent wetlands during the ecological characterization conducted by Facemire et al. (1990). Although the algal flora of Paddys Run have not been specifically characterized, attached filamentous green algae have been observed in the stream. The phytoplankton flora would probably overlap that of the Great Miami River, although it would be less diverse, given the much smaller size of Paddys Run.

3.8.2.5 Paddys Run Fish

Facemire et al. (1990) sampled fish in June 1986 and March and June 1987 in the pools and riffles of Paddys Run and recorded a variety of species within the FEMP boundary. The most abundant species were the bluntnose minnow, creek chub, and stoneroller minnow. Other common fishes occurring in smaller numbers included the rosefin shiner, Johnny darter, orangethroat darter, fantail darter, and spotfin shiner. The species composition within the FEMP property was similar to that reported for the entire length of Paddys Run by Bauer et al. (1978), who recorded 23 species of fish, 16 of which were also recorded by Facemire et al. (1990).

As part of the EM program, University of Cincinnati researchers sampled Paddys Run at New Haven Road for community diversity in 1992 (Miller et al., 1992). Thirteen species of fish were recorded, primarily minnows (8 species) and darters (3 species). The stream was dominated by stonerollers, blacknose dace, and bluntnose minnows.

3.8.2.6 Paddys Run Macroinvertebrates

Paddys Run supports a benthic macroinvertebrate community typical of small streams in the region. During RI/FS studies, approximately 70 taxa of benthic organisms were found in the stream (Table J.1-8). Extensive reaches of Paddys Run are usually dry during the summer and fall. Although this occurrence results in the loss of aquatic invertebrates in these areas, the populations are quickly reestablished when flowing water returns.

The type and number of benthic macroinvertebrates collected from Paddys Run by Facemire et al. (1990) were similar to those described above. Fifty-six kinds of organisms were collected from Paddys Run (Table J.1-8). Species diversity was similar to values reported for streams receiving moderate amounts of pollution and are also typical of macroinvertebrate community values for other streams in the area (Facemire et al. 1990; Wilhm 1967; Wilhm and Dorris 1968; Sheenan and Winner 1984).

3.8.3 Floodplains and Wetlands

Floodplains within the FEMP property are confined to the north-south corridor containing Paddys Run (Figure 3-67). Outside the boundaries of the FEMP, the 100-year floodplain of the Great Miami River extends west of the "big bend" area nearly to the eastern boundary of the facility.

The 1993 wetland delineation indicated that the FEMP contained 35.9 acres of wetlands, including a forested wetland of approximately 26 acres in the northern portion of the property and emergent wetlands and drainage ditches that feed into Paddys Run (EBASCO 1993) (Figure 3-69). This delineation was approved by the Corps of Engineers in August 1993 based on their 1987 wetlands delineation manual. Remedial actions affecting these areas would be subject to the substantive requirements of laws, regulations, and orders concerned with wetlands protection, including Executive Order (E.O.) 11990. Paddys Run and the remainder of its tributaries, including the SSOD, are characterized by unvegetated stream channels incised into surrounding uplands. These unvegetated stream channels do not meet the wetland criteria and would be classified as "other waters of the United States." As such, they would not be protected by E.O. 11990 or other wetlands regulations, but remedial actions affecting them would still be subject to the substantive requirements of the Clean Water Act.

Various vegetative species present throughout these areas characterized as wetlands include common species such as shellbark hickory, American elm and sycamore, roughleaf dogwood, cattail, boxelder, and several grass species (EBASCO 1993). Other common species may include the northern red oak and the Ohio buckeye (as canopy species), as well as goldenrod, chickweed, and Virginia creeper as common ground species.

3.8.4 Agriculture

The FEMP lies within the highly urbanized Hamilton and Butler counties. However, areas immediately surrounding the FEMP are primarily rural in nature. In both counties, the size of farms generally ranges from 123 to 150 acres. Crops grown include soybeans, corn, fruits, vegetables, alfalfa, and grasses for harvest as hay. Pasture vegetation is dominated by grasses. Fence rows and associated vegetation provide boundaries for many of the agricultural fields in the region.

Livestock production consists primarily of dairy and beef cattle. There are three dairy operations within two miles of the FEMP and dairy and beef cattle have grazed on land within FEMP boundaries for over 30 years. Currently only dairy cattle graze on approximately 425 acres of licensed allotments (Figure 3-68). Generally, grazing leases on FEMP land are in force for 30 to 40 years. Beef from local cattle is used for personal consumption by the producers and distributed regionally by a local slaughterhouse. Milk produced from the dairies is marketed and sold through regional commercial processors and vendors (IT 1990b). Results of radiological testing of this milk can be found in Appendix J, Table J.1-10.

The rural nature of the area around the FEMP has attracted many people who work in metropolitan Cincinnati but prefer a rural residence on 1 to 2 acres, as well as those who maintain "hobby" farms of 5 to 10 acres. Most of the fruits and vegetables are consumed by the growers. Agricultural statistics are not compiled on backyard gardens or small producers (IT 1990b), but radiological analysis of local produce has shown little variation from produce collected at distant locations.

3.8.5 Threatened and Endangered Species

To date, no federally listed threatened or endangered species have been observed at the FEMP site (Facemire et al. 1990; DOE 1993). However, two federally listed endangered species, the Indiana bat and the running buffalo clover, have ranges overlapping the area of the FEMP (DOE 1993). Several state-listed threatened and endangered plant and animal species are also known to occur in this

area or have been recorded during surveys on the FEMP property. Additional surveys are being conducted in the spring and summer of 1994.

3.8.5.1 Amphibians

The cave salamander (*Eurycea lucifuga*) is a state-listed endangered species. During the 1988 survey salamander populations were found at the former Ross Trails Girl Scout Camp and north of New London Road, but no individuals were found on the FEMP property. Marginal habitat was designated along the majority of Paddys Run on the property (DOE 1993).

During the 1993 follow-up survey, no individuals of this species were found on the property (Davis 1994). However, moderate cave salamander habitat exists in both an on-property limestone-lined well (Well 1124) east of the east access road and an off-property limestone-lined well (Well 1060) south of the FEMP property. Marginal habitat exists in a ravine in the north woodlot on the FEMP property. The areas along Paddys Run are no longer considered potential habitat because of additional knowledge regarding the life history of this species and the lack of surface limestone in these areas.

3.8.5.2 Mammals

During surveys for the federally listed endangered species the Indiana bat (*Myotis sodalis*), a total of 63 bats representing five species was captured using mist nets (DOE 1993). Eight of these, all captured at Site IV (Figure 2-49) were Indiana bats. Three were adult females, two of which had reproduced during the summer, two were immature females, two were immature males and one was an adult male. Species of Indiana bat may have been underrepresented at other net sites due to the positioning of the nets. Bats of this genus are frequently more difficult to catch than other genera. This is further indicated by the fact that the Indiana bat activity was recorded with echolocation equipment at three sites where no members of this genus were caught—II, V and VIII (Figure 3-71).

Echolocation by *Myotis* sp. was detected at net Sites II, III, V, VI, and VIII and additional bat detector sites C, D, and E (Figure 2-49). *Myotis* sp. accounted for 28.8 percent of the total activity recorded, with *Eptesicus* sp. and *Lasiurus* sp. responsible for the remainder. *Myotis* sp. accounted for 43 percent of the activity recorded at Sites VI and C, which were adjacent to each other (Figure 3-71) (DOE 1993). It should be noted that bat detector methods can only resolve individuals

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to the genus level. In southwestern Ohio, the genus *Myotis* sp. includes the Indiana bat (*Myotis sodalis*) and the little brown bat (*Myotis lucifugus*).

Habitat favored by bats within the study area ranged in quality from good to poor (Figure 2-49). Very little habitat was considered excellent because of a lack of dead trees suitable for maternal colonies. Of the habitat along the Great Miami River, one percent was classified as excellent, 19 percent good, 43 percent fair, and 40 percent poor. The habitat along Paddys Run was somewhat better, four percent being rated excellent, 23 percent good, 54 percent fair, and 19 percent poor. Most of the good habitat identified in the study was in the northern portion of the study area near Ross, Ohio (DOE 1993). An additional survey will be conducted in June 1994 to update the information regarding the status of this species and address concerns that echolocation methods are not accurate.

3.8.5.3 Arthropods

The state-listed threatened Sloan's crayfish (*Orconectes sloanii*) was recorded as common in Paddys Run in 1986-87 (incorrectly referred to as the Cincinnati crayfish) (Facemire et al. 1990). An updated survey was completed in October 1993 (St. John 1993). Despite the fact that Paddys Run was completely dry for most of the section on FEMP property, individuals from this species resided in the existing pools with *Orconectes rusticus*. These pools were in the north section of the property and downstream off-property. An additional survey to determine crayfish distribution when water flowed in Paddys Run throughout the entire length of the FEMP was conducted inMay 1994 (St. John 1994). The distribution of the crayfish is limited to a section of Paddys Run south of the train trestle in the northern section of the FEMP (samples 6-10) and an off-property location at New Haven Road (sample 24) (Figure 3-69). It appears that the crayfish migration is restricted because of the lack of suitable rocky habitat and limited periods of water flow. When the water level of Paddys Run decreased, the crayfish retreated to areas where water remained year round such as the pools under the train trestle.

The cobblestone tiger beetle (*Cicindela marginipennis*) was found during the Indiana bat survey on a gravel bar in the Great Miami River, approximately two river miles downstream of the bridge at New Baltimore, Ohio (DOE 1993). The three specimens captured were identified by Dr. William Buskirk, Professor of Biology at Earlham College. The total population on the gravel bar was estimated to be 30 to 40 individuals. Another gravel bar was surveyed during the course of the Indiana bat survey,

but no additional beetles of this species were found. This species is listed as a federal category two species, as well as a special interest species for the state of Ohio. A survey may be conducted in July-August 1994, pending the outcome from additional background research and U.S. Fish and Wildlife Service consultation.

3.8.5.4 Plants

Two listed plants, running buffalo clover (*Trifolium stoloniferum*) and spring coralroot (*Corallorhiza wisteriana*), have distributions which may include the FEMP property (ODNR 1992). A limited survey of habitats suitable for the running buffalo clover failed to find any populations on property. A comprehensive survey to determine the presence of the federally listed endangered running buffalo clover is planned for June 1994. Surveys for the Ohio-listed threatened spring coralroot at the FEMP were completed by May 1994; the field work for this species did not locate any individuals of spring coralroot (RUST 1994). It is likely that the appropriate mesic conditions and habitat do not exist at the FEMP.

Slender fingergrass (*Digitaria filiformis*), a state-listed endangered crabgrass, was recorded as rare in the riparian area along Paddys Run (Facemire et al. 1990). A survey to update the data for this species will be performed in August 1994.

State-listed endangered mountain bindweed (*Polygonum cilinode*) was also recorded during the 1986 botanical survey as rare in the riparian areas of Paddys Run and the pine plantations (Facemire et al. 1990). In June-August 1994, a survey will be performed to confirm the presence of this species at the FEMP.

3.8.5.5 Avians

The northern harrier (*Circus cyaneus*), a state-listed endangered species, was sighted on one occasion northeast of the production facility in 1990. The dark-eyed junco (*Junco hyemalis*), a state-listed endangered species, was observed throughout the FEMP during the winter of 1986-1987 by Facemire et al. The northern waterthrush (*Seiurus noveboracensis*), a state-listed endangered species, was recorded as a spring migrant along the riparian woodlands. The red-shouldered hawk (*Buteo lineatus*), listed as a state species of special interest, has been sighted once over the northern deciduous forest habitat of the FEMP. The Cooper's hawk (*Accipiter cooperii*), previously listed as a

threatened breeding species in Ohio, has since been removed from the ODNR list. Facemire reports observing the hawk over the introduced pine woodlands and pasture habitat throughout the FEMP.

3.8.6 Avian Population Studies

Several studies conducted on the FEMP property centered on reproductive success and growth parameters of mourning doves and American robins as compared to off-property populations (Facemire et al. 1990). It was reported that hatching and fledgling success of doves was lower in the northern as compared to southern pines. However, nestlings of on-property doves did not differ significantly from off-property nestlings in any of the six growth parameters measured. Reproduction and growth studies conducted on American robins indicated stunted growth in FEMP robins as compared to off-property populations (Facemire et al. 1990).

However, more recent studies designed to confirm these earlier observations show only a slight difference in growth between FEMP and off-property robins (Osborne and Jones 1991). According to Osborne and Jones (1991), FEMP robins showed a high property fidelity and a clumped distribution along roadside berms. However, they were not found nesting in the pine plantations as they did in 1987 (Facemire et al. 1990). The clumping of nests along roadside berms was interpreted by Osborne and Jones (1991) as a response to limited and restricted optimal foraging habitat. This was due to an unusually wet spring which resulted in high stands of vegetative cover and prevented the establishment of normal foraging territories and the cessation of mowing the strips between the rows of pines due to tree growth.

Nesting success was similar between FEMP and off-property robin populations. Clutch sizes did not differ significantly across sampling location, but were slightly lower when compared to the 1987 population reported by Facemire et al. (1990). These data, according to Osborne and Jones (1991), suggest that any stress before nesting was not an important factor affecting egg production. Egg weights were not reduced significantly.

Although FEMP robins produce normal-sized clutches, normal-sized eggs and a normal percentage of young, the nestlings are small. They showed suppressed growth in four of the five pre-fledgling growth parameters (a similar pattern to that reported for robins in 1987 by Facemire et al. [1990]). The FEMP nestling robins were reported to have shorter bills and wings, shorter primaries, and weighed less than off-property individuals (Osborne and Jones 1991). Due to the clumped

distribution, no conclusions could be made regarding the causes of growth suppression (Osborne and Jones 1991).

In the most recent study, (Osborne et al. 1992) few FEMP robins were found nested in either the northern or southern pine plantations. It was also found that the northern and southern entrance roads had few nesting birds and clumped nest distributions. However, nearby Nieman's Nursery, Miami University's Oxford and Hamilton campuses, and Greenwood and Spring Grove cemeteries had uniformly spaced nests in higher numbers than the FEMP property. This was probably because of the greater availability of optimal habitat (Osborne et al. 1992). Robin reproductive success across sampling sites was also evaluated. No significant statistical differences in reproductive success or hatching success were found. Soil and earthworm analyses also showed no strong evidence of bioaccumulation of heavy metals in earthworms. In 1987, Facemire et al. (1990) found FEMP robins showing suppressed growth in four of five of the growth parameters measured. A similar pattern of suppressed growth was found in 1990 (Osborne and Jones, 1991). In this most recent study, robin nestlings were suppressed in two of the four parameters measured (length of wing and length of the outermost primary) when compared to populations off property and to Nieman's Nursery. Although FEMP robin nestlings still showed suppressed growth in two of four growth parameters measured, they were not as pronounced as in previous years and this was believed to be related to land management practices and the resulting food availability and diet quality (Osborne et al. 1992).

3.8.7 Environmental Population Genetics

The ability of a species to survive and adapt to changing environmental conditions over evolutionary time may be increased by the species possessing a pool of genetic variability that can respond to varying selection forces. This genetic diversity may also be an important mechanism for adaption to toxic effects of environmental contaminants. It is thought that the genetic diversity of a population may moderate the toxic effects of pollutants and provide a type of survival mechanism. Therefore, the analysis of the genetic structure (allozyme diversity) of species of concern may act as a sensitive biological indicator of the health of these populations.

Facemire et al. (1990) examined the genetic structure of a number of sampled floral and fauna species using starch gel electrophoresis (the motion of proteins suspended in gel medium due to the influence of an electric field on the medium) to determine whether there are stress-induced genetic differences (from pollutants) among on- and off-property populations (Table 3-26).

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In one particular study, electrophoretic analysis of tree frogs and tadpoles found at the FEMP resulted in the discovery of a null allele (an inactive form of a gene which usually results from a point mutation in the deoxyribonucleic acid [DNA] material) for a specific enzyme (glucose phosphate isomerase) that was not present in the off-property sample. It was speculated that the null allele resulted from a mutation occurring in tree frogs found in the waste pit area at the FEMP. Additional studies were designed as follow-up investigations to the Facemire et al. (1990) study in order to characterize the tree frog null allele. The objectives of these studies (Guttman 1990, 1992) were to examine the geographic distribution of the glucose phosphate isomerase null allele with respect to the FEMP and to determine if the allele may be lethal to the host (i.e., "Is the homozygous condition fatal?"). The 1990 study examined tree frogs collected from a number of additional off-property locations. The 1992 study continued off-property tree frog collection and analysis and included genetic crossing experiments in order to determine the lethality of the homozygous null allele. These later studies, however, revealed the presence of the allele in a higher frequency over a much wider distribution than was previously indicated, and the range of the allele is now considered too extensive to be attributed to a FEMP origin (Guttman 1992).

Guttman (1990, 1992) found that the null allele from tadpoles 12.4 miles north of the FEMP occurs with a frequency approximately equal to that found on the FEMP. Also, reexamination of gel photographs from Facemire et al. (1990) determined that the glucose phosphate isomerase null allele had been erroneously classified as absent in the off-property population sample. Distributional data from other studies in Ohio, Indiana, and Kentucky demonstrate that it is not plausible to suggest that the FEMP might have been responsible for the origin of this null allele (Guttman 1992).

Another study, conducted as part of the original Facemire et al. (1990) study but reported separately, focused on potential population genetic differences, as determined by electrophoretic techniques, between on- and off-property populations of local cicadas. However, upon further investigations, no differences were found between the on- and off-property cicada populations (Reding and Guttman 1991).

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TABLE 3-1

**AMBIENT AIR TEMPERATURE
MEASURED BY THE FEMP METEOROLOGICAL SYSTEM**

Year	Average Annual Temperature (°F)	Average Annual Daily Minimum Temperature (°F)	Average Annual Daily Maximum Temperature (°F)
1987	50.7	41.0	61.5
1988	52.3	41.9	63.7
1989	52.2	44.1	62.8
1990	52.5	43.2	62.4
1991	55.4	46.8	65.1
1992	52.0	43.3	61.7
1993	52.4	43.5	61.3

0 0 0 6

TABLE 3-2

EVAPOTRANSPIRATION IN OHIO IN INCHES PER DAY[a]

	Weather (Hours of Sunshine)		
Dates	Cloudy (0-3)	Normal (4-10)	Bright (11-15)
April 15-30	0.05	0.07	0.09
May 1-14	0.07	0.09	0.12
May 15-31	0.09	0.12	0.15
June 1-14	0.11	0.14	0.18
June 15-30	0.14	0.17	0.21
July 1-14	0.15	0.20	0.24
July 15-31	0.16	0.20	0.25
August 1-14	0.15	0.19	0.24
August 15-31	0.13	0.17	0.21
September 1-14	0.11	0.14	0.18

[a]Estimates in this table were derived from cabbage, sweet corn, field corn, popcorn, potatoes, snap beans, soybeans, sugar beets, and tomatoes.

Source: U.S. Dept. of Agriculture, Soil Conservation Service, Ohio Dept. of Natural Resources, division of Lands and Soil, Cooperative Extension Service and Ohio Agricultural Research And Development Center, 1970, "Ohio Irrigation Guide," USDA, ODNR, Ohio Agricultural Research and Development Center, Ohio State University, and the U.S. Weather Bureau, n.p.

TABLE 3-3

THEORETICAL POTENTIAL MONTHLY EVAPOTRANSPIRATION

Month	T[a] (°F)	p (%)	k	PET (in.)	Avg. Monthly Rainfall	Precipitation Gain/Deficit (in.)
January	30.9	6.82	0.00	0.00	2.9	+2.9
February	34.0	6.76	0.02	0.05	2.05	+2.0
March	42.4	8.34	0.05	0.18	3.78	+3.6
April	54.3	8.93	0.18	0.87	3.67	+2.8
May	63.4	9.97	0.53	3.35	3.85	+0.5
June	72.1	10.02	0.78	5.63	3.53	-2.1
July	75.5	10.16	0.99	7.59	4.09	-3.5
August	73.9	9.51	0.90	6.32	3.02	-3.3
September	67.9	8.39	0.35	1.99	2.99	+1.0
October	56.5	7.78	0.15	0.66	2.16	+1.5
November	44.0	6.77	0.03	0.09	3.09	+3.0
December	34.6	6.66	0.00	0.00	2.8	+2.8

Total Annual (in./yr)		
	Normal	26.73
(-25% of normal)	Cloudy	20.05
(+25% of normal)	Bright	33.42

[a]U.S. Dept. of Agriculture, Soil Conservation Service, Ohio Dept. of Natural Resources, Division of Lands and Soil, and Ohio Agricultural Research and Development Center, 1980, "Soil Survey of Butler County, Ohio," USDA, ODNR, and Ohio Agricultural Research and Development Center, n.p. and 1982, "Soil Survey of Hamilton County, Ohio," USDA, ODNR, and Ohio Agricultural Research and Development Center, n.p.

k = monthly ET coefficient
T = mean monthly temperature in degrees Fahrenheit
p = monthly percentage of daytime hours of year

TABLE 3-4

STORM WATER RETENTION BASIN OVERFLOW EVENTS

Date	Gallons
November 26, 1986	311,000
November 27, 1986	1000
December 1, 1986	5000
December 2, 1986	1,057,000
December 3, 1986	776,000
July 13, 1987	76,000
February 1, 1988	29,000
February 2, 1988	1,535,000
February 3, 1988	2800
February 4, 1988	10,000
December 27, 1988	2500
April 4, 1989	582,000
May 31, 1989	16,000
May 17, 1990	608,000
May 18, 1990	10,000

TABLE 3-5

MINERALOGICAL SUMMARY OF FEMP GLACIAL OVERBURDEN

Phase/Ideal Formula	Modal Percent[a]
Calcite/$CaCO_3$	25.75 ± 11.62
Dolomite/$MgCa(CO_3)_2$	20.77 ± 10.53
Quartz/SiO_2	18.03 ± 8.58
Feldspar/$KAlSiO_3$	14.76 ± 6.49
Illite/$KAl_5Si_7O_{20}(OH)_4$	9.15 ± 17.37
Corrensite/$NaCaMg_8Fe_5Al_5Si_{14}O_{40}(OH)_{20}$	4.27 ± 8.30
Organic debris (humus)	3.49 ± 3.68
Chlorite/$Mg_7Fe_4Al_2Si_7O_{20}(OH)_{16}$	1.13 ± 1.50
Amphibole/$KCa_2Mg_2Fe_2Al_2Si_6O_{20}(OH)_4$	0.95 ± 0.72
Iron oxyhydroxide minerals/$Fe(OH)_3$, FeOOH, Fe_2O_3	0.83 ± 0.72

[a]Average and standard deviation of 20 FEMP glacial overburden samples analyzed by McCrone Associates, Inc. (1992). Modal percent is based on the mineral area exposed on a thin section prepared for microscopic examination.

TABLE 3-6

UNIFIED SOIL CLASSIFICATION SYSTEM (MODIFIED) USED BY FEMP RI/FS INVESTIGATIONS

Soil Type	Symbol	Description
Clean gravel	GW	Well-graded gravel, gravel-sand mixtures, little or no fines
	GP	Poorly-graded gravel, gravel-sand mixtures, little or no fines
Gravel with fines	GM	Silty gravel, gravel-sand-silt mixtures
	GC	Clayey gravel, gravel-sand-clay mixtures
Clean sand	SW	Well-graded sand, gravelly sand, little or no fines
	SP	Poorly-graded sand, gravelly sand, little or no fines
Sand with fines	SM	Silty sand, sand-silt mixtures
	SC	Clayey sand, sand-clay mixtures
Low plasticity silt and clay with liquid limit less than 50	ML	Inorganic silt and very fine sand, rock flour, silty or clayey fine sand, or clayey silt with slight plasticity
	CL	Inorganic clay of low to medium plasticity, gravelly clay, sandy clay, silty clay, lean clay
	OL	Organic silt and organic silty clay of low plasticity
Medium to high plasticity silt and clay with liquid limit greater than 50	MH	Inorganic silt, micaceous or diatamaceous fine sandy or silty soil
	CH	Inorganic clay of high plasticity, fat clay
	OH	Organic clay of medium to high plasticity, organic silt
Highly organic soil	PT	Peat, humus, swamp soil with high organic content

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TABLE 3-7

SUMMARY OF AVAILABLE GEOTECHNICAL DATA

Agency[a]	Study[a]	Boring	Coordinates North	Coordinates East	Elev.	Depth (ft)	Surf. Mat'l.[b]	Analytical Parameters[c] DIST	UNDS	GRSZ	PERM	ATBRG	SPGR	DRWT	WEWT	SLUG	CONS	COHS	MOIST	TRIAX
ASI/IT	EWMF	1748	477300.00	1382500.00	601.00	0.00	Till	x	x	x	x	x	x				x		x	x
ASI/IT	EWMF	1742	480213.00	1383000.00	594.00	0.00	Till	x	x	x	x	x	x				x		x	x
ASI/IT	EWMF	1741	480700.00	1383000.00	595.50	0.00	Till	x	x	x	x	x	x				x		x	x
ASI/IT	EWMF	1732	483300.00	1379500.00	620.00	0.00	Till	x		x		x	x						x	
ASI/IT	EWMF	1735	483300.00	1380500.00	594.00	0.00	Till	x	x	x	x	x	x				x		x	x
ASI/IT	EWMF	1747	477600.00	1382500.00	597.00	0.00	Till	x	x	x	x	x	x				x		x	x
ASI/IT	EWMF	2733	477070.67	1383161.03	604.90	0.00	Till	x		x		x	x						x	
ASI/IT	EWMF	1739	482400.00	1383000.00	617.00	0.00	Till	x		x		x	x						x	
ASI/IT	EWMF	1743	479100.00	1383000.00	589.50	0.00	Till	x		x		x	x						x	
ASI/IT	EWMF	1745	478500.00	1382000.00	586.00	0.00	Till	x	x	x	x	x	x				x		x	x
ASI/IT	EWMF	2731	484155.00	1382895.00	0.00	0.00	Till	x	x	x	x	x	x				x		x	x
ASI/IT	EWMF	1737	483306.00	1381957.00	606.50	0.00	Till	x		x			x						x	
ASI/IT	EWMF	1738	483359.00	1382635.00	616.50	0.00	Till	x		x		x	x						x	
ASI/IT	EWMF	1749	478000.00	1382900.00	598.00	0.00	Till	x		x		x	x						x	
ASI/IT	EWMF	1750	478500.00	1382500.00	593.00	0.00	Till	x		x		x	x						x	
ASI/IT	EWMF	1751	482740.00	1382575.00	607.00	0.00	Till	x	x	x	x	x	x				x		x	x
ASI/IT	EWMF	1752	483620.00	1381480.00	618.00	0.00	Till	x		x		x	x						x	
ASI/IT	EWMF	1753	483630.00	1380000.00	610.00	0.00	Till	x		x		x	x						x	
ASI/IT	EWMF	2754	484149.05	1383465.72	0.00	0.00	Till	x		x		x	x						x	
ASI/IT	EWMF	2728	483301.61	1377960.59	594.70	0.00	Till	x	x	x	x	x	x				x		x	x
ASI/IT	EWMF	1679	483924.53	1378264.61	585.80	0.00	Till	x		x		x	x						x	
ASI/IT	EWMF	1734	483300.00	1380000.00	592.00	0.00	Till	x		x		x	x						x	
ASI/IT	EWMF	1729	483300.00	1378500.00	591.00	0.00	Till	x	x	x	x	x	x				x		x	x
ASI/IT	EWMF	1070	476940.09	1382104.78	597.80	0.00	Till	x		x		x	x						x	

TABLE 3-7 (Continued)

Agency[a]	Study[a]	Boring	Coordinates North	Coordinates East	Elev.	Depth (ft)	Surf. Mat'l.[b]	Analytical Parameters[c] DIST	UNDS	GRSZ	PERM	ATBRG	SPGR	DRWT	WEWT	SLUG	CONS	COHS	MOIST	TRIAX
ASI/IT	OU4 Slant	1616	480469.31	1378315.91	577.7		LAC	x		x		x							x	
ASI/IT	OU4 Slant	1618	480307.07	1378575.33	577.4		LAC	x		x		x							x	
ASI/IT	OU4 Slant	1619	480412.98	1378593.22	578.8		LAC	x		x		x							x	
S&ME	SWRB	PWT-1	478865.49	1380509.12	573.49	13.00	LAC	x		x						x				
S&ME	SWRB	PWT-2	478628.86	1380200.56	575.29	20.40	LAC	x		x						x				
S&ME	SWRB	PWT-3	478352.70	1380093.98	574.20	20.30	LAC	x		x						x				
S&ME	SWRB	PWT-4	478267.45	1380321.71	572.60	20.30	LAC	x		x						x				
S&ME	SWRB	PWT-5	478498.46	1380433.06	573.30	20.40	LAC	x		x						x				
Parsons	Pit3&5	B5-1			572.00	19.00	Till	x	x	x		x							x	
Parsons	Pit3&5	B5-3			590.30	35.50	Till	x	x	x	x	x							x	
Parsons	Pit3&5	B5-4			571.20	21.50	Till	x	x	x		x							x	
Parsons	Pit3&5	B5-6			590.50	37.00	Till	x	x	x	x	x		x	x			x	x	
Parsons	Pit3&5	B5-7			570.40	17.00	Till	x	x	x	x	x		x	x			x	x	
Parsons	Pit3&5	B5-9			590.20	37.00	Till	x	x	x	x	x		x	x			x	x	
Parsons	Pit3&5	B5-10			576.10	21.50	Till	x	x	x		x		x	x			x	x	
Parsons	Pit3&5	B5-12			590.40	37.00	Till	x	x	x	x	x							x	
Parsons	Pit3&5	B5-13			580.00	22.50	Till	x	x	x	x	x		x	x			x	x	
Parsons	Pit3&5	B5-15			590.10	30.00	Till	x	x	x		x		x	x			x	x	
Parsons	Pit3&5	B5-A			590.30	38.00	Till	x	x	x		x		x	x			x	x	
Parsons	Pit3&5	B3-1			563.40	13.00	Till	x		x		x							x	
Parsons	Pit3&5	B3-3			585.80	24.00	Till	x	x	x	x	x		x	x			x	x	
Parsons	Pit3&5	B3-4			558.90	14.00	Till	x		x									x	
Parsons	Pit3&5	B3-6			580.90	26.00	Till	x		x		x							x	
Parsons	Pit3&5	BC-1			557.70	14.00	Till	x	x	x	x	x		x	x			x	x	
Parsons	Pit3&5	BC-3			576.40	26.00	Till	x		x		x							x	

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TABLE 3-7 (Continued)

Agency[a]	Study[a]	Boring	Coordinates North	Coordinates East	Elev.	Depth (ft)	Surf. Mat'l.[b]	Analytical Parameters[c] DIST	UNDS	GRSZ	PERM	ATBRG	SPGR	DRWT	WEWT	SLUG	CONS	COHS	MOIST	TRIAX
S&ME	MASTRSB	3(257)	480924.48	1378959.02	571.30	20.00		x				x							x	
S&ME	MASTRSB	3OFFSE	480924.48	137859.02	0.00	9.00			x			x								
S&ME	MASTRSB	C1-295			577.99	35.00													x	
S&ME	MASTRSB	C2-296	479917.10	1380241.82	576.61	35.00		x				x							x	
S&ME	MASTRSB	C3-297	479950.43	1380339.76	578.83	35.00		x				x							x	
S&ME	MASTRSB	C4-298			578.39	35.00		x											x	
S&ME	MASTRSB	C5-299			578.25	35.00		x											x	
S&ME	MASTRSB	C6-300			578.43	35.00		x											x	
S&ME	MASTRSB	C7-301	479944.66	1380550.66	578.57	35.00		x				x							x	
S&ME	MASTRSB	C8-302	479908.67	1380549.68	578.49	35.00		x				x							x	
COE	FOUNDAT	UD-1	480146.77	1381608.49	0.00	52.00	Till		x	x		x	x	x			x		x	
COE	FOUNDAT	UD-2	481465.31	1380944.38	0.00	34.50	Till		x	x		x	x	x			x		x	
COE	FOUNDAT	UD-3	480479.46	1380417.26	0.00	19.50	LAC		x	x		x	x	x			x		x	
COE	FOUNDAT	1	481384.51	1380241.97	576.60	80.00	Till	x												
COE	FOUNDAT	2	481373.57	1380641.79	591.60	50.00	Till	x		x		x								
COE	FOUNDAT	3	481362.63	1381041.60	588.70	50.00	Till	x		x		x								
COE	FOUNDAT	4	481351.68	1381441.41	587.60	80.00	Till	x												
COE	FOUNDAT	5	480984.70	1380231.03	576.10	50.00	LAC	x												
COE	FOUNDAT	6	480973.75	1380630.84	581.20	50.00	Till	x												
COE	FOUNDAT	7	480962.81	1381030.66	588.80	30.00	Till	x		x		x								
COE	FOUNDAT	9	480584.88	1380220.09	576.30	37.50	LAC	x												
COE	FOUNDAT	10	480573.94	1380619.90	575.90	50.00	LAC	x												
COE	FOUNDAT	11	480562.99	1381019.72	584.60	50.00	Till	x												
COE	FOUNDAT	12	480552.05	1381419.53	586.00	50.00	Till	x		x		x								
COE	FOUNDAT	13	480185.07	1380209.14	576.80	50.00	LAC	x		x		x								
COE	FOUNDAT	14	480174.13	1380608.91	573.10	50.00	LAC	x												

TABLE 3-7 (Continued)

Agency[a]	Study[a]	Boring	Coordinates North	Coordinates East	Elev.	Depth (ft)	Surf. Mat'l.[b]	Analytical Parameters[c] DIST	UNDS	GRSZ	PERM	ATBRG	SPGR	DRWT	WEWT	SLUG	CONS	COHS	MOIST	TRIAX
COE	FOUNDAT	15	480163.18	1381008.77	576.10	50.00	LAC	x												
COE	FOUNDAT	16	480152.24	1381408.59	578.80	50.00	LAC	x		x		x								
COE	FOUNDAT	17	479785.26	1380198.20	575.00	80.00	LAC	x		x		x								
COE	FOUNDAT	18	479774.31	1380598.02	575.00	50.00	LAC	x		x		x								
COE	FOUNDAT	19	479763.37	1380997.83	576.20	50.00	LAC	x		x		x								
COE	FOUNDAT	20	479757.90	1381194.74	0.00	50.00	LAC	x		x		x								
COE	FOUNDAT	21	479752.43	1381397.64	577.00	215.00	LAC	x												
COE	FOUNDAT	22	479541.89	1380866.73	575.60	41.00	LAC	x		x		x								
HCN	Tank Farm	1	480970*	1380950*		20.00	Till	x				x							x	
HCN	Tank Farm	2	481000*	1381000*		25.00	Till	x											x	
HCN	Tank Farm	3	480800*	1380950*		20.00	Till	x											x	
HCN	Tank Farm	4	480700*	1380975*		20.00	Till	x	x			x		x					x	
HCN	Tank Farm	5	480600*	1380925*		25.00	Till	x											x	
HCN	Tank Farm	6	480650*	1380900*		20.00	Till	x											x	
HCN	Tank Farm	7	480900*	1380900*		20.00	Till	x	x			x		x					x	
HCN	Tank Farm	8	481000*	1380900*		20.00	Till	x											x	
HCN	Tank Farm	9	480200*	1380200*		20.00	Till	x	x					x					x	
HCN	Tank Farm	10	480100*	1380250*		20.00	Till	x											x	
HCN	Tank Farm	11	480000*	1380400*		20.00	Till	x	x			x		x					x	
HCN	Tank Farm	12	480050*	1380500*		20.00	Till	x											x	
HCN	SANI L-F	1			583.00	71.00	Till	x		x										
HCN	SANI L-F	2			583.00	70.00	Till	x	x	x	x	x		x					x	
HCN	SANI L-F	3			581.00	70.00	Till	x		x										
HCN	SANI L-F	4			583.00	70.00	Till	x	x	x										

TABLE 3-7 (Continued)

Agency[a]	Study[a]	Boring	Coordinates North	Coordinates East	Elev.	Depth (ft)	Surf. Mat'l.[b]	Analytical Parameters[c] DIST	UNDS	GRSZ	PERM	ATBRG	SPGR	DRWT	WEWT	SLUG	CONS	COHS	MOIST	TRIAX
S&ME	K-65	1	480617*	1378500*	575*	71.5	LAC	x	x	x		x		x					x	
S&ME	K-65	2	480500*	1378593*	575*	51.5	LAC	x		x		x		x					x	
S&ME	Coal Stor.	B-1	481500*	1381200*	588.60	10.00	Till	x	x	x	x	x		x	x				x	
S&ME	Coal Stor.	B-2	481450*	1381000*	587.50	10.00	Till	x	x	x	x	x		x	x				x	
S&ME	Coal Stor.	B-3	481400*	1381100*	586.30	10.00	Till	x	x		x			x	x				x	
S&ME	Coal Stor.	B-4	481200*	1381100*	586.20	11.50	Till	x	x		x			x	x				x	
S&ME	Coal Stor.	B-5	481100*	1381150*	586.80	12.50	Till	x	x											
S&ME	Coal Stor.	B-6	481100*	1381000*	586.60	12.00	Till	x	x		x			x	x				x	

[a]Investigating Agency and Name of Study:

ASI/IT - Advanced Sciences, Inc., and IT Corporation
EWMF - (Draft) Engineering Evaluation For Engineered Waste Management Facility, December 1992; OU4 SLANT - Operable Unit 4 Slant Borings
COE - U.S. Army Corps of Engineers
FOUNDAT - Report of Foundation Investigation, Feed Materials Production Center, February 1952
HCN - H. C. Nutting Company
SANI L-F - Proposed Sanitary Landfill Report, March 1985; TANK FARM - Report of Geotechnical Investigation, 1984
Parsons - Parsons Engineering, Inc.
PIT3&5 - Waste Pits 3 and 5 and Clearwell Dikes Stability Analysis Report, January 1992
S&ME - Soil and Material Engineers, Inc.
SWRB - Hydrogeologic Investigation of the Proposed Storm Water Collection Basin, July 1985; MASTRSB - Master Soil Test Boring Plan, January 1988; K-65 - Silo area, Camargo Report, 1985; COAL STOR - Geotechnical Exploration of Coal Storage Facility, September 1988

[b]Surficial material: Till or Lake (lacustrine) deposits

[c]DIST - Disturbed sample; UNDS - Undisturbed sample; GRSZ - Grain size; PERM - Core permeability; ATBRG - Atterburg limits; SPGR - Specific gravity; DRWT - Dry unit weight; WEWT - Wet unit weight; SLUG - Slug test; CONS - Consolidation; COHS - Cohesion; MOIST - Moisture; TRIAX - Triaxial (consolidated-undrained) test

*Approximate coordinate or elevation

TABLE 3-8

GRAIN SIZE DATA, GLACIAL TILL CL MATERIAL

Study[a]	Boring	Depth (ft)	Soil-CL Field	Soil-CL Lab	Range (High, Low, Average)[b]			
					% Gravel	% Sand	% Silt	% Clay
EWMF	B-1747	5.5-9	CL		16	34	39	11
EWMF	B-1747u	12-14.5	CL		26	24	32	18
EWMF	B-1748	6-9	CL		12	24	44	20
EWMF	B-1748	15.5-18.5	CL		9	27	39	25
EWMF	B-1748u	9-12	CL		34	25	25	16
EWMF	B-1742	11-13	CL		10	28	37	25
EWMF	B-1742u	18-21	CL		9	29	39	23
EWMF	B-1741	6-8	CL		14	27	35	24
EWMF	B-1741	8-12	CL		14	29	36	21
EWMF	B-1741	12-14	CL		12	30	34	24
EWMF	B-1741	23-28	CL		15	25	35	25
EWMF	B-1741u	20-23	CL		9	28	37	26
EWMF	B-2733	4.5-8	CL		9	26	38	27
EWMF	B-1732	8-10	CL		0	4	43	53
EWMF	B-1732	12-14	CL		5	18	37	40
EWMF	B-1732	14-16	CL		0	3	40	57
EWMF	B-1735	0-4	CL		0	6	58	36
EWMF	B-1739	13-15	CL		23	24	32	21
EWMF	B-1739	17-19	CL		7	28	35	30
EWMF	B-1743	9-12	CL		2	30	40	28
EWMF	B-1745	9-13	CL		3	18	46	33
EWMF	B-1745u	6-9	CL		0	15	55	30
EWMF	B-2731	0-4.5	CL		0	2	53	45
EWMF	B-2731	22-29	CL		18	22	32	28
EWMF	B-2731u	8-11	CL		43	22	23	12
EWMF	B-1737	6-9	CL		5	32	49	14
EWMF	B-1738	10.5-12	CL		23	25	32	20
EWMF	B-1738	15-19	CL		8	24	47	21
EWMF	B-1749	4-8	CL		6	23	41	30
EWMF	B-1749	17-19	CL		7	32	38	23
EWMF	B-1749	22-28	CL		7	30	39	24
EWMF	B-1750	4-8	CL		5	25	45	25
EWMF	B-1750	24-28	CL		10	33	35	22
EWMF	B-1751	4-8	CL		10	28	38	24
EWMF	B-1751u	8-11	CL		25	37	26	12

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TABLE 3-8 (Continued)

Study[a]	Boring	Depth (ft)	Soil-CL Field	Soil-CL Lab	Range (High, Low, Average)[b]			
					% Gravel	% Sand	% Silt	% Clay
EWMF	B-1752	6-17	CL		9	16	36	39
EWMF	B-1752	25.3-27.5	CL		8	17	41	34
EWMF	B-1753	4-8	CL		5	9	35	51
EWMF	B-2754	4-8	CL		0	2	39	59
EWMF	B-2754	11-14	CL		0	1	44	55
EWMF	B-2754	22-28	CL		3	27	42	28
EWMF	B-2728	10-14	CL		4	27	37	32
EWMF	B-2728	25-29	CL		10	28	36	26
EWMF	B-2728u	22.5-25.5	CL		14	27	32	27
EWMF	B-1679	0-4.5	ML-CL ?		0	14	46	40
EWMF	B-1679	20.5-23.5	CL?		14	30	35	21
EWMF	B-1734	20.5-26	CL		9	34	37	20
EWMF	B-1729	23-28	CL		10	29	39	22
EWMF	B-1729u	18-21	CL		7	78	6	9
EWMF	B-1070	2-7.5			4	37	46	13
OU4 SLANT	1616	ELEV 556		CL?	14	44	31	11
OU4 SLANT	1616	ELEV 553		CL	6	24	52	18
PIT3&5	B5-1-6	15-17		CL	25	20	35	20
PIT3&5	B5-3-2,4&5	2.5-9		CL	8	39	33	20
PIT3&5	B5-3-6	8-9		CL	2	35	40	23
PIT3&5	B5-3-9,10,11 &12	12-18		CL	2	20	50	27
PIT3&5	B5-3-14,15& 16	19-20.5		CL	7	31	40	22
PIT3&5	B5-3-17,18,1 9&20	23.5-29.5		CL-ML	15	40	32	13
PIT3&5	B5-3-21,22,2 3&24	29.9-35.5		CL-ML	3	34	43	20
PIT3&5	B5-4-1A	1-3.5		CL	6	30	39	25
PIT3&5	B5-4-2B	4-6			6	28	40	26
PIT3&5	B5-4-7	17.5-19.5			5	24	46	25
PIT3&5	B5-6-1,2&3	1-5.5		CL	2	24	47	27
PIT3&5	B5-6-4,5&6	5.5-10		CL	5	20	45	30
PIT3&5	B5-6-14,15& 16	21-25		CL	10	25	42	23

TABLE 3-8 (Continued)

Study[a]	Boring	Depth (ft)	Soil-CL Field	Soil-CL Lab	Range (High, Low, Average)[b]			
					% Gravel	% Sand	% Silt	% Clay
PIT3&5	B5-6-21,22&23	31-37		CL	2	26	47	25
PIT3&5	B5-7-1	2-4		CL	10	23	40	27
PIT3&5	B5-7-5	13-15		CL	5	15	55	25
PIT3&5	B5-9-10A	19-19.5			0	30	44	26
PIT3&5	B5-9-10B	20-21		CL	3	40	39	18
PIT3&5	B5-9-14&15	27-31		CL-ML	11	44	32	13
PIT3&5	B5-10-4C	9-10		CL	0	2	51	47
PIT3&5	B5-10-6	14-16		CL	6	25	43	26
PIT3&5	B5-12-1B	8-10			10	28	41	21
PIT3&5	B5-12-5&6	33-37		CL-ML	4	25	43	28
PIT3&5	B5-13-8	20-22.5		CL-ML	5	30	45	20
PIT3&5	B5-15-1	8-9		CL	9	24	42	25
PIT3&5	B5-15-4A	14-16		CL	0	26	54	20
PIT3&5	B5-15-7A	20-22		CL	0	17	53	30
PIT3&5	B5-15-8A	22-24		CL	4	22	48	26
PIT3&5	B5-15-12A	30-32		CL	12	24	58	22
PIT3&5	B5-A-1	1-3			13	24	41	22
PIT3&5	B5-A-3	8-10		CL	9	31	40	20
PIT3&5	B5-A-4C	11-13		CL	6	30	40	24
PIT3&5	B5-A-7	29-31		CL	9	25	41	25
PIT3&5	B5-A-C1	19			7	24	41	28
PIT3&5	B5-A-C2	21			5	24	41	30
PIT3&5	B5-A-C3	27			2	24	44	30
PIT3&5	B5-A-C4	30			6	20	44	30
PIT3&5	B3-1-2&3	5-9			4	25	41	30
PIT3&5	B3-3-3&4	5-10.5			9	29	41	21
PIT3&5	B3-3-4D	8-10.5			8	23	45	24
PIT3&5	B3-3-5B	11-13		CL	19	26	35	20
PIT3&5	B3-3-6&7	14-18		CL	7	37	31	25
PIT3&5	B3-3-C1	9			4	28	42	26
PIT3&5	B3-4-2&6	2-6			10	32	43	15
PIT3&5	B3-4-4	8-10			15	23	39	23
PIT3&5	B3-6-3	6-8			28	24	32	16
PIT3&5	B3-6-6&7	16-20			20	25	34	21
PIT3&5	B3-6-C1	10			26	23	31	20
PIT3&5	B3-6-C3	24-26			5	26	44	25

TABLE 3-8 (Continued) 5696

Study[a]	Boring	Depth (ft)	Soil-CL Field	Soil-CL Lab	Range (High, Low, Average)[b] % Gravel	% Sand	% Silt	% Clay
PIT3&5	BC-1-1	1-3.5			2	44	42	12
PIT3&5	BC-3-1&2	2-6			15	26	39	20
PIT3&5	BC-3-6&7	14-18			6	24	43	27
PIT3&5	BC-3-9	20-22			10	28	42	20
FOUNDAT	UD-1	2.3-3.0	CL	CL	14	21	45	20
FOUNDAT	UD-1	3.5-6.0	CL	CL	0	1	79	20
FOUNDAT	UD-1	7.5-9.0	CL	CL	3	12	60	25
FOUNDAT	UD-1	9.5-11.0	CL	CL	8	22	50	20
FOUNDAT	UD-1	11.5-13.0	CL	CL	8	22	46	24
FOUNDAT	UD-1	13.6-15.0	CL	CL	8	22	46	24
FOUNDAT	UD-1	15.5-17.0	CL	CL	12	25	43	20
FOUNDAT	UD-1	17.5-18.5	CL	CL	8	22	47	23
FOUNDAT	UD-1	18.5-20.0	CL	CL	8	22	47	23
FOUNDAT	UD-1	20.5-22.0	CL		10	27	43	20
FOUNDAT	UD-2	1.5-3.5	CH/CL	CH	0	4	59	37
FOUNDAT	UD-2	3.5-5.5	CL	CL	3	25	50	22
FOUNDAT	UD-2	5.5-7.5	CL	CL	0	50	35	15
FOUNDAT	UD-2	15.5-17.5	CL	CL	9	35	46	10
FOUNDAT	UD-2	17.5-19.5	CL	CL	10	37	39	14
FOUNDAT	UD-2	19.5-21.5	CL	CL	10	29	43	18
FOUNDAT	UD-2	21.5-23.5	CL	CL	4	33	44	19
FOUNDAT	UD-2	23.5-25.5	CL	CL	8	27	50	15
FOUNDAT	UD-2	25.5-27.5	CL	CL	18	34	36	12
FOUNDAT	UD-2	27.5-29.5	CL	CL	10	35	38	17
FOUNDAT	UD-2	29.5-31.5	CL	CL	6	32	47	15
FOUNDAT	UD-2	31.5-32.5	CL	CL	2	26	49	23
FOUNDAT	UD-2	32.5-34.5	CL	CL	7	29	48	16
FOUNDAT	UD-3	13.5-15.5	CL	CL	0	24	60	16
FOUNDAT	UD-3	15.5-17.5	CL	CL	4	19	51	26
FOUNDAT	UD-3	17.5-19.5	CL	CL	5	24	47	24
FOUNDAT	2	3.0-4.0	CL	CL	8	29	48	15
FOUNDAT	2	10.0-12.0	CL	CL	10	35	45	10
FOUNDAT	2	27.0-33.0	CL	CL	18	28	44	10
FOUNDAT	3	2.0-4.0	CL	CL	3	22	55	20
FOUNDAT	3	12.0-17.0	CL	CL	8	25	47	20
FOUNDAT	7	4.0-6.0	CL	CL	0	25	53	22

8 0 0 2

TABLE 3-8 (Continued)

Study[a]	Boring	Depth (ft)	Soil-CL Field	Soil-CL Lab	Range (High, Low, Average)[b]			
					% Gravel	% Sand	% Silt	% Clay
FOUNDAT	12	5.0	CL	CL	8	24	48	20
FOUNDAT	12	14.0	CL	CL	0	4	61	35
FOUNDAT	12	19.0	CL	CL	4	21	53	22
FOUNDAT	13	20.0	CL	CL	5	33	47	15
FOUNDAT	16	21.0	CL	CL	14	24	45	17
SANI L-F	2	3-5		CL	0	10	40	50
SANI L-F	2	10-12		CL	11	23	33	33
SANI L-F	2	19.5-21		CL	7	29	32	32
COAL STOR	B-1	3-5		CL	7	21	51	21
COAL STOR	B-2	2-3		CL	0	8	53	39
K-65	1	15-17		CL-ML	5	18	59	18

[a]Name of Study:
EWMF - (Draft) Engineering Evaluation For Engineered Waste Management Facility, December 1992
OU4 SLANT - Operable Unit 4 Slant Borings
PIT3&5 - Waste Pits 3 and 5 and Clearwell Dikes Stability Analysis Report, January 1992
FOUNDAT - Report of Foundation Investigation, Feed Materials Production Center, February 1952
-SANI L-F - Proposed Sanitary Landfill Report, March 1985
COAL STOR - Geotechnical Exploration of Coal Storage Facility, September 1988
K-65 - Silo area, Camargo Report 1985

[b]Range:

	% Gravel	% Sand	% Silt	% Clay
High	43.00	78.00	79.00	59.00
Low	0.00	1.00	6.00	9.00
Average	8.23	25.24	42.39	24.25

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TABLE 3-9

GRAIN SIZE DATA, LACUSTRINE CL MATERIAL

Study[a]	Boring	Depth (ft)	Soil-CL Field	Soil-CL Lab	Range (High, Low, Average)[b] % Gravel	% Sand	% Silt	% Clay
OU4 SLANT	1618	Elev. 572		CL	0	5	61	34
OU4 SLANT	1618	Elev. 571		CL	0	4	76	20
OU4 SLANT	1618	Elev. 569		CL	0	2	76	22
OU4 SLANT	1618	Elev. 568		CL	0	0	74	26
OU4 SLANT	1618	Elev. 566		CL	0	2	76	22
OU4 SLANT	1619	Elev. 569		CL	0	2	75	23
OU4 SLANT	1619	Elev. 565		CL-ML	0	9	77	14
FOUNDAT	UD-3	3.5-5.5	CL	CL	0	0	54	46
FOUNDAT	UD-3	5.5-7.5	CL	CL	0	10	50	40
FOUNDAT	13	3.0	CH	CH	0	0	75	25
FOUNDAT	13	7.0	CL	CL	0	25	60	15
FOUNDAT	13	11.0	CL	CL	0	5	77	18
FOUNDAT	16	1.0	CL	CL	0	20	47	33
FOUNDAT	16	7.5	CL	CL	7	25	53	15
FOUNDAT	17	5.0	CL	CL	0	5	55	40
FOUNDAT	17	15	CL	CL	0	5	80	15
FOUNDAT	17	19	CL	CL	8	25	47	20
FOUNDAT	18	5.0	CL	CL	0	2	58	40
FOUNDAT	18	9.0	CL	CL	0	10	67	23
FOUNDAT	18	20	CL	CL	4	26	52	18
FOUNDAT	19	3.0	CL	CL	0	5	57	38
FOUNDAT	19	15	CL	CL	7	23	45	25
FOUNDAT	20	2.0	CL	CL	0	5	59	36
FOUNDAT	20	15	CL	CL	3	25	52	20
FOUNDAT	22	3.0	CL	CL	0	5	55	40
FOUNDAT	22	5.0	CL	CL	0	25	63	12
K-65	5-7			CL-ML	0	8	69	23

[a]Name of Study:
OU4 SLANT - Operable Unit 4 Slant Borings
FOUNDAT - Report of Foundation Investigation, Feed Materials Production Center, February 1952
K-65 - Silo area, Camargo Report 1985
[b]Range:

	% Gravel	% Sand	% Silt	% Clay
High	8.00	26.00	80.00	46.00
Low	0.00	0.00	45.00	12.00
Average	1.07	10.30	62.59	26.04

TABLE 3-10

GRAIN-SIZE DATA, TILL AREA COARSE GRAINED MATERIAL

				Range (High. Low, Average)[b]			
Study	Boring	Depth	Soil-CL	%Gravel	%Sand	%Silt	%Clay
EWMF	B-1735u	8-11	CL-SM/SC	0	36	47	17
EWMF	B-1738	26-27.5	SM/SC	8	30	41	21
PIT3&5	B5-15-9C	24-26	CL-SM	9	59	25	7
FOUNDAT	UD-1	1.5-2.3	GC	54	21	20	5
FOUNDAT	UD-2	11.5-13.5	SC	20	46	24	10
FOUNDAT	3	41.0-46.0	SM	0	75	25	0
FOUNDAT	12	34.0	SM	0	85	15	0
FOUNDAT	13	30.0	SM	0	80	19	1
FOUNDAT	16	25.0	SM	0	80	20	0
FOUNDAT	16	30.0	SM	0	75	25	0
FOUNDAT	17	29.0	SM	0	80	20	0
FOUNDAT	17	35.0	SM	3	59	35	3
FOUNDAT	18	35.0	SM	0	75	25	0
FOUNDAT	18	38.0	SW	40	52	8	0
FOUNDAT	18	45.0	SM	25	49	26	0
FOUNDAT	19	30.5-34.2	SM	5	85	10	0
FOUNDAT	19	39.0	SM	2	80	18	0
FOUNDAT	22	9.0	SC	20	46	24	10
FOUNDAT	22	24.0	SM	1	83	16	0
SANI L-F	1	39.5-41	SW-SM	13	77	10	W/SILT
SANI L-F	1	49.5-51	SW-SM	11	79	10	W/SILT
SANI L-F	1	59.5-61	SP-SM	30	63	7	W/SILT
SANI L-F	2	40-41	SM	3	84	13	W/SILT
SANI L-F	2	68.6-70	SP-SM	5	90	5	W/SILT
SANI L-F	4	44.5-46	SP-SM	39	52	9	W/SILT

[a]Name of Study:

EWMF - (Draft) Engineering Evaluation For Engineered Waste Management Facility, December 1992

PIT3&5 - Waste Pits 3 and 5 and Clearwell Dikes Stability Analysis Report, January 1992

FOUNDAT - Report of Foundation Investigation, Feed Materials Production Center, February 1952

SANI L-F - Proposed Sanitary Landfill Report, March 1985

[b]Range:	% Gravel	% Sand	% Silt	% Clay
High	54.00	90.00	47.00	21.00
Low	0.00	21.00	5.00	0.00
Average	11.52	65.64	19.98	2.96

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TABLE 3-11

GRAIN-SIZE DATA, LACUSTRINE AREA GLACIO-FLUVIAL MATERIAL

Study[a]	Boring	Depth (ft)	Soil-CL Field	Soil-CL Lab	Range (High, Low, Average)[b]			
					% Gravel	% Sand	% Silt	% Clay
OU4 SLANT	1619	ELEV 562		SC[c]	8	50	34	8
K-65	1	20-22		SC	14	40	28	18
K-65	2	10-12		SM	0	57	47	2
K-65	2	15-17		SM	34	49	10	7
K-65	2	20-22		SC-SM	7	46	36	11
K-65	2	25-27		SC-SM	18	35	35	12
SWRB	PWT-2	15.0-16.5	SW/SM	SM	0	95	5	0
SWRB	PWT-3	13.5-14.0	SM	SW	37	61	2	0
SWRB	PWT-4	13.7-14.0	SM	SW	37	61	2	0
SWRB	PWT-5	10.8-11.5	SW	SW	23	75	2	0
FOUNDAT	UD-3	13.0-13.5	SW	SW	0	95	5	0
FOUNDAT	17	9.5-10.0	SM	SM	0	65	30	5
FOUNDAT	22	9.0	SC	SC	20	46	24	10
FOUNDAT	22	24.0	SM	SM	1	83	16	0

[a]Name of Study:
OU4 SLANT - Operable Unit 4 Slant Borings
K-65 - Silo area, Camargo Report 1985
SWRB - Hydrogeologic Investigation of the Proposed Storm Water Collection Basin, July 1985
FOUNDAT - Report of Foundation Investigation, Feed Materials Production Center, February 1952

[b]Range:	% Gravel	% Sand	% Silt	% Clay
High	37.00	95.00	47.00	18.00
Low	0.00	35.00	2.00	0.00
Average	14.21	61.29	19.71	5.21

0 0 0 3

TABLE 3-12

SOIL CONSERVATION SERVICE DRAINAGE CLASSIFICATIONS OF SOILS FOUND ON THE FEMP[a]

Symbol	Name	Slopes (%)	Drainage Classification
DaB	Dana silt loam	2-6	Moderately well drained
EcE2	Eden silty clay loam	15-25	Well drained
EcF2	Eden silty clay loam	25-50	Well drained
FcA and FdA	Fincastle silt loam	0-2	Somewhat poorly drained
FeA	Fincastle-Urban land complex	0-2	Somewhat poorly drained
FoA	Fox loam	0-2	Well drained
Gn	Genessee loam	0-2	Well drained
HeF	Hennepin silt loam	35-60	Well drained
HoA	Henshaw silt loam	0-2	Somewhat poorly drained
MaB	Markland silty clay loam	2-6	Moderately well drained
MaC2	Markland silty clay loam	6-12	Moderately well drained
McA	Martinsville silt loam	0-2	Well drained
MnC2	Miamian silt loam	8-15, eroded	Well drained
MoE2	Miamian-Hennepin silt loams	25-35, eroded	Well drained
MsC2	Miamian-Russell silt loams	2-6	Well drained
MsD2	Miamian-Russell silt loams	12-18, moderately eroded	Well drained
Ra	Ragsdale silty clay loam	level	Very poorly drained
RdA	Raub silt loam	0-2	Somewhat poorly drained
RvB	Russell-Miamian silt loams	2-6	Well drained
RwB2	Russell silt loam	3-8, eroded	Well drained
UnA	Uniontown silt loam	0-2	Well drained
UnB	Uniontown silt loam	2-6	Well drained
XeB	Xenia silt loam	2-6	Moderately well drained
XeB2	Xenia silt loam	2-6	Moderately well drained
XfA	Xenia silt loam	0-2	Moderately well drained
XfB2	Xenia silt loam	0-2, eroded	Moderately well drained

[a]USDA, et al. 1980, 1982, "Soil Survey of Butler County [Hamilton County], Ohio," USDA, n.p.

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TABLE 3-13

MINERAL SATURATION INDICES FOR GROUNDWATER

Mineral	Saturation Index[a]	
	Glacial Overburden	Great Miami Aquifer
Calcite $CaCO_3$	0.587	0.260
Dolomite $MgCa(CO_3)_2$	2.087	1.308
Quartz SiO_2	0.625	0.310
Feldspar $KAlSiO_3$	4.981	3.161
Illite $KAl_5Si_7O_{20}(OH)_4$	8.915	7.744
Iron hydroxide $Fe(OH)_3$	1.556	1.085
Goethite FeOOH	6.812	6.340
Hematite Fe_2O_3	14.56	13.61

[a]Saturation index = log (ion activity product/solubility product)

TABLE 3-14

AQUEOUS SPECIES FOR MAJOR CONSTITUENTS IN GROUNDWATER[a]

Constituent		Species	Abundance in Molal Percent	
			Glacial Overburden	Great Miami Aquifer
Al^{+3}	Aluminum	$Al(OH)_{4+7}^{-}$	96.36	80.56
		$Al_{13}O_4(OH)_{24}$	—	11.38
		$Al(OH)_3^0$	2.84	4.74
		$Al(OH)_2^+$	—	1.38
		AlF_2^+	—	1.25
Ca^{+2}	Calcium	Ca^{+2}	89.94	88.63
		$CaHCO_3^+$	4.79	4.34
		$CaSO_4^0$	4.43	6.44
F^-	Fluoride	F^-	94.43	89.51
		AsO_3F^{-2}	2.35	7.18
		MgF^+	2.31	1.68
		CaF^+	—	0.75
Fe^{+2}	Iron	$Fe(OH)_3^0$	55.15	10.19
		Fe^{+2}	19.55	45.53
		$FeHCO_3^+$	10.39	22.30
		$FeCO_3^0$	6.44	6.92
		$Fe(OH)_2^+$	6.37	3.82
		$FeSO_4^0$	1.25	4.30
		$FeHPO_4^0$	—	0.69

TABLE 3-14 (Continued)

Constituent		Species	Abundance in Molal Percent	
			Glacial Overburden	Great Miami Aquifer
HPO_4^{-2}	Phosphorous	HPO_4^{-2}	37.55	34.04
		$CaHPO_4^0$	22.01	20.30
		$MgHPO_4^0$	19.68	13.01
		$H2PO_4^-$	13.96	25.22
		$CaPO_4^-$	1.97	0.91
		$MgPO_4^-$	1.60	0.56
		$MgH_2PO_4^+$	0.70	0.96
		$FeHPO_4^0$	0.68	1.65
		$CaH_2PO_4^+$	0.63	1.17
		$NaHPO_4^-$	0.45	0.39
		$MgHPO_4^0$	—	0.52
K^+	Potassium	K^+	99.51	99.40
Mg^{+2}	Magnesium	Mg^{+2}	87.51	84.86
		$MgSO_4^0$	7.25	10.37
		$MgHCO_3^+$	4.66	4.16

TABLE 3-14 (Continued)

Constituent		Species	Abundance in Molal Percent	
			Glacial Overburden	Great Miami Aquifer
Mn^{+2}	Manganese	Mn^{+2}	75.37	79.05
		$MnCO_3^0$	15.30	7.40
		$MnSO_4^0$	6.16	9.53
		$MnHCO_3^+$	2.72	2.63
		$MgHCO_4^0$	—	1.14
NO_3^-	Nitrogen	N_2^0	100.00	100.00
Na^+	Sodium	Na^+	98.53	98.40
		$NaHCO_3^0$	1.01	0.93
SO_4^{-2}	Sulfate	SO_4^{-2}	78.61	80.48
		$CaSO_4^0$	10.24	10.66
		$MgSO_4^0$	10.08	7.87
		$NaSO_4^-$	0.74	---

TABLE 3-14 (Continued)

Constituent		Species	Abundance in Molal Percent	
			Glacial Overburden	Great Miami Aquifer
SiO_2^0	Silicon	SiO_2^0	95.79	99.72
		$H_6(H_2SiO_4)_4^{-2}$	3.87	---

[a]Based on EQ3/6 Geochemical Code taken from Wolery, 1992, "EQ3NR, A Computer Program for Geochemical Aqueous Speciation-Solubility Calculations: Theoretical Manual, User's Guide, and Related Documentation (Version 7.0)," and Wolery, T. J., and S. A. Daveler, 1992, "EQ6, A Computer Program for Reaction Math Modeling of Geochemical Systems: Theoretical Manual, User's Guide, and Related Documentation (Version 7.0)."

[b]The sum of individual species accounts for more than 99% of constituent in groundwater in mols/L.

TABLE 3-15

CORE PERMEABILITY TEST DATA AT THE FEMP

Boring	Depth (feet)	Core Permeability (ft/d)	Core Permeability (cm/s)
1729[a]	18 to 21	1.1×10^{-5}	3.9×10^{-9}
1735[a]	8 to 11	1.1×10^{-3}	3.8×10^{-7}
1742[a]	18 to 21	4.3×10^{-4}	1.5×10^{-7}
1741[a]	20 to 23	1.2×10^{-5}	4.3×10^{-9}
1745[a]	6 to 9	3.1×10^{-4}	1.1×10^{-7}
1748[a]	9 to 12	2.0×10^{-3}	7.2×10^{-7}
1747[a]	12 to 14.5	2.2×10^{-5}	7.6×10^{-9}
1751[a]	8 to 11	1.2×10^{-3}	4.1×10^{-7}
2731[a]	8 to 11	3.7×10^{-4}	1.3×10^{-7}
B3-3-3[b]	5 to 7.5	7.4×10^{-5}	2.6×10^{-8}
B3-3-4[b]	8 to 10.5	1.5×10^{-3}	5.3×10^{-7}
B5-3-6[b]	8 to 9	2.6×10^{-4}	9.3×10^{-8}
B5-6-13[b]	19 to 20.5	8.8×10^{-5}	3.1×10^{-8}
B5-12-3[b]	20 to 22	1.8×10^{-5}	6.5×10^{-9}
B5-13-4[b]	9 to 11.5	2.8×10^{-3}	1.0×10^{-6}
B5-7-3[b]	7 to 9.5	2.2×10^{-4}	7.9×10^{-8}
B5-9-16[b]	31 to 33	2.6×10^{-5}	9.3×10^{-9}
BC-1-1[b]	1 to 3.5	5.7×10^{-4}	2.0×10^{-7}
B-1[c]	3 to 5	2.3×10^{-4}	8.0×10^{-8}
B-2[c]	3 to 5	1.1×10^{-4}	3.8×10^{-8}
B-3[c]	3 to 5	1.8×10^{-4}	6.2×10^{-8}
B-4[c]	3 to 5	1.4×10^{-4}	4.9×10^{-8}
B-4[c]	10 to 12	1.4×10^{-4}	5.0×10^{-8}
B-6[c]	3 to 5	1.6×10^{-4}	5.7×10^{-8}
B-6[c]	10 to 12	7.9×10^{-5}	2.8×10^{-8}
2[d]	3 to 5	7.1×10^{-5}	2.5×10^{-8}
2[d]	10 to 12	3.7×10^{-5}	1.3×10^{-8}
2[d]	19.5 to 21	1.6×10^{-5}	5.7×10^{-9}

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TABLE 3-15 (Continued)

Boring	Depth (feet)	Core Permeability (ft/d)	Core Permeability (cm/s)
11112	14.5 to 17.0	5.4×10^{-5}	1.9×10^{-8}
11112	17.0 to 19.5	4.5×10^{-5}	1.6×10^{-8}
11113	31.5 to 34.5	6.8×10^{-6}	2.4×10^{-9}
11113	34.5 to 37.5	1.9×10^{-4}	6.7×10^{-8}
11133	10.5 to 13.0	4.3×10^{-5}	1.5×10^{-8}
11133	18.0 to 20.5	7.7×10^{-5}	2.7×10^{-8}
11131	20.5 to 25.0	4.8×10^{-5}	1.7×10^{-8}
11127	21.5 to 22.5	6.5×10^{-5}	2.3×10^{-8}
11127	20.5 to 22.5	5.4×10^{-5}	1.9×10^{-8}
11129	10.5 to 13.0	7.7×10^{-5}	2.7×10^{-8}
11129	13.0 to 15.0	9.9×10^{-5}	3.5×10^{-8}
11134	16.5 to 19.0	6.8×10^{-5}	2.4×10^{-8}
11134	19.0 to 21.5	1.8×10^{-4}	6.4×10^{-8}

[a]IT, in progress, "Technical Report 5.1A Engineering Evaluation Report for On-site Disposal"
[b]Parsons, Inc., 1992, "Waste Pits 3 and 5 and Clearwell Dikes Stability Analysis Report," prepared for WEMCO
[c]WMCO, 1988, "Geotechnical Exploration of Coal Storage Facility"
[d]H. C. Nutting Company, 1985, "Proposed Sanitary Landfill Report," prepared for WMCO

TABLE 3-16
SUMMARY OF SLUG TEST RESULTS BY MATERIAL TYPE

Well Number	Material Type	Material Color	Dominant Material Description	Aquifer Type U-Unconfined C-Confined	Water Level within Effective Screened Interval?	Result by Optimal Method of Analysis K (ft/day)	Result by Optimal Method of Analysis K (cm/s)	Optimal Method B-Bouwer-Rice C-Cooper et al. FH-Falling Head RH-Rising Head	Comments[a]	Geometric Mean of Conductivity for Mat'l Type (cm/s)
1299	Clay	Gray	Gray clay trace sand and gravel	U	NO	1.25e-03	4.40e-07	B-FH	E	
1301	Clay	Gray	Gray silty gravelly clay	U	NO	2.22e-03	7.84e-07	B-FH	E	
1064	Clay	Gray	Silty gray gravelly clay some silt	U	NO	4.32e-03	1.52e-06	B-RH	C,E,A	
1317	Clay	Gray	Dark gray clay little gravel and sand	U	NO	6.76e-03	2.38e-06	B-RH		
1843	Clay	Gray	Gray silty clay with sand and gravel	U	NO	7.44e-03	2.62e-06	B-RH		
1047	Clay	Gray	Gray sandy clay some silt and gravel	U	YES	7.56e-03	2.67e-06	B-RH	C	
1084	Clay	Gray	Olive gray clay some gravel and sand trace silt	U	YES	1.68e-02	5.92e-06	B-RH	C,E,A	
1606	Clay	Gray	Gray to yellow brown silty clay	U	YES	2.11e-02	7.44e-06	B-RH	E	
1113	Clay	Gray	Brownish gray clay some sand	U	YES	4.11e-02	1.45e-05	B-FH	D,A	
1029	Clay	Gray	Olive gray gravelly clay	U	YES	1.38e-01	4.88e-05	B-FH	E,A	
1778	Clay	Gray	Gray silty clay trace gravel	U	YES	3.20e-01	1.13e-04	B-FH	D,A	
1041	Clay	Gray	Gray clay some silt	U	YES	8.14e-01	2.87e-04	B-FH	E,A	
1324	Clay	Gray	Dark gray clay little gravel trace sand	U	NO	6.28e+00	2.22e-03	B-RH	A	1.87e-06
1444	Clay	Brown	Light olive brown silty clay trace gravel	U	NO	2.70e-03	9.51e-07	B-RH	E	
1137	Clay	Brown	Brownish yellow clay	U	NO	6.47e-03	2.28e-06	B-FH	C,E,A	
1075	Clay	Brown	Olive brown clay some silt some gravel	U	NO	9.57e-03	3.38e-06	B-RH	C	
1145	Clay	Brown	Brownish yellow clay	U	NO	3.50e-02	1.24e-05	B-FH	E	
1082	Clay	Brown	Yellowish brown clay some silt trace gravel and sand	U	NO	3.85e-02	1.36e-05	B-FH	E	
1509	Clay	Brown	Light olive brown silty clay	U	YES	4.49e-02	1.58e-05	B-FH	D,A	
1952	Clay	Brown	Yellow brown silty clay	U	YES	4.93e-02	1.74e-05	B-RH		
1514	Clay	Brown	Light olive brown silty clay	U	YES	6.54e-02	2.31e-05	B-RH		
1279	Clay	Brown	Yellowish brown silty clay some gravel	U	NO	7.30e-02	2.58e-05	B-FH	E	
1676	Clay	Brown	Grayish brown silty clay trace gravel	U	NO	7.73e-02	2.73e-05	B-FH	E	
1934	Clay	Brown	Grayish olive brown silty clay	U	NO	9.23e-02	3.26e-05	B-RH		

TABLE 3-16 (Continued)

Well Number	Material Type	Material Color	Dominant Material Description	Aquifer Type U-Unconfined C-Confined	Water Level within Effective Screened Interval?	Result by Optimal Method of Analysis K (ft/day)	Result by Optimal Method of Analysis K (cm/s)	Optimal Method B-Bouwer-Rice C-Cooper et al. FH-Falling Head RH-Rising Head	Comments[a]	Geometric Mean of Conductivity for Mat'l Type (cm/s)
1081	Clay	Brown	Grayish brown clay some gravel silt and sand	U	NO	1.10e-01	3.87e-05	B-FH	E	
1283	Clay	Brown	Gray to yellowish brown silty clay	U	YES	2.39e-01	8.44e-05	B-FH	D,E,A	
1947	Clay	Brown	Yellowish brown silty clay	U	YES	2.50e-01	8.83e-05	B-RH		
1508	Clay	Brown	Light olive brown sandy clay	U	YES	2.67e-01	9.42e-05	B-RH		
1215	Clay	Brown	Olive brown silty clay	U	YES	2.75e-01	9.71e-05	B-RH		
1954	Clay	Brown	Gray silty clay with gravel	U	YES	3.27e-01	1.15e-04	B-RH		
1433	Clay	Brown	Olive brown silty clay with sand and gravel	U	YES	6.11e-01	2.15e-04	B-RH		
1020	Clay	Brown	Olive brown silty clay	U	NO	6.93e-01	2.44e-04	B-RH		
1152	Clay	Brown	Yellowish brown silty clay	U	YES	8.26e-01	2.91e-04	B-RH		3.59e-05
1950	Silt	Gray	Gray silt and sand	C	NO	3.23e-02	1.14e-05	C-FH		
1733	Silt	Gray	Gray clayey silt with some gravel	C	NO	4.52e-01	1.60e-04	C-FH	E	
1149	Silt	Gray	Yellowish brown clayey silt and sand	C	YES	1.07e+00	3.78e-04	C-RH		
1608	Silt	Gray	Gray clayey silt trace gravel	C	YES	4.86e+00	1.72e-03	B-RH	A	8.83e-05
1087	Silt	Brown	Brown silt trace gravel	U	YES	1.30e-03	4.58e-07	B-FH	E,A	
1836	Silt	Brown	Light olive brown clayey silt with intermitent sand lenses	U	YES	4.97e-02	1.75e-05	B-RH		
1942	Silt	Brown	Olive yellow silt and sand	C	YES	1.08e-01	3.81e-05	C-RH		
1153	Silt	Brown	Interbedded brown clay sand and silt	C	YES	4.85e-01	1.71e-04	C-RH		
1263	Silt	Brown	Olive brown clayey silt trace sand	U	YES	5.41e-01	1.91e-04	B-RH		
1204	Silt	Brown	Olive brown clayey silt	C	NO	5.50e-01	1.94e-04	C-RH		
1346	Silt	Brown	Light brown silt and sand	C	NO	6.23e-01	2.20e-04	C-RH		9.88e-05
1038	Sand	Gray	Gray sand some silt trace gravel	C	NO	3.41e-01	1.20e-04	C-RH		
1035	Sand	Gray	Gray well graded sand-gravel mixture	C	NO	6.60e-01	2.33e-04	C-FH	E	
1937	Sand	Gray	Light olive gray silty fine sand	C	NO	8.59e-01	3.03e-04	C-FH	E	
1046	Sand	Gray	Gray silt clay and sand	C	YES	1.66e+00	5.85e-04	C-RH		
1033	Sand	Gray	Gray silty sand	C	YES	2.00e+00	7.06e-04	C-RH		
1048	Sand	Gray	Yellowish brown silt sand and gravel	C	YES	2.33e+00	8.22e-04	C-RH		

TABLE 3-16 (Continued)

Well Number	Material Type	Material Color	Dominant Material Description	Aquifer Type U-Unconfined C-Confined	Water Level within Effective Screened Interval?	Result by Optimal Method of Analysis K (ft/day)	Result by Optimal Method of Analysis K (cm/s)	Optimal Method B-Bouwer-Rice C-Cooper et al. FH-Falling Head RH-Rising Head	Comments[a]	Geometric Mean of Conductivity for Mat'l Type (cm/s)
1042	Sand	Gray	Gray silty sand	C	NO	8.02e+00	2.83e-03	C-RH		
1332	Sand	Gray	Olive gray silt and sand	C	NO	1.02e+01	3.61e-03	C-RH		
1039	Sand	Gray	Gray well graded gravelly sand	C	NO	1.35e+01	4.76e-03	C-FH	B	8.04e-04
1293	Sand	Brown	Yellowish brown clayey sand some gravel	C	NO	1.64e-01	5.80e-05	C-RH		
1134	Sand	Brown	Brownish yellow fine sand	C	NO	2.46e-01	8.67e-05	C-RH		
1277	Sand	Brown	Yellow brown sand trace gravel and clay	U	YES	2.98e-01	1.05e-04	B-FH	E,A	
1241	Sand	Brown	Brownish yellow silty sand	C	NO	4.36e-01	1.54e-04	C-FH	D	
1941	Sand	Brown	Olive brown clayey sand	U	YES	1.02e+00	3.62e-04	B-RH		
1338	Sand	Brown	Brown pooly graded sand trace gravel	C	YES	3.61e+00	1.27e-03	C-RH		
11085	Sand	Brown	Light olive brown well graded sand some silt	C	YES	4.12e+00	1.45e-03	C-RH		
1420	Sand	Brown	Olive brown silty sand	C	NO	3.02e+01	1.06e-02	C-RH		
1351	Sand	Brown	Brown sand-silt mixture	C	NO	3.22e+01	1.14e-02	C-RH		
1177	Sand	Brown	Brown sand trace gravel	C	YES	4.19e+01	1.48e-02	C-RH		
1227	Sand	Brown	Brownish yellow silty sand	C	YES	5.98e+01	2.11e-02	C-RH		
1336	Sand	Brown	Brown well graded sand trace gravel	C	YES	6.72e+01	2.37e-02	C-RH		1.75e-03
1024	Gravel	Gray	Olive gray fine to coarse sand and gravel	C	NO	2.76e+00	9.73e-04	C-RH		
1077	Gravel	Gray	Gray well graded gravel with sand	C	NO	4.72e+01	1.67e-02	C-FH	E	4.03e-03
1675	Gravel	Brown	Yellow brown clayey gravel	C	YES	4.56e+01	1.61e-02	C-RH	E,C	
1182	Gravel	Brown	Light olive brown clayey gravel	C	NO	6.68e+01	2.36e-02	C-RH		
1111	Gravel	Brown	Brown clayey gravel some sand	C	YES	2.16e+02	7.62e-02	C-RH		3.07e-02

[a]A - Results not valid, not included in high, low or geometric mean
B - Two falling head tests averaged
C - Falling head data not valid or unable to analyze
D - Rising head data not valid or unable to analyze
E - Water level not equalized before start of rising head test

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TABLE 3-17

YIELD TEST RESULTS AT THE FEMP

Location/Well	Sediment Tested	Sustained Yield (gpm)	Test Duration (minutes)	Flow (gpm)	Recovery Notes
Northeast corner of production area/ Well 1274	Gray clay and sand lense	Dewatered	3.5	0.85	--
Plant 1 pad/Well 1339	Brown sand	2.0	10,000	2.0	--
Plant 1 pad/Well 11112	Brown sand/gravel	2.0	10,000	2.0	95% in 30 minutes
Plant 2-3/Well 1785	Fine to coarse sand	1.5	10,000	1.5	90% in 60 minutes
South of the pilot plant/Well 1259	Brown silt	Dewatered	11	0.65	--
Waste pit area/Well 11214	Sand and gravel	2.5	10,000	2.5	76% in 20 minutes
Waste pit area/Well 1077	Sand and gravel	1.0	10,000	1.0	Very slow

TABLE 3-18

GRAY CLAY DATA FROM LABORATORY CORE TESTS

Well Number	Depth (BGS) (ft)	Dry Density (pcf)	Dry Density (gr/cm3)	Wet Density (pcf)	Specific Gravity (gr/cm^3)	Moisture Content %	Soil Content	Volume of Solids (ft^3)	Volume of Void Spaces (ft^3)	Void Ratio	Total Porosity (%)	Weight of Moisture in Soil (lbs)	Degree of Saturation (%)	Coefficient of Permeability (cm/s)
11112	14.5 to 17.0	118.92	1.9110	136.26	2.7380	13.8	Gray clay	0.696	0.304	0.437	30.4	17.34	91.4	1.9E-08
11112	17.0 to 19.5	120.91	1.9430	137.75	2.7417	14.3	Gray clay	0.707	0.293	0.415	29.3	16.84	92.0	1.6E-08
11113	31.5 to 34.5	121.87	1.9585	144.37	2.7486	25.4	Gray clay	0.711	0.289	0.407	28.9	22.50	124.6	2.4E-09
11113	34.5 to 37.5	126.70	2.0361	139.92	2.7302	13.8	Gray clay	0.744	0.256	0.345	25.6	13.22	82.7	6.7E-08
11131	10.5 to 13.0	132.46	2.1286	143.19	2.7452	18.0	Brown/gray clay	0.773	0.227	0.293	22.7	10.73	75.8	1.5E-08
11131	18.0 to 20.5	127.61	2.0507	142.07	2.7341	12.5	Gray clay	0.748	0.252	0.337	25.2	14.46	91.9	2.7E-08
11131	20.5 to 25.0	127.87	2.0549	139.34	2.7392	10.3	Gray clay	0.748	0.252	0.337	25.2	11.47	73.0	1.7E-08
11127	21.5 to 22.5	127.43	2.0478	143.94	2.7460	13.0	Gray clay	0.744	0.256	0.345	25.6	16.51	103.2	2.3E-08
11127	20.5 to 22.5	128.72	2.0685	143.14	2.7526	14.9	Gray clay	0.749	0.251	0.334	25.1	14.42	92.2	1.9E-08
11129	10.5 to 13.0	123.88	1.9908	140.76	2.7432	10.6	Gray clay	0.724	0.276	0.382	27.6	16.88	97.9	2.7E-08
11129	13.0 to 15.0	130.04	2.0897	146.00	2.7625	15.6	Gray clay	0.754	0.246	0.326	24.6	15.96	104.1	3.5E-08
11134	16.5 to 19.0	132.57	2.1304	148.07	2.7563	12.2	Gray clay	0.771	0.229	0.297	22.9	15.50	108.4	2.4E-08
11134	19.0 to 21.5	125.98	2.0245	141.13	2.7531	11.3	Gray clay	0.733	0.267	0.364	26.7	15.15	91.0	6.4E-08

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TABLE 3-19

LYSIMETER DATA

Location	Date	Parameter	Result	Units
11129	09/24/93	Alkalinity as $CaCO_3$	250.00	mg/L
		Bicarbonate alkalinity	300.00	mg/L
		Calcium	79,500.00	µg/L
		Carbonate alkalinity	< 1.00	mg/L
		Chloride	46.00	mg/L
		Gross alpha	< .12	pCi/mL
		Gross beta	< .19	pCi/mL
		Magnesium	19,100.00	µg/L
		Potassium	5900.00	µg/L
		Sodium	29,200.00	mg/L
		Sulfate	88.00	µg/L
		Total uranium	15.00	µg/L
	03/21/94	Total uranium	16.00	µg/L
	03/22/94	Total uranium	29.00	µg/L
	03/23/94	Total uranium	28.00	µg/L
11130	09/30/93	Calcium	99,300.00	µg/L
		Gross alpha	< .14	pCi/mL
		Gross beta	< .26	pCi/mL
		Magnesium	40,000.00	µg/L
		Potassium	3820.00	µg/L
		Sodium	16,300.00	µg/L
		Total uranium	7.90	µg/L
	03/21/94	Total uranium	13.00	µg/L
	03/22/94	Total uranium	2.90	µg/L
	03/23/94	Total uranium	2.80	µg/L
	03/24/94	Total uranium	2.80	µg/L
11131	09/24/93	Alkalinity as $CaCO_3$	190.00	mg/L
		Bicarbonate alkalinity	240.00	mg/L
		Calcium	59,800.00	µg/L
		Carbonate alkalinity	< 1.00	mg/L
		Chloride	57.00	mg/L
		Gross alpha	< .12	pCi/mL
		Gross beta	< .19	pCi/mL
		Magnesium	23,200.00	µg/L
		Potassium	8260.00	µg/L
		Sodium	29,000.00	µg/L
		Sulfate	62.00	mg/L
		Total uranium	11.00	µg/L
	03/21/94	Total uranium	3.40	µg/L
	03/22/94	Total uranium	12.00	µg/L
	03/23/94	Total uranium	12.00	µg/L
	03/23/94	Total uranium (duplicate)	12.00	µg/L

TABLE 3-19 (Continued)

Location	Date	Parameter	Result	Units
11132	09/29/93	Alkalinity as $CaCO_3$	190.00	mg/L
		Bicarbonate alkalinity	240.00	mg/L
		Calcium	59,500.00	µg/L
		Carbonate alkalinity	< 1.00	mg/L
		Chloride	25.00	mg/L
		Magnesium	23,900.00	µg/L
		Potassium	2280.00	µg/L
		Sodium	19,500.00	µg/L
		Sulfate	62.00	mg/L
	03/21/94	Total uranium	4.60	µg/L
	03/22/94	Total uranium	2.50	µg/L
	03/23/94	Total uranium	2.30	µg/L
	03/24/94	Total uranium	3.50	µg/L
11133	09/28/93	Alkalinity as $CaCO_3$	250.00	mg/L
		Bicarbonate alkalinity	310.00	mg/L
		Calcium	87,400.00	µg/L
		Carbonate alkalinity	< 1.00	mg/L
		Chloride	39.00	mg/L
		Magnesium	24,200.00	µg/L
		Potassium	4270.00	µg/L
		Sodium	27,700.00	µg/L
		Sulfate	67.00	mg/L
		Total uranium	52.00	µg/L
	03/21/94	Total uranium	47.00	µg/L
	03/22/94	Total uranium	16.00	µg/L
	03/23/94	Total uranium	17.00	µg/L
	03/23/94	Total uranium (duplicate)	14.00	µg/L
	03/24/94	Total uranium	16.00	µg/L
11234	03/21/94	Total uranium	4.10	µg/L
	03/22/94	Total uranium	3.90	µg/L
	03/23/94	Total uranium	4.60	µg/L
	03/23/94	Total uranium (duplicate)	4.20	µg/L
	03/24/94	Total uranium	4.90	µg/L

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TABLE 3-20

HORIZONTAL SEEPAGE VELOCITIES

Parameter[a]	Brown Clay	Brown/Gray Sand	Brown/Clay Sand
K_h (ft/day)	1.02×10^{-1} ft/day	3.119 ft/day	1.996×10^{-1} ft/day
N (%)	.26	.30	.30
V (ft/day) @ I = .008	3.138×10^{-3}	0.08	5.32×10^{-3}
V (ft/day) @ I = 0.15	5.885×10^{-3}	0.16	9.98×10^{-3}
Time of Travel[b]	931 yrs.	34 yrs.	549 yrs.

[a] K_h = Horizontal hydraulic conductivity
V = Seepage velocity N = Porosity
I = Gradient

[b]Time of travel based on a gradient of 0.15 and a distance of 2000 feet

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TABLE 3-21

VERTICAL SEEPAGE VELOCITIES AND TIME OF TRAVEL CALCULATIONS

Zone	Description of Section	K (ft/day)	K_z[a] (ft/day)	Seepage Velocity (ft/yr)	Time of Travel (yrs)
I	5 ft. brown clay	1.02×10^{-2}	1.02×10^{-3}	1.42	28.1
	15 ft. brown/gray sand	3.12×10^{-1}			
	20 ft. gray clay	5.30×10^{-4}			
I	5 ft. brown clay	1.02×10^{-2}	1.55×10^{-3}	2.15	13.95
	15 ft. brown/gray sand	3.12×10^{-1}			
	10 ft. gray clay	5.30×10^{-4}			
II	5 ft. brown clay	1.02×10^{-2}	6.13×10^{-4}	.85	41.4
	30 ft. gray clay	5.30×10^{-4}			
III	15 ft. brown clay/sand	9.98×10^{-2}	1.318×10^{-3}	1.85	13.54
	10 ft. gray clay	5.30×10^{-4}			
IV	15 ft. brown clay	1.02×10^{-2}	8.926×10^{-4}	1.27	27.6
	20 ft. gray clay	5.30×10^{-4}			

Total porosity = 26%
$K_v = K_h^b/10$

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[a]K_z = vertical hydraulic conductivity
[b]K_h = horizontal hydraulic conductivity

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TABLE 3-22

HYDRAULIC CONDUCTIVITY FROM PUMPING TESTS IN THE GREAT MIAMI AQUIFER NEAR THE FEMP

Reference	Location	Hydraulic Conductivity[a] (ft/day)	Hydraulic Conductivity[a] cm/s
Dove, 1961	SOWC Wells/A	375 to 400	1.3×10^{-1} to 1.4×10^{-1}
Smith, 1962	Bolton Wellfield/B	328	1.2×10^{-1}
Klaer, 1948	Bolton Wellfield/B	120	4.2×10^{-2}
Kazmann, 1950	SOWC Wells/A	318 to 369	1.1×10^{-1}
Klaer and Kazmann, 1943	Hamilton South Wellfield/C	313 to 324	1.3×10^{-1}
Speiker and Norris, 1962	FEMP Production Well/D	267	1.1×10^{-1}
Lewis, 1968	SOWC Wells/A	334 to 404	1.2×10^{-1} to 1.4×10^{-1}
Smith, 1960	ChemDyne - Hamilton/E	214 to 412	7.5×10^{-2} to 1.5×10^{-1}
DOE, 1933d	Fernald - FEMP Removal Action 3/F	413	1.5×10^{-1}
Smith, 1962	Ross - west bank of Great Miami River/G	534	1.9×10^{-1}
Smith, 1960	New Miami - mouth of Four Mile Creek/H	774	2.7×10^{-1}

[a]Summary statistics:

Minimum K_h	=	120 ft/day	4.2×10^{-2} cm/s
Maximum K_h	=	774 ft/day	2.7×10^{-1} cm/s
Average K_h	=	386 ft/day	1.4×10^{-1} cm/s
Standard deviation	=	164 ft/day	5.8×10^{-2} cm/s

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TABLE 3-23

MAJOR WATER USERS
HAMILTON - NEW BALTIMORE AREA

Name of Water User	Type of Water Supply	Number of People Served
Potable Water		
Cincinnati - Bolton Plant	Municipal	86,000[a]
Hamilton South	Municipal	60,000[b]
Fairfield City	Municipal	35,000
Fernald Environmental Management Project	Non-Community	800
Southwest Regional Water District	Public	23,000
Nonpotable Water		
Southwestern Ohio Water Company	Industrial	13 industries
Chevrolet - Pontiac Canada Group, General Motors Corp.	Industrial	1 factory

[a]Approximately 10% of the population of the Greater Cincinnati Area.
[b]Includes people served from Hamilton North Plant.

Source: Miami Conservancy District, 1993, "Hydrologic Data for the Hamilton-New Baltimore Area - 1992," The Water Conservation Subdistrict of the Miami Conservancy District, Dayton, OH.

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TABLE 3-24

HAMILTON - NEW BALTIMORE AREA WATER USE (MILLION GALLONS PER DAY)

Year	Hamilton South	Fairfield City[a]	SOWC[b]	SW Reg. District	Cincinnati Bolton	FEMP	GMC[c]	Total
1952			9.77			[d]	[e]	9.77
1953			11.86					11.86
1954			11.39					11.39
1955			13.93					13.93
1956	5.26[e]	[e]	13.35					18.61
1957	7.82	0.17	14.72					22.71
1958	7.70	0.20	13.05					20.95
1959	7.71	0.31	14.79					22.81
1960	7.39	0.36	14.37					22.12
1961	7.35	0.40	12.95					20.70
1962	7.39	0.47	12.61					20.47
1963	7.83	0.58	12.86					21.27
1964	7.57	0.66	13.87					22.10
1965	7.93	0.62	14.20					22.75
1966	7.87	0.71	15.69					24.27
1967	7.70	0.87	17.89					26.46
1968	8.17	0.91	18.34					27.42
1969	8.32	0.92	17.08					26.32
1970	8.71	0.96	16.66			[d]		26.66
1971	9.15	1.09	16.77	0.01[e]		0.73[f]	0.14[d]	27.75
1972	9.39	1.15	17.19	0.42		0.73[f]	0.17	28.88
1973	8.80	1.15	17.68	0.60		0.73[f]	0.15	28.96
1974	10.06	1.30	16.71	0.67		0.73[f]	0.13	29.47
1975	11.07	1.34	14.85	0.77		0.63	0.12	28.66
1976	11.62	1.36	16.04	0.84	1.93[e]	0.48	0.13	32.27
1977	11.28	1.33	16.72	0.86	12.30	0.31	0.14	42.80
1978	12.11	1.40	17.66	1.06	13.34	0.32	0.15	45.89
1979	11.77	1.29	18.07	1.32	10.73	0.27	0.15	43.45
1980	12.12	1.12	17.84	1.38	11.73	0.35	0.14	44.54

TABLE 3-24
(Continued)

Year	Hamilton South	Fairfield City[a]	SOWC[b]	SW Reg. District	Cincinnati Bolton	FEMP	GMC[c]	Total
1981	12.47	0.79	16.75	1.42	15.05	0.39	0.14	46.87
1982	13.14	0.65	16.12	1.49	14.93	0.36	0.12	46.69
1983	12.51	1.59	16.46	1.68	14.86	0.31	0.13	47.41
1984	12.92	1.72	17.38	1.73	15.10	0.42	0.13	49.40
1985	12.58	2.57	17.98	1.74	14.90	0.44	0.12	50.33
1986	12.28	3.69	18.44	1.83	15.94	0.48	0.10	52.76
1987	13.53	4.01	18.94	1.96	15.21	0.46	0.09	54.22
1988	14.51	4.65	17.93	2.19	17.32	0.35	0.05	57.03
1989	14.46	4.36	17.17	2.09	16.00	0.31	[g]	54.39
1990	14.81	4.49	17.12	2.05	16.63	0.27		55.37
1991	15.34	5.20	18.51	2.32	17.16	0.32		58.85
1992	17.10	4.56	18.09	2.18	15.98	0.30		59.99

[a]Does not include water purchased from Hamilton until July 1985 and from Cincinnati until September 1984
[b]Southwestern Ohio Water Company
[c]Chevrolet - Pontiac Canada Group, General Motors Corporation
[d]No data available before 1971
[e]First year for groundwater pumpage
[f]Estimated
[g]Plant sold to Panda Motors Corp., pumpage less than 0.1 Mgd

Source: Miami Conservancy District, 1993, "Hydrologic Data for the Hamilton-New Baltimore Area - 1992," the Water Conservation Subdistrict of the Miami Conservancy District, Dayton, OH

TABLE 3-25

AREA OF THE SAMPLED HABITATS AT THE FEMP

Habitat Type	Area (acres)	% of Total
Ungrazed pasture	268.5	29.8
Grazed pasture	229.7	25.5
Woodlands	179.1	19.9
Riparian woodlands	106.0	11.8
Pine plantations	99.0	11.0
Reclaimed flyash pile	18.0	2.0
Totals	900.3	100.0

Source: Facemire, C.F., et al., 1990, "Biological and Ecological Site Characterization of the Feed Materials Production Center," FMPC-SUB018, prepared for Westinghouse Materials Company of Ohio, Cincinnati, OH.

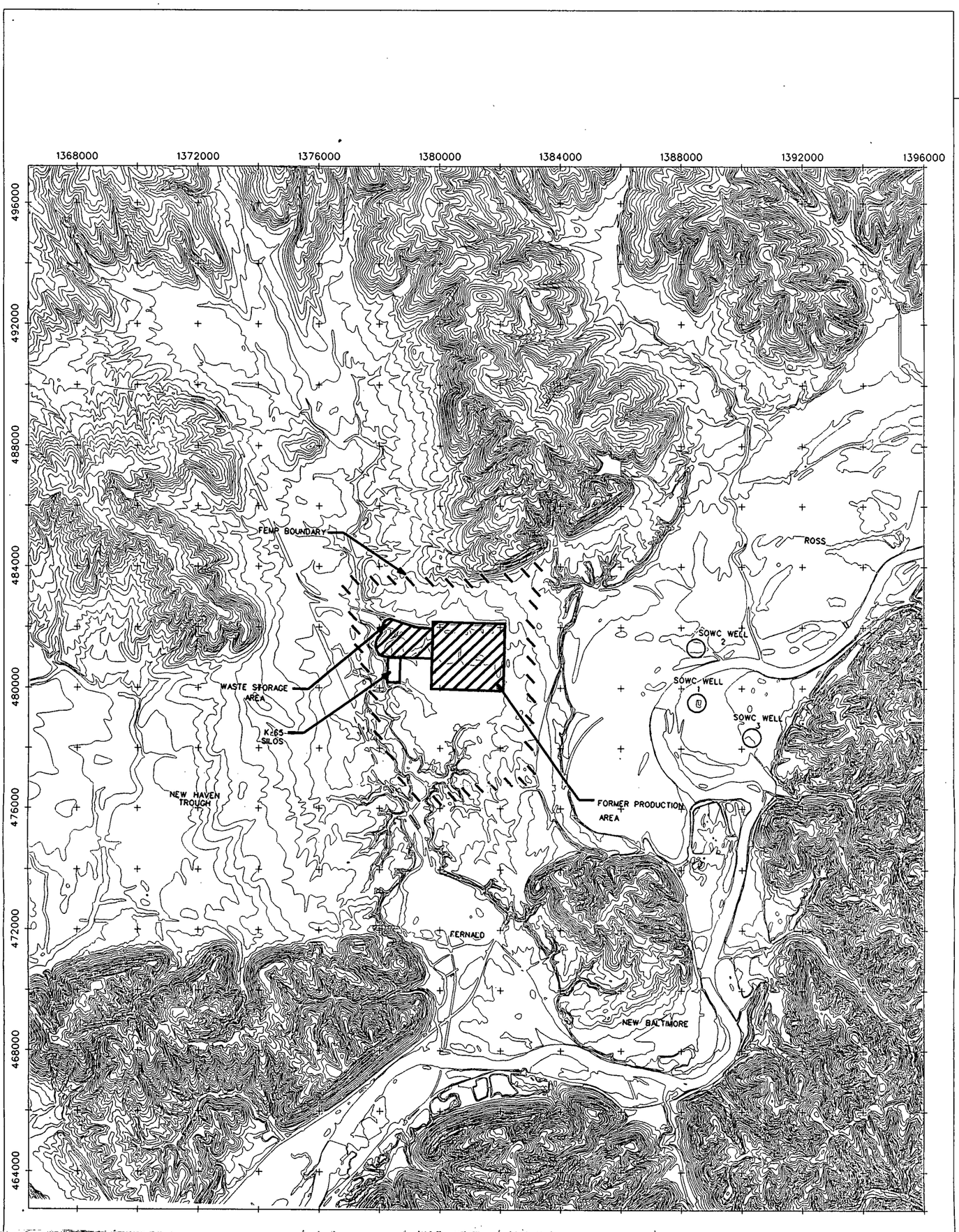
6 0 0 6

TABLE 3-26

PLANT AND ANIMAL SPECIES SAMPLED FOR GENETIC ANALYSIS BY FACEMIRE

Common Name	Scientific Name
Plants	
Common Dandelion	*Taraxacum officinale*
Milkweed	*Asclepias syrica*
Amphibians	
Spring peeper, treefrog	*Hyla crucifer*
American toad	*Bufo americanus*
Fish	
Blacknose dace	*Rhinichthys atratulus*
Bluntnose minnow	*Pimephales notatus*
Stoneroller minnow	*Campostoma anomalum*
Silverjaw minnow	*Ericymba buccata*
Spotfin shiner	*Notropis spilopterus*
Rosefin shiner	*Notropis ardens*
White sucker	*Catostomus commersoni*
Johnny darter	*Etheostoma nigrum*
Orangethroat darter	*Etheostoma spectabile*
Fantail darter	*Etheostoma flabellare*
Benthic macroinvertebrates	
Mayfly	*Stenonema feoratum*
Midge	*Chironomus tentans*
Isopod	*Lirceus fontinalis*
Mammals	
Eastern cottontail	*Sylvilagus floridanus*
Insects	
Grasshopper	*Melanoplus femorubrum*
Grasshopper	*Conocephalus strictus*

Source: Facemire C.F., et al. 1990, "Biological and Ecological Site Characterization of the Feed Materials Production Center," FMPC-SUB018, prepared for Westinghouse Materials Company of Ohio, Cincinnati, OH.



LEGEND:

10 FOOT CONTOURS

FEMP BOUNADRY

NOTE:

SOURCE: SHANDON 7.5 MINUTE TOPOGRAPHIC QUADRANGLE USGS 1981

000452

c110058.dgn FER OU5 RIDATA 5-31-94 STATE PLANER COORDINATE SYSTEM 1927

DRAFT

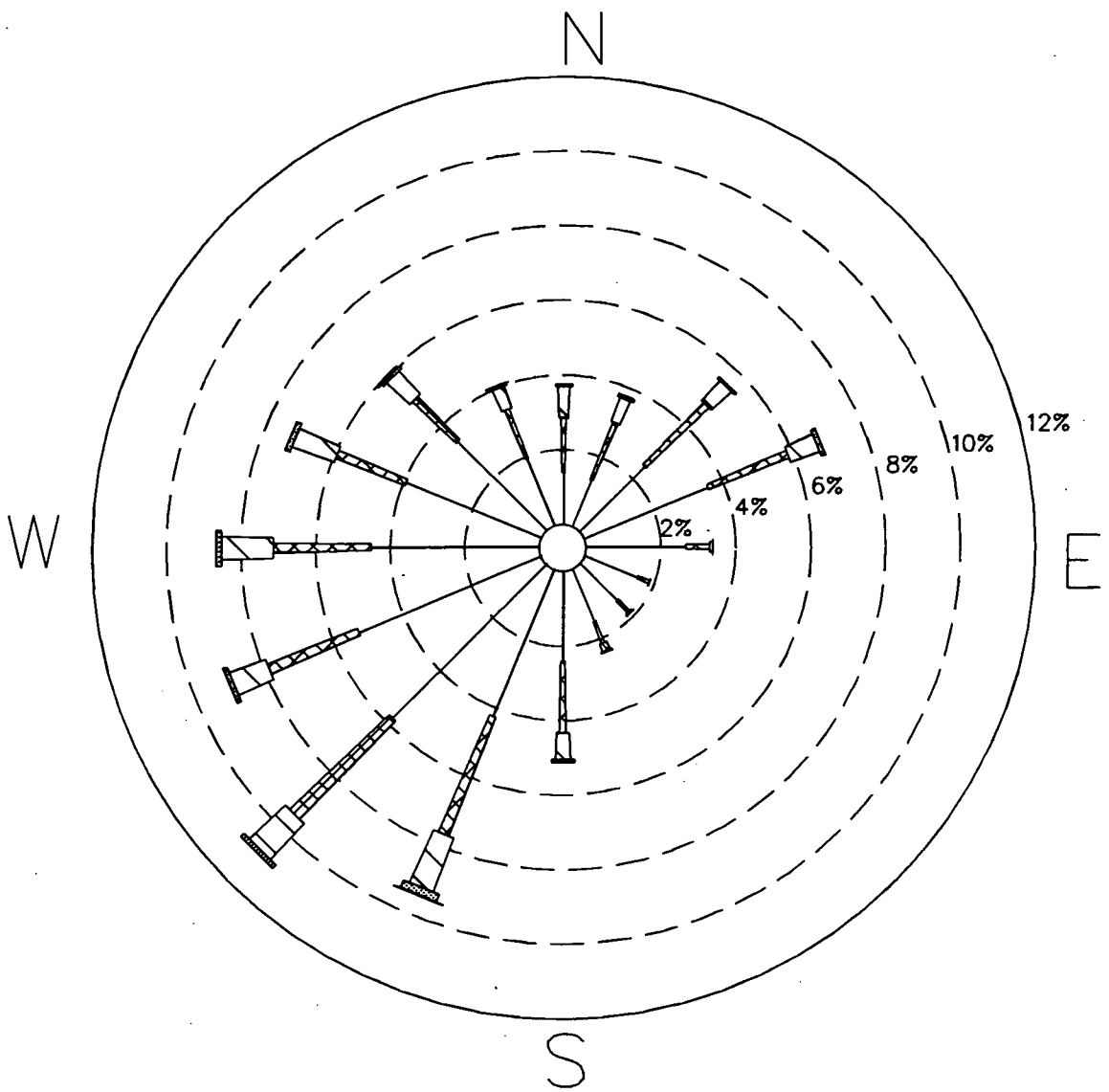
SCALE

3500 1750 0 3500 FEET

FIGURE 3-1. FEMP TOPOGRAPHIC MAP

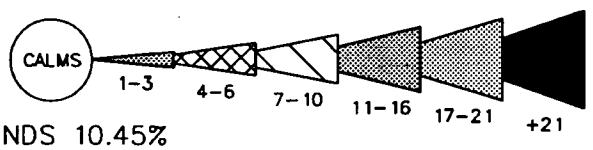
5696

FEMP WIND ROSE



NOTE: Frequencies indicate direction from which the wind is blowing.
Readings are at 33 feet above ground.

WIND SPEED IN KNOTS

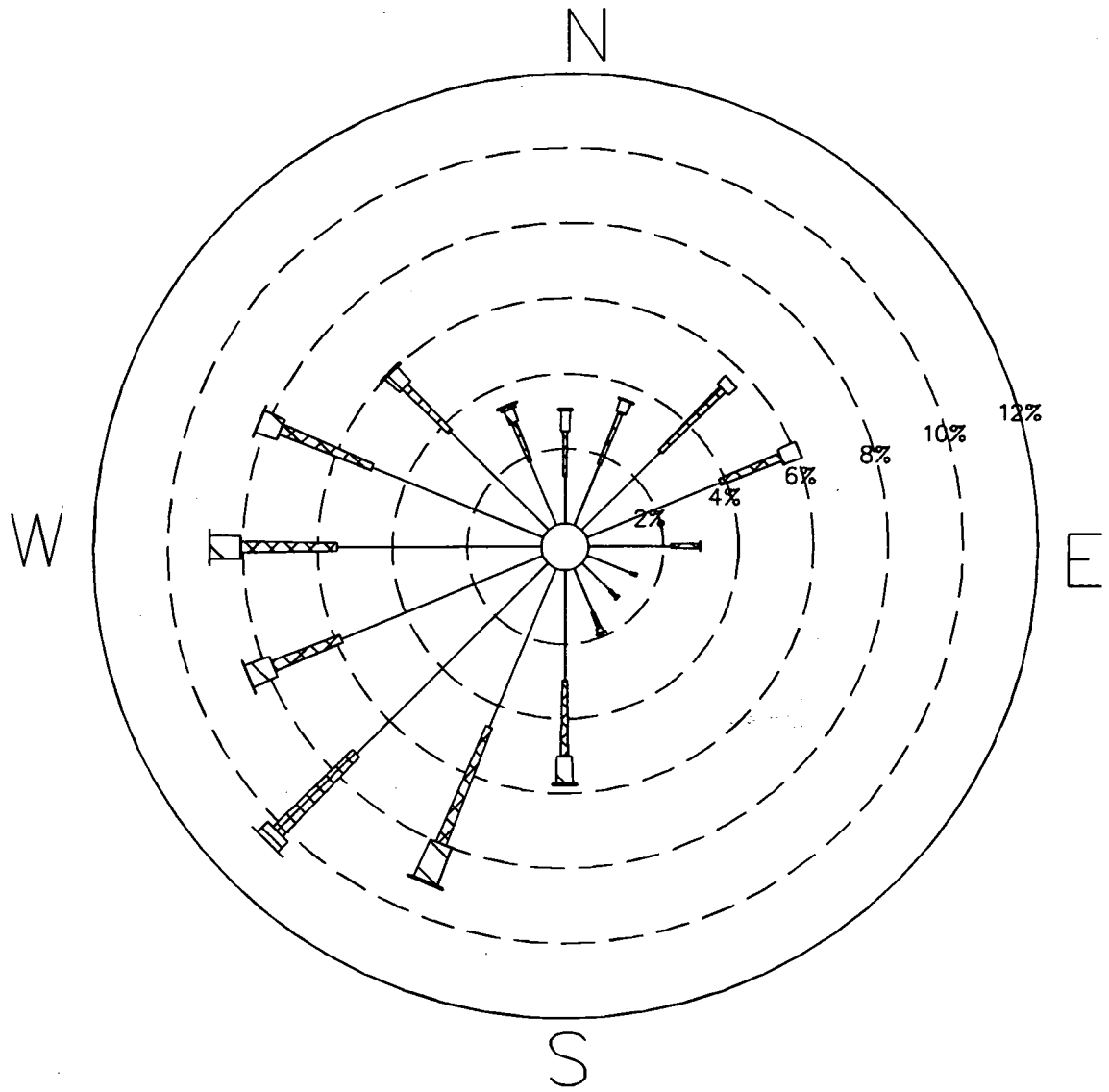


CALM WINDS 10.45%

DRAFT

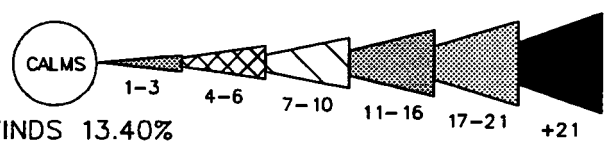
FIGURE 3-2. FEMP WIND ROSE COMPOSITE OF 1988, 1989, 1991, and 1992.

1993 FEMP WIND ROSE



NOTE: Frequencies indicate direction from which the wind is blowing.
Readings are at 33 feet above ground.

WIND SPEED IN KNOTS



DRAFT

CALM WINDS 13.40%

FIGURE 3-3. FEMP WIND ROSE OF 1993

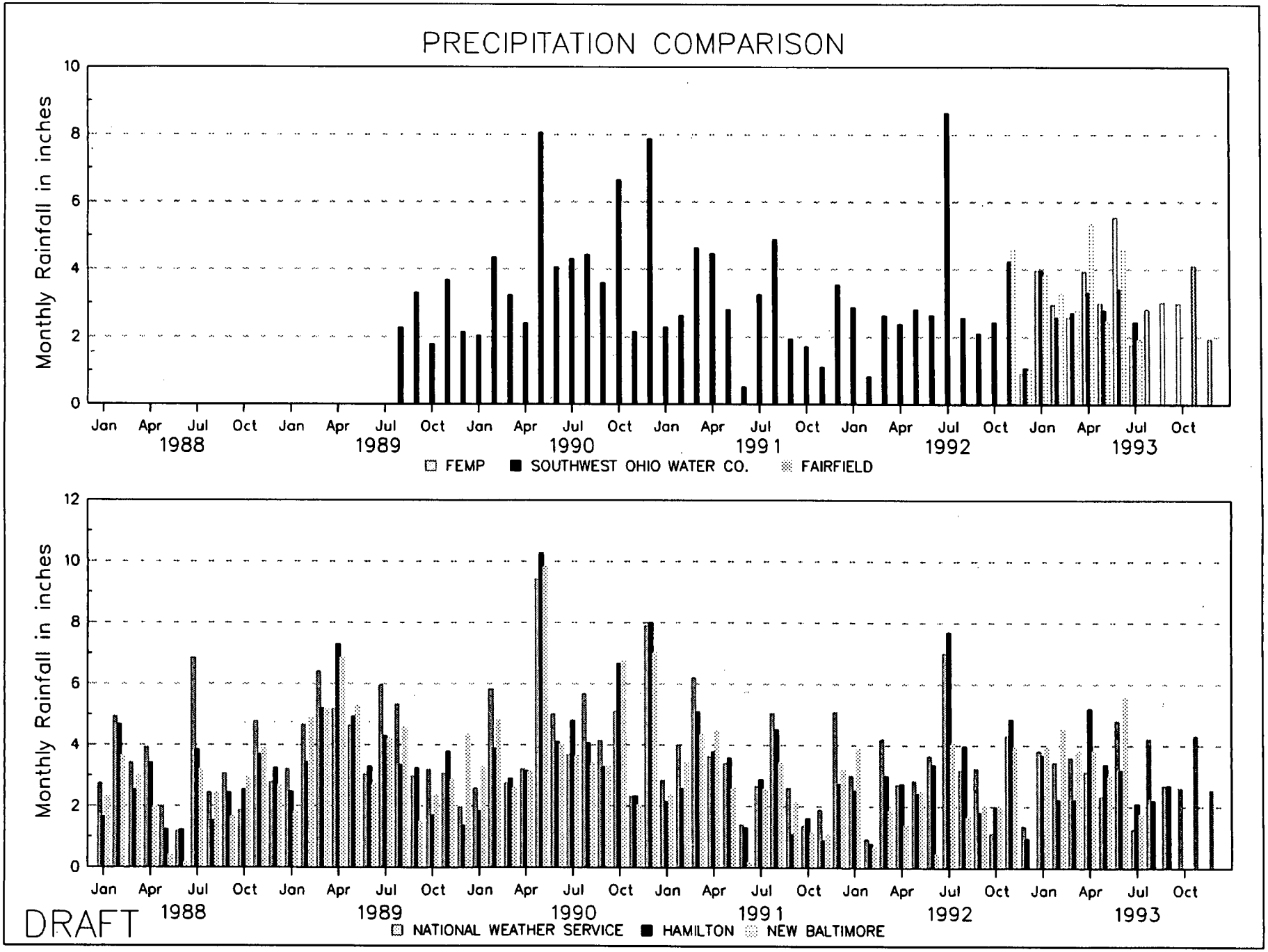
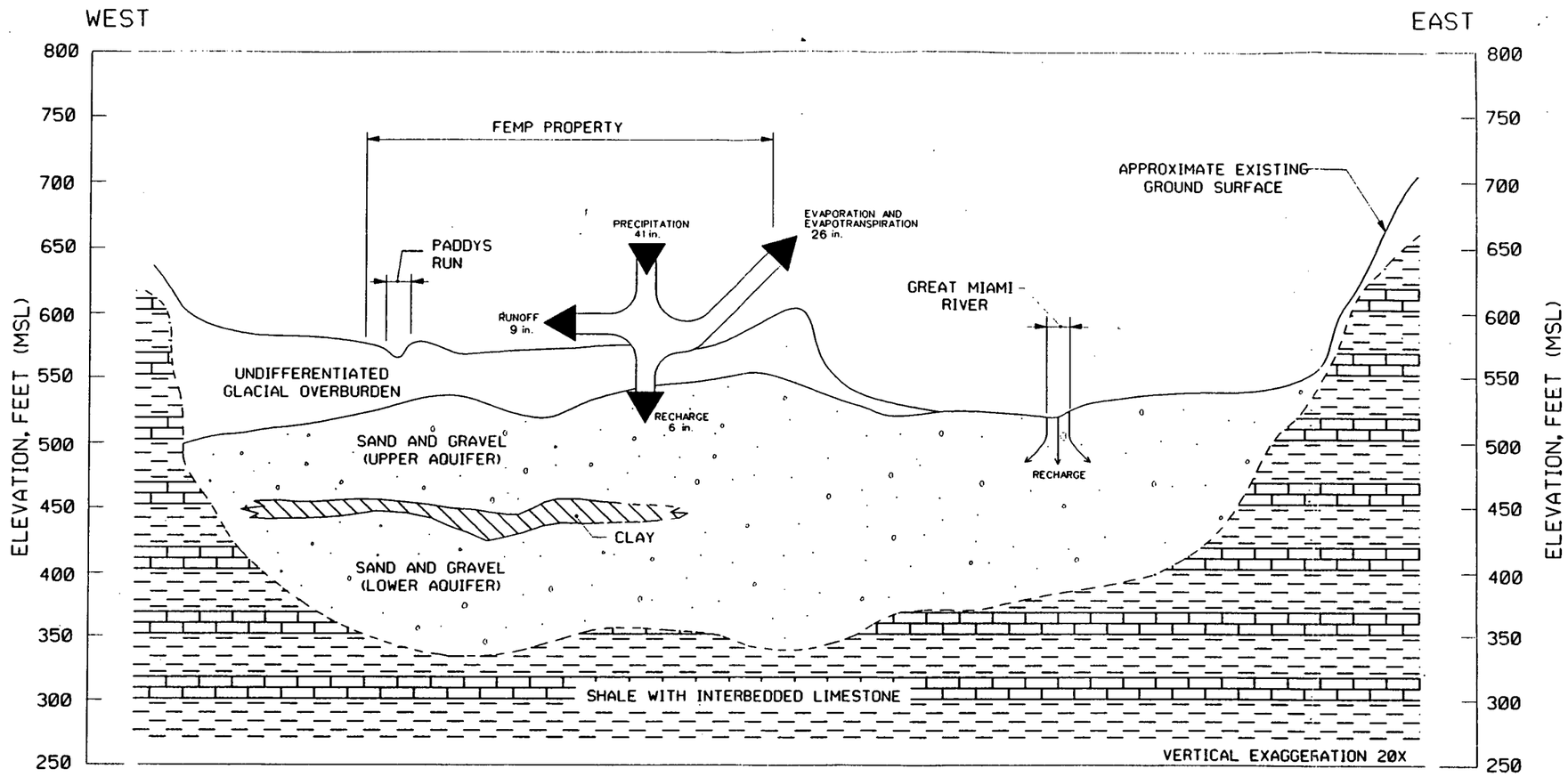
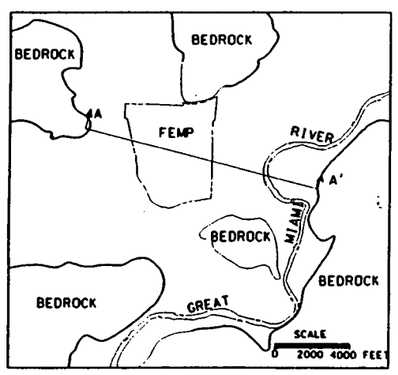


FIGURE 3-4. MONTHLY PRECIPITATION COMPARISON IN THE VICINITY OF THE FEMP



GENERALIZED CROSS SECTION



LOCATION OF CROSS SECTION

VERTICAL SCALE
0 100 200 FEET

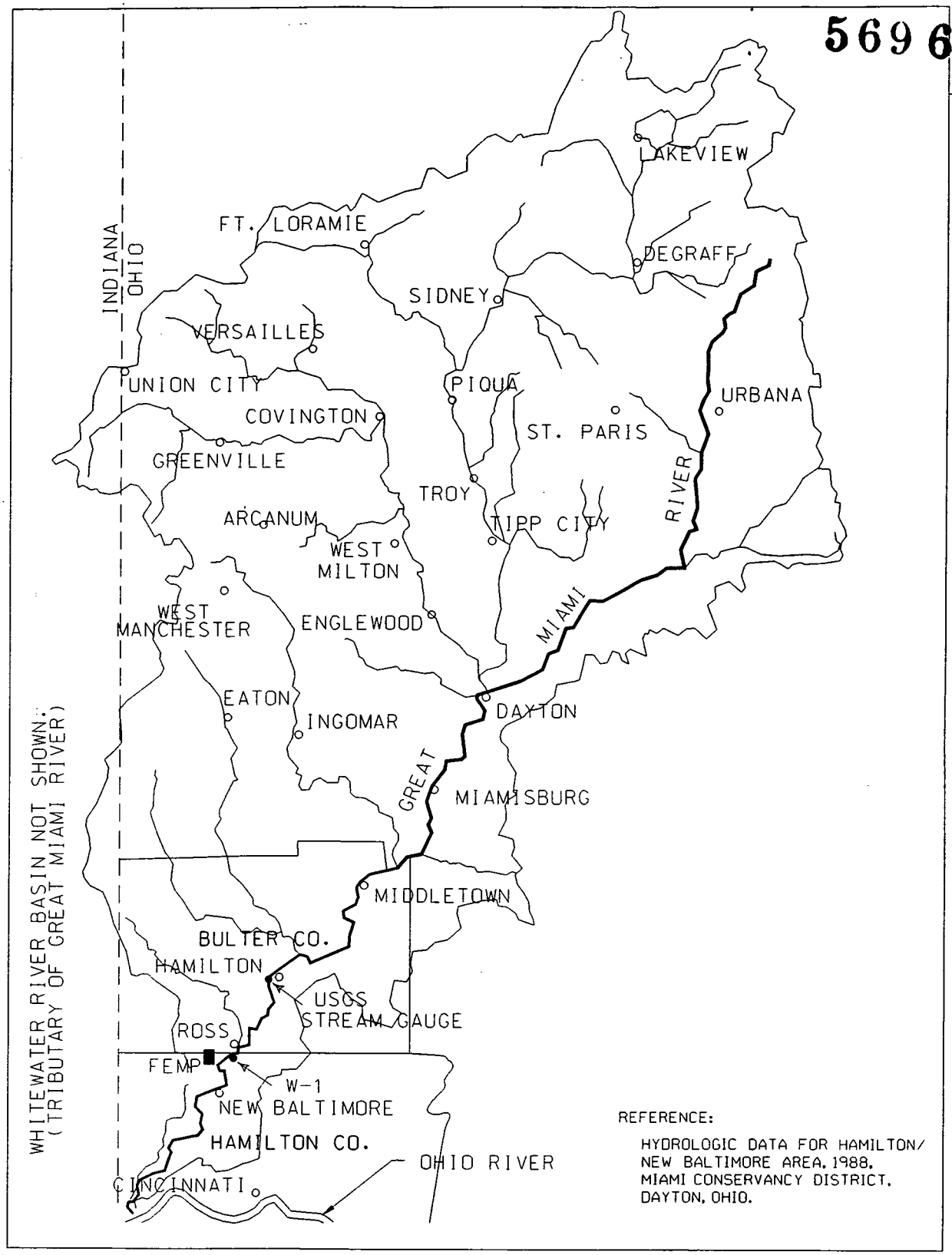
HORIZONTAL SCALE
0 2000 4000 FEET

NOTE:
ALL VALUES ARE ANNUAL AVERAGES

DRAFT

/usr/ermo3/fmpc/idx/b90.dgn ou5 RI data 06/12/94

FIGURE 3-5.
FEMP HYDRAULIC BUDGET AND CONCEPTUAL PATHWAYS



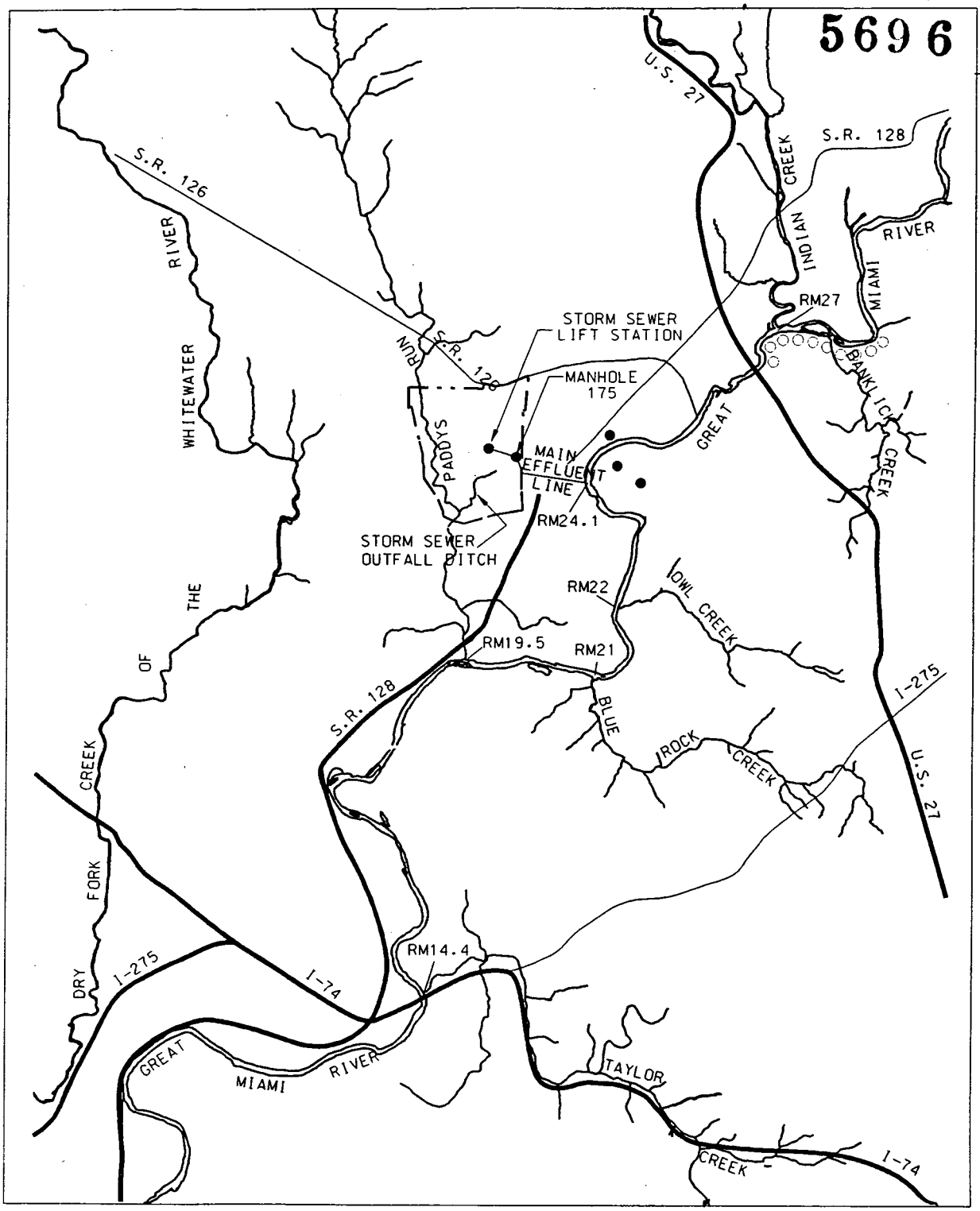
A106.DGN OU5 R1

DRAFT

SCALE

1125 562 0 1125 FEET

FIGURE 3-6. GREAT MIAMI RIVER BASIN



LEGEND:

- - - FEMP PROPERTY BOUNDARY

RM22 RIVER MILE (RM)

● SOUTHWESTERN OHIO WATER CO. WELL FIELD

○ CINCINNATI WELL FIELD

SCALE

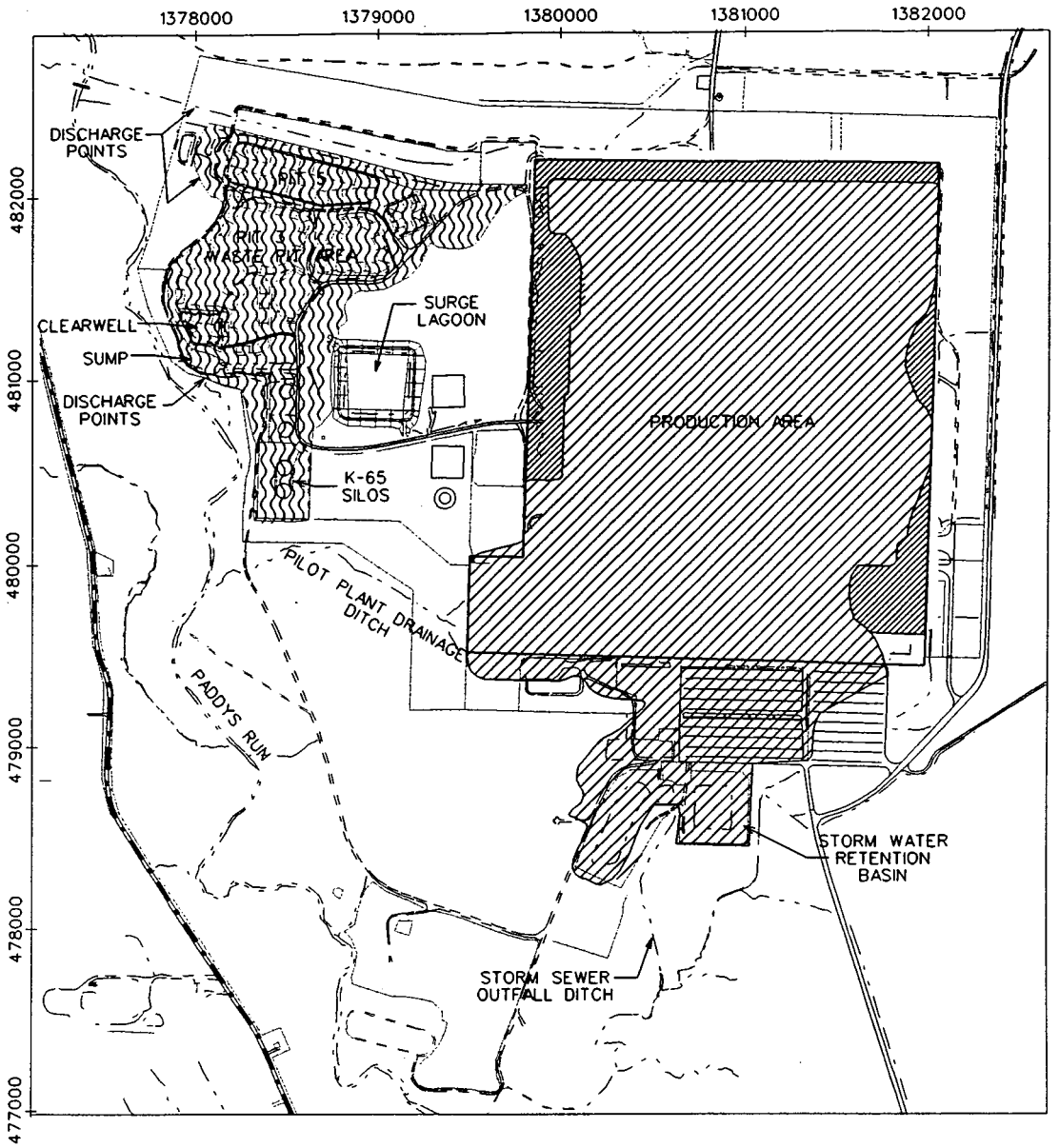
9000 4500 0 9000 FEET

A107.DGN OU5 RI

DRAFT

FIGURE 3-7. REGIONAL SURFACE WATER

5696



NOTE:

DRAWING IS BASED ON 1992 AERIAL PHOTOGRAPHS.

LEGEND:

- REMOVAL ACTION 16
- PRE-REMOVAL ACTION CONTOLLED AREA
- REMOVAL ACTION 2
- FEMP PROPERTY BOUNDARY

SCALE

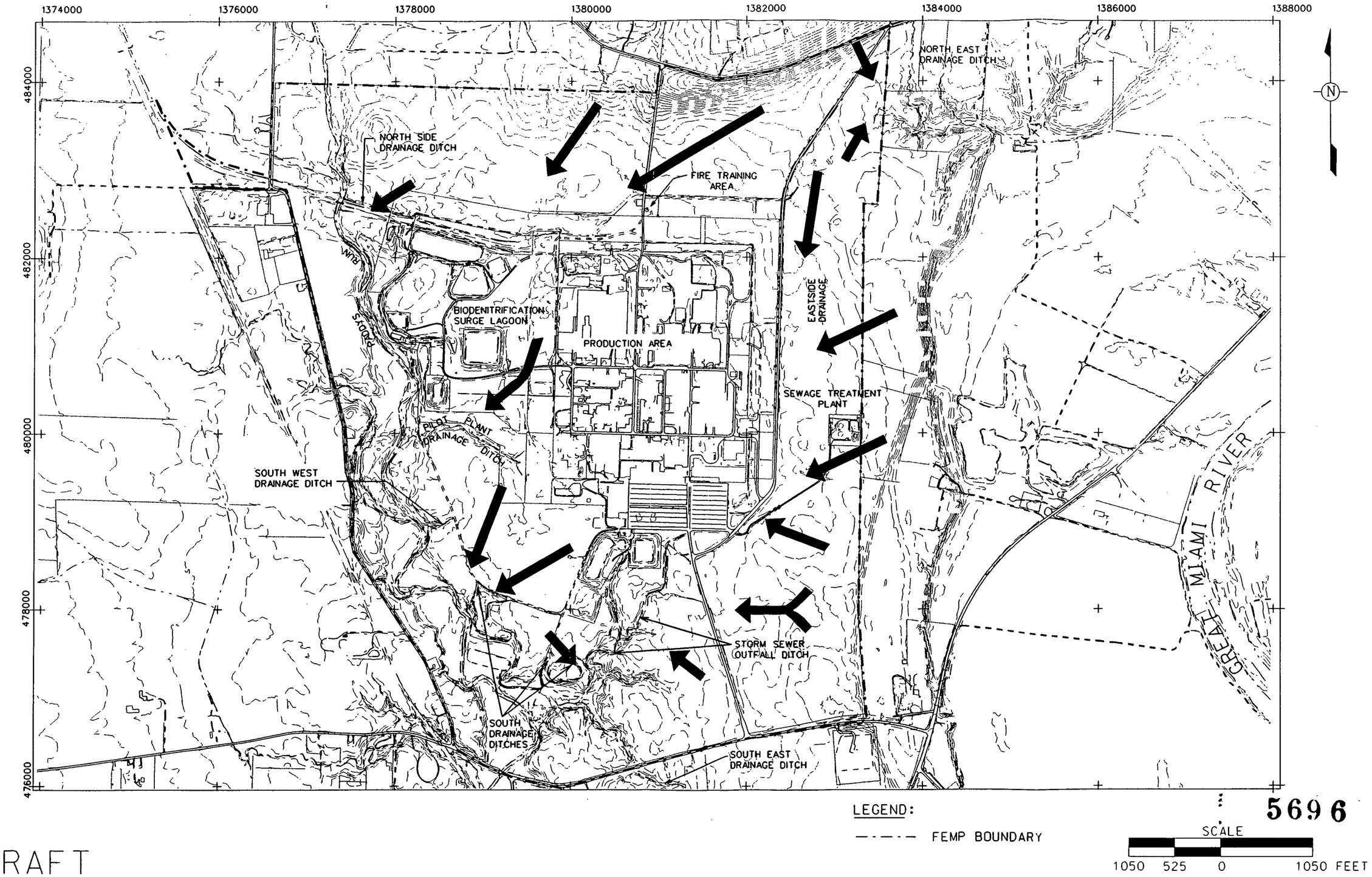
1000 500 0 1000 FEET

DRAFT

/USR/ERMA3/FMPC/DGN/MAP/HOR/DPTH/C110045.DGN OU RI STATE PLANAR COORDINATE SYSTEM 1927

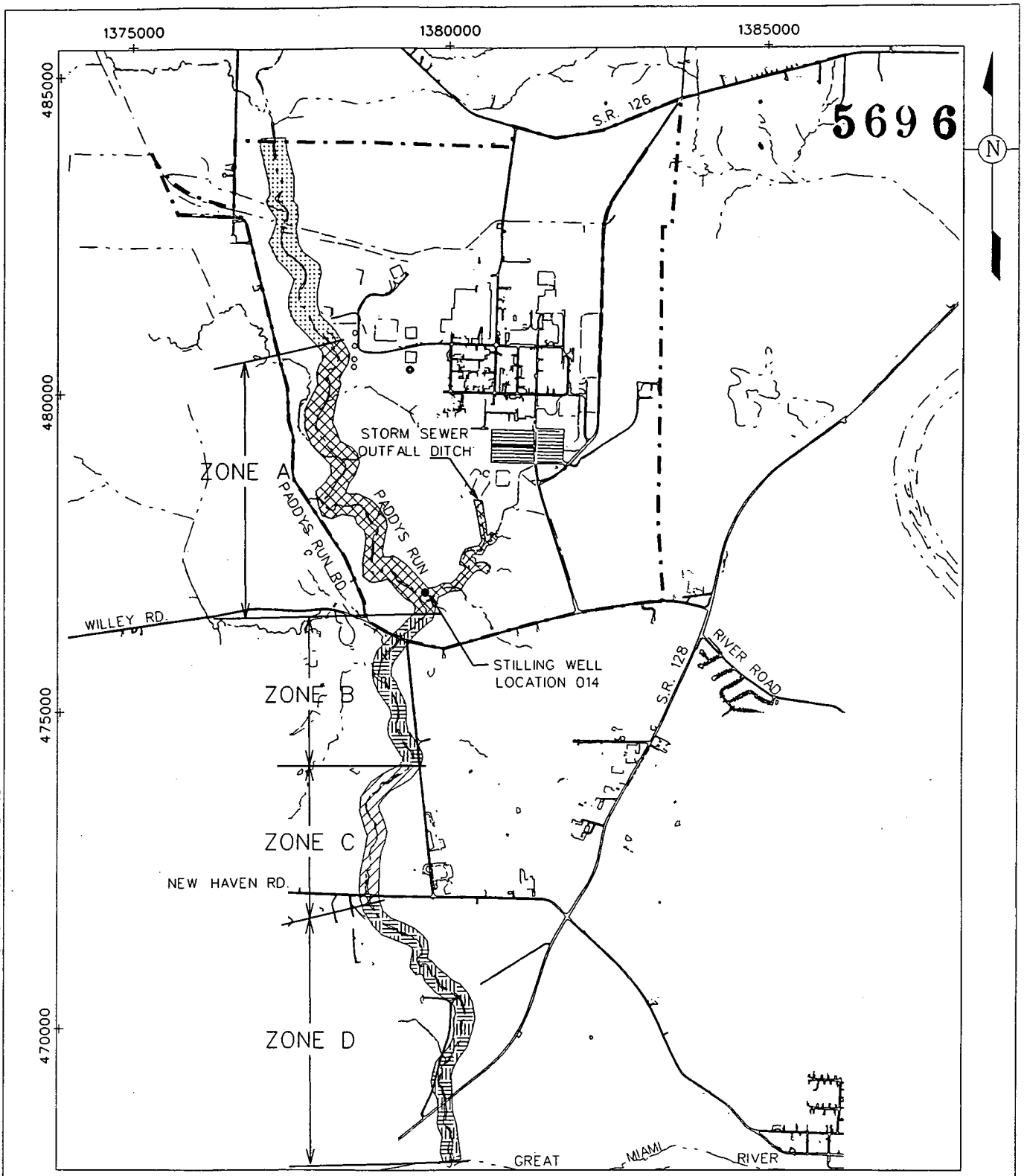
FIGURE 3-8. CONTROLLED AREA SURFACE WATER RUNOFF

000459



5696

FIGURE 3-9. UNCONTROLLED SURFACE WATER RUNOFF



NOTE:
ZONE AREAS
ARE APPROXIMATE

LEGEND:

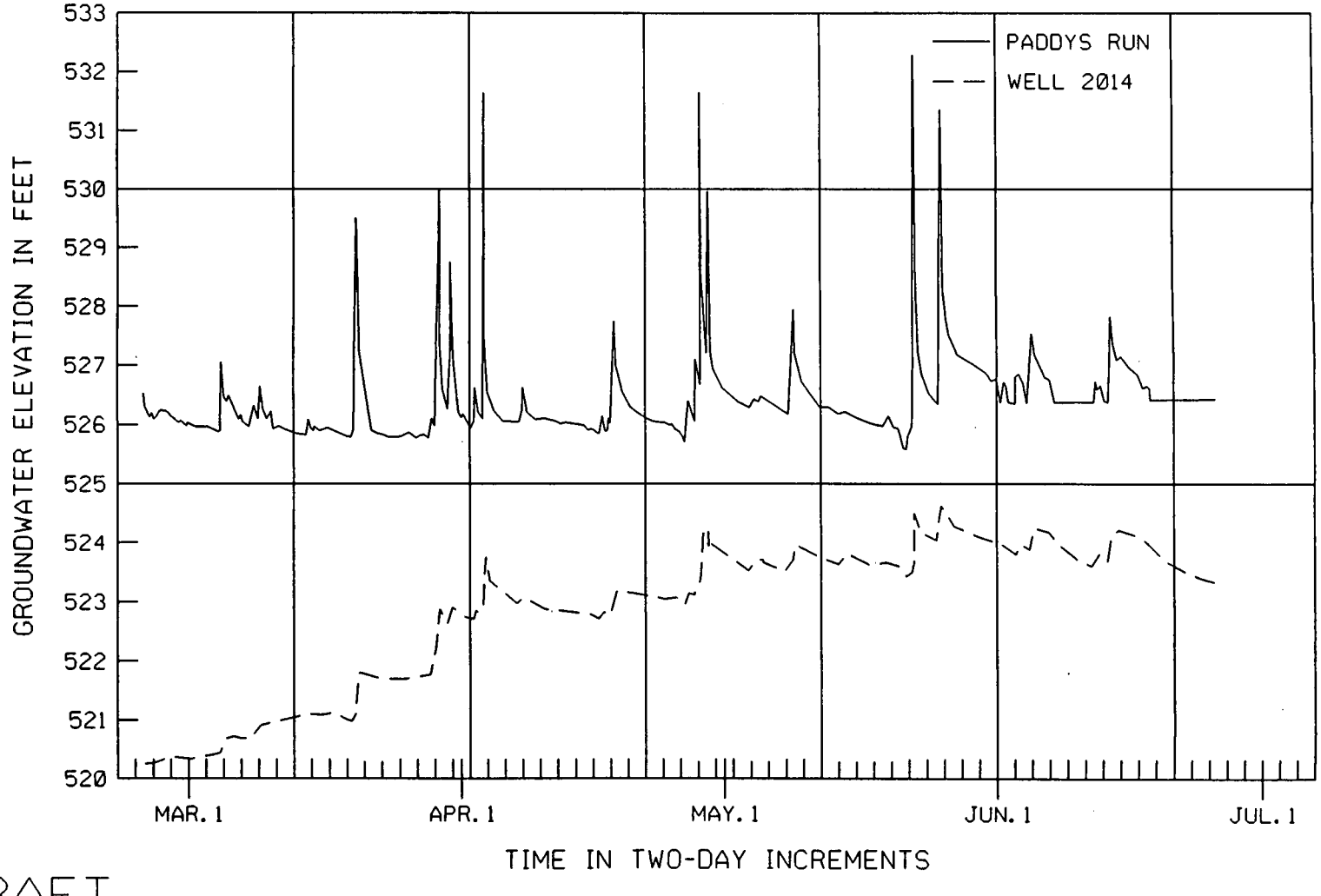
- ON GLACIAL OVERBURDEN MINIMUM INFILTRATION
- INFILTRATION ALWAYS OCCURS
- INFILTRATION DEPENDENT ON WATER TABLE ELEV.
- GROUNDWATER DISCHARGE IN ALL SEASONS
- FEMP PROPERTY BOUNDARY

SCALE
2250 1125 0 2250 FEET

DRAFT

/USR/ERMA3/FMPC/DGN/MAP/HOR/DPTH/C110046.DGN OU5 R1 STATE PLANAR COORDINATE 1927

FIGURE 3-10. SURFACE WATER INFILTRATION TO THE GREAT MIAMI AQUIFER ALONG PADDYS RUN AND THE STORM SEWER OUTFALL DITCH



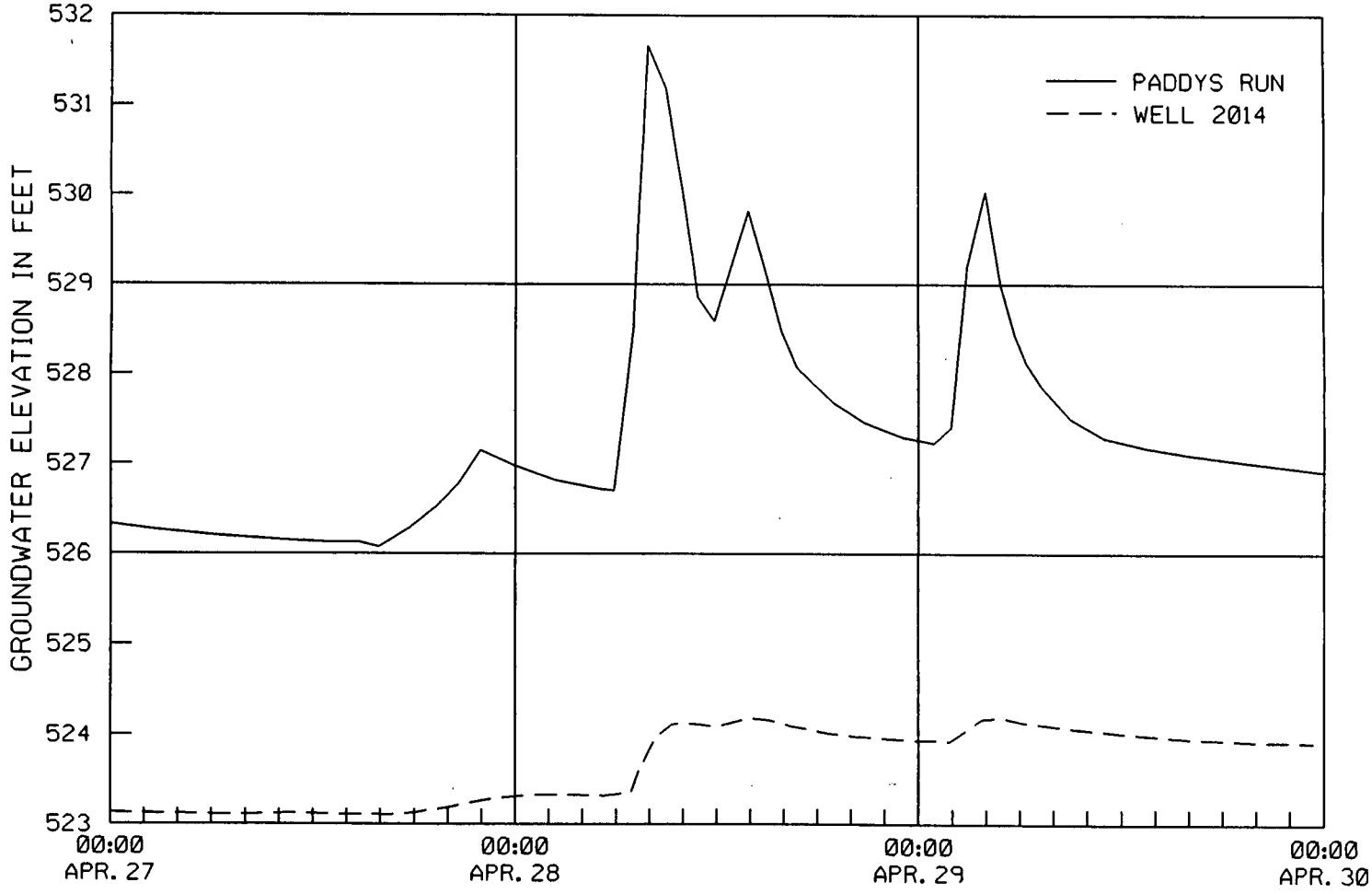
DRAFT

/USR/ERMA3/FMPC/IDX/A115 (OU5)

5696

FIGURE 3-11. HYDROGRAPH OF PADDYS RUN AND GREAT MIAMI AQUIFER AT WELL LOCATION 14, FEBRUARY 24, 1989 - JUNE 26, 1989

000462



DRAFT

A114 (OU5)

FIGURE 3-12. HYDROGRAPH OF PADDYS RUN AND GREAT MIAMI AQUIFER
AT WELL LOCATION 14, APRIL 27, 1989 - APRIL 30, 1989

5696

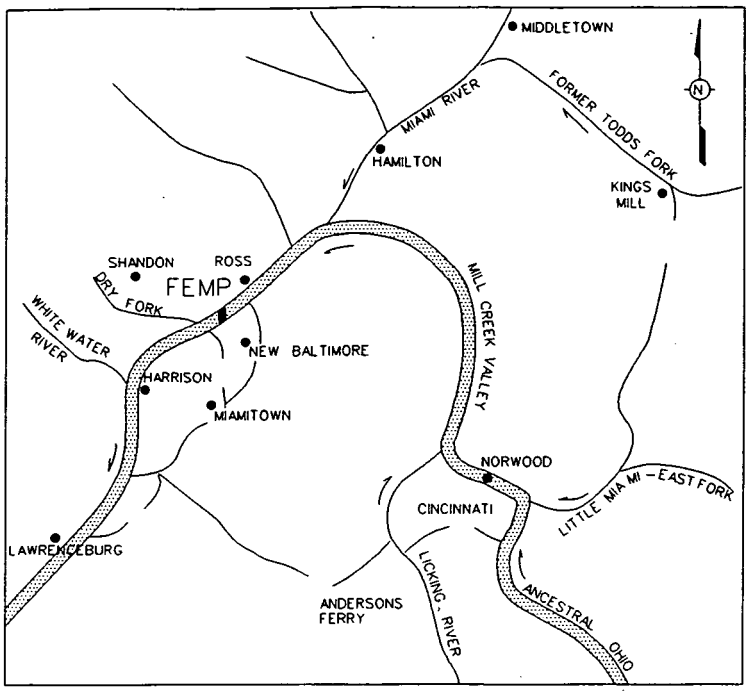


FIGURE 3-13A. DEEP STAGE DRAINAGE SYSTEM

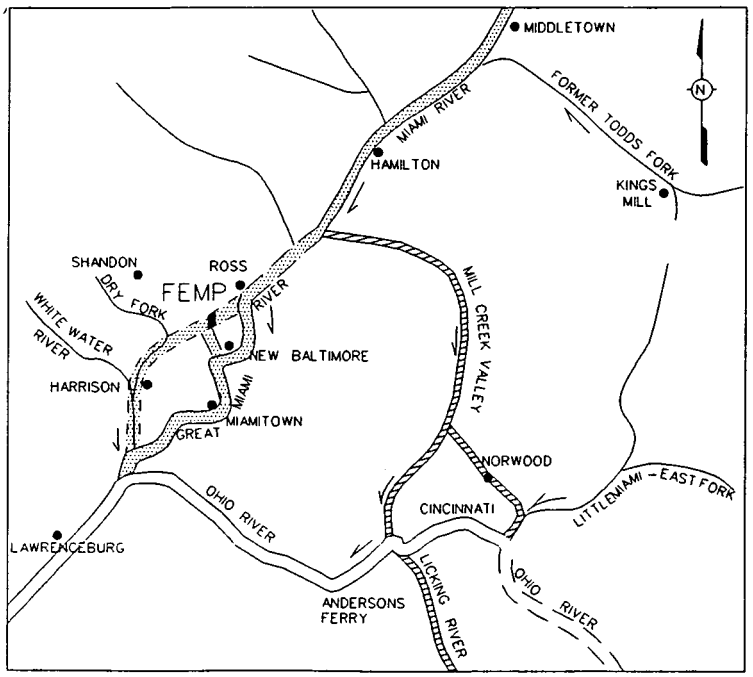


FIGURE 3-13B. PRESENT DRAINAGE SYSTEM

LEGEND:

- DIRECTION OF FLOW
- ANCESTRAL OHIO RIVER

LEGEND:

- DIRECTION OF FLOW
- GREAT MIAMI RIVER
- PRESENT OHIO RIVER
- NEW HAVEN TROUGH
- MILL CREEK BASIN

SOURCE:

FENNEMAN, N.M., 1916
"THE GEOLOGY OF CINCINNATI AND VICINITY", GEOLOGICAL SURVEY OF OHIO, BULLETIN 19.

NOT TO SCALE

DRAFT

A136 (OU5)

FIGURE 3-13. SCHEMATIC DIAGRAM OF THE DEEP STAGE DRAINAGE SYSTEM AND THE PRESENT DRAINAGE SYSTEM

SYSTEM	GROUP	FORMATIONS AND MEMBERS		MAP SYMBOL	LITHOLOGY	THICKNESS IN FEET		ROCK UNIT DESCRIPTION
ORDOVICIAN	CINCINNATI GROUP	WAYNESVILLE FORMATION	UNDIFFERENTIATED	O_{aw}		60+		INTERBEDDED SHALE AND LIMESTONE. SHALE MAKES UP 65 PERCENT OR MORE OF UNIT.
		ARNHEIM FORMATION (INFORMAL UNIT)						INTERBEDDED LIMESTONE AND SHALE. LIMESTONE (BEDS ARE IRREGULAR TO PLANAR) MAKES UP 50 PERCENT OR MORE OF UNIT.
		GRANT LAKE FORMATION: MOUNT AUBURN MEMBER		O_{glm}		15-20	75-90	LIMESTONE AND SHALE. LIMESTONE (IRREGULAR BEDS) MAKES UP 60 PERCENT OR MORE OF UNIT.
		GRANT LAKE FORMATION: CORRYVILLE MEMBER	UNDIFFERENTIATED	O_{glbc}		60-70		INTERBEDDED SHALE AND LIMESTONE. SHALE MAKES UP 60 PERCENT OR MORE OF UNIT.
		GRANT LAKE FORMATION: BELLVUE MEMBER						LIMESTONE, IRREGULAR BEDS.
		MIAMITOWN SHALE		O_m		15-35		INTERBEDDED SHALE AND LIMESTONE. SHALE MAKES UP 75 PERCENT OR MORE OF UNIT.
		FAIRVIEW FORMATION		O_f		40-90		INTERBEDDED LIMESTONE AND SHALE. LIMESTONE MAKES UP 50 PERCENT OR MORE OF UNIT.
		KOPE FORMATION		O_k		260-280		INTERBEDDED SHALE AND LIMESTONE. SHALE MAKES UP 75 PERCENT OR MORE OF UNIT.
		POINT PLEASANT TONGUE OF THE CLAYS FERRY FORMATION		O_p		30+		INTERBEDDED LIMESTONE AND SHALE. LIMESTONE MAKES UP 50 PERCENT OR MORE OF UNIT.

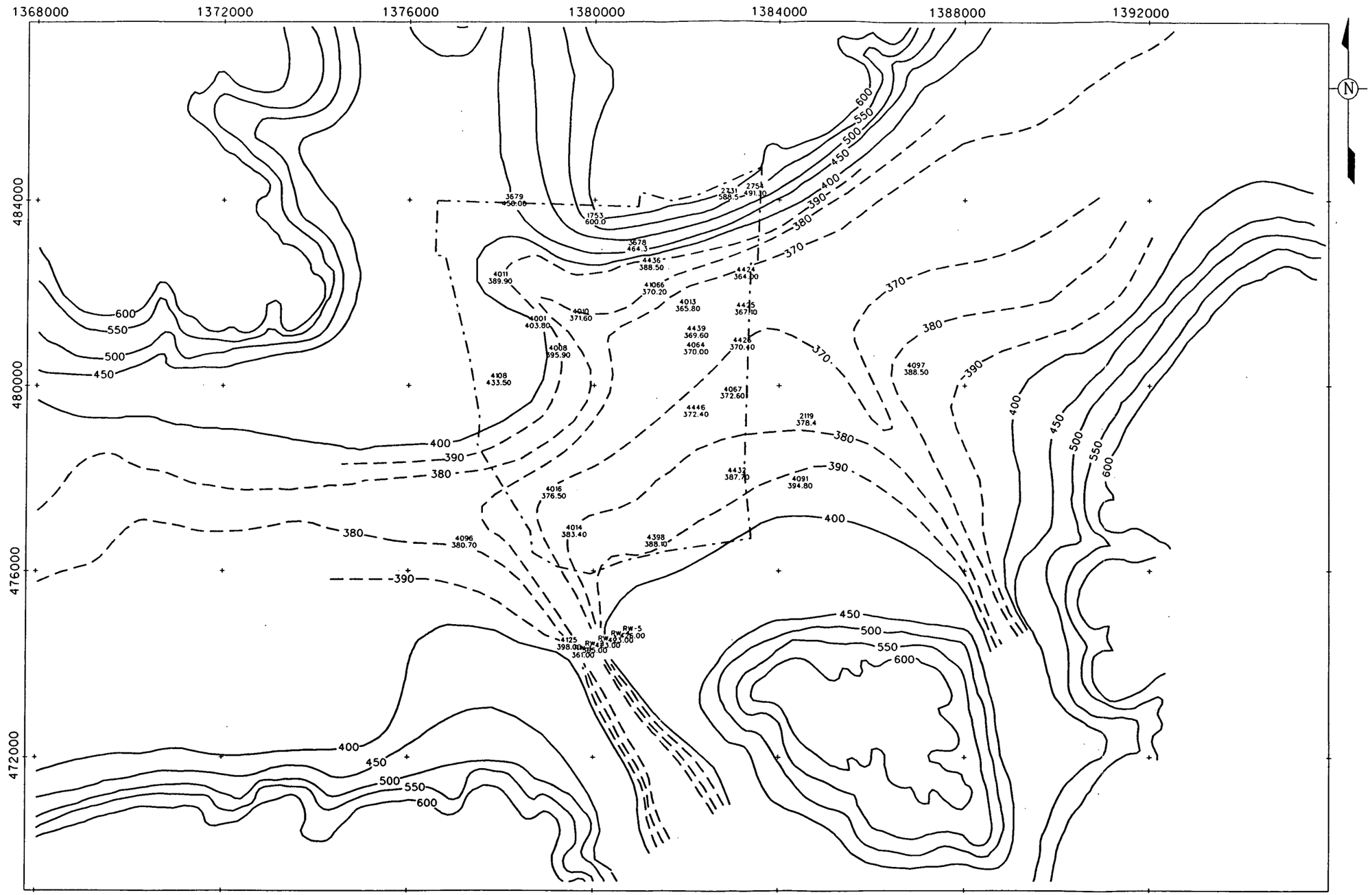
REFERENCE:

MODIFIED FROM THE STATE OF OHIO, DEPT. OF NATURAL RESOURCES, DIVISION OF GEOLOGICAL SURVEY, BEDROCK OF THE SHANDON QUADRANGLE (HAMILTON CO. PORTION), E.M. SWINFORD, 1990

A138 (OU5)

DRAFT

FIGURE 3-14. GENERALIZED STRATIGRAPHIC SECTION OF THE BEDROCK IN THE FEMP AREA



000466

LEGEND:

4096 WELL/BORING NUMBER

380.70 BEDROCK ELEVATION

FEMP BOUNDARY

10 FOOT BEDROCK CONTOUR (RI/FS WELL DATA)

50 FOOT BEDROCK CONTOUR (WATKINS & SPIEKER, 1971)

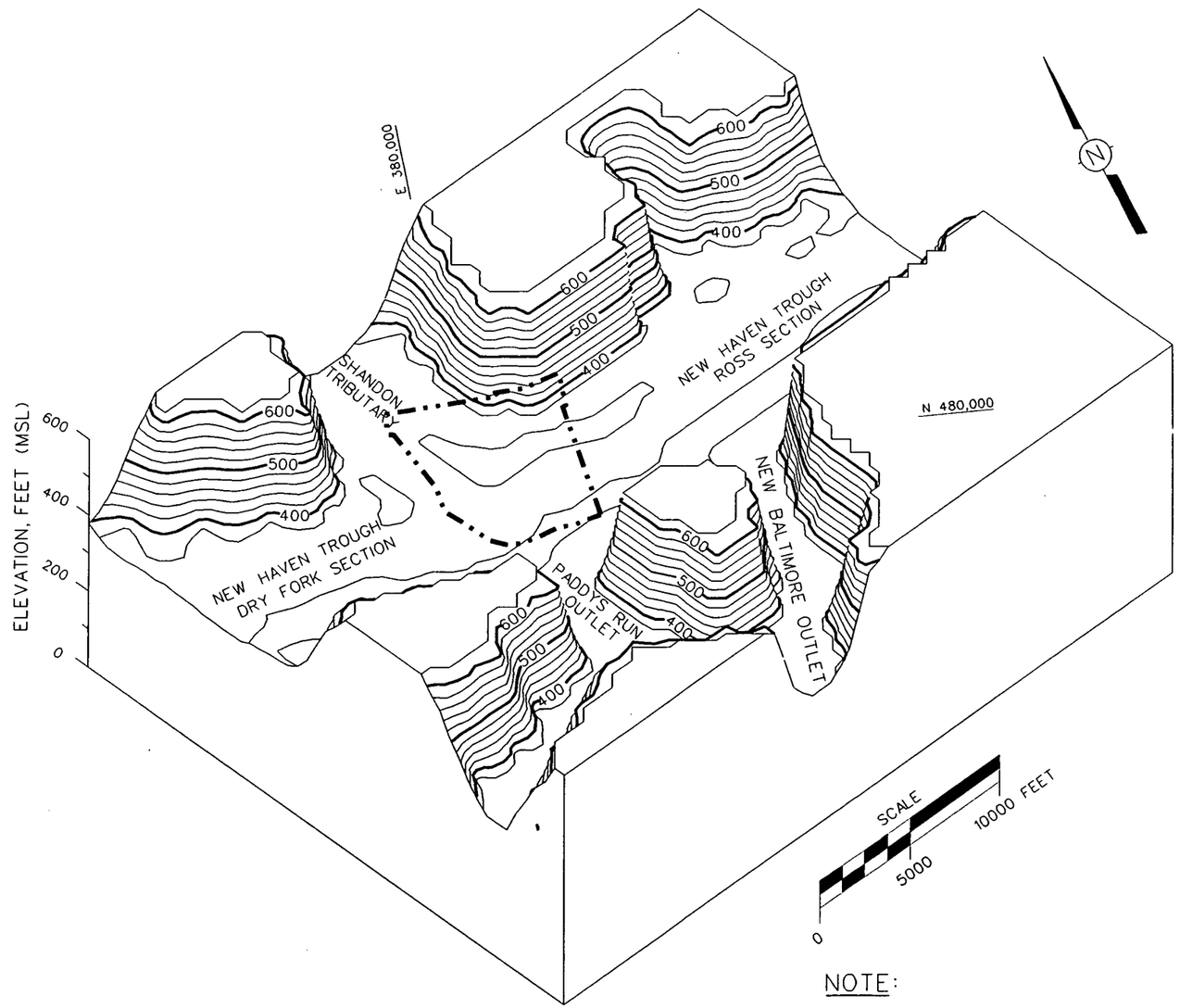
SCALE

2500 1250 0 2500 FEET

DRAFT

/USR/ERMA3/SARN1/DGN/MAP/HOR/DPTH/BEDROCK.DGN FER OU5 RIDATA 06/13/94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 3-15. BEDROCK TOPOGRAPHIC SURFACE



NOTE:
VERTICAL EXAGGERATION
= 20X

LEGEND:

400 CONTOUR

FEMP BOUNDARY

000467

DRAFT

/USR/ERMA3/FMPC/IDX/A146.DGN FER OU5 RIDATA 6-10-94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 3-16. 3-DIMENSIONAL BEDROCK CONFIGERATION

LEGEND:

10 FOOT CONTOURS

FEMP BOUNDARY

ICE FLOW DIRECTION

TERMINAL MORAINE

RIVER TERRACE

NOTE:

SOURCE: SHANDON 7.5 MINUTE TOPOGRAPHIC QUADRANGLE USGS 1981

5696

c110059.dgn FER OU5 RIDATA 5-31-94 STATE PLANAR COORDINATE SYSTEM 1927

DRAFT

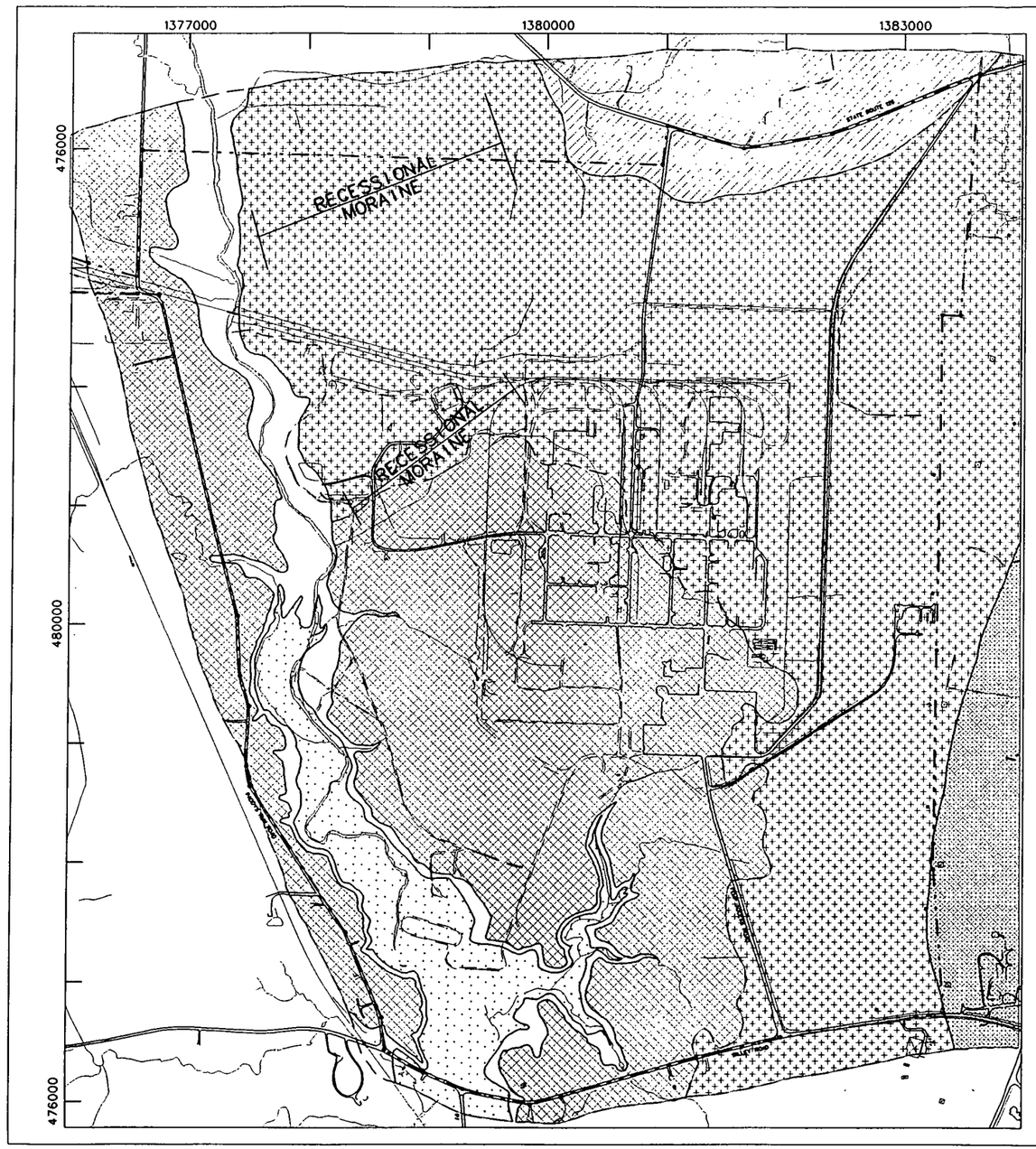
SCALE

3500 1750 0 3500 FEET

FIGURE 3-17. GLACIAL GEOMORPHOLOGY

000468

5696



LEGEND:

- ALLUVIUM, FLUVIAL DEPOSITS OF RECENT (HOLOCENE) ORIGIN. INCLUDES A VARIETY OF TEXTURAL CLASSES FROM CLAYS TO BOULDERS. THIS ALLUVIUM LIES DIRECTLY UPON SAND AND GRAVEL OUTWASH DEPOSITS OF THE GREAT MIAMI AQUIFER.
- TILL, WISCONSIN AGE. SHELBYVILLE TILL EXPOSED ON ERODED SLOPES AND FLOOR OF PADDYS RUN VALLEY. LOCALLY, MAY BE COVERED WITH A THIN VENEER OF RECENT ALLUVIUM
- FINE TO COARSE SAND. CONTAINS LESSER AMOUNTS OF DISSEMINATED GRAVEL AND THIN GRAVEL OR SILT LENSES. THE MAPPED UNIT IS ALLUVIUM THAT LIES UNCONFORMABLY UPON SHELBYVILLE TILL: AN ALLUVIAL TERRACE OF THE GREAT MIAMI RIVER.
- LACUSTRINE DEPOSITS OF LATE WISCONSIN (?) AGE. INCLUDES A VARIETY OF TEXTURAL CLASSES FROM SILTY CLAY TO COARSE SAND. THE MAPPED UNIT IS A REMNANT SURFACE LAKE FILL THAT OCCURRED BEHIND (UPGRADIENT OF) THE TERMINAL MORAINE LOCATED AT THE SOUTHERN EDGE OF THE FEMP
- TILL, WISCONSIN AGE (SHELBYVILLE TILL). TILL CONTAINS THIN AND DISCONTINUOUS SILT, SAND AND GRAVEL LENSES. BOTH ABLATIONAL AND LODGEMENT FACIES EXIST, WITH LODGEMENT FACIES BEING THE MAJORITY. GENERALLY OVERLAIN BY A LOESS CAP UP TO 36 INCHES THICK
- BEDROCK WITH A TILL/LOESS CAP OF VARIABLE THICKNESS. ORDOVICIAN AGE BEDROCK IS ALTERNATING LAYERS OF LIMESTONE AND SHALE. BEDROCK IS CAPPED BY WISCONSIN TILL, LOESS AND COLLUVIUM OF VARIABLE THICKNESS, GENERALLY LESS THAN 10 FEET THICK.
- APPROXIMATED CONTACT OF MAP UNITS
- CONTACT OF MAP UNITS
- FEMP BOUNDARY

NOTE:

GENERALIZED GEOLOGY BASED ON FEMP RI/FS DATA AND MAPPING OF BROCKMAN (1988, ODNR GEOLOGICAL SURVEY OPEN FILE REPORT). THIS MAP PORTRAYS THE GEOLOGY OF STRATA EXPOSED AT THE GROUND SURFACE PRIOR TO GRADING, EXCAVATION AND CONSTRUCTION OF THE FEMP

000469

SCALE

1150 575 0 1150 FEET

DRAFT

FILE NAME /res2233/pre-geo2.dgn 11x17 cru5 10-29-93 GES STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 3-18. PRE-CONSTRUCTION SURFACE GEOLOGY OF THE FEMP

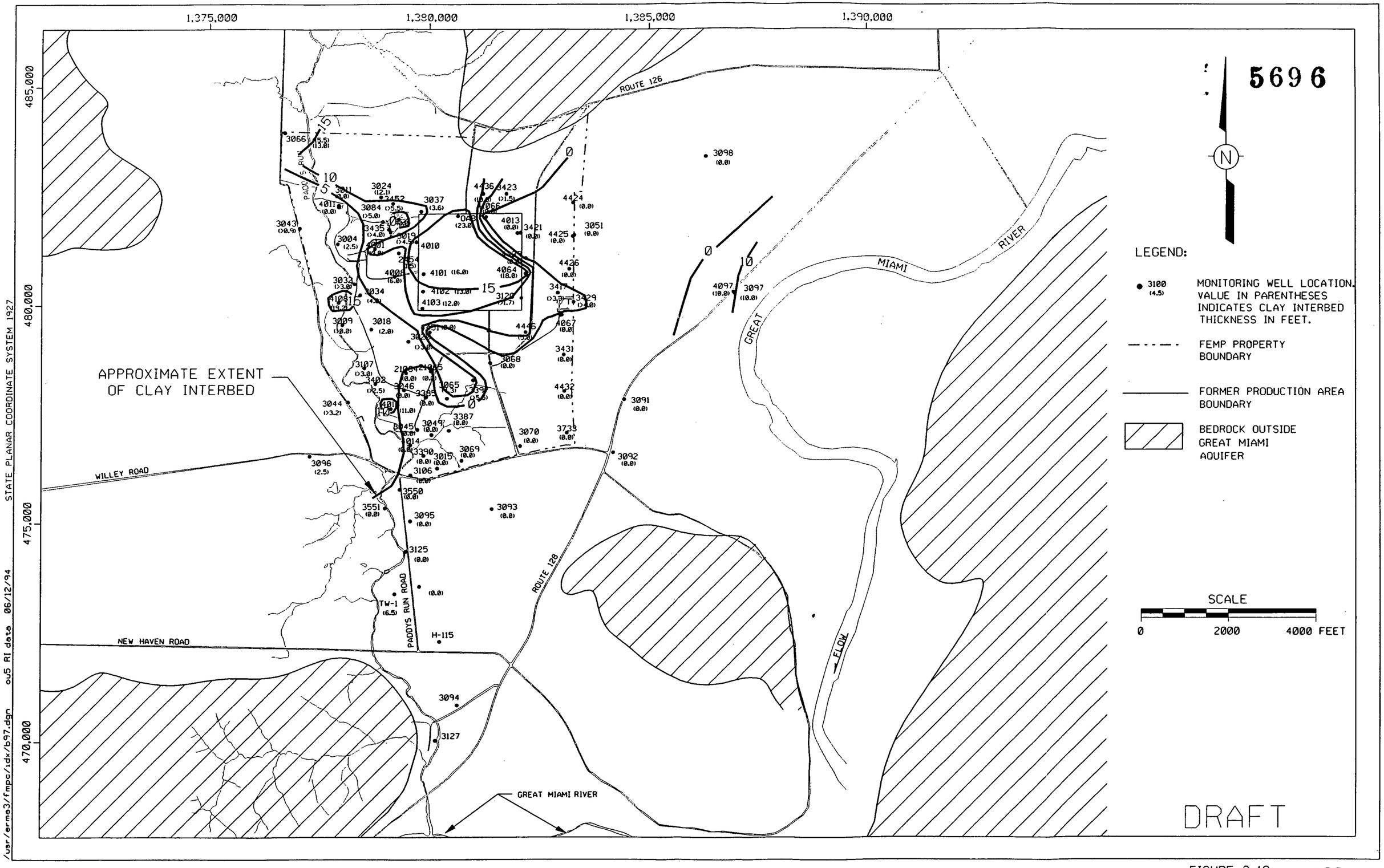


FIGURE 3-19
CLAY INTERBED ISOPACH

000470

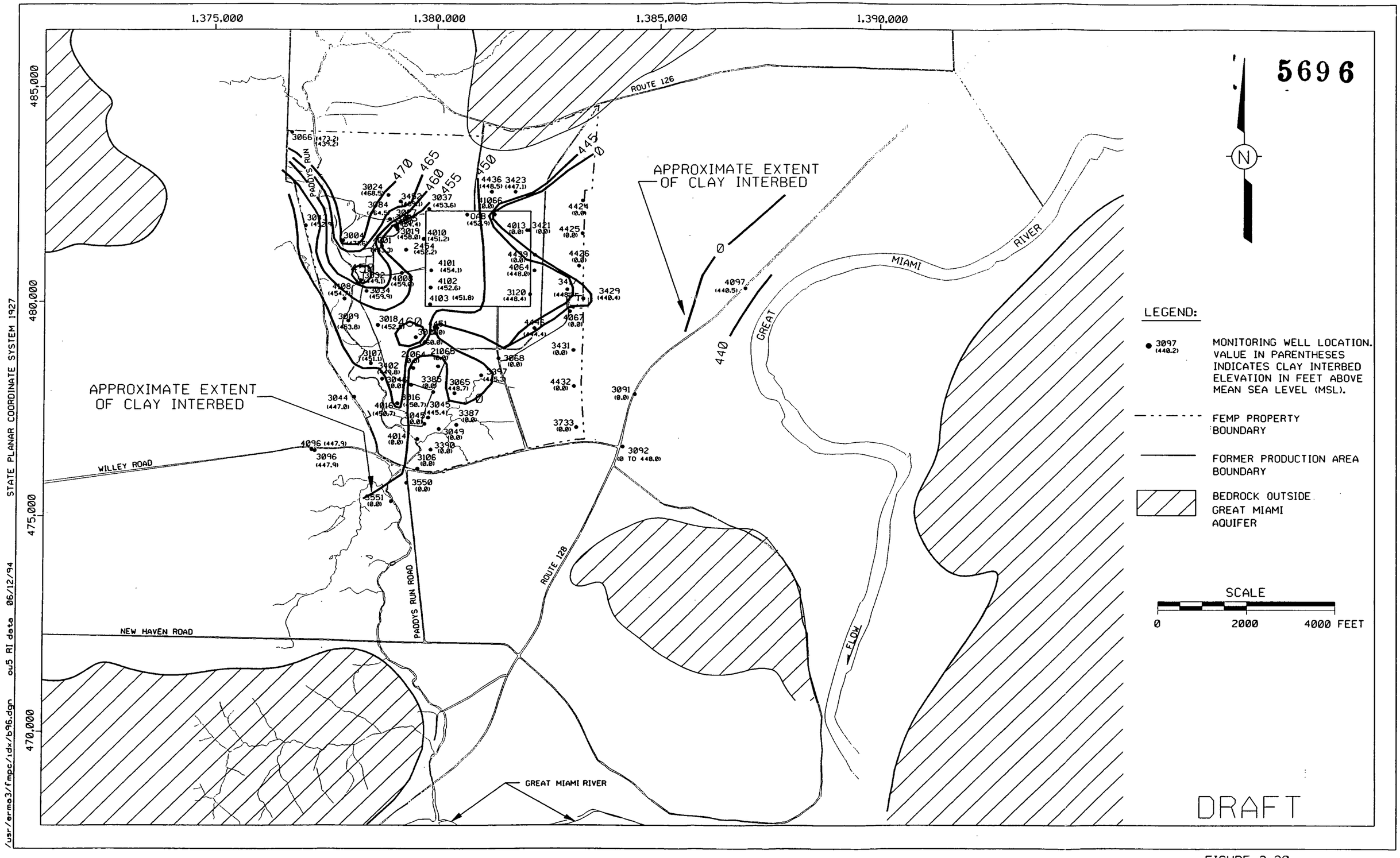
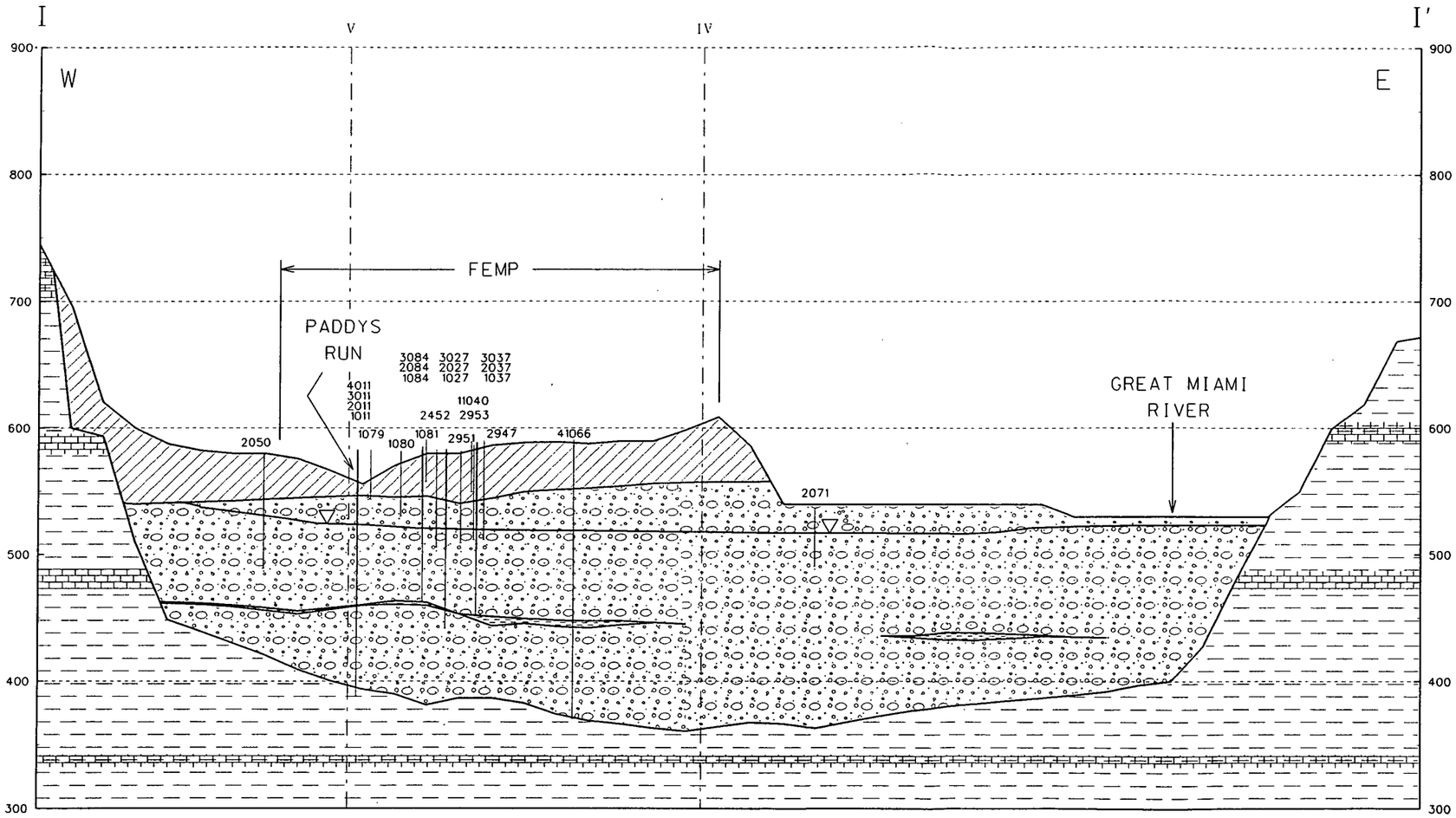
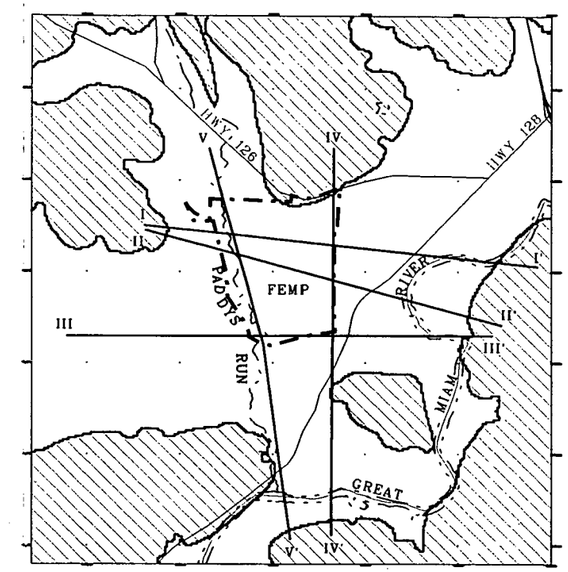


FIGURE 3-20
CLAY INTERBED
TOPOGRAPHIC SURFACE





BEDROCK

SCALE

0 500 1500 2500 FEET

LEGEND:

▽	WATER TABLE
⊥	BORING DEPTH
1771	MONITORING WELL NUMBER / BORING NUMBER

BEDROCK

CLAY INTERBED

GREAT MIAMI AQUIFER

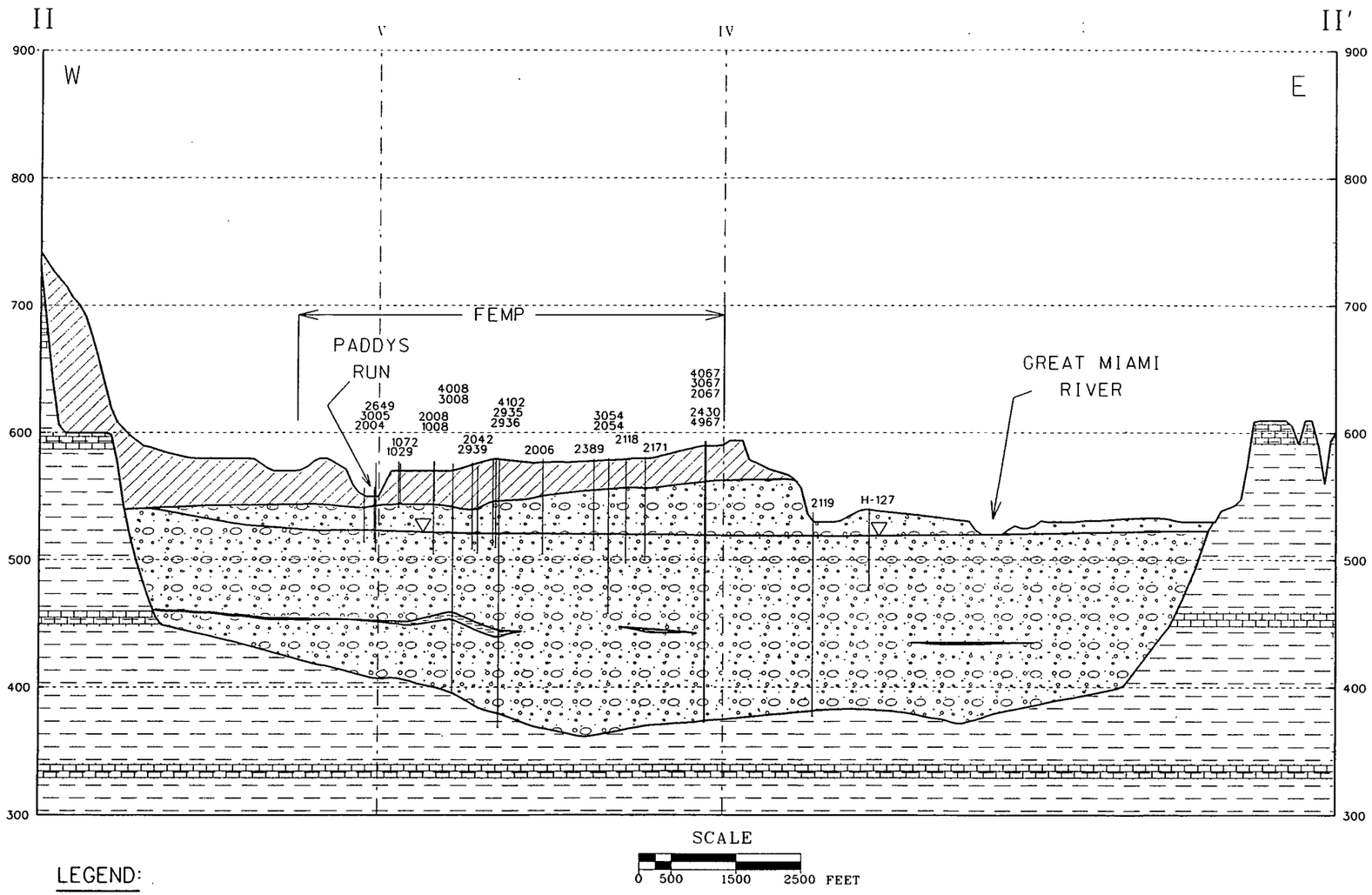
GLACIAL OVERBURDEN

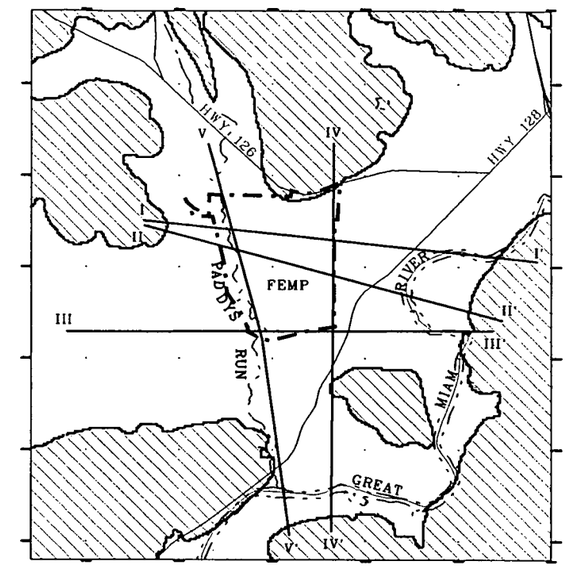
DRAFT

/usr/ermis/5arnl/dgn/map/hor/dpth/reg_xsect.dgn 0u5 Ridata 06/03/94

FIGURE 3-21.
REGIONAL CROSS-SECTION I-I'

5696





BEDROCK

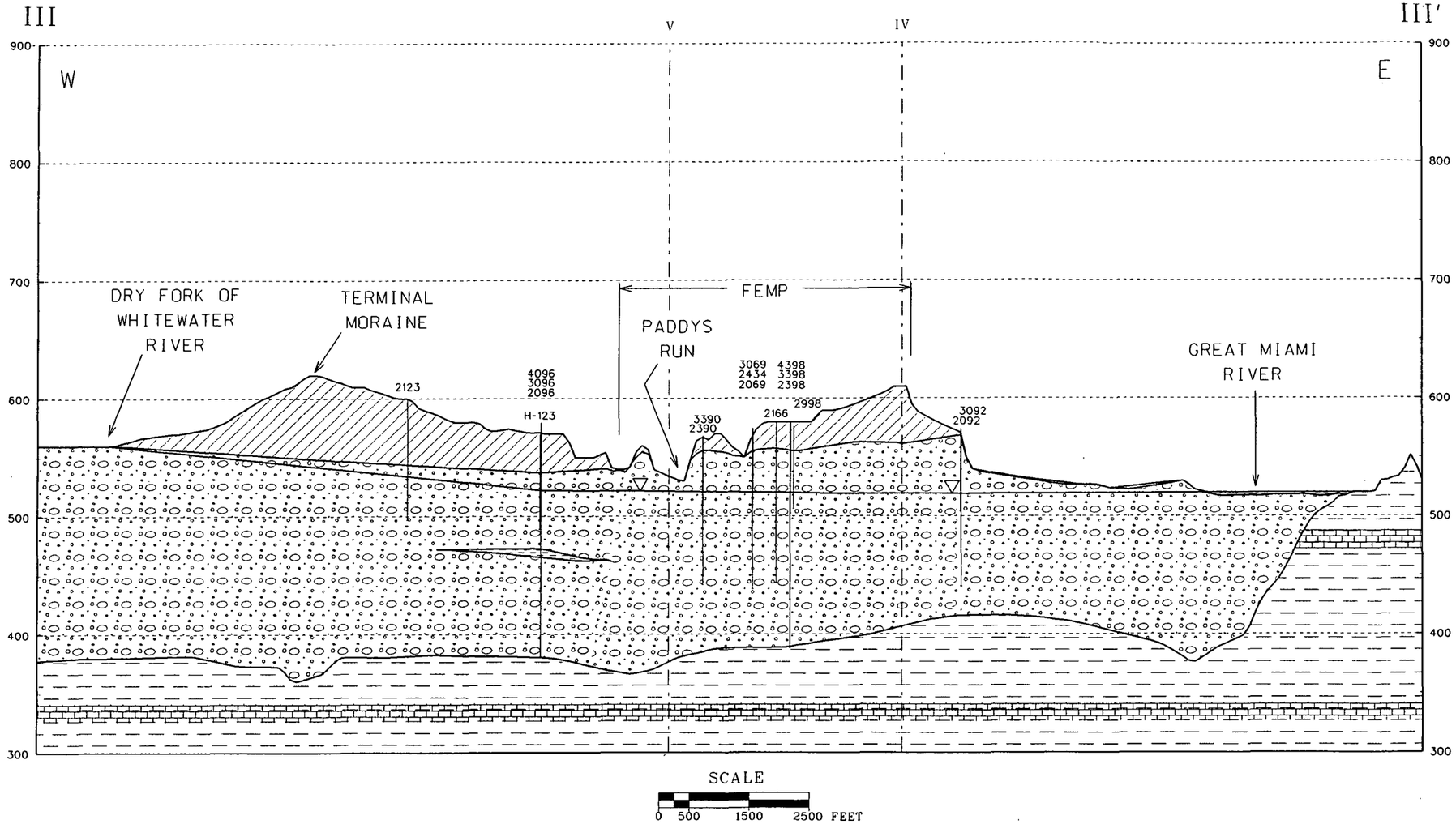
LEGEND:

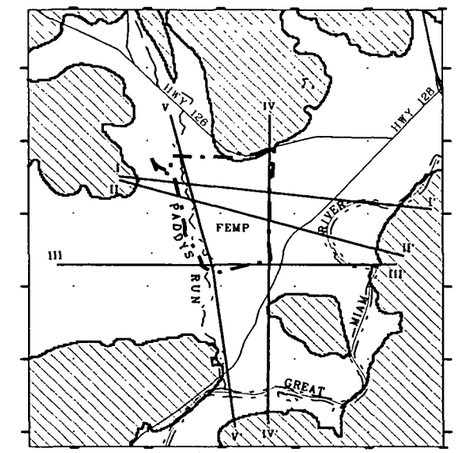
- WATER TABLE
- BORING DEPTH
- 1771 MONITORING WELL NUMBER / BORING NUMBER
- BEDROCK
- CLAY INTERBED
- GREAT MIAMI AQUIFER
- GLACIAL OVERBURDEN

DRAFT

/usr/ermo3/5arnl/dgn/map/hor/dpth/reg_xsect.dgn 06/08/94

FIGURE 3-22.
REGIONAL CROSS-SECTION II-II'





BEDROCK

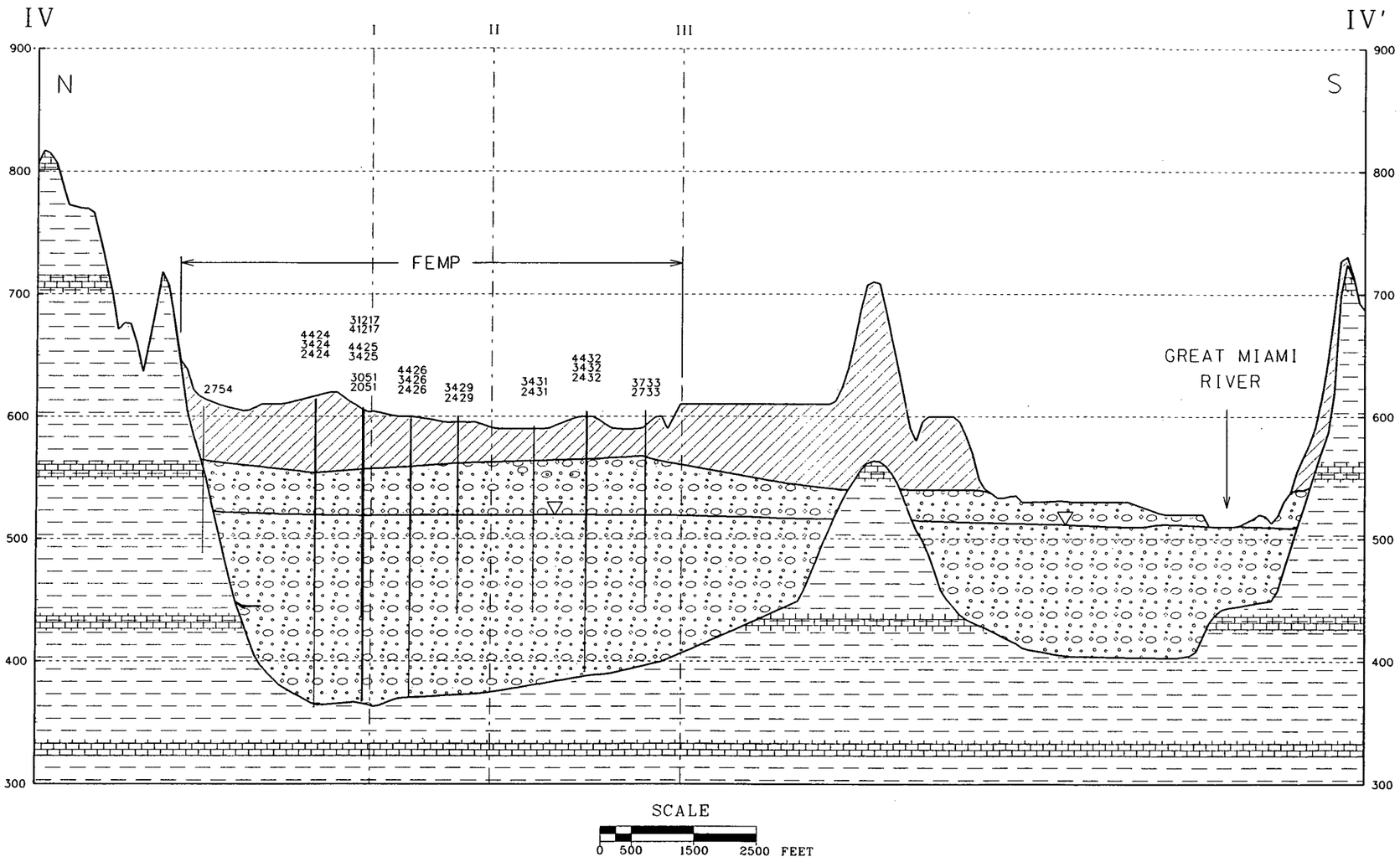
LEGEND:

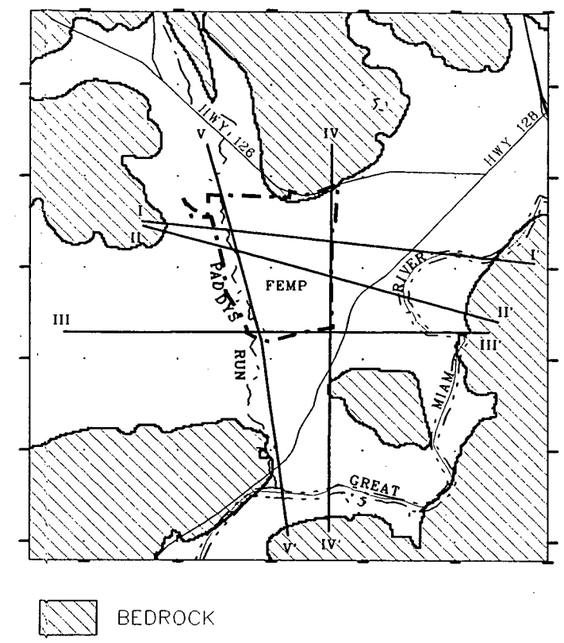
- WATER TABLE
- BORING DEPTH
- 1771 MONITORING WELL NUMBER / BORING NUMBER
- BEDROCK
- CLAY INTERBED
- GREAT MIAMI AQUIFER
- GLACIAL OVERBURDEN

DRAFT

/usr/ermo3/5arn1/dgn/map/hor/dpth/reg_xsect.dgn ou5 Rldata 06/08/94

FIGURE 3-23.
REGIONAL CROSS-SECTION III-III'





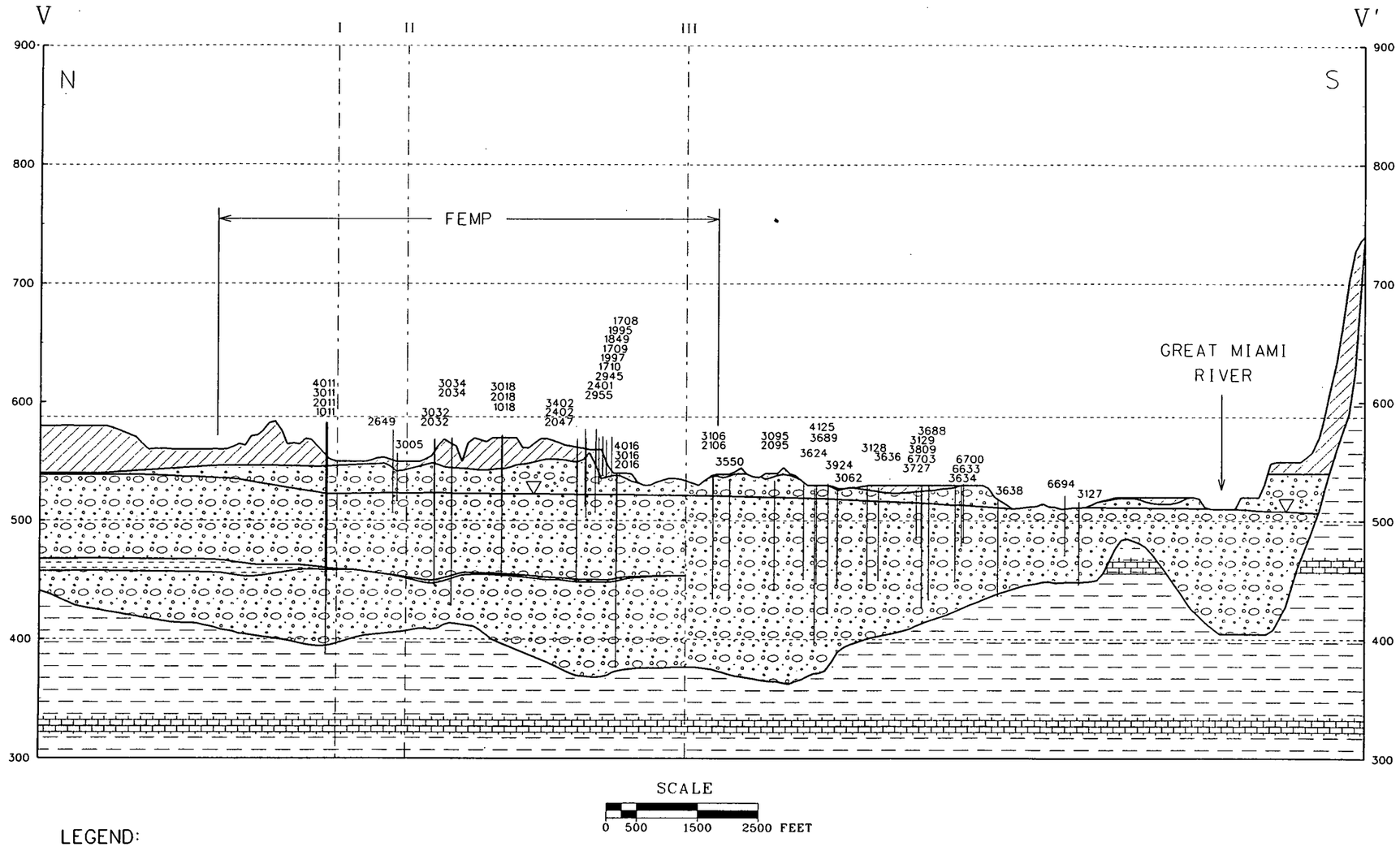
LEGEND:

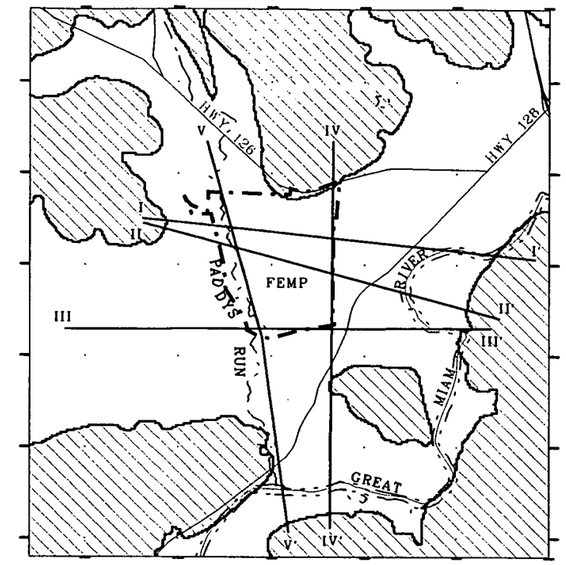
- WATER TABLE
- BORING DEPTH
- 1771 MONITORING WELL NUMBER / BORING NUMBER
- BEDROCK
- CLAY INTERBED
- GREAT MIAMI AQUIFER
- GLACIAL OVERBURDEN

DRAFT

/usr/ermo3/5arnl/dgn/map/hor/dpth/reg_xsect.dgn Ju5 Rl data 06/08/94

FIGURE 3-24.
REGIONAL CROSS-SECTION IV-IV'





BEDROCK

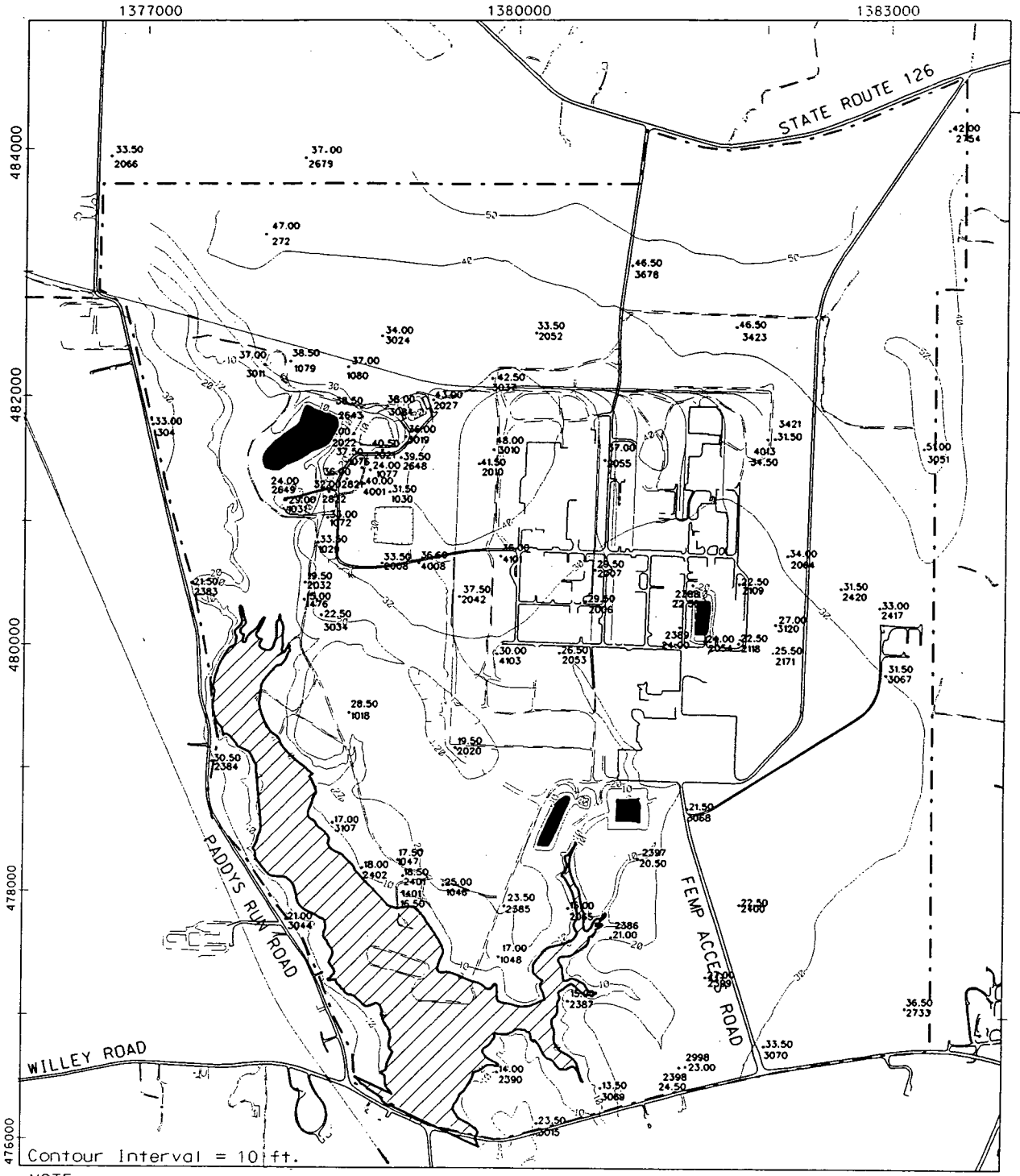
LEGEND:

- WATER TABLE
- BORING DEPTH
- 1771 MONITORING WELL NUMBER / BORING NUMBER
- BEDROCK
- CLAY INTERBED
- GREAT MIAMI AQUIFER
- GLACIAL OVERBURDEN

DRAFT

/usr/ermg3/5arn1/dgn/map/hor/dpth/reg_xsect.dgn ou5 Rldata 06/03/94

FIGURE 3-25.
REGIONAL CROSS-SECTION V-V'



STATE PLANAR COORDINATE SYSTEM 1927

NOTE:

THIS MAP PORTRAYS THE THICKNESS OF UNDISTURBED GLACIAL OVERBURDEN. UNDISTURBED GLACIAL OVERBURDEN IS SEDIMENT THAT HAS REMAINED IN SITU SINCE ITS DEPOSITION BY NATURAL PROCESSES. THE MAP WAS CONSTRUCTED. FIRST. OBY DETERMINING THE THICKNESS OF STRATA BETWEEN THE BASE OF GLACIAL OVERBURDEN STRUCTURE MAP AND THE PRESENT SITE TOPOGRAPHY (E.G. THE 1987 TOPOGRAPHIC MAP) AND SECOND. BY SUBTRACTING FROM THE FIRST THICKNESS ANY SIGNIFICANT AREAS OF FILL OR EXCAVATION.

LEGEND:

- GLACIAL OVERBURDEN REMOVED AND REPLACED DURING CONSTRUCTION
- GLACIAL OVERBURDEN REMOVED BY EROSION
- 33.50 OVERBURDEN THICKNESS IN FEET
- °3093 BORING NO.
- — - — FEMP BOUNDARY

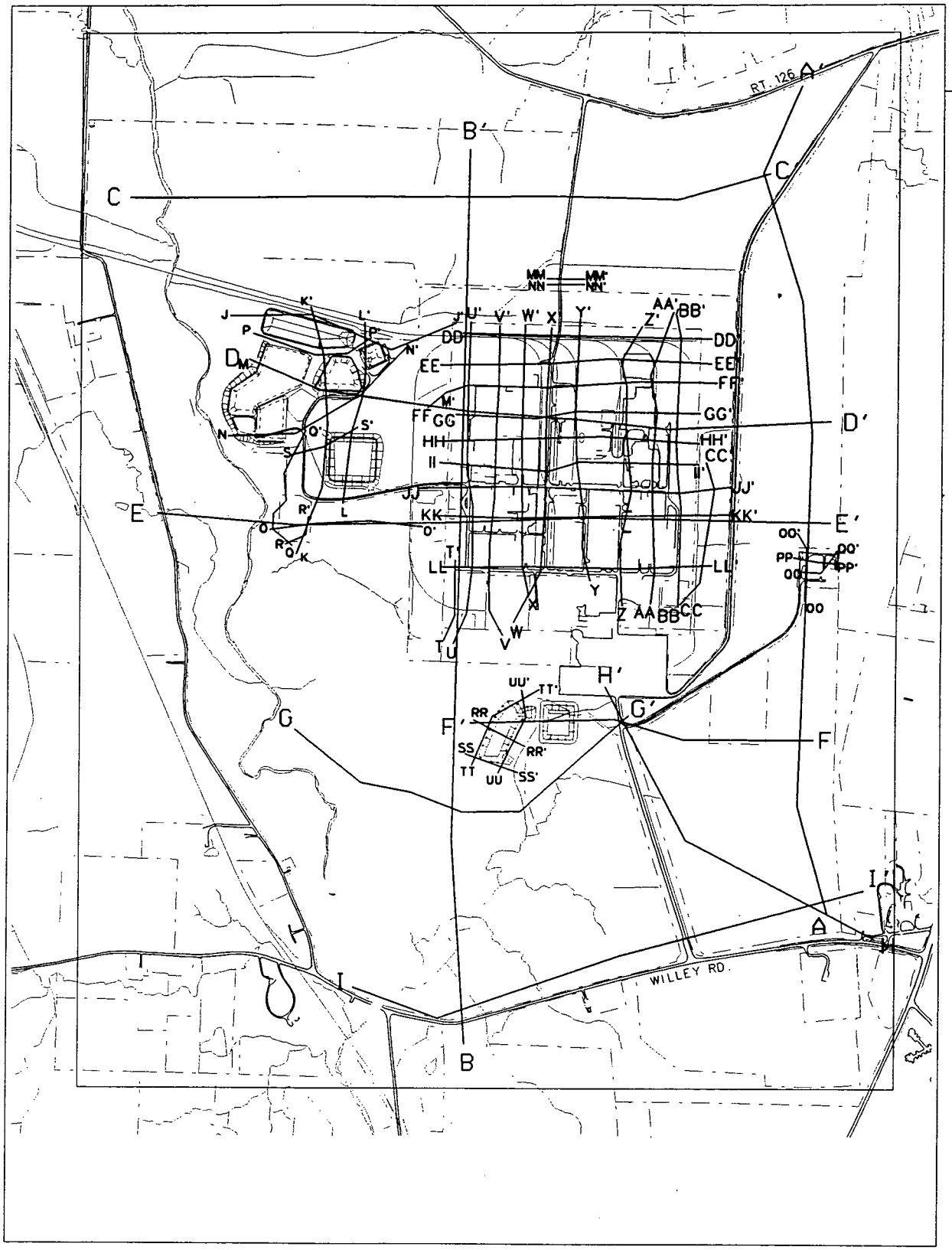
DRAFT

SCALE

1250 625 0 1250 FEET

88A811.DGN OU5 RI R1

FIGURE 3-26.
GLACIAL OVERBURDEN THINNED BY CONSTRUCTION OR REMOVED BY EROSION



LEGEND:

SCALE

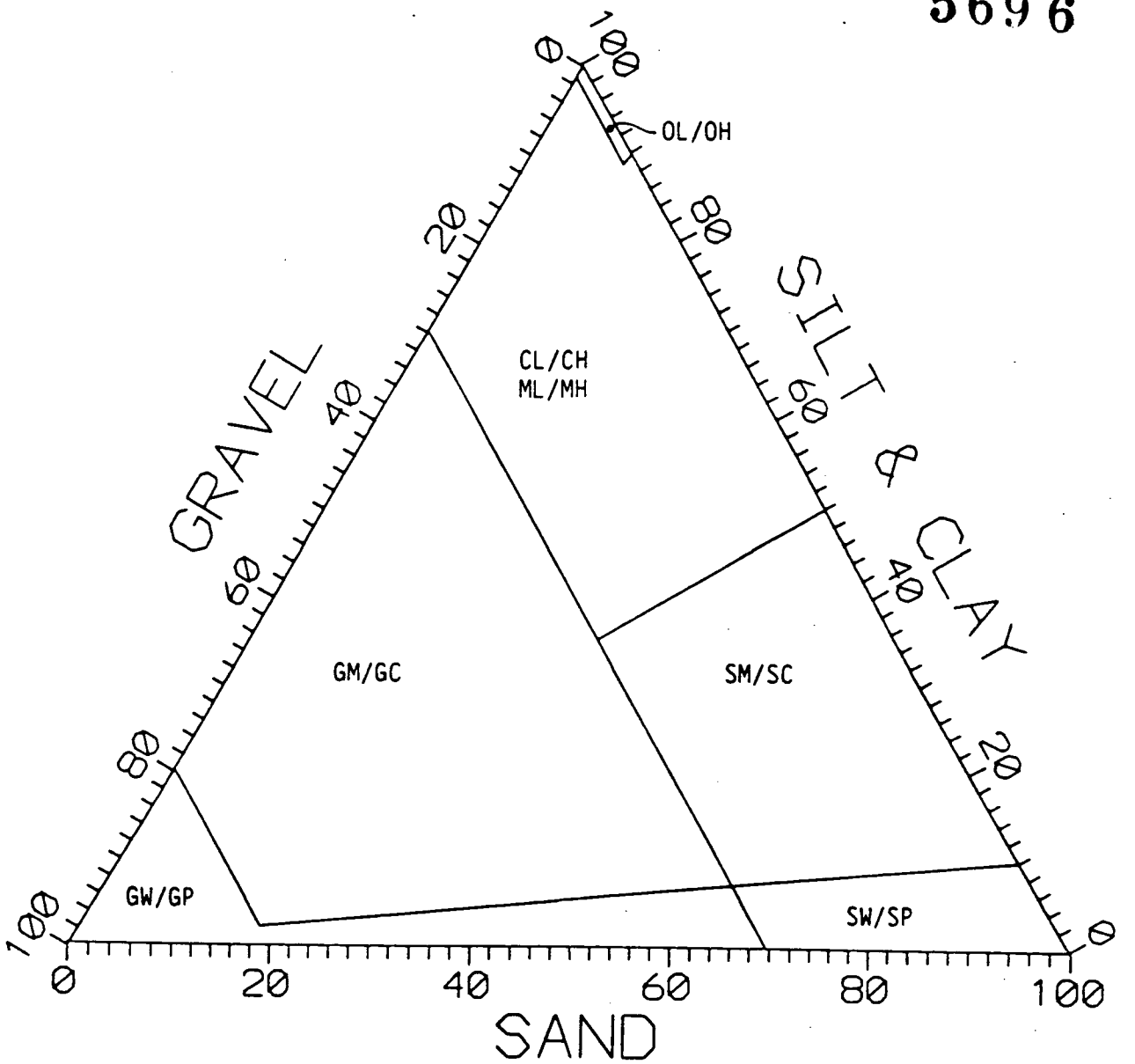
1300 650 0 1300FEET

DRAFT

@FILED: /USR/LARRY/TABOR/ASICUTS1.DGN

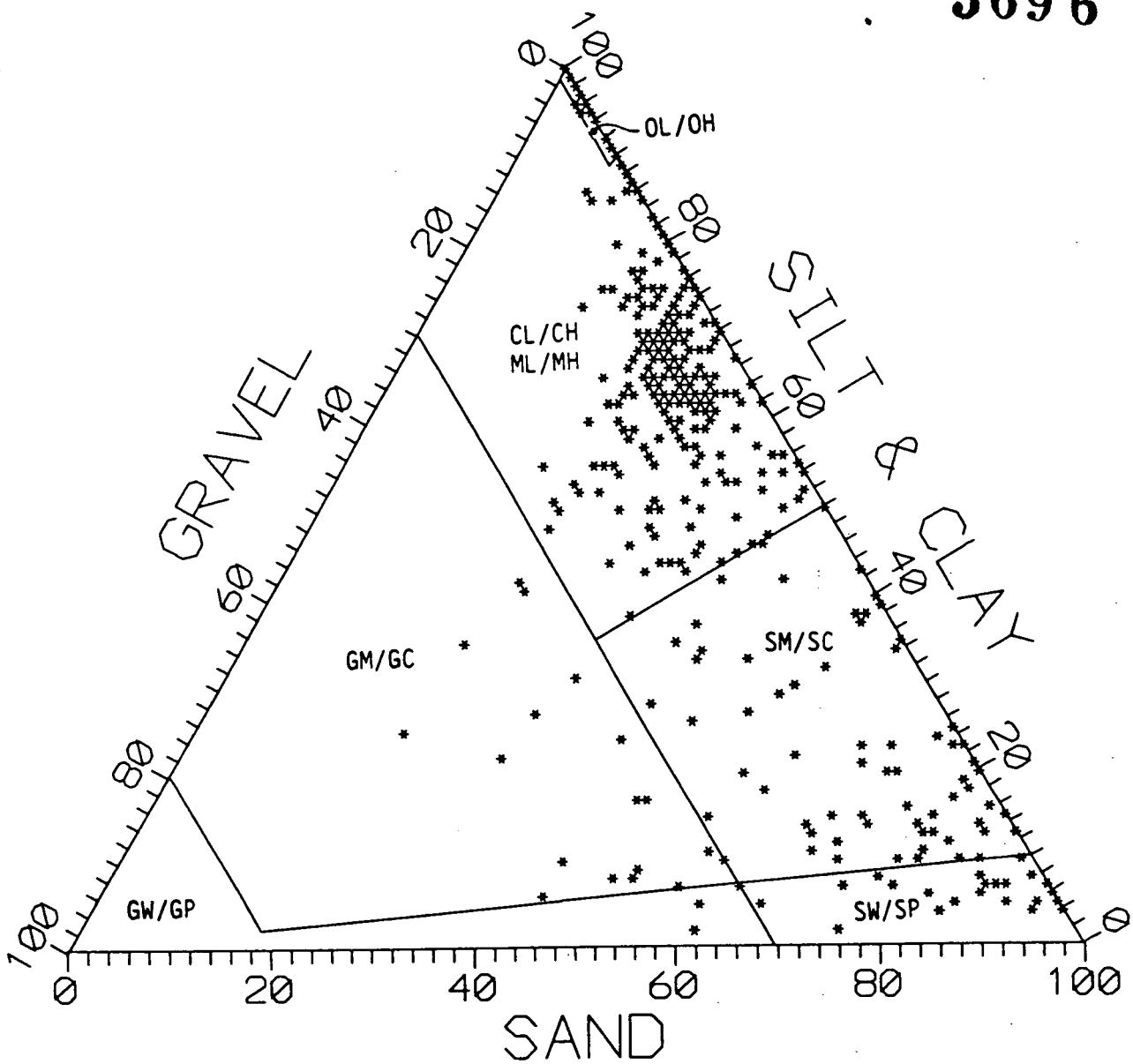
FIGURE 3-27. CONCEPTUAL CROSS-SECTION LINE LOCATIONS

5696



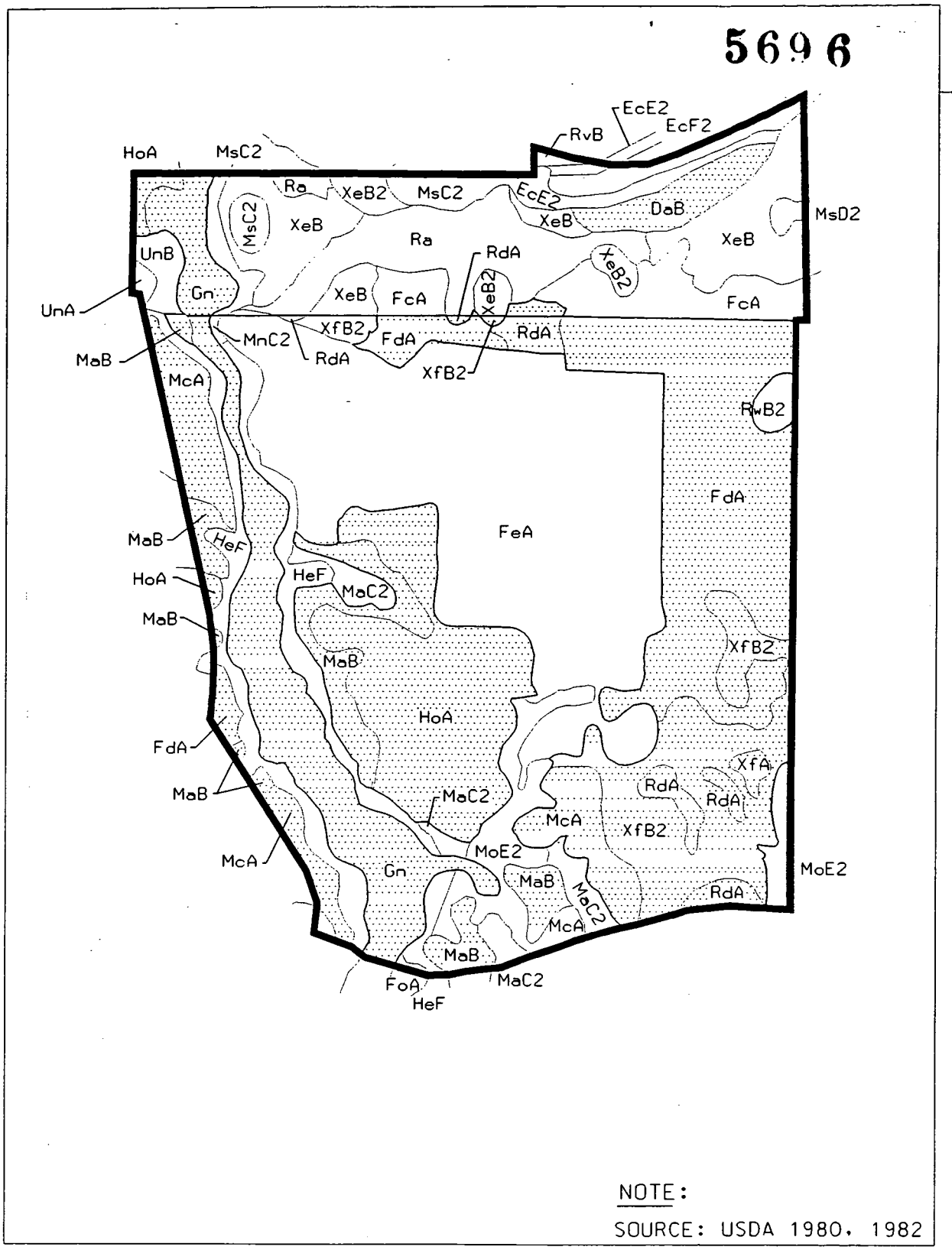
DRAFT

FIGURE 3-28. TEXTURAL TRIANGLE



DRAFT

FIGURE 3-29. SIEVE ANALYSIS SUMMARY



NOTE:

SOURCE: USDA 1980, 1982

LEGEND:

PRIME AGRICULTURAL LAND

FEMP BOUNDARY

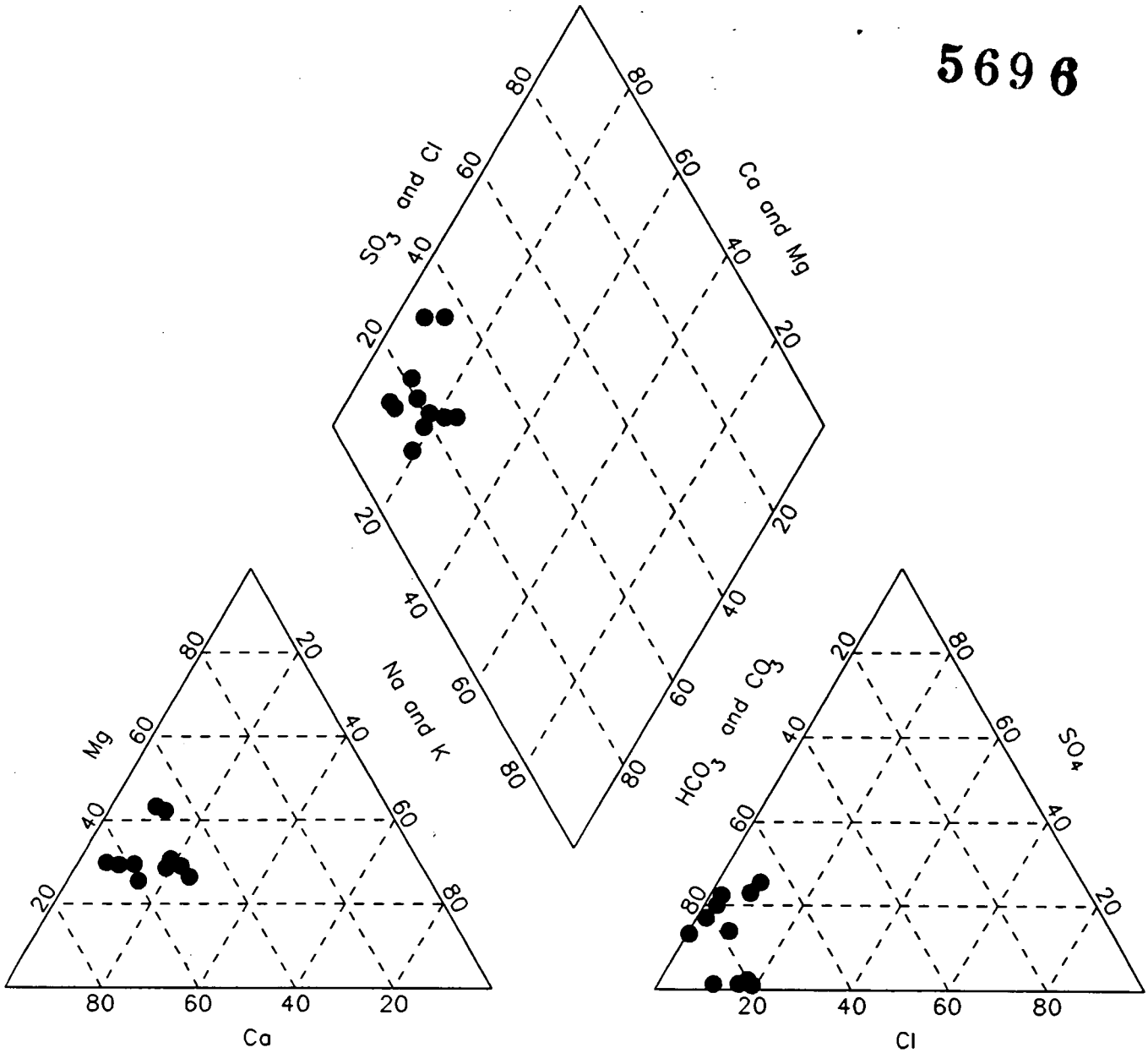
SCALE

1800 900 0 1800 FEET

DRAFT

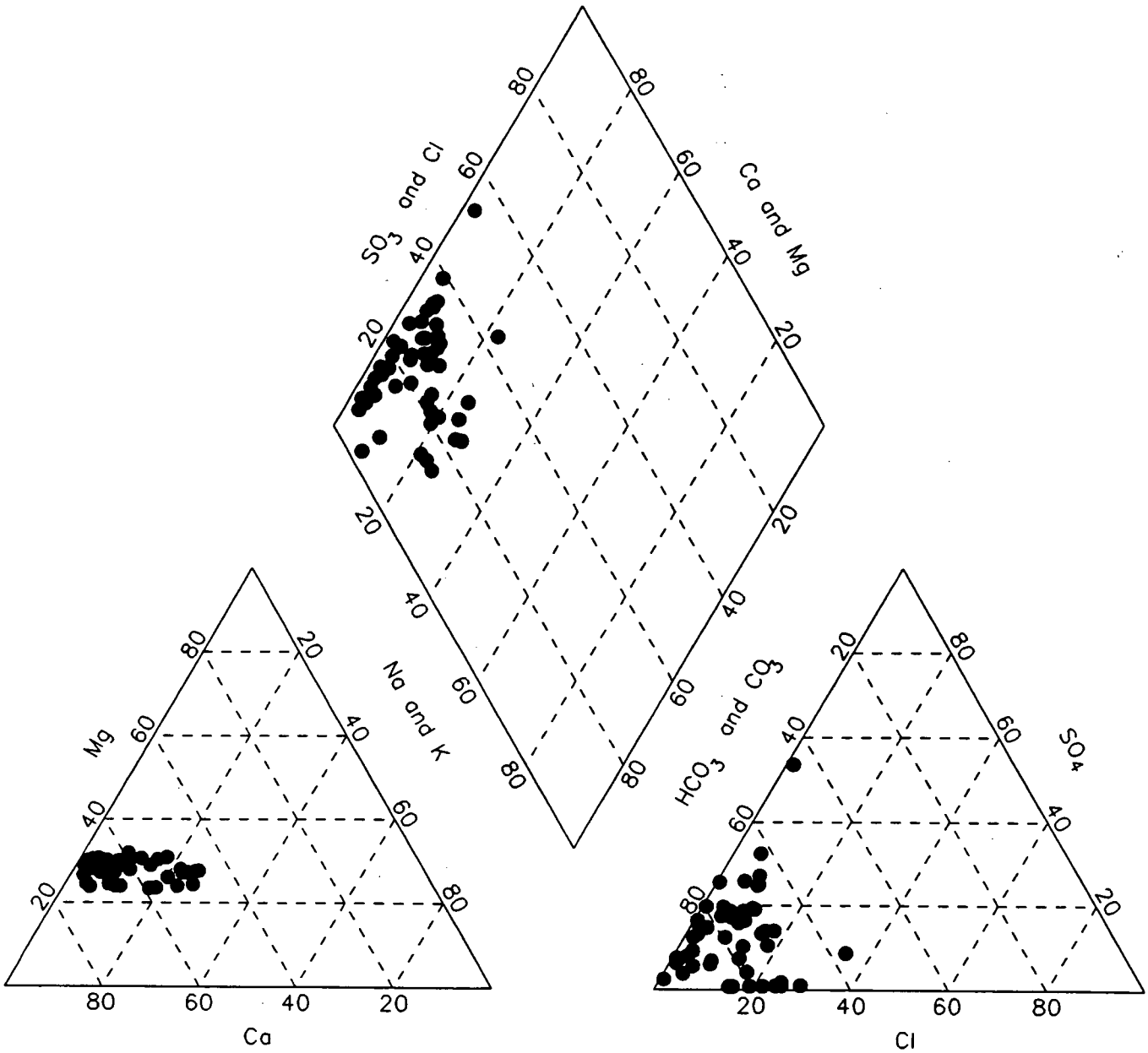
/USR/ERMA3/FMPC/IDX/AB9.DGN FER OU5 RIDATA 6-11-94

FIGURE 3-30. FEMP SOIL MAP



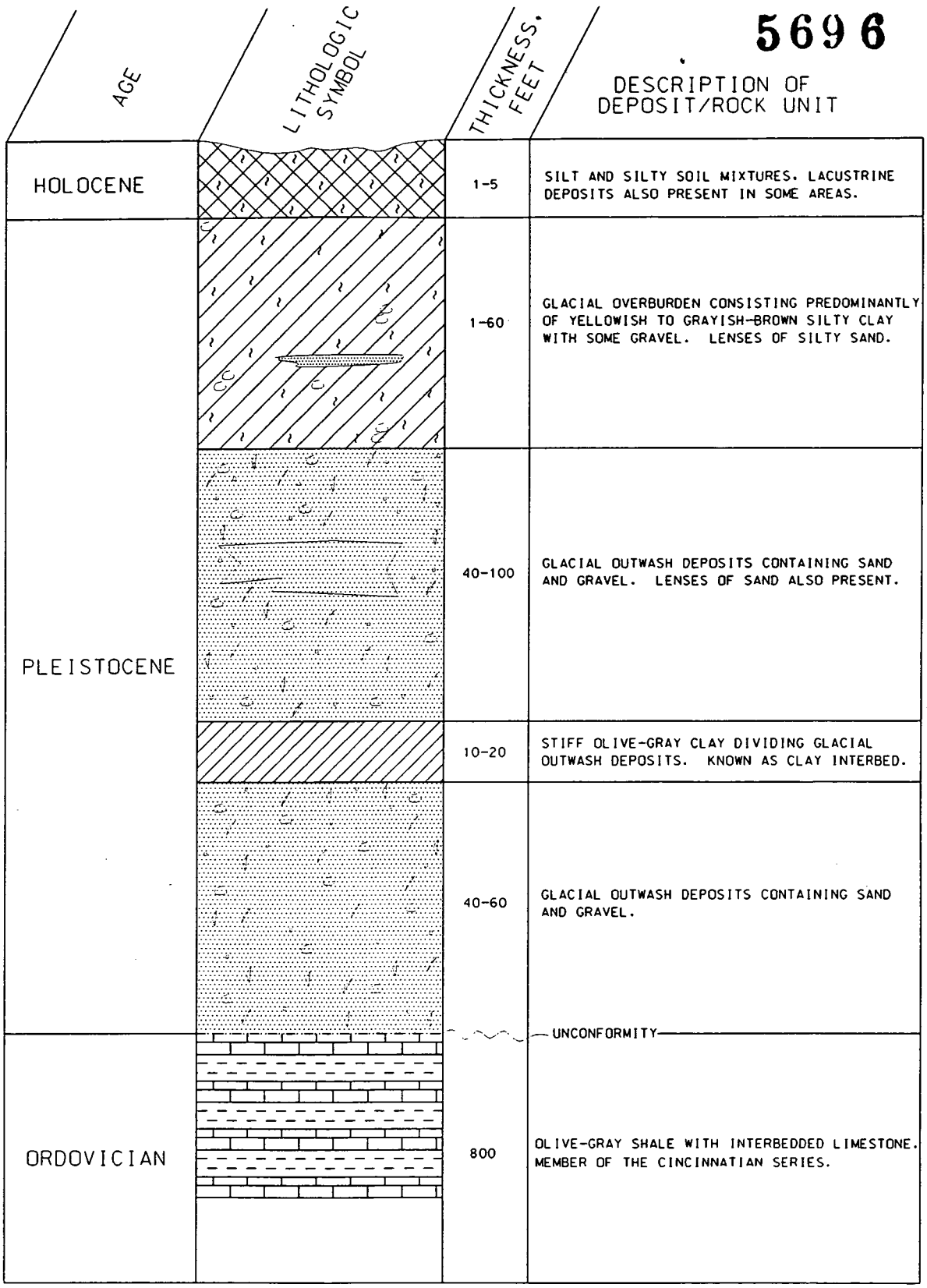
DRAFT

FIGURE 3-31. TRILINEAR DIAGRAM OF GENERAL WATER CHEMISTRY IN THE GLACIAL OVERBURDEN BACKGROUND WELLS



DRAFT

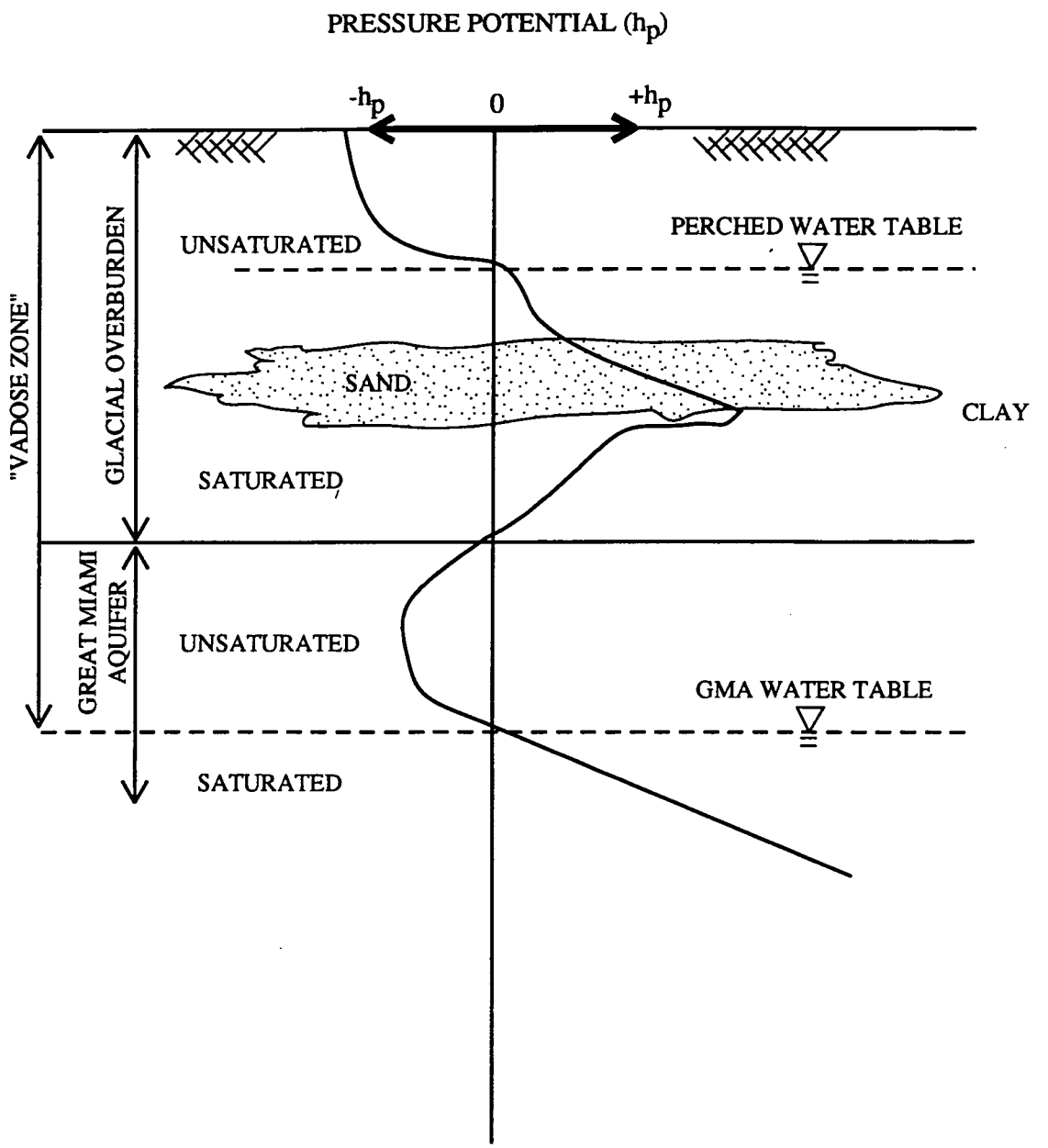
FIGURE 3-32. TRILINEAR DIAGRAM OF GENERAL WATER CHEMISTRY IN THE GREAT MIAMI AQUIFER BACKGROUND WELLS



DRAFT

A137 (OU5)

FIGURE 3-33. GENERALIZED STRATIGRAPHIC COLUMN FOR THE FEMP



"ILLUS\OU-5\PO-116\PRESSURE HEAD PROF.EPS

DRAFT

NOT TO SCALE

FIGURE 3-34. GENERAL PRESSURE HEAD PROFILE

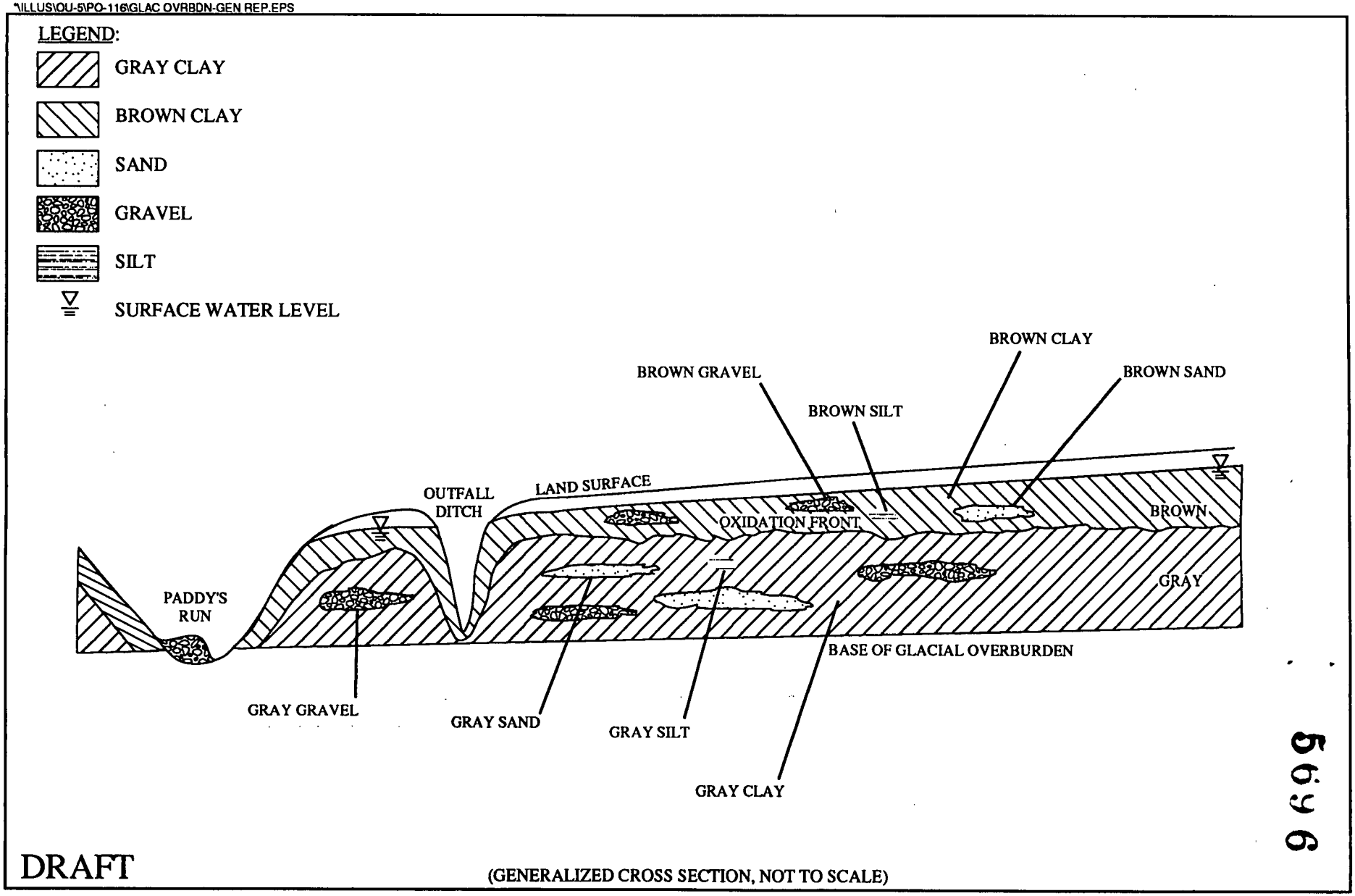
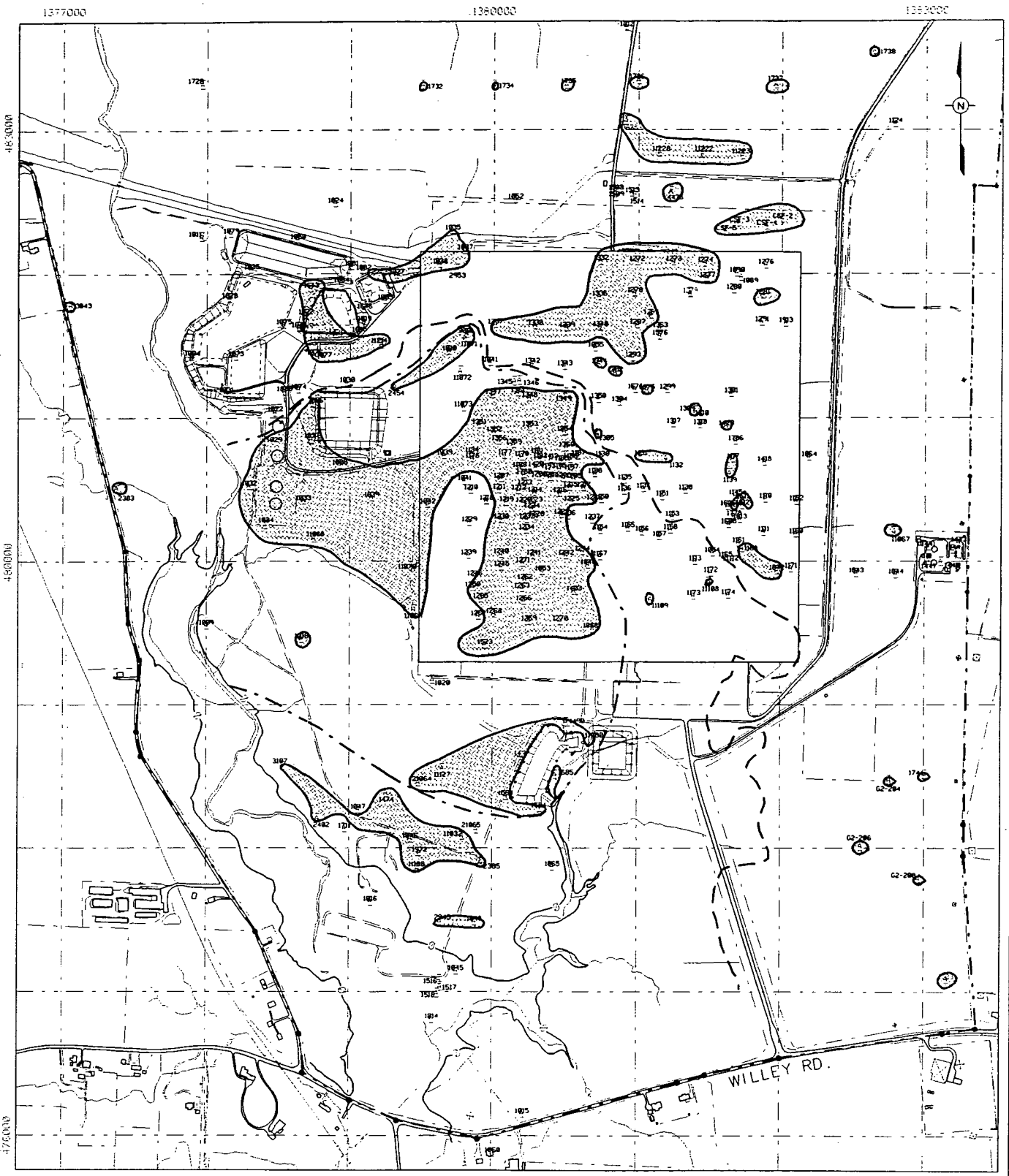


FIGURE 3-35. GENERAL REPRESENTATION OF THE GLACIAL OVERBURDEN

FILE NAME /well/gis/well1x.dgn 8x11 cru5 5-25-94 GES STATE PLANAR COORDINATE SYSTEM 1927



SCALE

0 750 1500 FEET

NOTE:

LOCATIONS CSF SERIES ARE APPROXIMATE.

LEGEND:

- FEMP BOUNDARY
- COARSE GRAINED SEDIMENT
- UNDIFFERENTIATED GLACIAL OUTWASH
- LACUSTRINE UNIT
- NO GLACIAL OVERBURDEN
- 1047 WELL/BORING LOCATION

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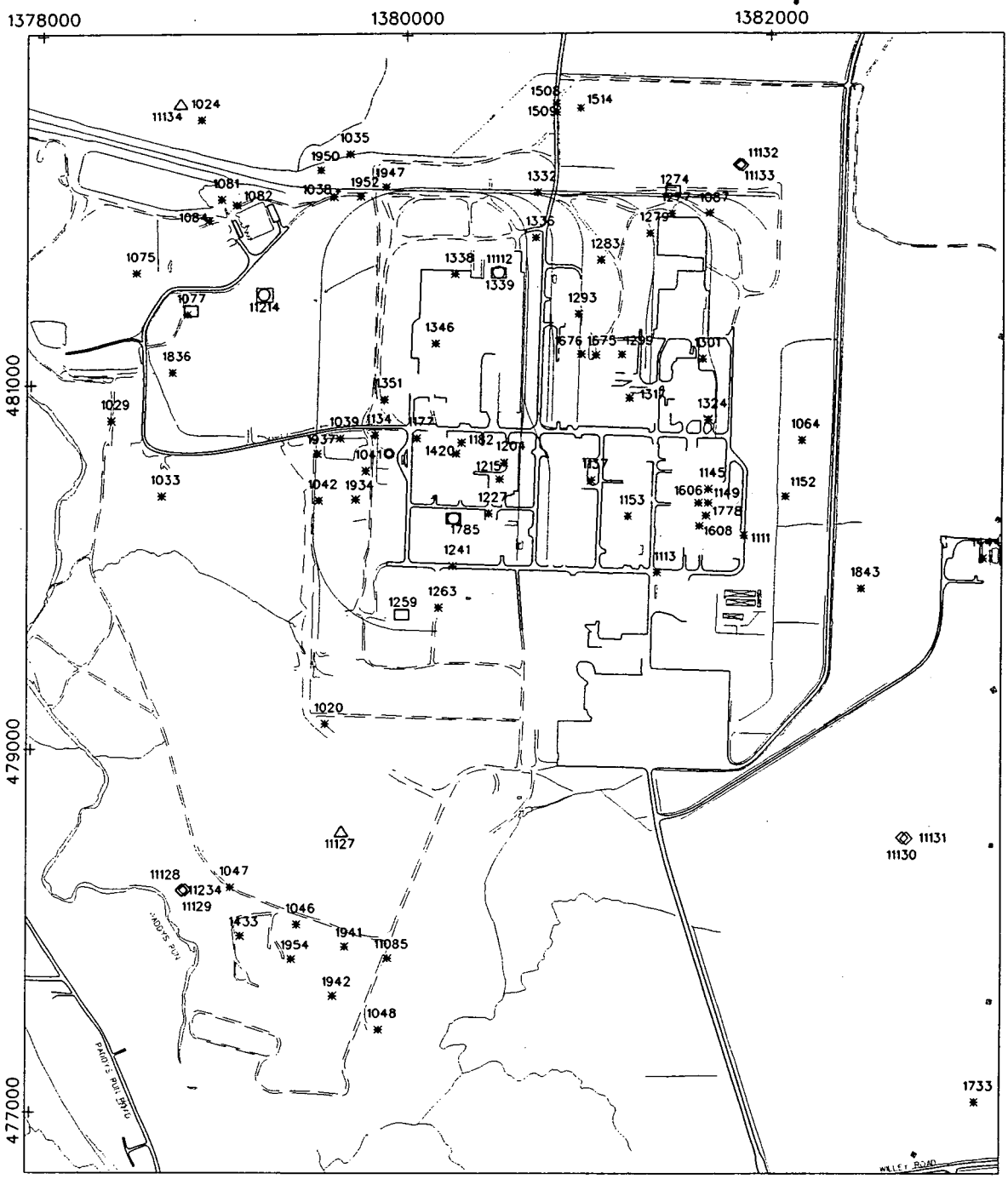
FIGURE 3-36. DISTRIBUTION OF COARSE GRAINED SEDIMENT BODIES



STATE PLANAR
COORDINATE SYSTEM 1927

/USR/ERMAI/CRU2/DGN/C5TSTLK.DGN OU5 RI

LEGEND:

- ✱ SLUG TEST LOCATIONS
- ◇ LYSIMETER LOCATIONS
- △ PACKER TEST LOCATIONS
- ▭ YIELD TEST LOCATIONS
- ○ PUMPING TEST LOCATIONS

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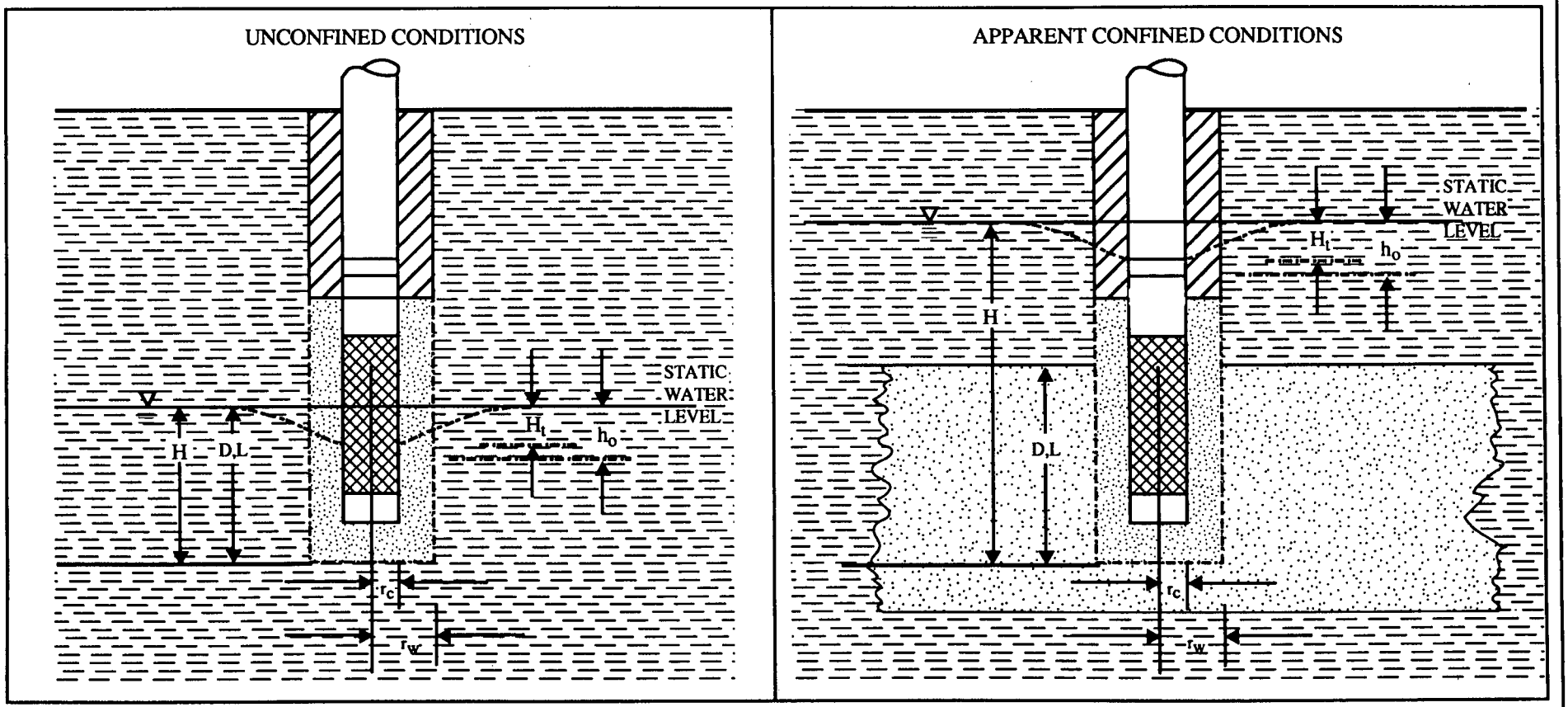
SCALE

900 450 0 900 FEET

FIGURE 3-37. HYDRAULIC TESTING LOCATIONS

^\ILLUSOU-5\PO-116\AQUIFERS.EPS



KEY:

- BENTONITE GROUT
- SCREEN
- AQUIFER
- SAND PACK
- AQUITARD

LEGEND:

H_t = DRAWDOWN AFTER TIME (t)
h_o = INITIAL DRAWDOWN
r_c = CASING RADIUS
r_w = DISTANCE TO UNDISTURBED MATERIAL FROM WELL CENTER
L = EFFECTIVE SCREEN LENGTH
D = EFFECTIVE SATURATED THICKNESS
H = HEIGHT OF STATIC WATER IN WELL

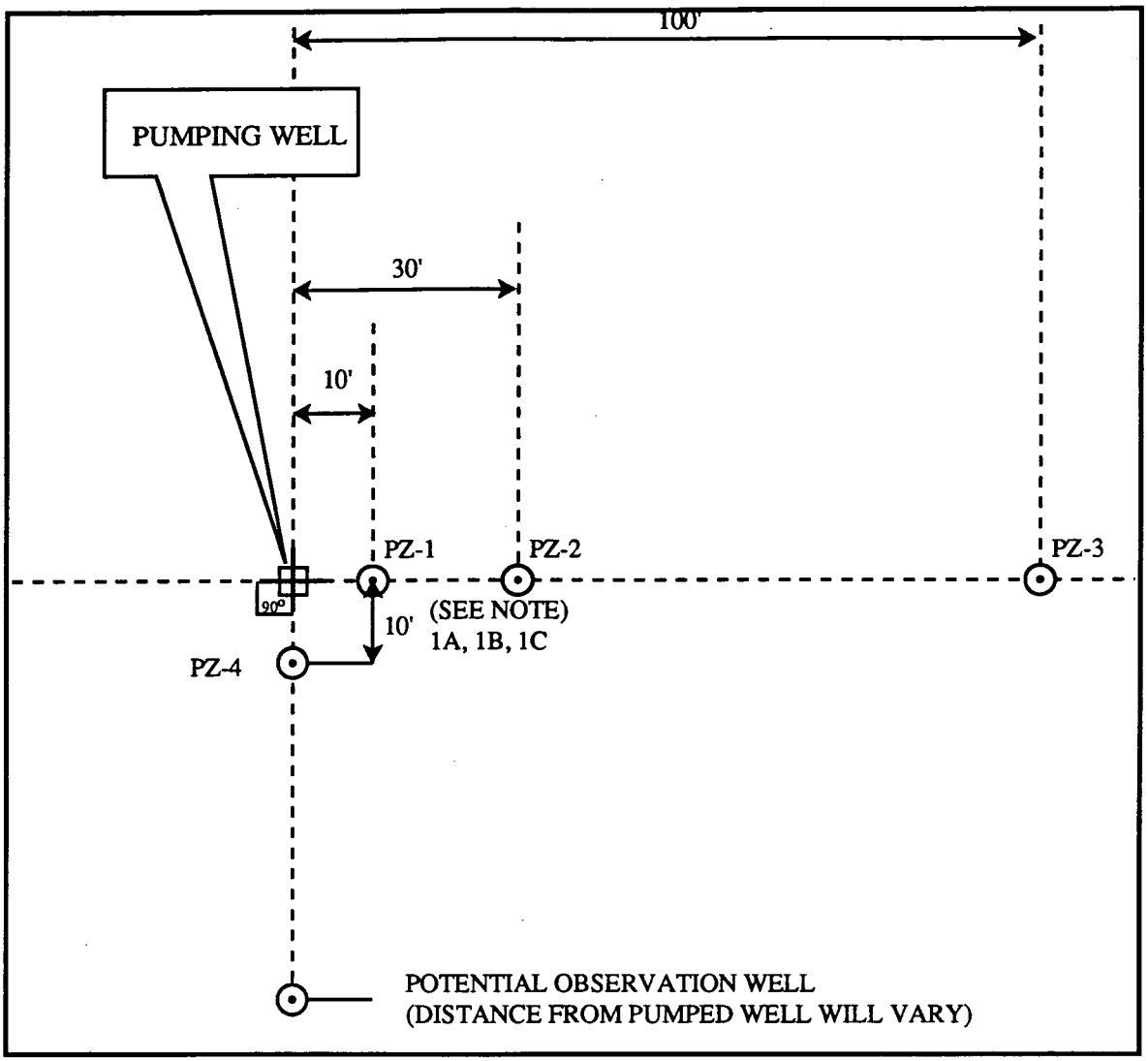
000489

DRAFT

NOT TO SCALE

5696

FIGURE 3-38. APPARENT UNCONFINED OR UNCONFINED CONDITIONS



OBSERVATION WELL

PUMPED WELL

BEARING WELL

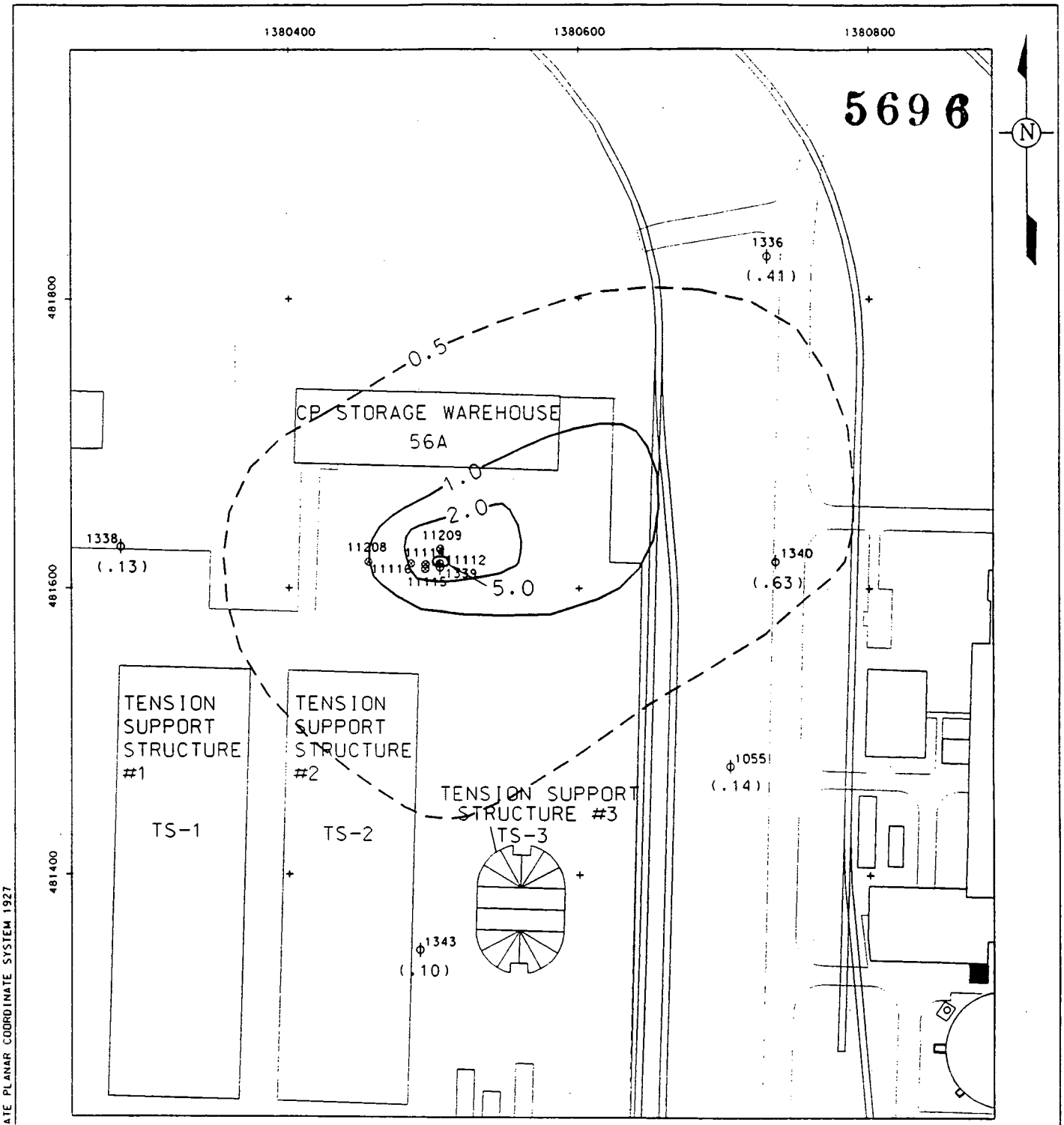
NOTE: PZ-1 CONSISTS OF 1A, 1B, 1C

DRAFT

NOT TO SCALE

ILLUS\OU-5\PO-116\PUMP TEST CONFIG.EPS

FIGURE 3-39. PUMPING TEST CONFIGURATIONS



LEGEND:

SCALE 0 25 50 100 FEET

1338 (.13) DRAWDOWN (IN FEET) AT WELL 1338

CONTOUR

MONITORING WELL

PIEZOMETER

PUMPING WELL

NOTES:

1. CUMULATIVE DRAWDOWN AFTER PUMPING WELL 11112 FOR 5875 MINUTES AT 1.75 GPM.
2. SOLID LINE INDICATES CONTOUR WITH HIGH CONFIDENCE
3. DRAWN LINE INDICATES CONTOUR WITH LOWER CONFIDENCE

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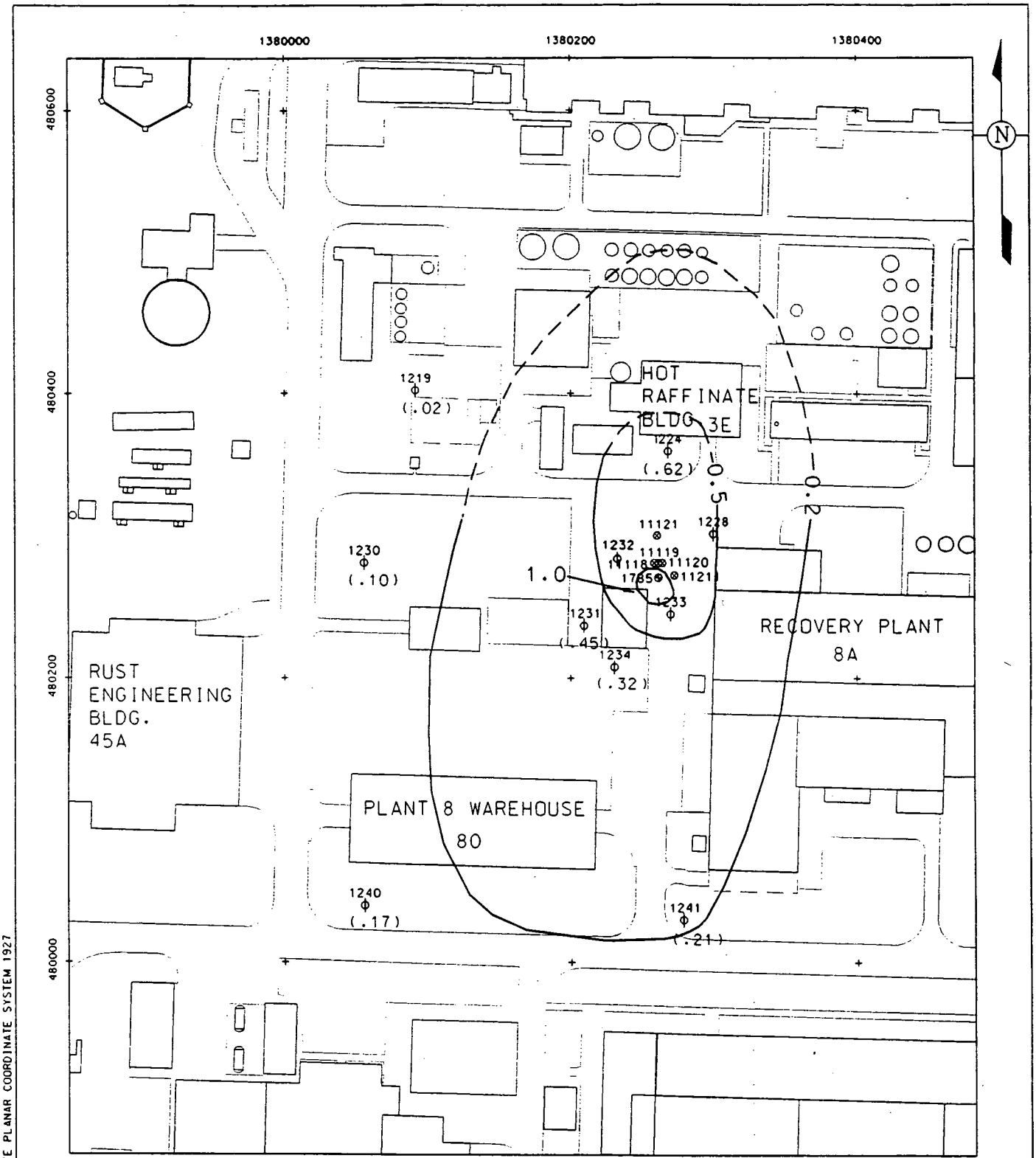
PD116/SKX02909.DGN OU5 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 3-40. DRAWDOWN PUMPING TEST IN PLANT 1 PAD AREA



LEGEND:

SCALE 0 25 50 100 FEET

1240 (.17) DRAWDOWN (IN FEET) AT WELL 1240

CONTOUR

MONITORING WELL

PIEZOMETER

PUMPING WELL

NOTES:

1. CUMULATIVE DRAWDOWN AFTER PUMPING WELL 1785 FOR 3685 MINUTES AT 1.25 GPM.
2. SOLID LINE INDICATES CONTOUR WITH HIGH CONFIDENCE
3. DASHED LINE INDICATES CONTOUR WITH LOWER CONFIDENCE

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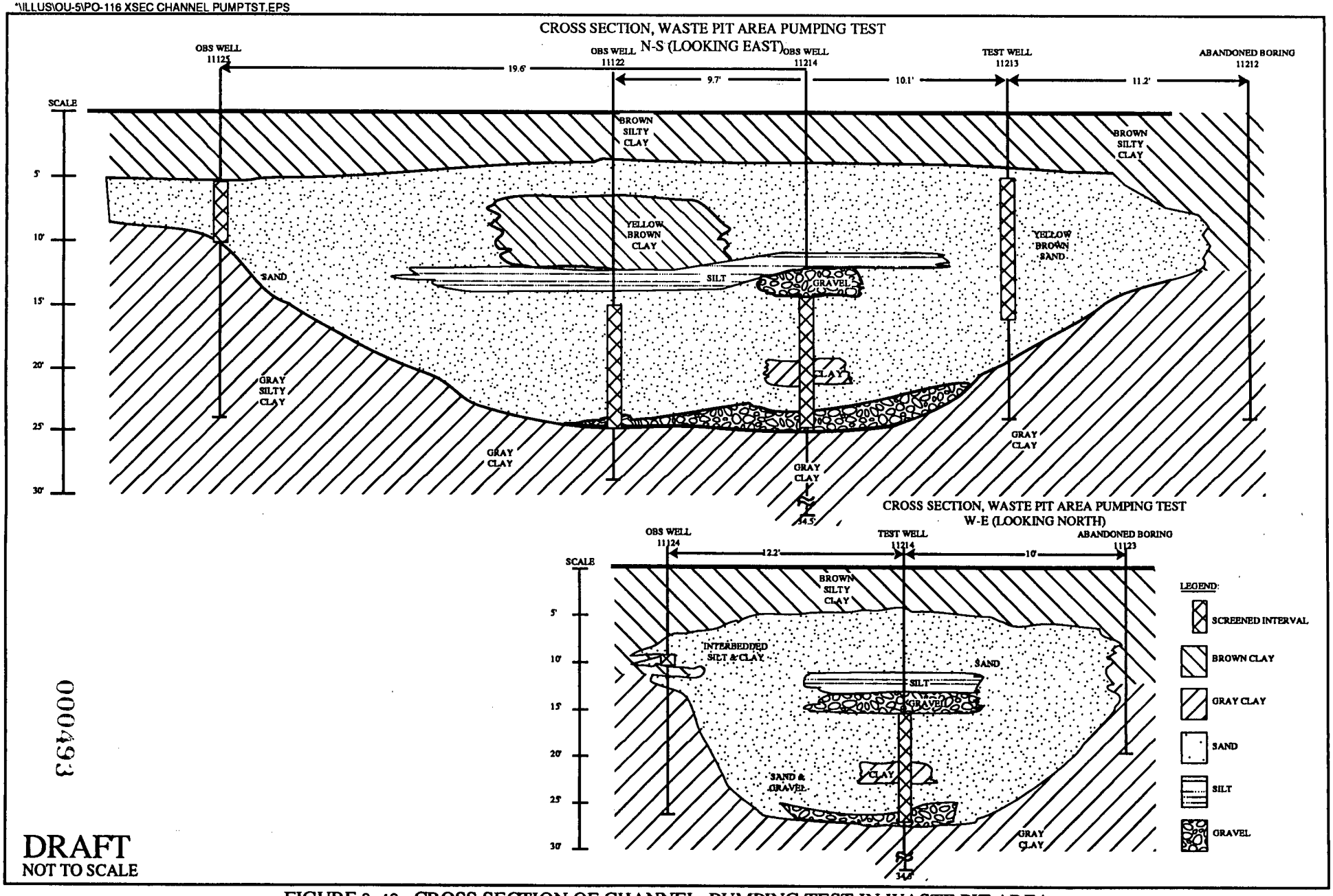
STATE PLANAR COORDINATE SYSTEM 1927

P0116/SKX02908.DGN 0U5

FIGURE 3-41. DRAWDOWN PUMPING TEST IN PLANT 8 AREA

*\ILLUS\OU-5\PO-116 XSEC CHANNEL PUMPTST.EPS

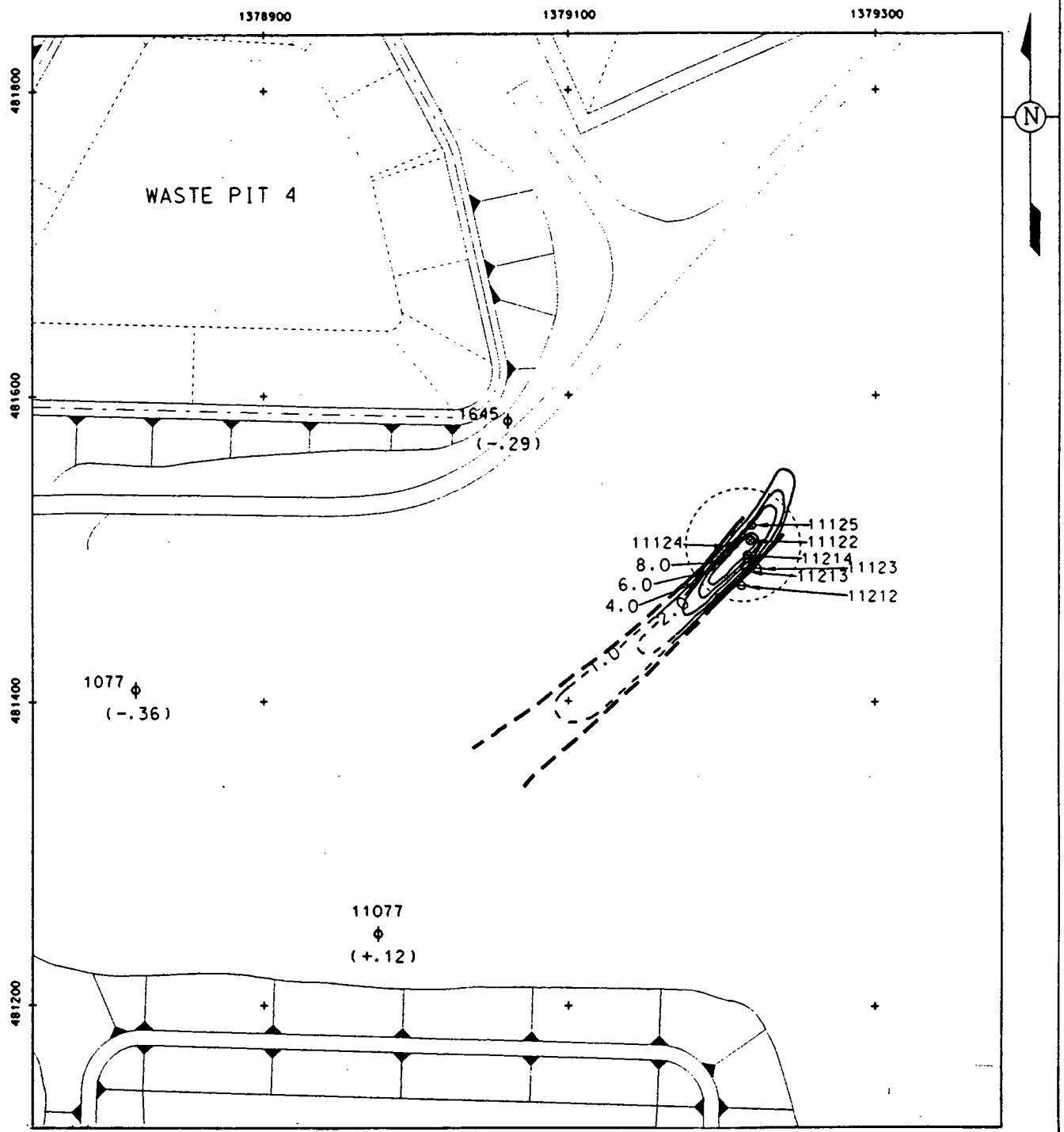


000493

DRAFT
NOT TO SCALE

FIGURE 3-42. CROSS SECTION OF CHANNEL, PUMPING TEST IN WASTE PIT AREA

5696



LEGEND:

1077 (-.36) DRAWDOWN (IN FEET) AT WELL 1077

BURIED CHANNEL

CONTOUR

MONITORING WELL

PIEZOMETER

PUMPING WELL

ABANDONED BORING

SCALE 0 25 50 100 FEET

NOTES:

1. CUMULATIVE DRAWDOWN AFTER PUMPING WELL 11214 FOR 8740 MINUTES AT 2.0 GPM.
2. SOLID LINE INDICATES HIGH CONFIDENCE
3. DASHED LINE INDICATES LOWER CONFIDENCE

STATE PLANAR COORDINATE SYSTEM 1927

SKX02907.DGN 005

DRAFT

FIGURE 3-43. DRAWDOWN PUMPING TEST IN WASTE PIT AREA

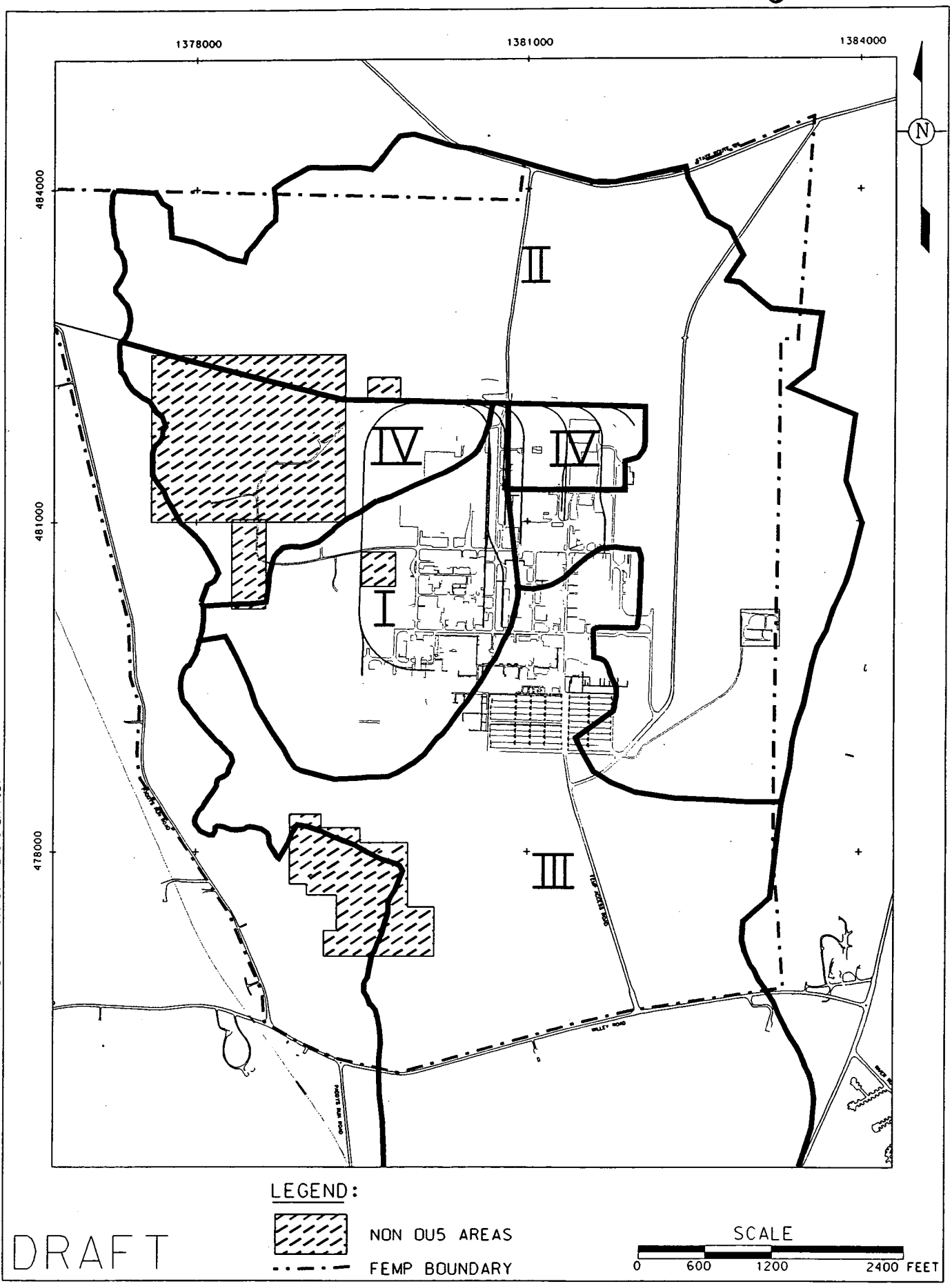
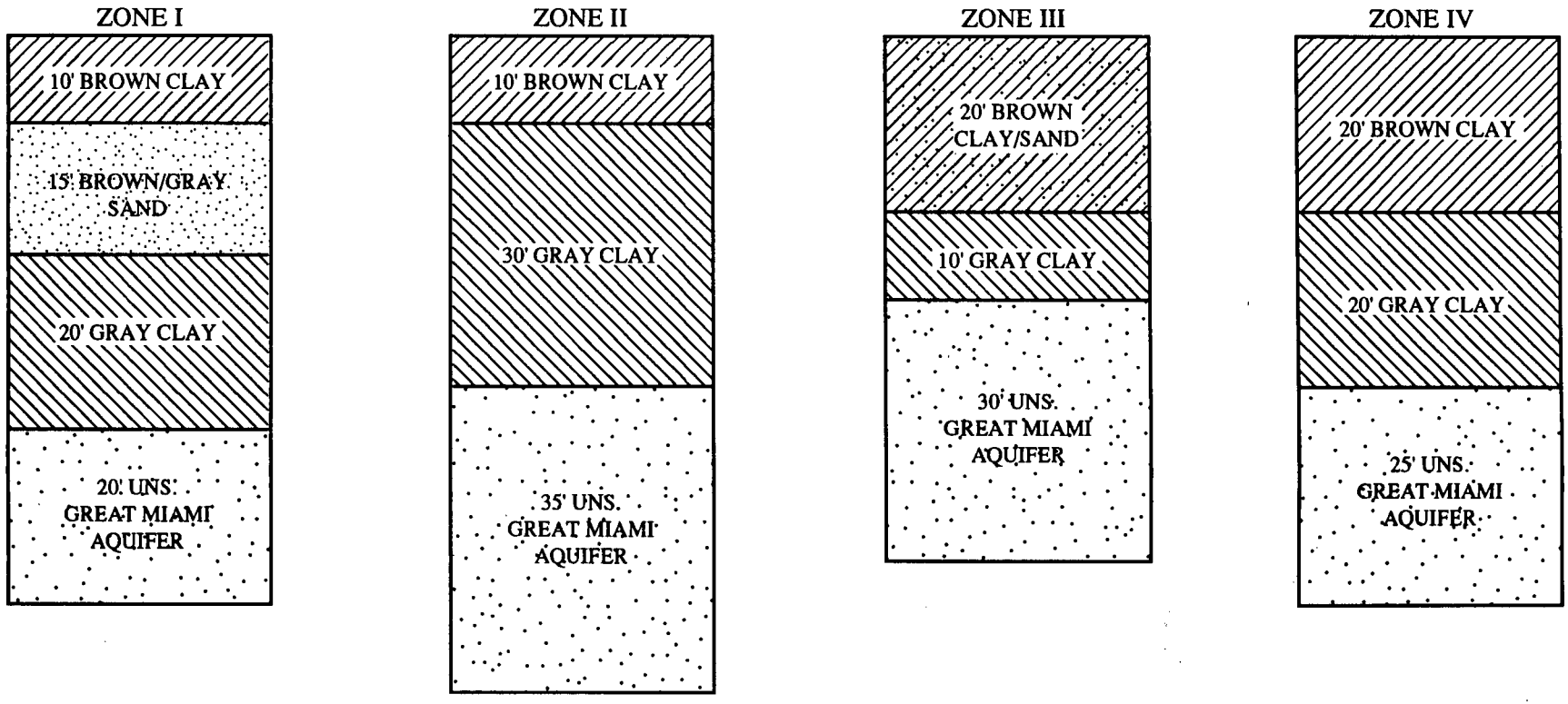


FIGURE 3-44. ZONATION OF GLACIAL OVERBURDEN BASED ON THICKNESS OF GRAY CLAY

*\ILLUS\OU-5\PO-116\GEN XSEC GLAC OBRDN.EPS



LEGEND:

FORMATION -	K_h (cm/s)	NOTE: DATA SOURCE -
BROWN CLAY	3.59E -05	GEOMETRIC MEAN OF K_h FROM SLUG TESTS
GRAY CLAY	1.87E -06	GEOMETRIC MEAN OF K_h FROM SLUG TESTS
BROWN/GRAY SAND	1.10E -03	HARMONIC MEAN OF K_h FROM SLUG TESTS
BROWN CLAY/SAND	7.04E -05	HARMONIC MEAN OF K_h FROM SLUG TESTS

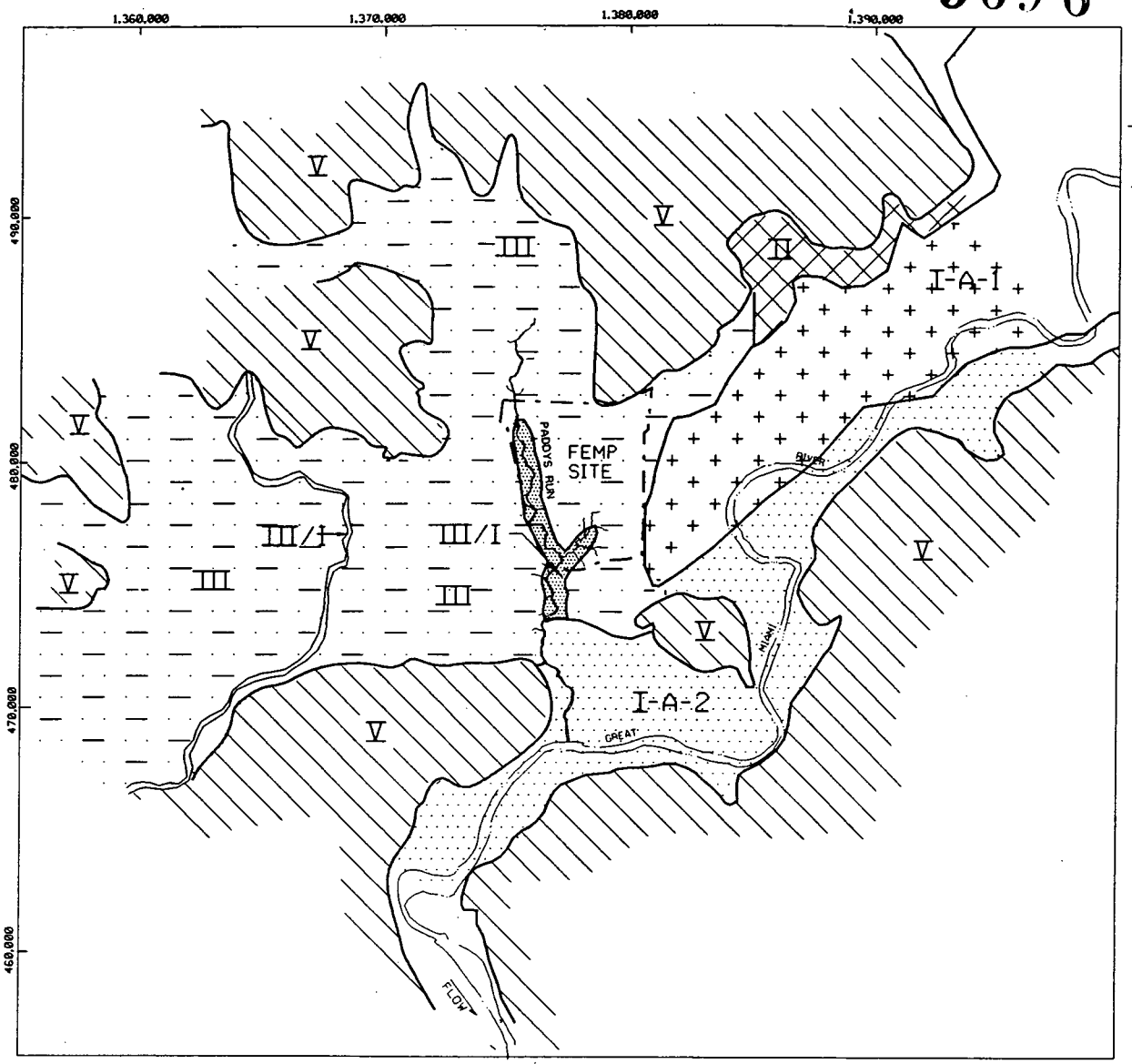
DRAFT

NOT TO SCALE

FIGURE 3-45. GENERALIZED CROSS SECTIONS THROUGH GLACIAL OVERBURDEN ZONES

5696

000496



LEGEND:

I-A-1 GREAT MIAMI AQUIFER. 150-200 FEET OR MORE THICK; NO AREALLY EXTENSIVE CLAYLAYERS PRESENT: RECHARGE BY INDUCED STREAM INFILTRATION AVAILABLE.

I-A-2 GREAT MIAMI AQUIFER. LESS THAN 150 FEET THICK. NO AREALLY EXTENSIVE CLAY LAYERS PRESENT: RECHARGE BY STREAM INFILTRATION AVAILABLE.

II GREAT MIAMI AQUIFER. LESS THAN 150 FEET THICK. NO AREALLY EXTENSIVE CLAY LAYERS PRESENT: RECHARGE BY STREAM INFILTRATION NOT AVAILABLE.

III GREAT MIAMI AQUIFER. OVERLAIN BY CLAY. STREAM RECHARGE GENERALLY NOT AVAILABLE.

V SHALE BEDROCK OVERLAIN BY 50 FEET OR LESS OF RELATIVELY IMPERMEABLE GLACIAL OVERBURDEN.

III/I STREAM VALLEYS INCISED THROUGH GLACIAL OVERBURDEN TO SAND AND GRAVEL AQUIFER.

— · — · FEMP BOUNDARY

SCALE

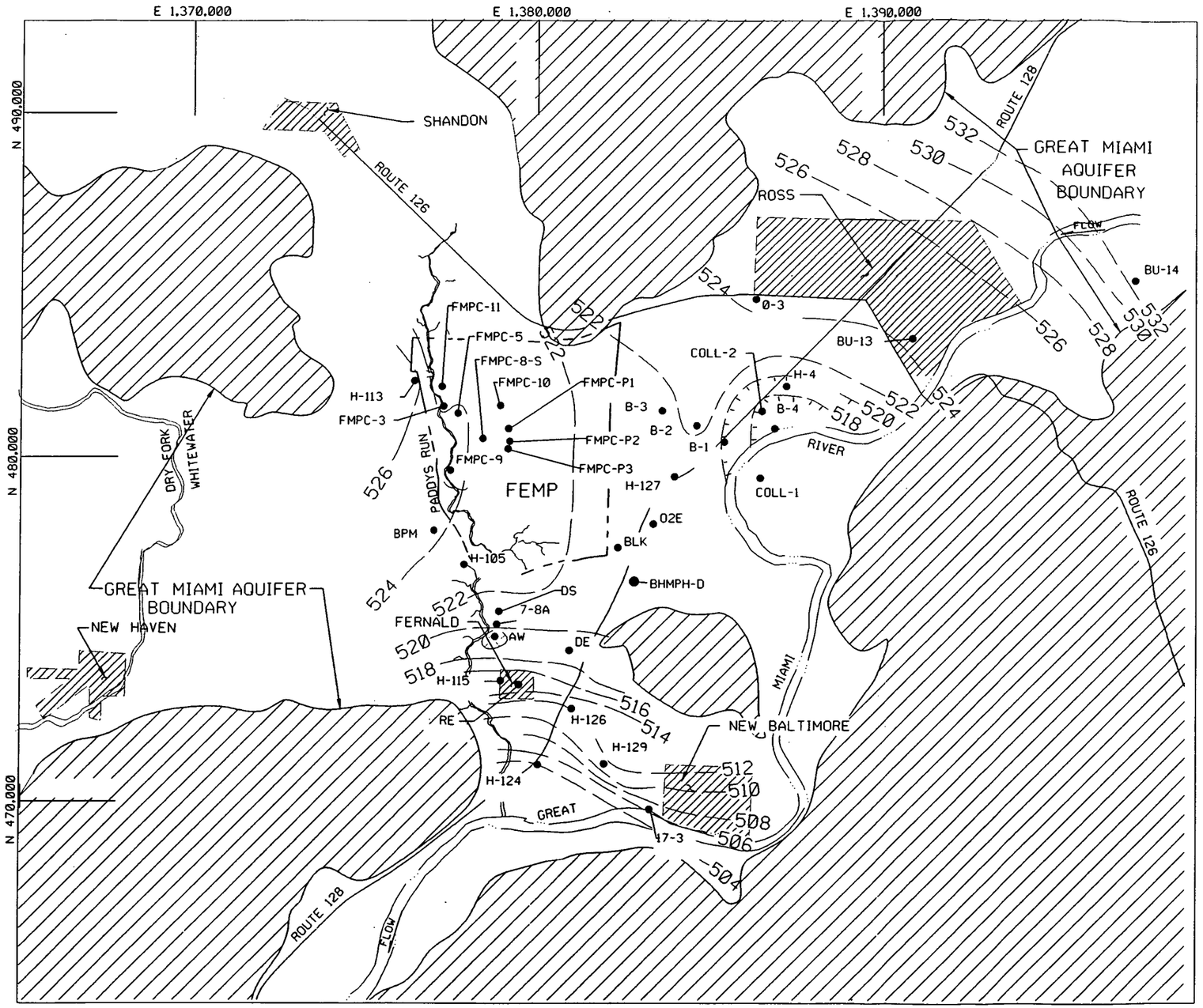
1 ½ 0 1 MILE

STATE PLANAR COORDINATE SYSTEM 1927

A111.DGN OU5 RI

DRAFT

FIGURE 3-46. HYDROGEOLOGIC ENVIRONMENTS OF THE GREAT MIAMI AQUIFER



LEGEND:

- BU-14 — WELL NAME AND LOCATION
- (524.2) — MEASURED GROUNDWATER LEVEL ELEVATION (FEET MSL)
- —526 — GROUNDWATER CONTOUR (FEET MSL)
- — — — INDICATES AREA OF UNCERTAINTY
- - - - FEMP PROPERTY BOUNDARY
- BEDROCK OUTSIDE GREAT MIAMI AQUIFER
- MUNICIPAL AREA

NOTES:

THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUNDWATER CONTOUR MAP ARE ALL COMPLETED IN THE SAND AND GRAVEL AQUIFER. HOWEVER, COMPLETION DEPTHS FOR SOME WELLS ARE UNKNOWN. IN THE VICINITY OF THE COLLECTOR WELLS, GROUNDWATER ELEVATIONS WOULD DEPEND ON COMPLETION DEPTH. DEEPER WELLS IN THE AQUIFER WOULD INDICATE LOWER WATER LEVEL ELEVATIONS BECAUSE OF VERTICAL GRADIENTS CREATED BY PUMPING AT DEPTH. THEREFORE, WATER TABLE ELEVATION CONTOURS SHOWN IN THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.

GROUNDWATER ELEVATIONS AT PUMPING WELLS FMPC-P3, COLL-1, AND COLL-2 WERE NOT USED FOR CONSTRUCTION OF THIS MAP.

BASED ON WATER LEVEL MEASUREMENTS FROM MIAMI CONSERVANCY DISTRICT HYDROLOGIC DATA FOR THE HAMILTON - NEW BALTIMORE AREA, 1982 AND U.S.G.S OPEN FILE REPORT 85-099, " DEPTH TO WATER MEASUREMENTS." GROUNDWATER ELEVATION DATA WERE COMPUTED USING IT OR MIAMI CONSERVANCY DISTRICT WELL ELEVATIONS FROM THE U.S.G.S. DATA.

000498

SCALE
3500 1750 0 3500 FEET

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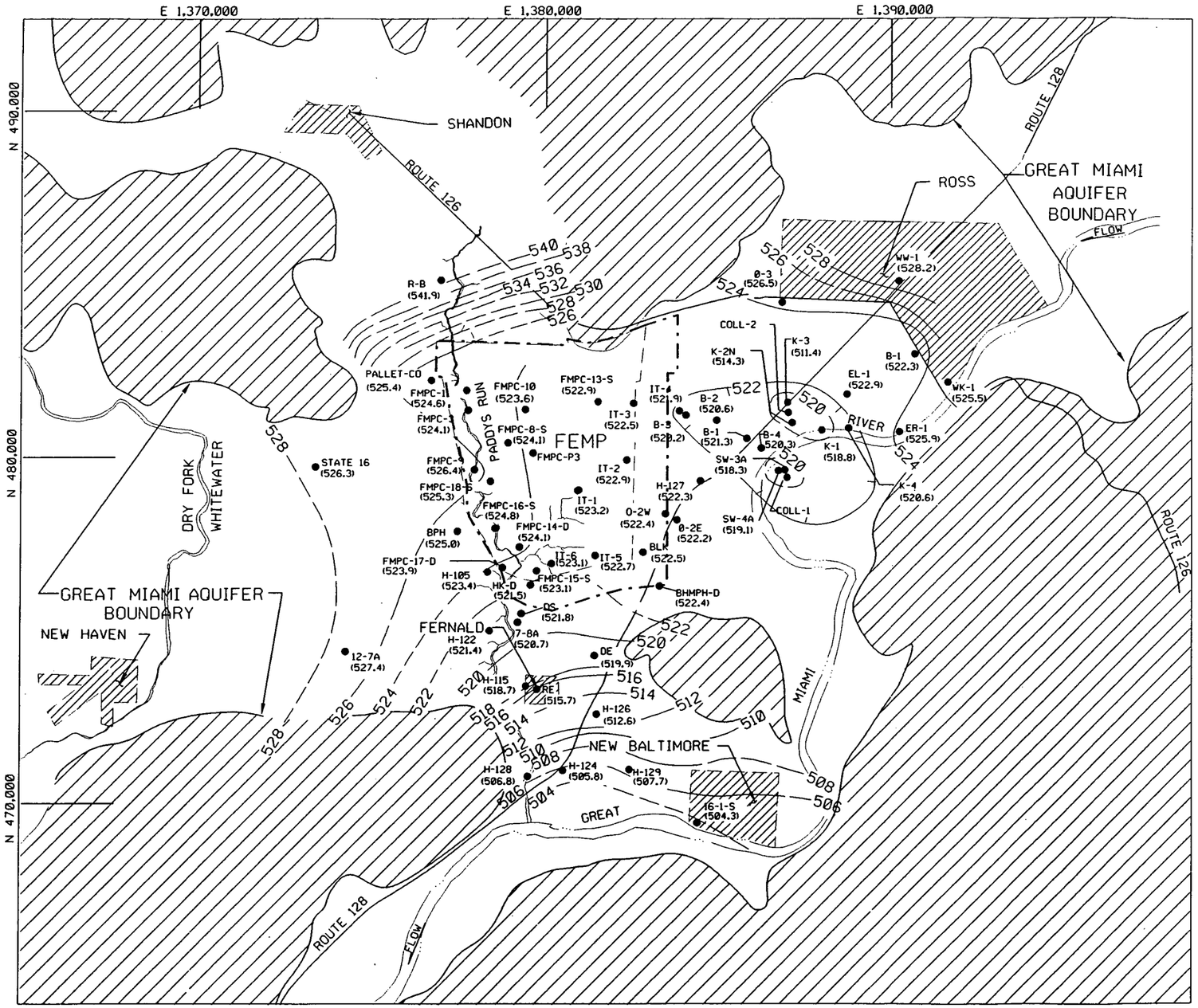
STATE PLANAR COORDINATE SYSTEM 1927

B109.DGN OU5 RI

FIGURE 3-47.
REGIONAL GROUNDWATER ELEVATIONS
AUGUST 1982



LEGEND:

- •H-122 WELL NAME AND LOCATION
- (521.4) MEASURED GROUNDWATER LEVEL ELEVATION (FEET MSL)
- —524 GROUNDWATER CONTOUR (FEET MSL)
- — — — INDICATES AREA OF UNCERTAINTY
- - - - FEMP PROPERTY BOUNDARY
- BEDROCK OUTSIDE GREAT MIAMI AQUIFER
- MUNICIPAL AREA

NOTES:

THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUNDWATER CONTOUR MAP ARE ALL COMPLETED IN THE SAND AND GRAVEL AQUIFER. HOWEVER COMPLETION DEPTHS FOR SOME WELLS ARE UNKNOWN. IN THE VICINITY OF THE COLLECTOR WELLS, GROUNDWATER ELEVATIONS WOULD DEPEND ON COMPLETION DEPTH. DEEPER WELLS IN THE AQUIFER WOULD INDICATE LOWER WATER LEVEL ELEVATIONS BECAUSE OF VERTICAL GRADIENTS CREATED BY PUMPING AT DEPTH. THEREFORE, WATER TABLE ELEVATION CONTOURS SHOWN IN THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.

GROUNDWATER ELEVATIONS AT PUMPING WELLS FMPC-P3, COLL-1, AND COLL-2 WERE NOT USED FOR CONSTRUCTION OF THIS MAP.

BASED ON WATER ELEVATION MEASUREMENT FROM MIAMI CONSFRVENCY DISTRICT MONITORING WELLS AND FEMP WELLS.

000499

SCALE

3500 1750 0 3500 FEET

STATE PLANAR COORDINATE SYSTEM 1927

B110.DGN OU5 R1

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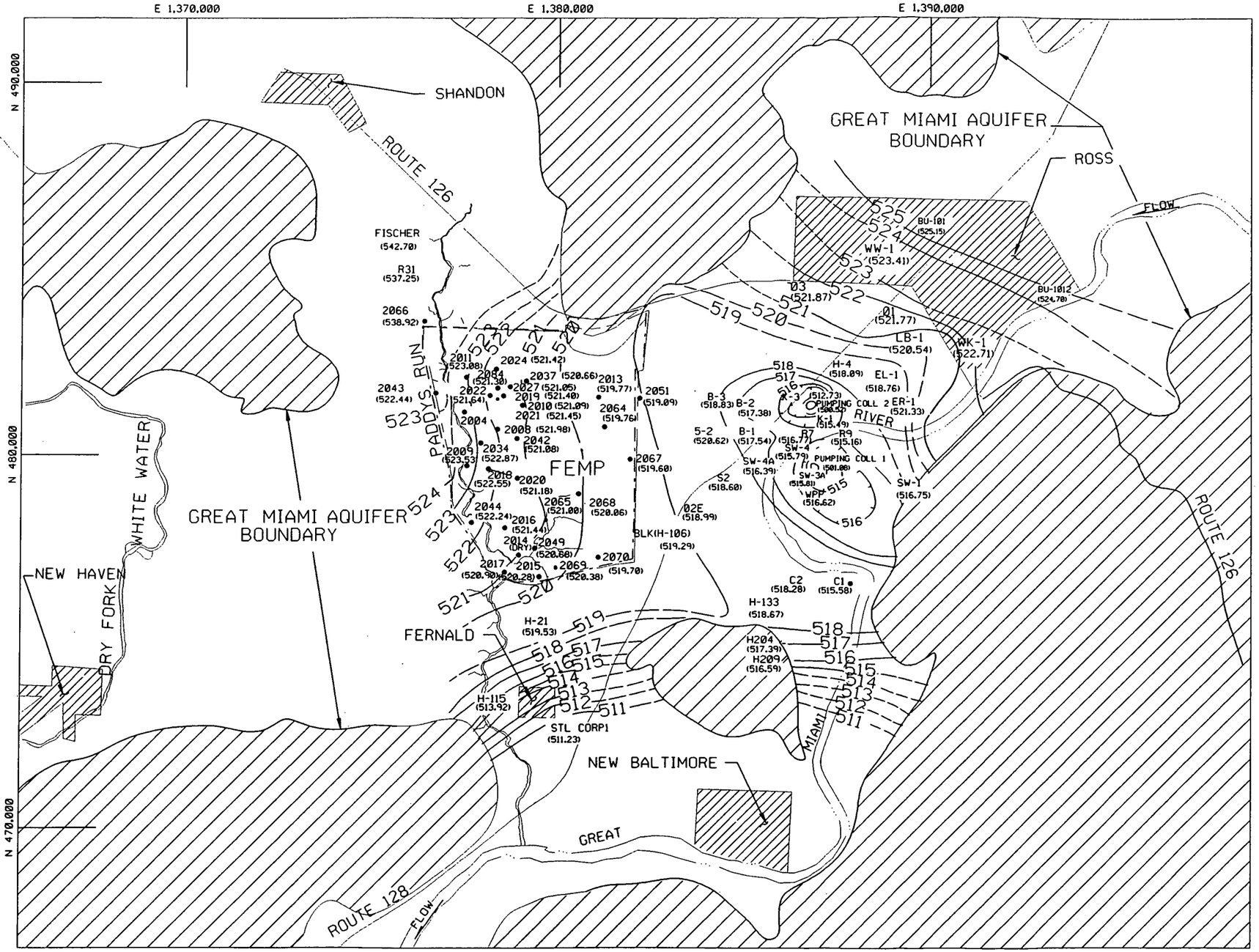
FIGURE 3-48.
REGIONAL GROUNDWATER ELEVATIONS
APRIL 1986



LEGEND:

- • 2017 WELL NAME AND LOCATION
- (521.4) MEASURED GROUNDWATER LEVEL ELEVATION (FEET MSL)
- —— 524 GROUNDWATER CONTOUR (FEET MSL)
- - - - INDICATES AREA OF UNCERTAINTY
- - - - FEMP BOUNDARY
- BEDROCK OUTSIDE GREAT MIAMI AQUIFER
- MUNICIPAL AREA

NOTES:

THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUNDWATER CONTOUR MAP ARE ALL COMPLETED IN THE SAND AND GRAVEL AQUIFER. HOWEVER, COMPLETION DEPTHS FOR SOME WELLS ARE UNKNOWN. IN THE VICINITY OF THE COLLECTOR WELLS, GROUNDWATER ELEVATIONS WOULD DEPEND ON COMPLETION DEPTH. DEEPER WELLS IN AQUIFER WOULD INDICATE LOWER WATER LEVEL ELEVATIONS BECAUSE OF VERTICAL GRADIENTS CREATED BY PUMPING AT DEPTH. THERE, WATER TABLE ELEVATION CONTOURS SHOWN IN THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.

GROUNDWATER ELEVATIONS AT PUMPING WELLS FMPC-P3, COLL-1, AND COLL-2 WERE NOT USED FOR CONSTRUCTION OF THIS MAP.

BASED ON WATER ELEVATION MEASUREMENTS FROM MIAMI CONSERVANCY DISTRICT, MONITORING WELLS AND RI/FS WELLS.

000500

SCALE

3000 1500 0 3000 FEET

DRAFT

B111.DGN 2-16-94

FIGURE 3-49.
REGIONAL GROUNDWATER ELEVATIONS
MAY 1988

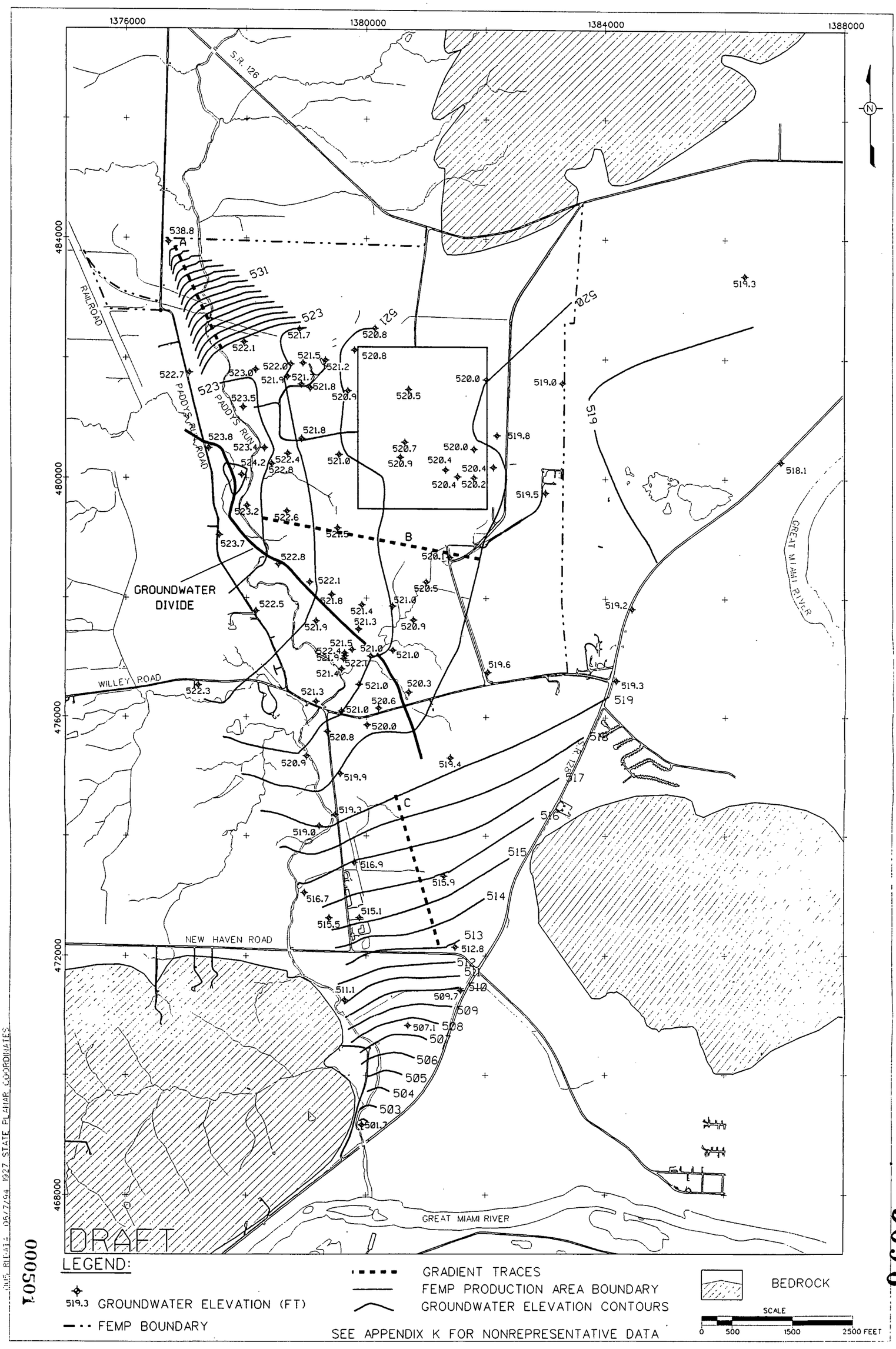


FIGURE 3-50. GROUNDWATER ELEVATIONS, TYPE 2 WELLS, AVERAGE FOR 1988 THRU 1993

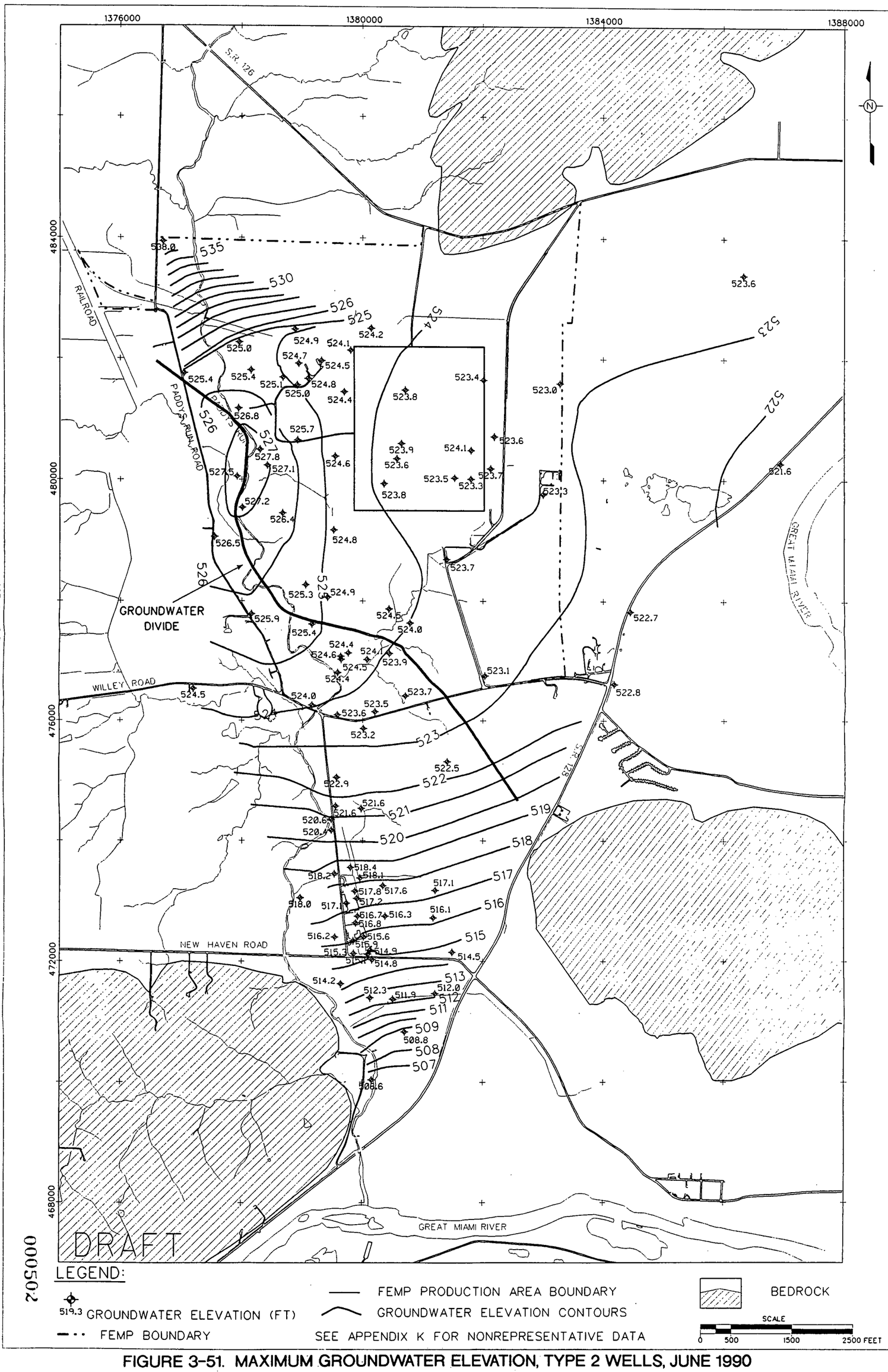


FIGURE 3-51. MAXIMUM GROUNDWATER ELEVATION, TYPE 2 WELLS, JUNE 1990

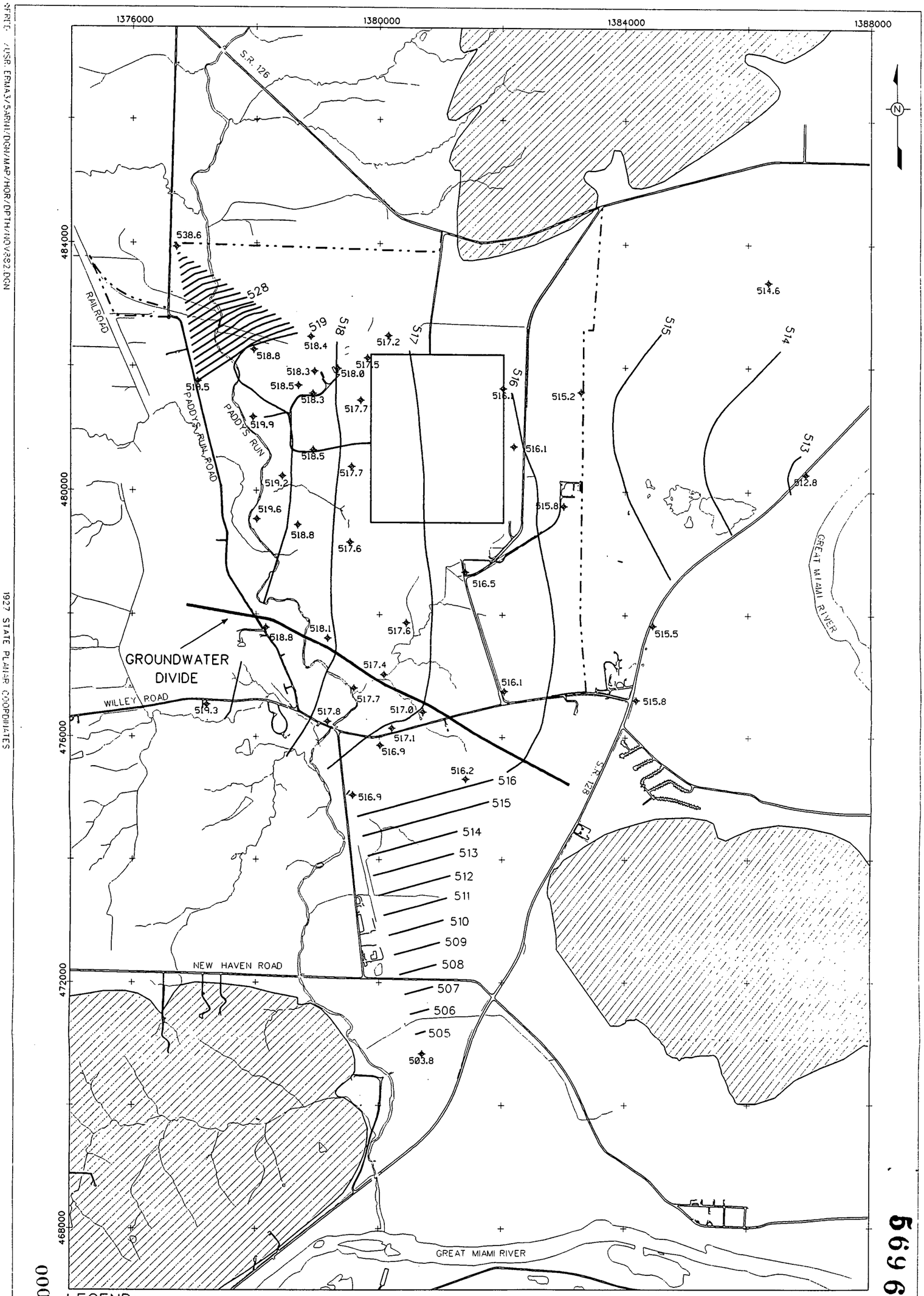


FIGURE 3-52. MINIMUM GROUNDWATER ELEVATIONS, TYPE 2 WELLS, NOVEMBER 1988

000503

5696

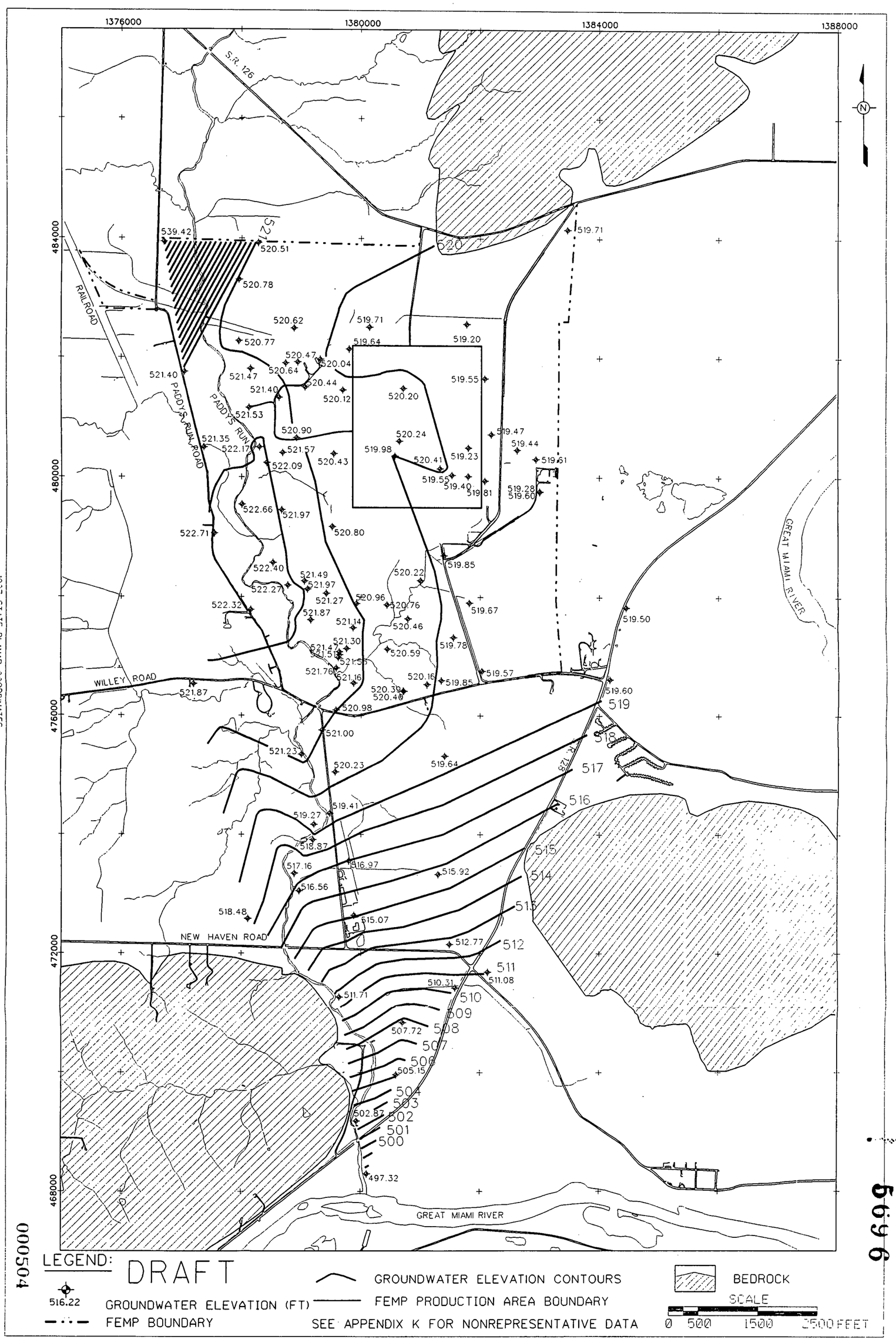


FIGURE 3-53. GROUNDWATER ELEVATIONS, TYPE 2 WELLS, JANUARY 1993

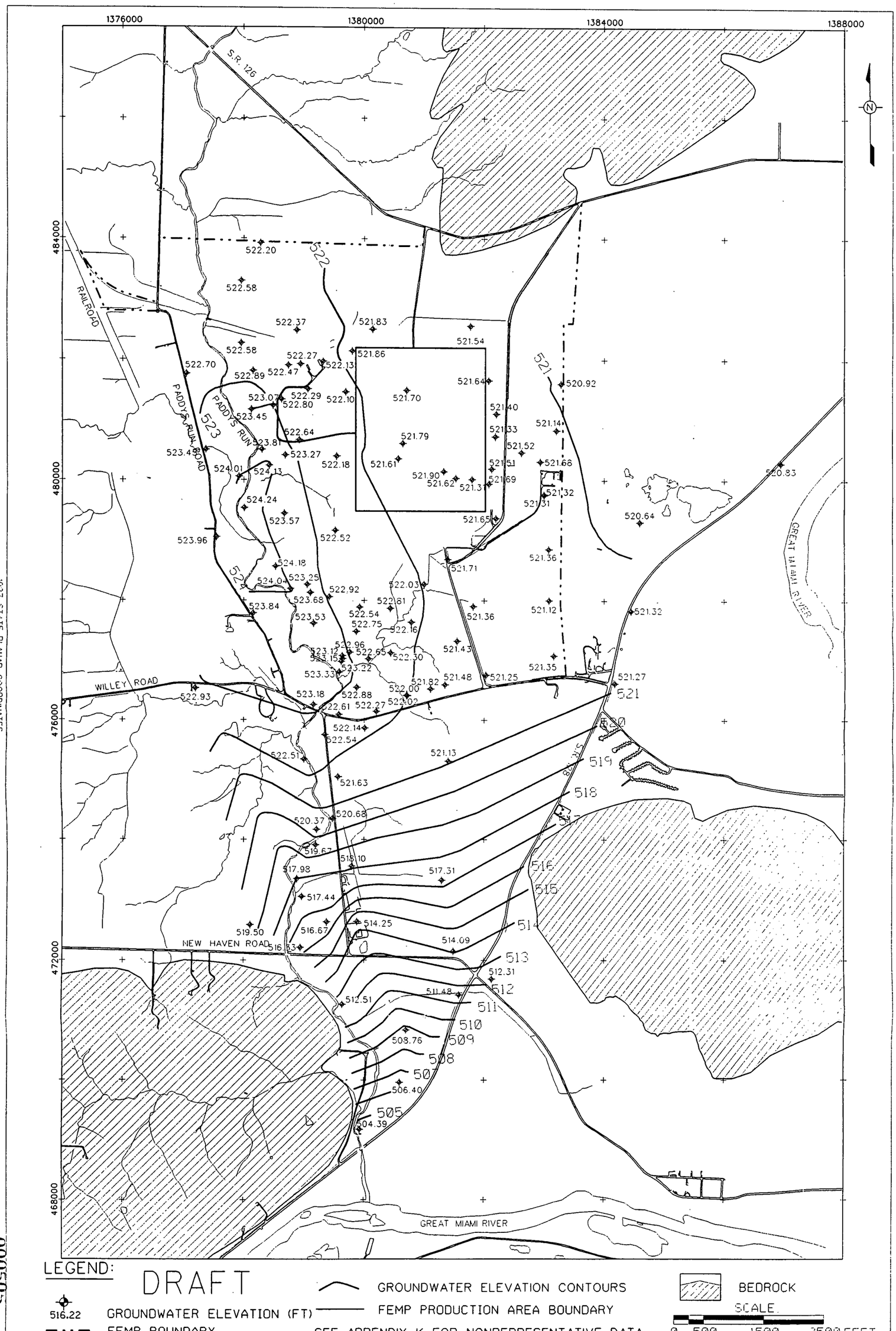


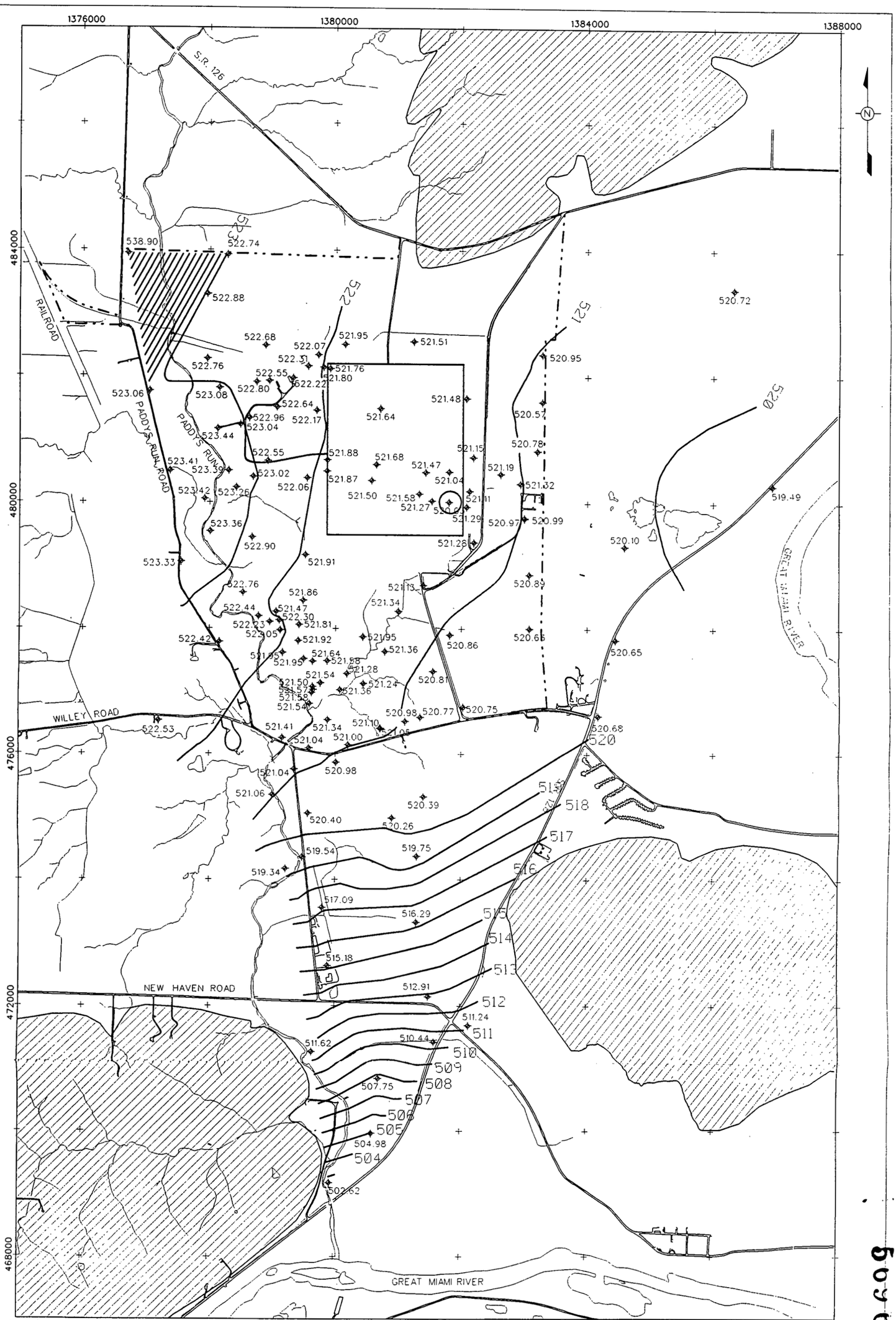
FIGURE 3-54. GROUNDWATER ELEVATIONS, TYPE 2 WELLS, APRIL 1993

/USR/FERMAI/CRU5GW/DGN/APR932.DGN

1927 STATE PLANAR COORDINATES

000505

9999



LEGEND:

DRAFT

516.22 GROUNDWATER ELEVATION (FT)

FEMP BOUNDARY

GROUNDWATER ELEVATION CONTOURS

FEMP PRODUCTION AREA BOUNDARY

SEE APPENDIX FOR K NONREPRESENTATIVE DATA

BEDROCK

SCALE

0 500 1500 2500 FEET

FIGURE 3-55. GROUNDWATER ELEVATIONS, TYPE 2 WELLS, JULY 1993

/USR/FERMAT/CPUSCW/DGN/JUL932.DGN

1927 STATE PLANAR COORDINATES

000509

6096

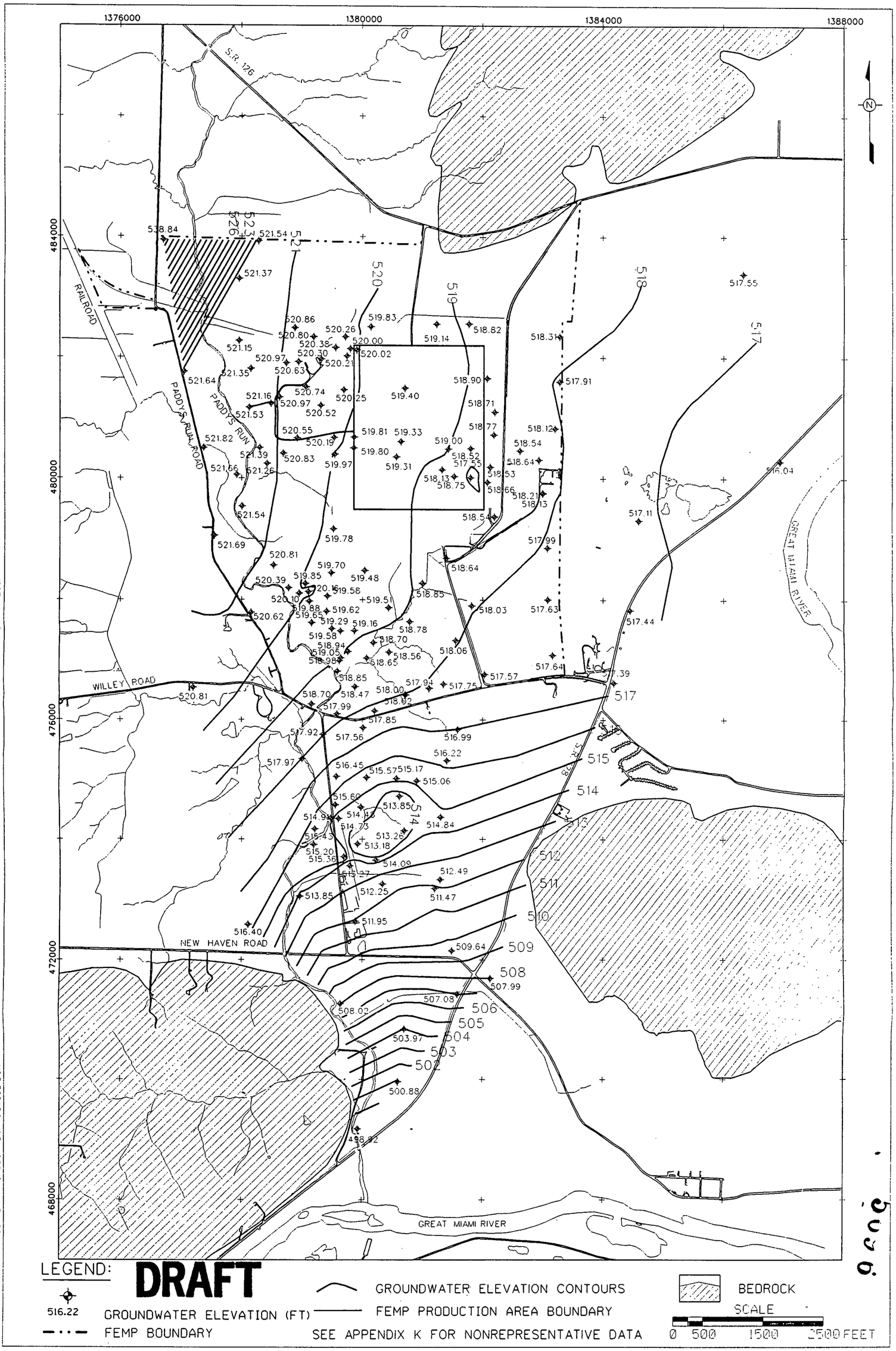


FIGURE 3-56. GROUNDWATER ELEVATIONS, TYPE 2 WELLS, OCTOBER 1993

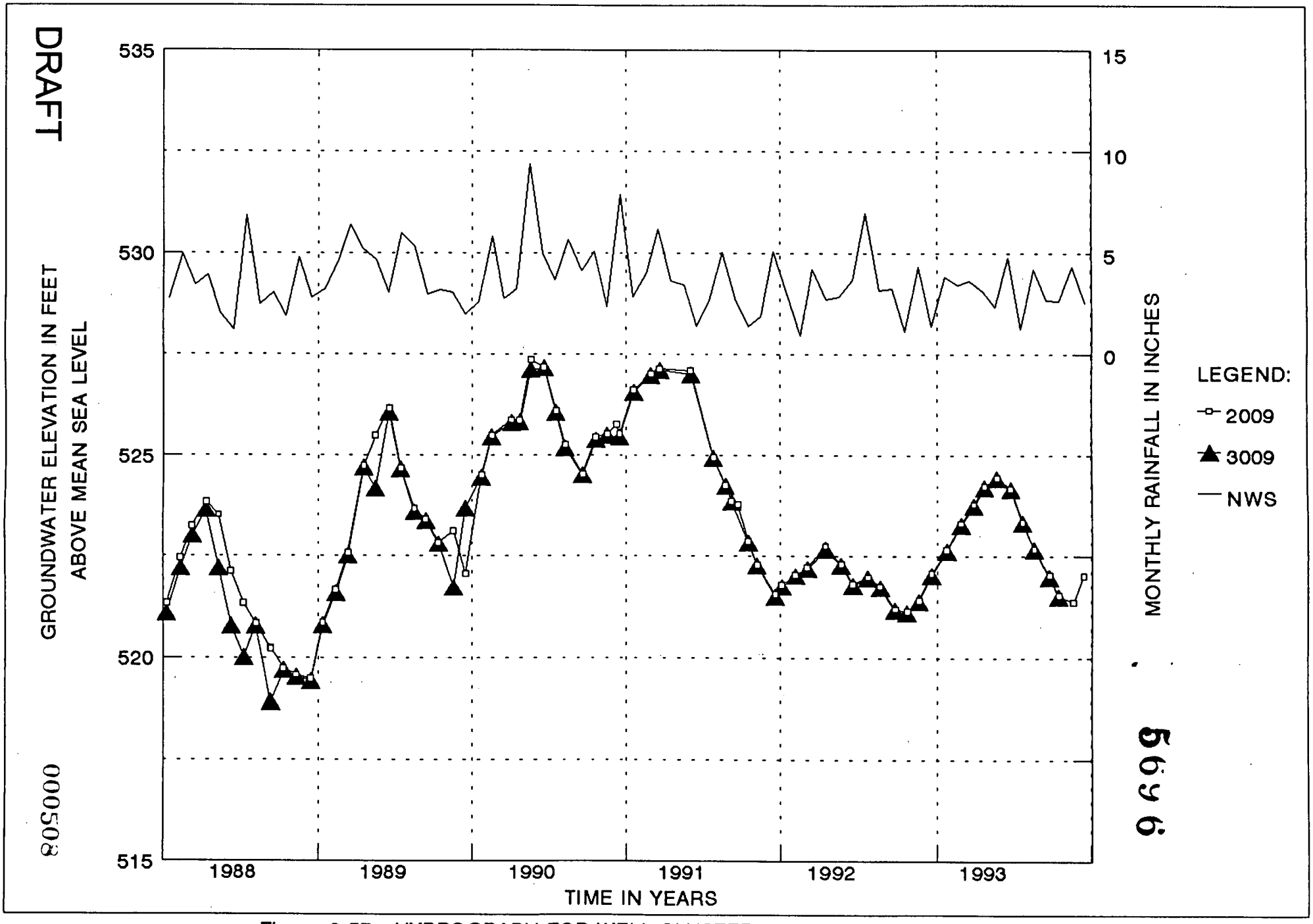


Figure 3-57. HYDROGRAPH FOR WELL CLUSTER 009 AND MONTHLY RAINFALL

DRAFT

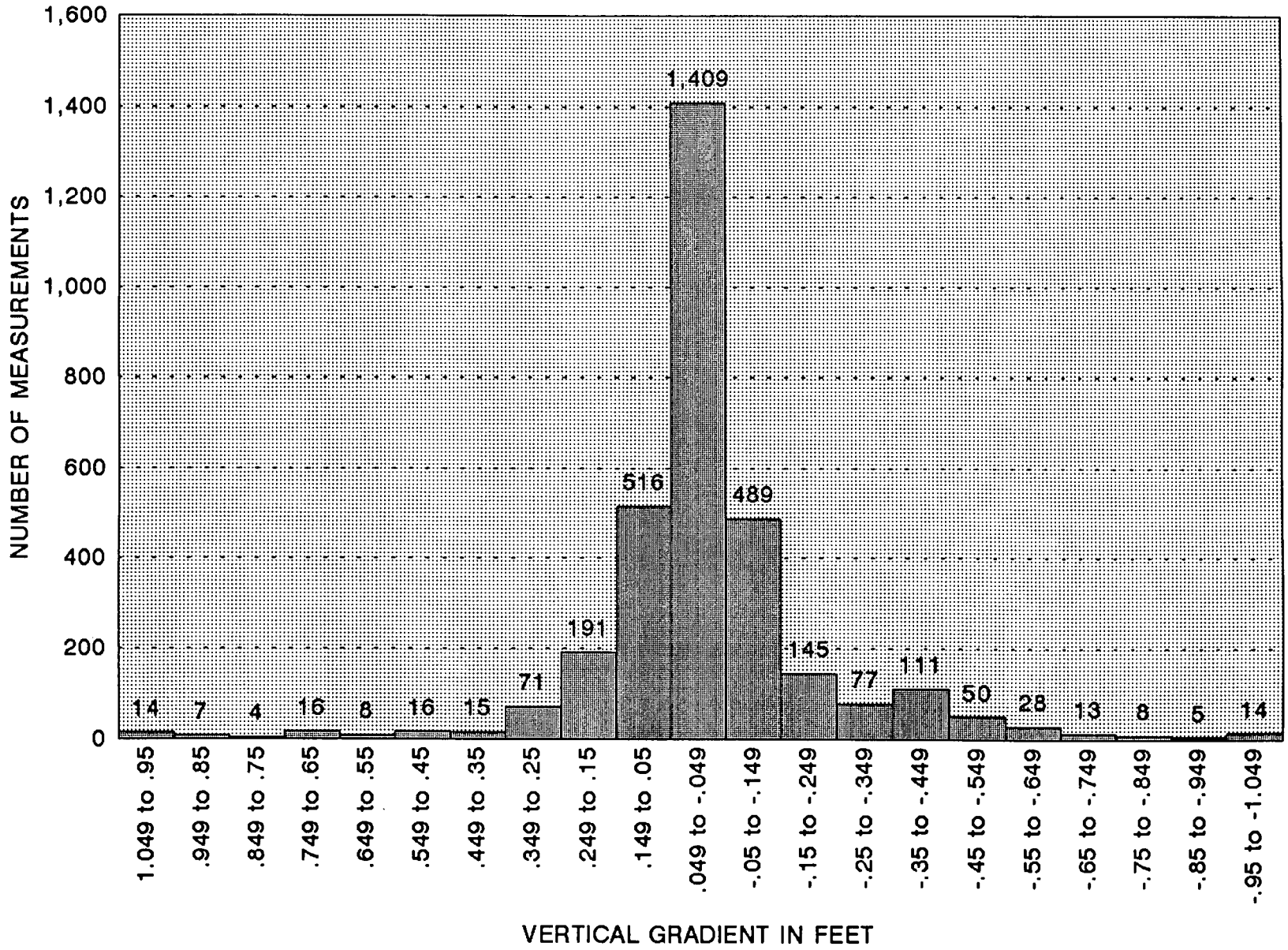


FIGURE 3-58. FREQUENCY AND MAGNITUDE OF VERTICAL GRADIENTS

000509

5696

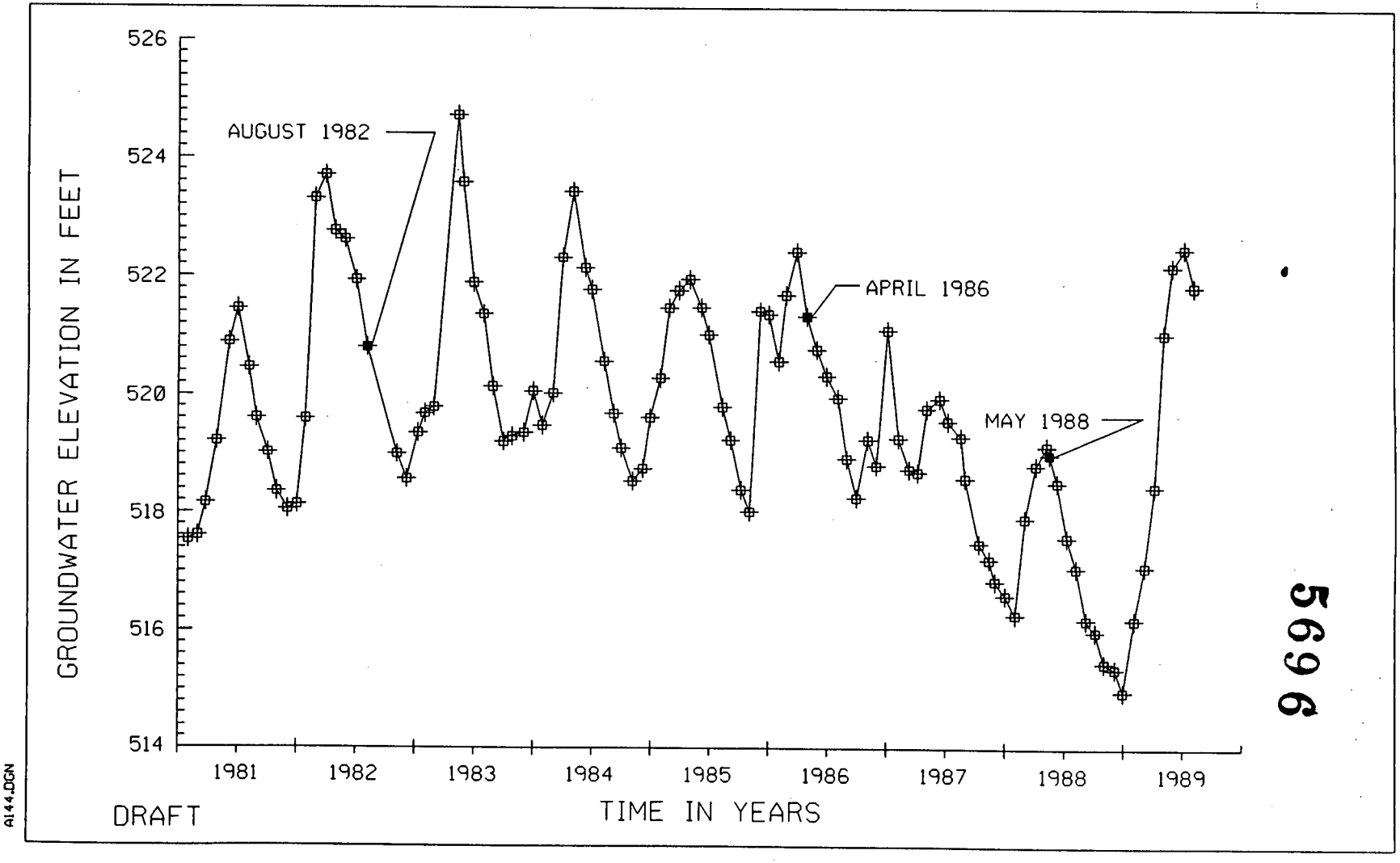


FIGURE 3-59. HYDROGRAPH OF WELL 02E JANUARY 1981 - DECEMBER 1989

5696

000510

^\ILLUS\OU-5\PO-116\CONCEPT MOD FEATURES.EPS

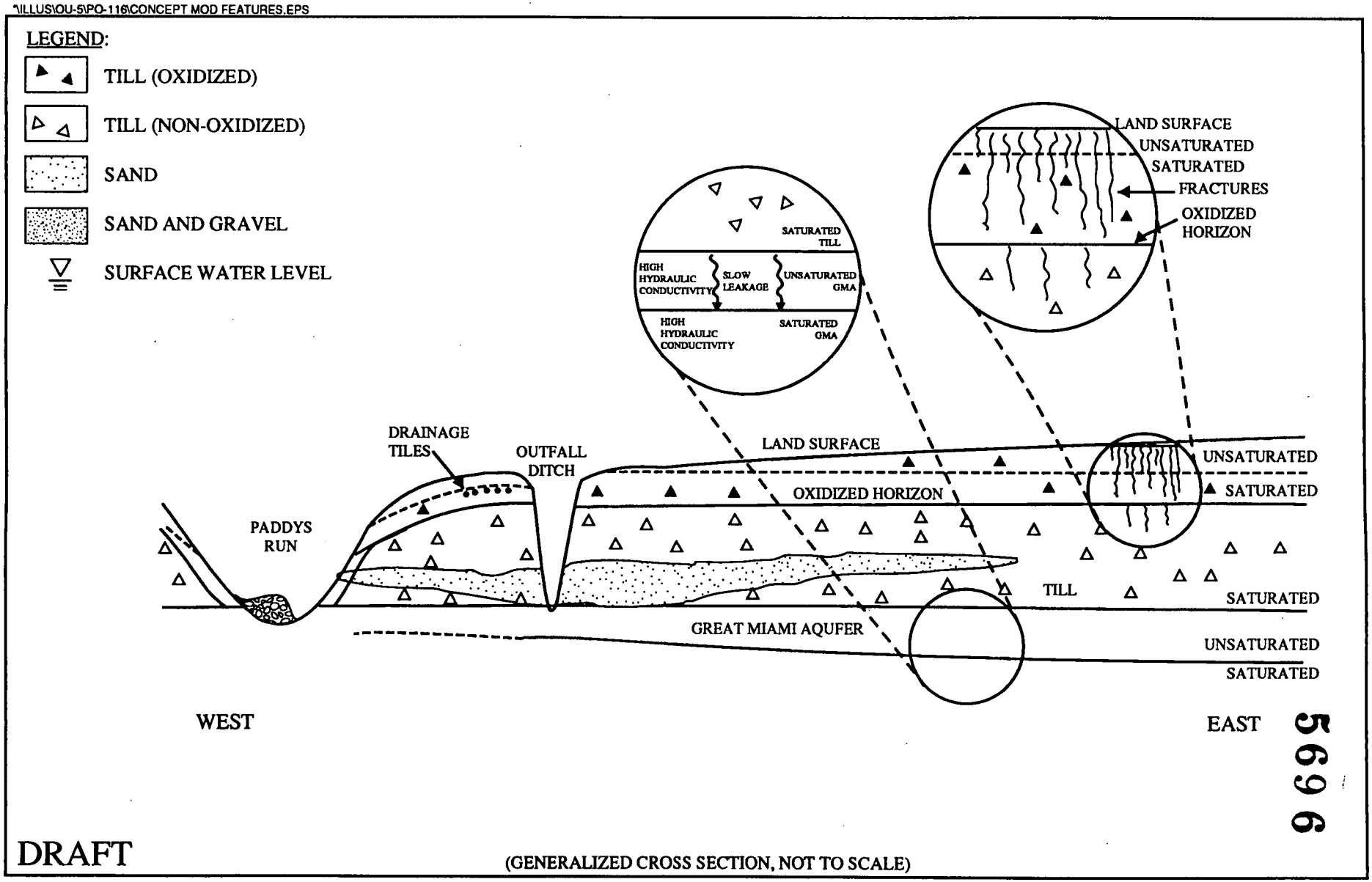
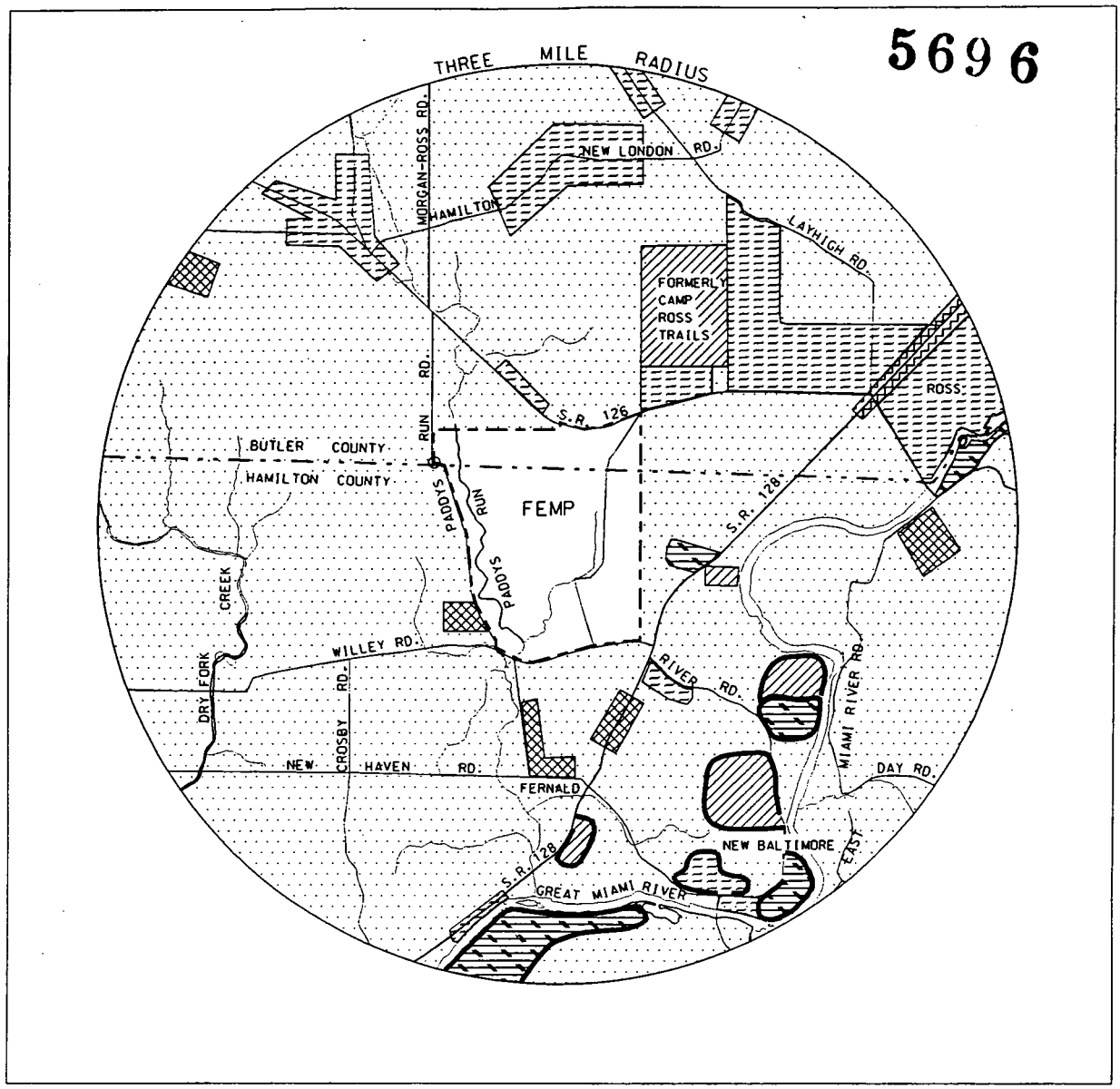


FIGURE 3-60. MAJOR FEATURES OF THE CONCEPTUAL MODEL OF THE HYDROLOGY OF THE FEMP AREA

000511



LEGEND:

- — · · — COUNTY LINE
- — — — FEMP PROPERTY BOUNDARY
- RESIDENTIAL
- INDUSTRIAL
- RECREATION
- MINING
- MIXED USE
- AGRICULTURE/OPEN LAND

SCALE

2 1 0 2 MILES

DRAFT

A124.DGN OU5 R1

FIGURE 3-61. LAND USE ADJACENT TO THE FEMP

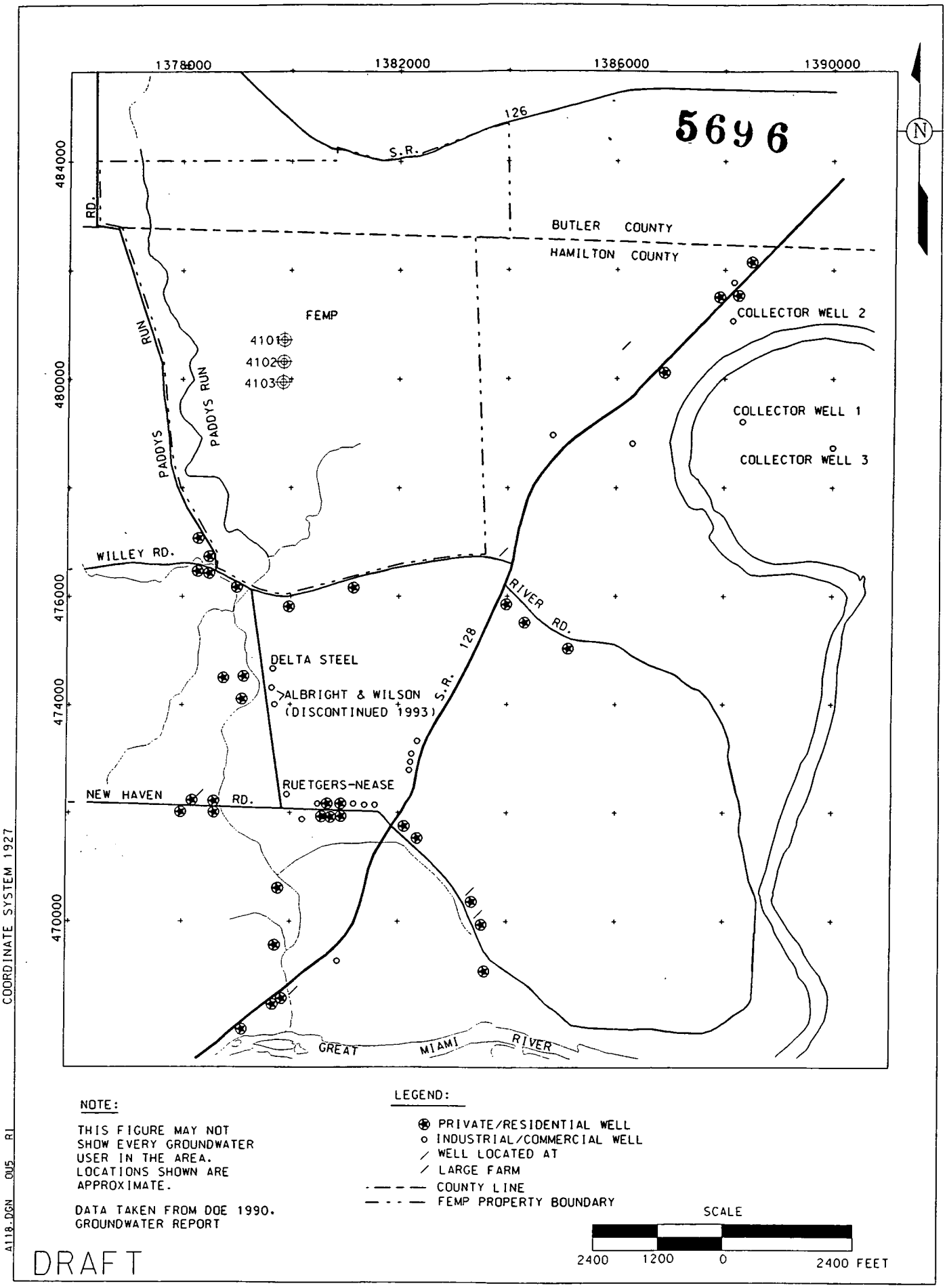
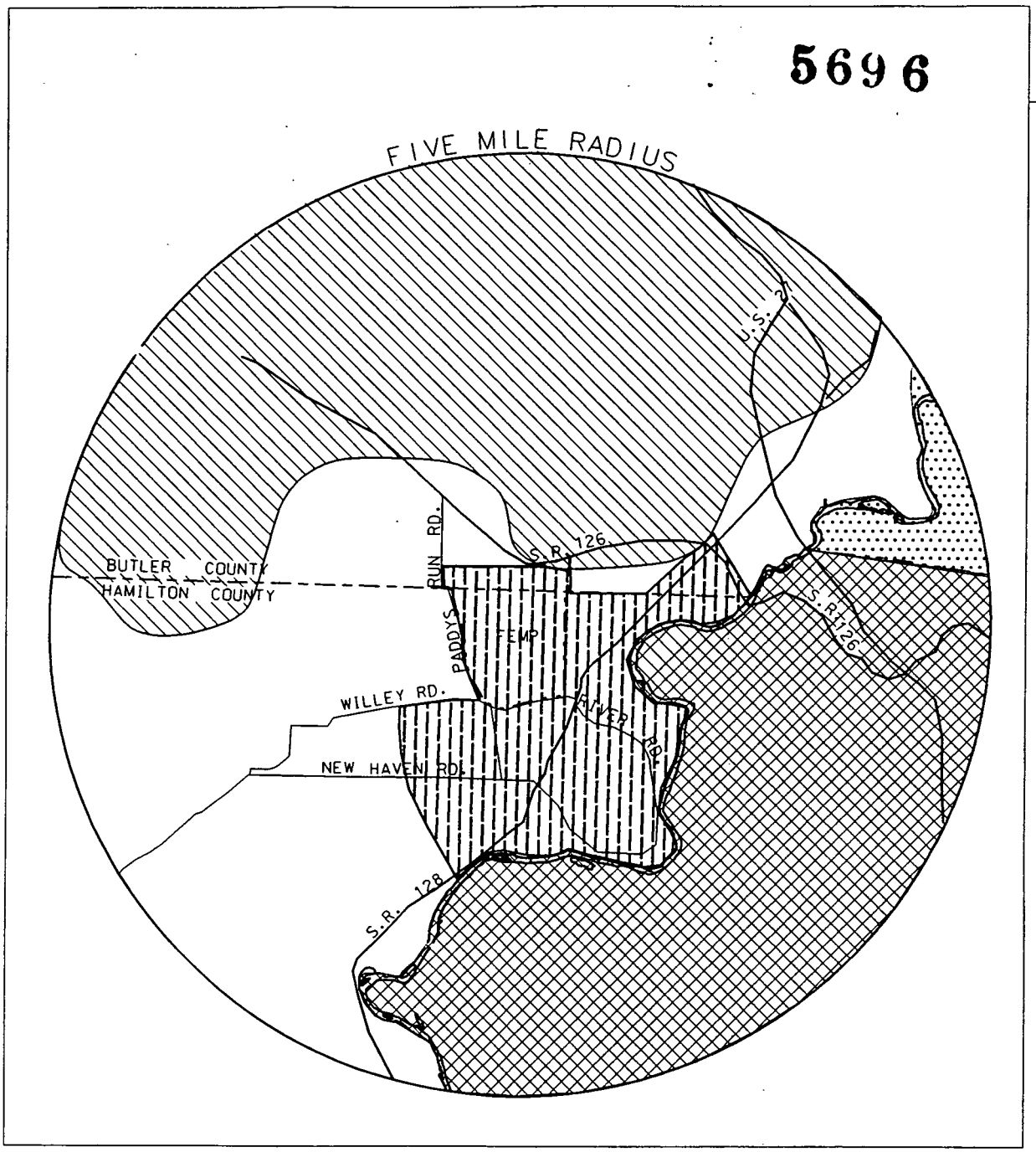


FIGURE 3-62. KNOWN GROUNDWATER USERS DOWNGRADIENT OF THE FEMP



LEGEND:

- AREA WITHOUT WATER SERVICE
- SOUTHWEST REGINAL WATER DISTRICT
- CINCINNATI WATER WORKS (CWW)
- NEW SERVICE AREA (CWW)
- FAIRFIELD WATER DISTRICT
- FEMP BOUNDARY

SCALE

9000 4500 0 9000 FEET

STATE PLANAR COORDINATE SYSTEM 1927

A119A.DGN OU5 RI

DRAFT

FIGURE 3-63. WATER SERVICE AREAS WITHIN A FIVE-MILE RADIUS OF THE FEMP

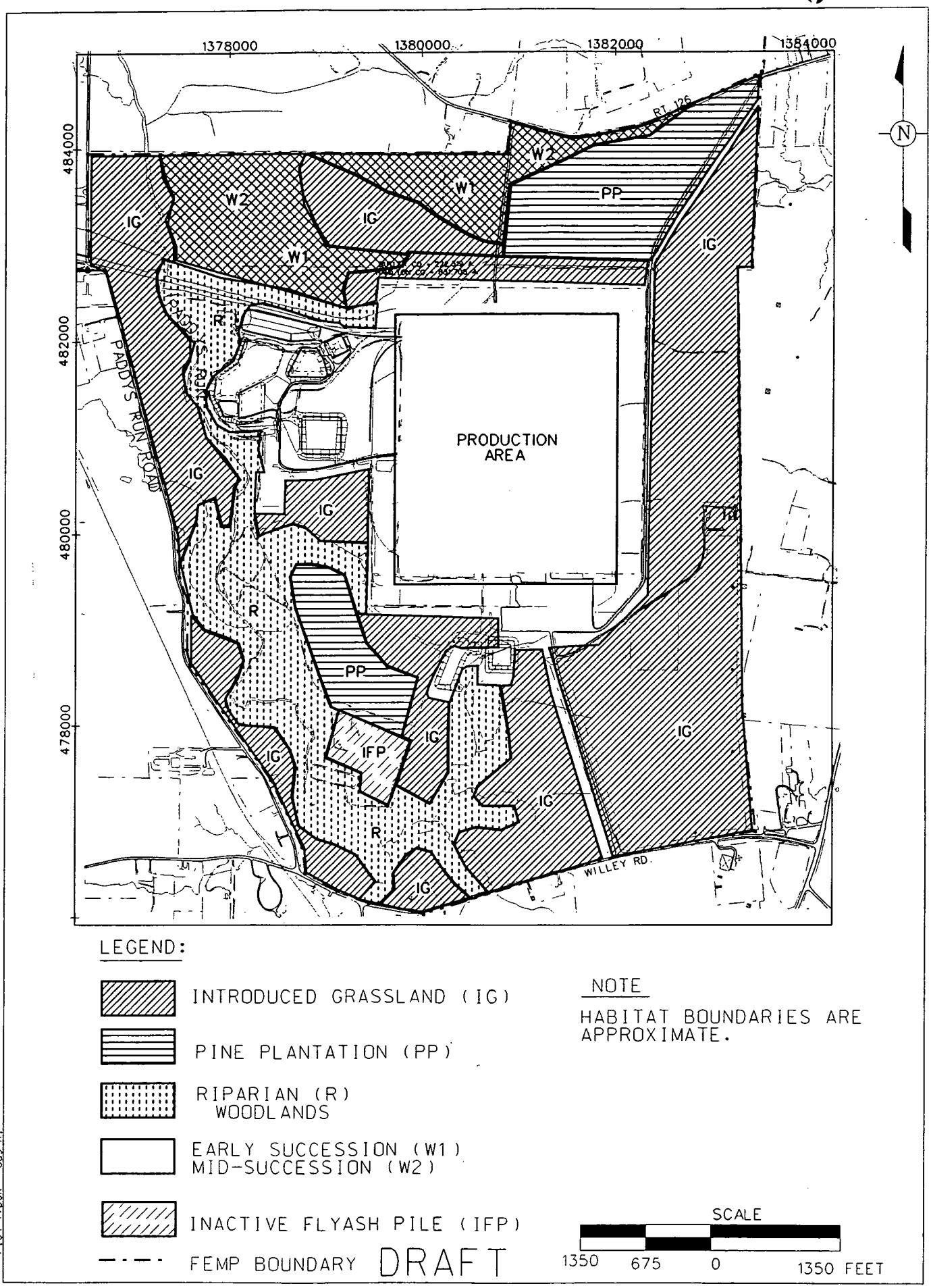


FIGURE 3-64. HABITAT TYPES PRESENT ON THE FEMP

INTRODUCED GRASSLAND

Ungrazed

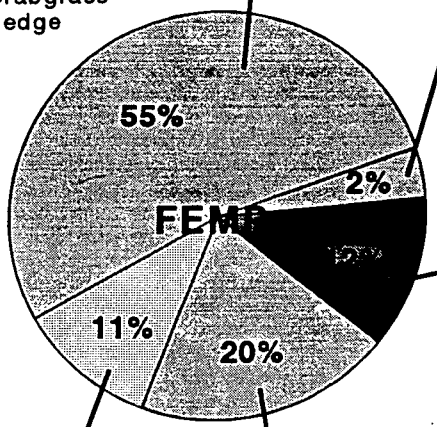
- ★ Fescue
- ★ Timothy
- ★ Redtop Grass
- ★ Moth Mullein
- ★ Kentucky Bluegrass
- ★ Orchard Grass
- White Clover
- Red Clover
- Brome Grass
- Chickweed
- Buttercup
- Winter Cress
- Wild Onion
- Ironweed
- Thistle
- Yarrow
- Goldenrod
- Dandelion

Grazed

- ★ Fescue
- ★ Timothy
- ★ Red Top Grass
- ★ Kentucky Bluegrass
- ★ Moth Mullein
- White Clover
- English Plantain
- Orchard Grass
- Crabgrass
- Sedge

INACTIVE FLYASH PILE

- ★ Eastern Cottonwood
- ★ Black Locust
- ★ American Elm
- Prarie Rose
- Redbud
- Burning Bush
- Boxelder
- Fescue
- Kentucky Bluegrass
- Poison Ivy



RIPARIAN WOODLANDS

North

- ★ Eastern Cottonwood
- ★ Hackberry
- ★ Boxelder
- ★ American Elm
- Black Walnut
- Swamp White Oak
- Slippery Elm
- American Sycamore
- Honey Locust
- ★ Poison Ivy
- Trumpet Creeper
- Black Maple
- Sawbrier
- Hawthorn
- ★ Garlic Mustard
- ★ Goldenrod

South

- ★ American Elm
- ★ Boxelder
- ★ Ohio Buckeye
- Black Walnut
- Hackberry
- Slippery Elm
- American Sycamore
- ★ Poison Ivy
- Black Maple
- Swamp White Oak
- Hawthorn
- Sawbrier
- ★ Garlic Mustard
- ★ Goldenrod

PINE PLANTATIONS

- ★ White Pine
- ★ Austrian Pine
- Norway Spruce
- ★ Red Fescue
- ★ Brome Grass
- ★ Kentucky Bluegrass
- ★ Goldenrod
- ★ Blackberry
- ★ Copperleaf
- ★ Meadow Fescue

DECIDUOUS WOODLANDS

Early Succession

- ★ White Ash
- ★ American Elm
- American Sycamore
- Boxelder
- Hackberry
- ★ Honeysuckle
- Wild Black Cherry
- ★ Multiflora Rose
- ★ Blackberry
- Roughleaf Dogwood
- Virginia Creeper
- Grapevine

Mid Succession (East)

- White Ash
- ★ American Elm
- ★ Shellbark Hickory
- ★ Black Locust
- ★ Hackberry
- Northern Red Oak
- Wild Black Cherry
- ★ Multiflora Rose
- Shingle Oak
- ★ Roughleaf Dogwood
- Virginia Creeper
- Grapevine
- Eastern Red Cedar
- Chesnut Oak

Mid Succession (west)

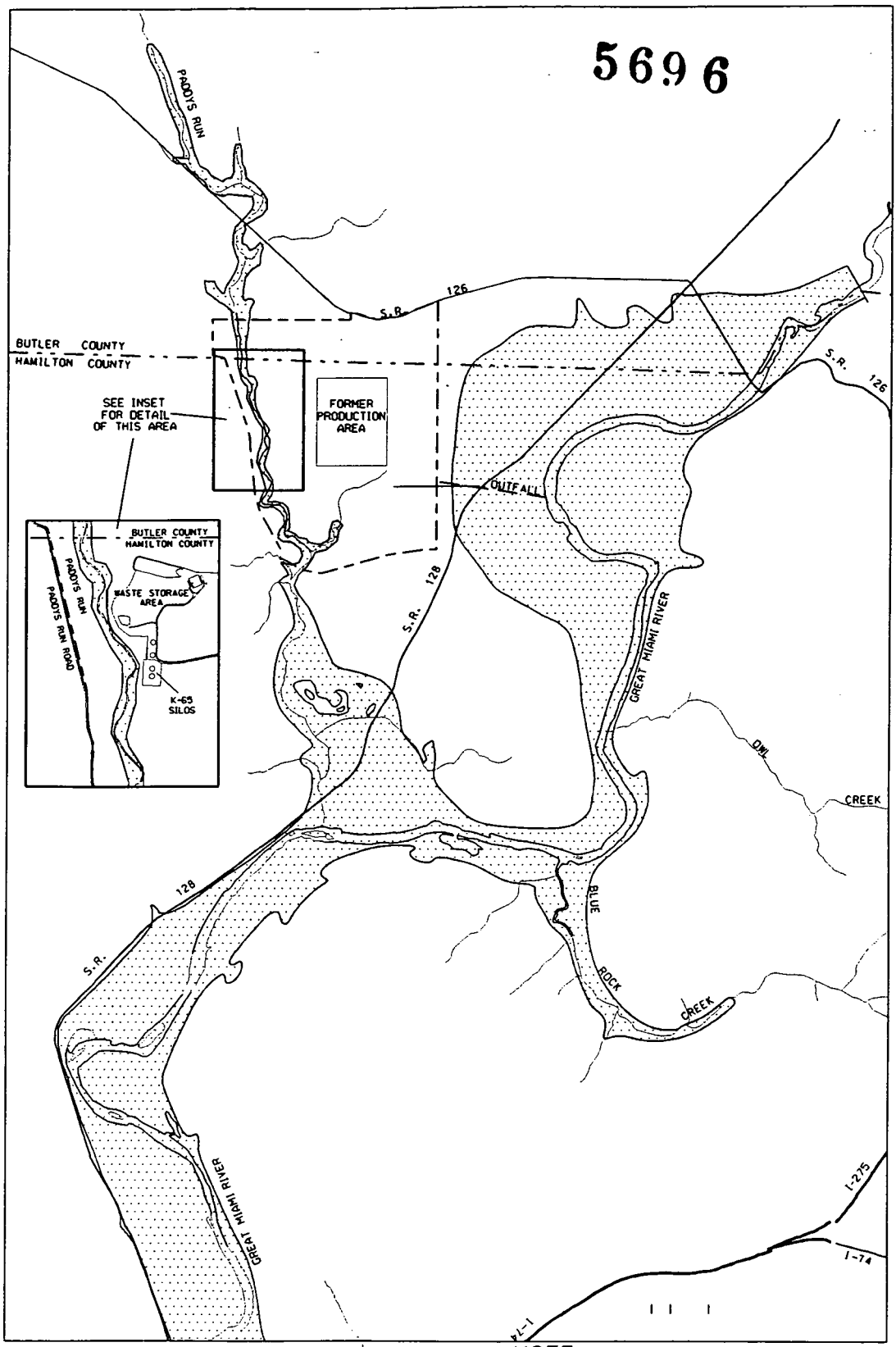
- ★ Ohio Buckeye
- ★ American Elm
- Sugar Maple
- Boxelder
- Hackberry
- ★ Honeysuckle
- Wild Black Cherry
- Black Walnut
- White Ash
- Roughleaf Dogwood
- Virginia Creeper
- Grapevine

LEGEND:

HABITAT	=	Habitat Type
20%	=	Percent of FEMP area covered by habitat type
★ Plant Name	=	Dominant Plant in habitat as determined by Facemire et al, 1990
Plant Name	=	Common plant type found

DRAFT

FIGURE 3-65. PLANT SPECIES AT FEMP



LEGEND:

- FEMP PROPERTY BOUNDARY
- COUNTY LINE
- 100-YEAR FLOOD LEVEL

NOTE:

DATA TAKEN FROM FEMA 1982, FLOOD INSURANCE RATE MAP

SCALE

5000 2500 0 5000 FEET

DRAFT

A131.DGN OU5 R1

FIGURE 3-66. GREAT MIAMI RIVER AND PADDYS RUN 100-YEAR FLOOD LEVEL

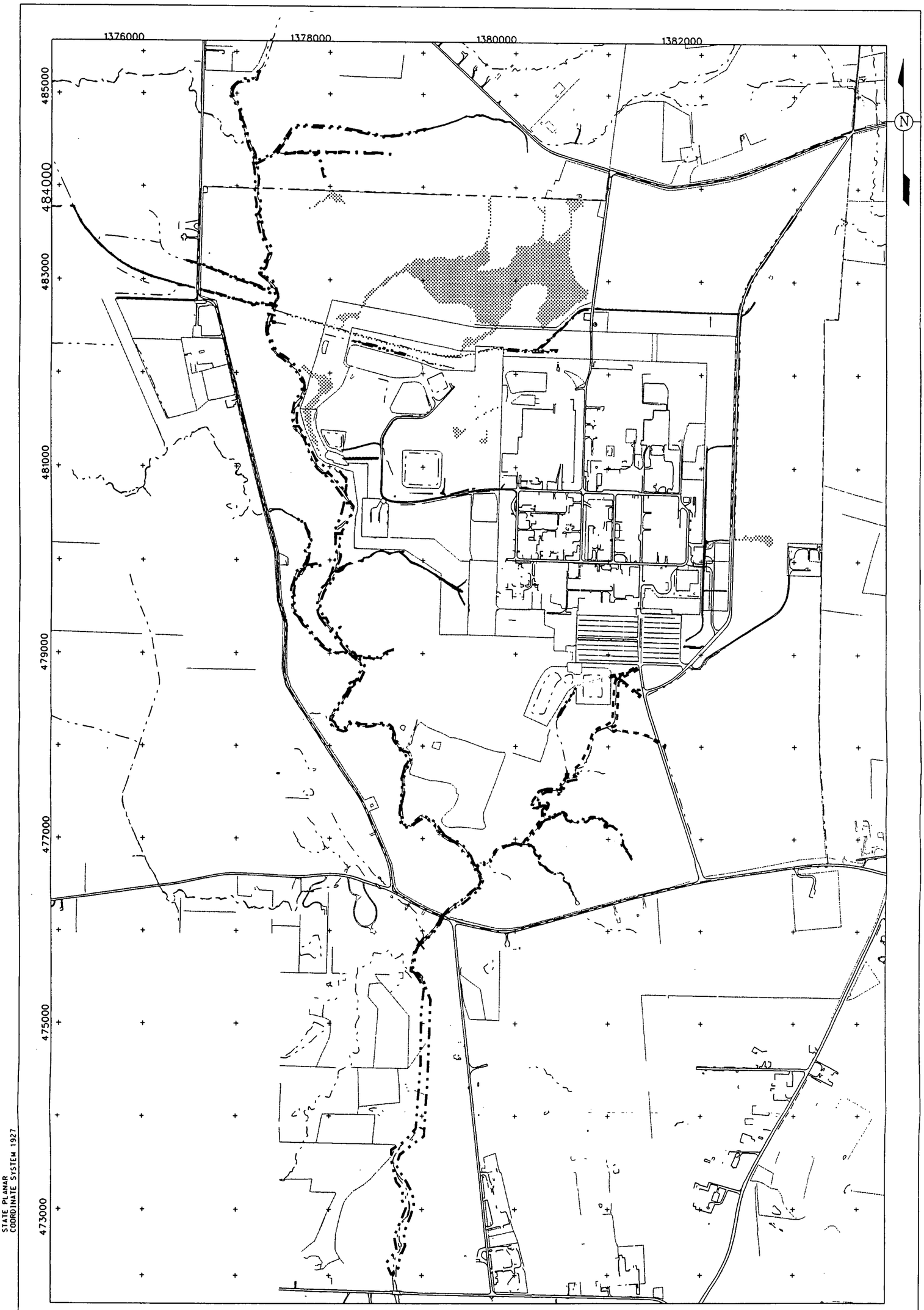
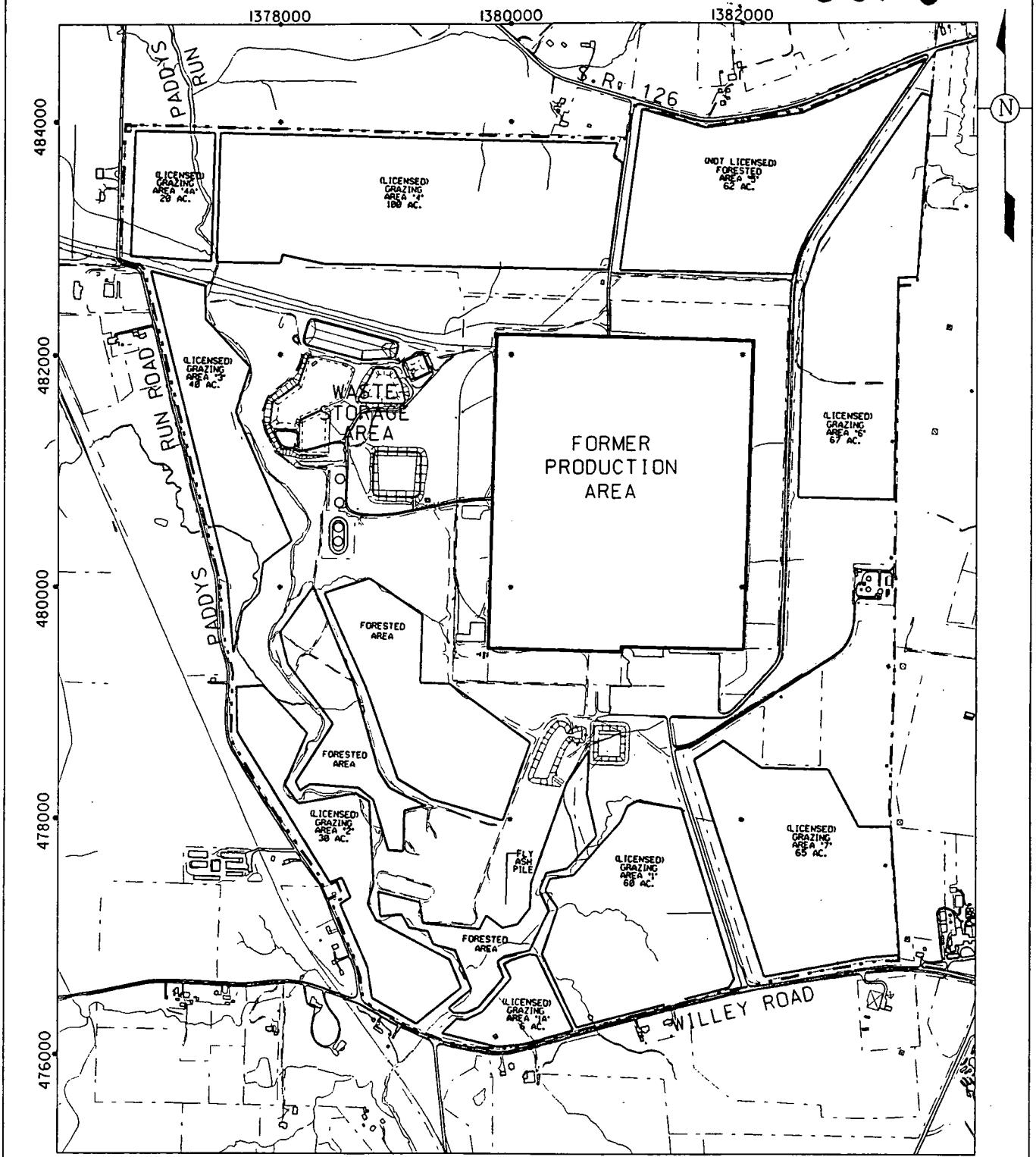


FIGURE 3-67. WETLANDS AND WATERS OF THE UNITED STATES



STATE PLANAR COORDINATE SYSTEM 1927

A133.DGN OU5 R1

LEGEND:

—·—· FEMP BOUNDARY

NOTE:

DATA TAKEN FROM LICENSE AGREEMENT BETWEEN DOE AND GRANTEE.

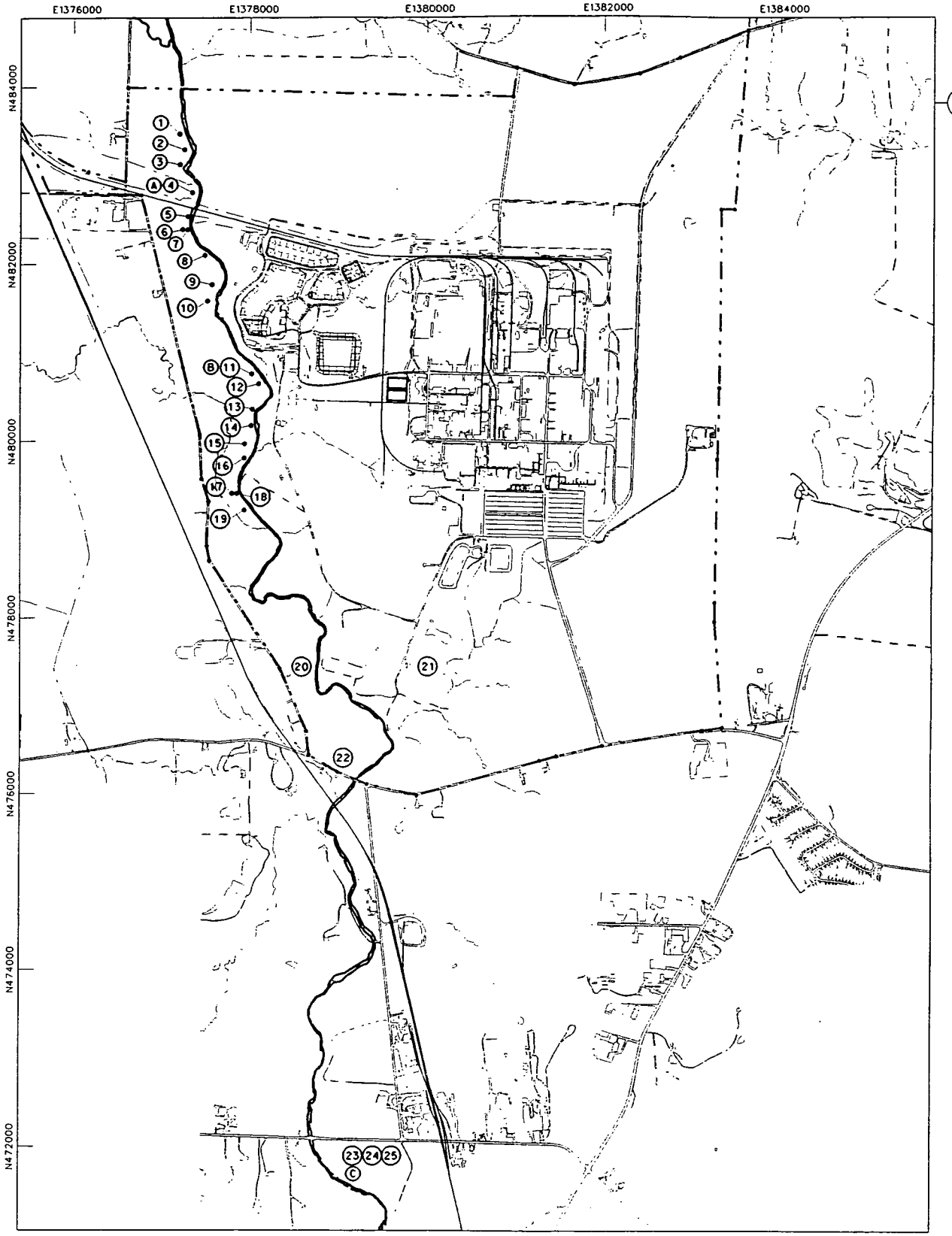
SCALE

1250 625 0 1250 FEET

DRAFT

FIGURE 3-68. LEASED GRAZING AREAS ON FEMP PROPERTY

FILE NAME /res2233/fish.dgn 8x11 cru5 5-25-94 GES STATE PLANAR COORDINATE SYSTEM 1927



LEGEND:

—·—·—	FEMP BOUNDARY
A-C	1993 SAMPLING LOCATIONS
1-25	1994 SAMPLING LOCATIONS

SCALE

1500 750 0 1500 FEET

DRAFT

FIGURE 3-69. 1993/1994 SLOAN'S CRAYFISH SURVEY LOCATIONS

4.0 NATURE AND EXTENT OF CONTAMINATION

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This section presents data that define the nature and extent of radiological and chemical contaminants identified in the Operable Unit 5 study area. Also included is ecological characterization and source and background information.

The objective of the Remedial Investigation (RI) is to determine the nature and extent of contamination sufficiently to (1) perform a baseline risk assessment and (2) develop and evaluate remedial action alternatives. Data acquisition and evaluations presented herein focus on the quality and quantity of data necessary to meet these two RI objectives.

Conclusions regarding the nature and extent of radiological and chemical constituents within Operable Unit 5 are based on data collected during the RI and previous studies. The processes that generated the wastes contained in Operable Unit 5 are well known. Section 1.3 provides an overview of those processes performed at the Fernald Environmental Management Project (FEMP) and provides a general description of the potential contaminants. Thus, the sampling associated with the RI confirms the presence of known constituents and identifies the presence of others.

The primary radiological constituents expected in Operable Unit 5, based on process knowledge and the findings of the other operable units, are uranium (U) isotopes (U-238, U-234, U-235) and their more stable progeny (radium [Ra]-226 and thorium [Th]-230). Thorium-232 and its more stable progeny (Ra-228, Th-228, and Ra-224) are also expected in lesser amounts. Because the FEMP also processed recycled uranium from other DOE facilities, uranium activation and fission products, including technetium (Tc)-99, strontium (Sr)-90, cesium (Cs)-127, and plutonium (Pu)-238, -239, and -240, are anticipated at low levels. Radiological analyses were performed to confirm and quantitate the presence and location of these constituents in the Operable Unit 5 environmental media.

Chemical analyses were also performed to evaluate the concentrations of organic and inorganic contaminants at the FEMP. Chemical constituents likely to be encountered in Operable Unit 5, based upon process knowledge and findings of other operable units, include tributyl phosphate, a reagent used in the extraction of uranium; polychlorinated biphenyls (PCBs); polynuclear aromatic hydrocarbons (PAHs) from flyash, incinerator ash, and fuel oils; chlorinated phenoxy acid herbicides that were used for weed control; common solvents such as acetone and benzene; chlorinated solvents

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that were used as degreasers or paint solvents; various oils that were used as lubricants and coolants; and various inorganics species such as calcium, magnesium, fluoride, and heavy metals.

Contaminant migration is governed by both hydrologic and geochemical factors. The physical properties of the subsurface soil (as discussed in Section 3.0) control the velocity and dispersion of solutes transported through the media. The porosity, saturated hydraulic conductivity, and relative permeability/water retention relationships (also discussed in Section 3.0) influence moisture movement in variably saturated soils. The boundary conditions of the groundwater system also affect the flow paths from the various sources. Hydrodynamic dispersion, which results in spreading of a contaminant plume, acts to attenuate the movement of contaminants.

The geochemical factors influencing solute concentration include aqueous speciation, reduction oxidation, solubility, ion-exchange, and specific-ion adsorption reactions (see Appendix F.3.I). The separation of mixtures of compounds into components and oxidation reduction reactions can control the distribution of species in solution and their thermodynamic activities. Interactions between groundwater or leachate with soil minerals alter the composition of the pore water through adsorption, ion-exchange, and solubility reactions. These mass-transfer reactions also retard solute velocities and attenuate their concentrations relative to a conservative tracer. Thus, the spatial and temporal distribution of contaminants are a complex function of both hydrologic and geochemical variables. Specific details describing the data quality objectives (DQOs), methods, sampling, and analysis of the environmental media are provided in Section 2.0, Study Area Investigations. Table 2-2 identifies the primary data sources used to evaluate the nature and extent of contamination associated with Operable Unit 5. Section 2.0 also includes a discussion of the quality assurance (QA) status of each data set used in this report.

The following three subsections provide general information that will be useful in understanding the detailed analyses of the nature and extent of contamination in the Operable Unit 5 media. Section 4.1 provides a brief explanation of concepts of radioactivity, including radioactive decay, half-lives and decay relationships, and analytical considerations. Section 4.2 presents the background data used to determine the significance of data collected during the RI. Section 4.3 provides a brief discussion of the sources of contamination to the Operable Unit 5 media and, based on these, the expected contaminants.

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Sections 4.4 through 4.9 present summary analyses of the nature and extent of contamination in surface water and sediment, soil, perched groundwater, the Great Miami Aquifer, and biota, respectively. Also included are summary sections that describe how the contamination affects the baseline risk assessment.

4.1 RADIOLOGICAL CONSIDERATIONS

Many of the terms and concepts used in discussing radiological data collected for the FEMP Operable Unit 5 RI are unique to nuclear science. The concepts are not necessarily complex, but because most people are not routinely exposed to them, their use can be confusing. The following discussion provides a background to better understand the data analysis in the remainder of the section.

4.1.1 Principles of Radioactive Decay

To explain the concept of radioactivity, it is useful to briefly discuss the structure and behavior of atoms. Atoms are comprised of electrons orbiting around a nucleus made up of protons and neutrons. The electrons are responsible for chemical properties, whereas the protons and neutrons determine what are called nuclear properties. Most atoms found in nature have stable nuclei. This means that the nucleus is in a very favorable configuration and it never changes unless acted on from the outside. There are, however, other atoms in which the nucleus contains excess energy or has an undesirable configuration. Such nuclei are called unstable, and will undergo a process known as radioactive decay in which the nucleus atom spontaneously disintegrates or "decays" to form a new nucleus. An example of this is one type of radium (radium-226) which decays to form radon (radon-222) gas.

Radioactive decay is accompanied by the emission of energetic particles and energy in other forms such as high-energy photons. These particles and energy are known collectively as radiation. The three most common and important types of radiation are alpha and beta particles, and gamma rays. An alpha particle is a helium atom without its electrons, a beta particle is an energetic electron, and a gamma ray is a high-energy photon similar to an x-ray. The distinguishing feature of these radiations is that they are emitted from the nucleus of an atom.

In defining the chemical properties of an element, only the number of an atom's electrons is important, so most of the information needed can be provided by simply stating the element's name or its chemical symbol. This is not sufficient for nuclear properties because each element has multiple isotopes. The difference between the isotopes is in the number of neutrons in the nucleus.

All isotopes of an element have the same number of protons, but each isotope has a different number of neutrons. As a consequence, each of an element's isotopes has different nuclear properties, including whether it is radioactive, the type and energy of radiation emitted, and the rate of decay.

When describing an isotope, the elemental symbol or name and the mass number must be stated. The mass number is equal to the total number of protons and neutrons in the nucleus. Since each element has a set number of protons, this provides a unique identification of the isotope. As an example, U-235 and U-238 (which each have 92 protons and differ only in the number of neutrons) are two isotopes of uranium. When an isotope is radioactive, the term radioisotope is generally used.

Although the terms nuclide and radionuclide are similar to isotope and are often used interchangeably, such usage is incorrect. Nuclide refers to a material with any combination of neutrons and protons. Isotope is properly used only when referring to a particular element. Uranium-235 and uranium-238 are isotopes, but when referring to a list such as plutonium-239, uranium-235, carbon-12, and lead-208, nuclide is the proper term. Radionuclide applies to those nuclides that will undergo radioactive decay.

Typically, discussions of radioactive materials emphasize the individual isotopes. This is done because for most radionuclides, the hazards associated with them and the methods of analysis are dependent upon nuclear properties. Thorium and uranium are unusual in this regard. Under certain exposure scenarios, the chemical toxicity is comparable to and may exceed the hazards associated with the radiation. Because of this, thorium and uranium are often analyzed using techniques that do not distinguish between the isotopes. When isotopic techniques are used, the results for the individual isotopes are sometimes summed and reported as the total amount of the element present. When data are reported as the elemental content rather than isotopic, the data are reported in mass concentration units such as grams per liter or parts per million. To distinguish from isotopic data, the terms "total thorium" and "total uranium" are often used for the elemental analyses.

4.1.2 Activity and Half-Lives

Radioactive decay is a random process. One cannot accurately state when any particular atom will decay; instead, there is a probability that each atom will decay within a given time period. When a large number of atoms are being observed, the average number of decays that occur in a time period is related to the probability of decay for each atom. This probability is defined by the structure of the

nucleus. Each radionuclide has a unique half-life. This is the time for half of the total number of atoms to decay. As an example, the half-life for radium-226 is about 1600 years. This means that if we started with 100,000 atoms of radium, after 1600 years there would be 50,000 atoms of radium-226 left (plus 50,000 atoms of various decay products), and after 3200 years, 25,000 atoms of radium-226 would remain (plus 75,000 atoms of various decay products).

The product of the decay of some radionuclides is another radionuclide. This is the case for the radium-226 discussed above. Radium-226 decays to radon-222, which in turn decays to polonium-218. In fact, these are only three members of a natural decay chain that begins with uranium-238 and ends with stable lead-206. There are 19 members of the uranium decay chain. Natural decay chains will be further discussed in Section 4.1.4. When discussing a decay chain, it is common to refer to the initial member of a chain as the parent and the decay products as progeny. The relationship between a radionuclide and its decay product is then known as a parent-progeny relationship.

The term activity is used to define the quantity of radioactive material present. The activity is the number of atoms that decay in a period of time. The activity of some quantity of radioactive material is dependent upon only two things: the half-life and the number of atoms of material present. The shorter the half-life, the greater the number of disintegrations per unit time for a given quantity of material. If the identity of a material and its activity are known, the number of atoms can be calculated. Activity is expressed as the number of disintegrations per unit time, such as disintegrations per second (dps or d/s) or disintegrations per minute (dpm or d/m). The SI unit for radiation is the becquerel (Bq), which is defined as 1 disintegration per second. Another unit in very common use is the curie (Ci), which is defined as 3.7×10^{10} Bq. A curie is a very large quantity of radioactive material, so for quantifying activity in environmental media, prefixes such as "pico" (10^{-12}) are commonly used. A picocurie (pCi) is equal to 3.7×10^{-2} Bq or 2.22 disintegrations per minute. Environmental levels of radionuclides may be as low as fractional picocuries per gram or as high as thousands of picocuries per gram.

The interaction of ionizing radiation with matter results in an absorbed dose. The SI Derived Unit of absorbed dose is the gray (Gy), the absorbed dose when the energy per unit mass is 1.0 joule per kilogram. Different types of radiation can result in different biological damage. The SI Derived Unit of dose equivalent is the sievert (Sv), which is the dose equivalent when the absorbed dose of ionizing

radiation is multiplied by a factor stipulated by the International Council on Radiological Protection (ICRP) to give 1.0 joule per kilogram.

The rad and rem are sometimes still used in place of the gray and sievert, (the gray is 100 rad and the sievert is 100 rem). The roentgen is another unit of radiation which relates electrostatic charge in air caused by electromagnetic radiation. Biological effects have traditionally been given in either rem (Rem) or milliren (mRem) of exposure. The dose rate is usually given in rad (R)/hour or milliard (mR)/hour as determined by survey instruments.

Radiation exposure is related to radioactivity, but the relationship depends on decay characteristics and the energy of the interaction. Generally, electromagnetic radiation is an external dose concern, whereas alpha and beta radiation are internal dose concerns.

4.1.3 Radioactive Materials in the Environment

Many radioactive materials are present in the environment. Some of these have been produced by the cosmic rays that are constantly bombarding the earth, some have been released from facilities using radioactive materials such as nuclear power plants and hospitals, and some have come from past atmospheric nuclear-weapons tests, but the overwhelming majority are from radionuclides that were created at the time the earth was formed.

Three naturally occurring radioactive materials that have been processed or stored in large quantities at the FEMP are uranium, thorium, and radium. The uranium and thorium were created during the formation of the earth. The radium is a result of radioactive decay of the uranium. Thorium-232, uranium-238, and uranium-235 are the initial members of three natural decay chains. These chains are shown schematically in Figures 4-1, 4-2, and 4-3, respectively. Each of these chains begins with a radionuclide with a very long half-life and ends with a stable isotope of lead. The intermediary radionuclides have half-lives of varying lengths; some are tens of thousands of years, and some are microseconds. The types of radiation emitted include alpha, beta, and gamma.

4.1.4 Decay-Chain Relationships

In many cases, the relationship between a radionuclide and its decay products allows the known activity of a radionuclide to be used to calculate the activities of other members of the decay chain. One such relationship, secular equilibrium, occurs when a radionuclide has a half-life that is much

longer than that of its decay products. The half-life difference must be such that the parent radionuclide does not decay appreciably over many half-lives of the decay product. As a rule of thumb, when half-lives differ by a factor of ten, secular equilibrium is considered to be possible. Two decay-chain members that are in secular equilibrium will have nearly equal activities. This equilibrium is achieved following a time period equivalent to about ten times the decay product's half-life, after any chemical separation or disruption of the decay chain has occurred. As an example, radium-226 decays with a 1600-year half-life to form radon-222, which has a half-life of about 3 days. If 1 pCi of radium were sealed in a container to prevent escape of the radon gas, after a period of 30 days, the radon activity would also be equal to 1 pCi. Because of its long half-life, the activity of the radium would have decreased by only a negligible amount.

In a long decay chain such as for the natural radionuclides shown in Figures 4-1, 4-2, and 4-3, there are many radionuclides for which the decay product has a longer half-life than that of the parent. In such cases, there is no equilibrium between the two. However, as long as the initial member of the decay chain has a half-life much longer than subsequent members of the chain, the equilibrium between the initial parent and the decay products can be maintained. As an example, in the uranium-235 decay series, thorium-231 decays with a half-life of 25.52 hours to protactinium-231, which has a half-life of 32,760 years. Because both of these have much shorter half-lives than uranium-235, their rate of decay is limited by that of the uranium. If a quantity of uranium-235 remains undisturbed for a long enough period, both the thorium and protactinium will be in secular equilibrium with the uranium, and all three will have approximately equal activities.

There are naturally occurring background concentrations of thorium and uranium and all the members of their decay chains in soil, groundwater, and surface water. The radionuclides found in the water result from their dissolution from soil and their presence in suspended soil particles. The uranium-238, uranium-235, and thorium-232 are considered to be primordial radionuclides; that is, they were formed during the formation of the solar system. As a general rule, it is reasonable to assume that most soils have not been affected by any processes that would have resulted in chemical separations of most of the natural decay-chain members over the past few million years. The exceptions to this are the radon isotopes, which are gases and can be readily released to the atmosphere. For background soils, all the members of the uranium-238 decay chain (Figure 4-1) would be expected to be in secular equilibrium with uranium-238 through radium-226. The loss of a fraction of the radon-222 would disrupt the equilibrium, so the relationship would no longer be valid

for later members of the chain. However, at depths of several yards, the rate of radon emanation is retarded, and equilibrium values are often seen for all members of the chain.

Radon gas is also in the uranium-235 and thorium decay chains (Figures 4-2 and 4-3). Half-lives of the radon-219 (uranium-235 chain) and radon-220 (thorium chain) are 3.96 seconds and 55.6 seconds, respectively. The radon gas tends to be adsorbed onto soil particles long enough for such short-lived radionuclides to decay to their solid products, except for soil very near the surface. Because of this, for background soil, secular equilibrium is likely to be observed between the initial uranium-235 or thorium-232 and all of its decay products.

Secular equilibrium relationships are not always observed for background natural radionuclides in groundwater and surface water. This is a consequence of the different solubilities of the chemical compounds containing the radionuclides. Natural radionuclides are introduced into water either through the suspension of soil particles or by dissolution of the radionuclide from the soil that is in contact with the water. As the radionuclides undergo decay, they are usually converted into new elements. Compounds of these elements will have chemical characteristics that differ from those of their parents, including solubility in water. The extent of these differences is dependent upon the chemical composition of the soil and the water, as well as the chemical behavior of the radionuclide compounds. This variable dissolution disrupts the decay equilibrium. Equilibrium can be expected in groundwater only for radionuclides in which the decay products have half-lives of the order of a few hours or less. An example of a disruption of equilibrium is seen in the ratios observed between uranium-238 and uranium-234. Thorium-234 is an intermediate decay product between these isotopes, so its compounds will have different solubilities from the uranium. If the uranium isotopes are in secular equilibrium, they have an activity ratio of 1. This is seen in background soil. In groundwater, the ratio has been observed to vary between 0.7 and 32 (EPA 1991).

Secular equilibrium is a very useful concept in evaluating potential contamination from members of the natural decay chains illustrated in Figure 4-1, 4-2, and 4-3. As was discussed above, background soil is often assumed to have all members of the decay chain in equilibrium. Whenever equilibrium is not observed, it is taken as an indication that the radionuclides are from a source other than natural background, or that some process has disrupted the equilibrium. Knowledge of the decay relationships can be used to design plans for analysis of samples. By examining the decay chains, it is possible to identify radionuclides that have such short half-lives that they would not be present in

samples unless their parent radionuclides were also present. An example of this is lead-214, part of the uranium decay series. With its half-life of only 26.8 minutes, it would not be found unless there were a source of radon-222 present within a few hours of analyzing the sample. In addition, since the radon has a half-life of only about 3.8 days, a source of its parent radium-226 would be needed to find either the radon or its products. There is, then, often no need to analyze samples for radon-220 or lead-214, since the presence of radium-226 indicates the presence of the others.

Sampling and analysis plans consider the decay-chain relationships. Radionuclides such as uranium-238, uranium-234, thorium-232, or radium-226 are analyzed separately, if there is a potential source for them, because they are sufficiently long-lived that they could be present without their parents. The short-lived radionuclides are not specifically analyzed unless they are easier to measure than their parents, in which case they are measured and the results reported as the parent activity.

4.1.5 Potential FEMP Contaminants

In nature, uranium consists of three principal isotopes: uranium-234 (0.0055 percent), uranium-235 (0.72 percent), and uranium-238 (99.2745 percent). These relative percentages are constant throughout the earth's crust with only minor variations resulting from unique local conditions. During the period in which it was operated as a production facility, one of the principal materials processed at the FEMP was uranium in which the percentages of uranium-235 varied from below the natural abundance (depleted) to 2.5 percent of the total uranium (2.5 percent enrichment). Most of this material was depleted to normal enrichment status and was received as a uranium compound or metal. Because of the long half-lives of the uranium isotopes and that of their early decay products, the only decay-chain members of concern from this material are the uranium isotopes themselves.

Some of the uranium processed at the FEMP was material that had been recycled from reactors used to produce nuclear weapons material. The recycled uranium contained trace amounts of fission products such as cesium-137 or technetium-99, transuranic radionuclides such as plutonium-239 or neptunium-237, and uranium-236. The fission products are formed when uranium-235 undergoes fission, and the transuranics are formed through a series of successive neutron captures by uranium-238, decay of the capture products, and subsequent decays. The uranium-236 is an activation product of uranium-235 and a decay product of plutonium-240. There is the possibility that, during the processing of recycled material, small quantities of fission products, uranium-236, and transuranics were released to the environment and may have contributed to contamination in the

vicinity of the FEMP. Because they are expected to be seen only in very low concentrations and many are difficult to measure at low levels, it is not practical to analyze samples for all possible fission products and transuranic nuclides. Instead, certain radionuclides that would serve as indicators of fission products of transuranics are chosen for analysis. The selections are based on the concentrations of the nuclides present in the uranium and their potential risk to human health. At the FEMP, samples have been analyzed for cesium-147, strontium-90, technetium-99, plutonium-238, plutonium-239/240, and neptunium-237.

Thorium was also processed at the FEMP, and the U.S. Department of Energy (DOE) used the FEMP for storage of its thorium inventory. Natural thorium is 100 percent thorium-232, which is the initial nuclide for the thorium decay series. Other than the thorium-232, none of the nuclides in the series have a very long half-life. This means that if any thorium had been released during operation of the FEMP, its decay products would also be present in concentrations approaching that of the thorium. Thorium-232, radium-228, and thorium-228 are the only members of the decay series that have half-lives long enough to be found in the environment without their parent radionuclides also being present.

Another source of radionuclides at the FEMP is the handling and storage of uranium-ore residues. These ores were processed to remove a portion of the uranium prior to shipment to the FEMP, but contain all of the long-lived decay products of uranium-238 and uranium-235. The long-lived radionuclides likely to be present in these residues are protactinium-231, actinium-227, thorium-230, radium-226, and lead-210.

4.1.6 Analyses of Radionuclides

Radionuclides can be identified and quantified by examining the radiation emitted during their decay. The analysis of radionuclides is referred to as radiochemistry. The specific technique used depends upon the type of radiation emitted. Radiochemical techniques can be very sensitive with very low detection limits. In most cases, samples being analyzed for radionuclides are first processed to remove the radionuclides from the sample matrix. The principal exception to this is gamma analysis. For soil, processing is usually done by leaching with strong acids, or a total dissolution by fusion with a salt or caustic. Biota samples and others containing combustible material are usually ashed in an oven, then treated as soil. Aqueous samples are typically evaporated to reduce the volume and

residues dissolved in acids. There are many specific sample processing techniques in use, but they are mostly variations of these.

Alpha Spectrometry

Alpha spectrometry is used for the analysis of alpha-emitting radionuclides of concern at the FEMP. These include the many isotopes of uranium, plutonium, thorium, polonium, and neptunium. Alpha particles are emitted with discrete energies that are characteristic of specific radionuclides. During the processing of samples, "tracers" are usually added to samples being analyzed for alphas. Tracers are radioactive isotopes that are not expected to be in the sample, but are the same element as those isotopes expected. As an example, when a sample is being analyzed for plutonium-239, the tracer is often plutonium-236. This tracer is used because these two isotopes are produced through different methods and are not usually found together.

Following processing, the elements of interest are isolated through a series of chemical separations, usually involving ion exchange or solvent extractions. Each element is removed from its final solution in a manner that deposits it on a small disk or filter paper with a minimum of solid material. These prepared samples are then placed in an alpha spectrometer, which has detectors and electronics to allow the alpha particles to be counted, their energies determined, and an alpha energy spectrum created. The alpha particles of each of an element's isotopes have unique energies, so an evaluation of the energy spectrum can be used to determine which isotopes are present and quantify them.

The quality of alpha spectrometry data is largely dependent upon the effectiveness of the chemical separations. While each radionuclide has a set of alphas with a unique energy distribution, the energies may be so close to one another that they are difficult and often impossible to resolve. For this reason, it is important to prepare a final sample that contains only one element; a spectrum with alphas from many elements would be too complex to be useful. This limits the number of energies that may be present, and also removes most of the solid material. Excess solid material can severely degrade an alpha spectrum and make it difficult to resolve energies. Poor resolution of the energies can cause misidentification of isotopes, and errors in their quantification.

Incomplete separation of the elements can lead to inaccurate analyses even if only a small amount of one radionuclide is present in a final sample for another element. This could occur if the "wrong" radionuclide had an energy nearly the same as one of those that was expected. As an example, if a

sample being analyzed for plutonium-238 also has thorium-228 present, and the plutonium and thorium are not properly separated, the thorium-228 may be misidentified as plutonium-238. The confusion is possible because the alpha energies of the two isotopes are very close to one another and are difficult to resolve. This misidentification could lead to a false conclusion that plutonium-238 is present in a sample.

Even when the chemical separations are effective, there are some interferences that cannot be resolved. Some elements have isotopes with alpha energies so close to one another that alpha spectrometry cannot distinguish between them. In those cases, data are reported as the combination of two isotopes. For the FEMP data, this is seen for uranium-235/236 and plutonium-239/240. This type of designation simply means that alphas were observed at the energies characteristic of both of the isotopes. Other information must be used to determine whether the samples are likely to contain both isotopes or only one of them. Such information might include knowledge of the source of the isotopes, or alternative analyses. One alternative type of analysis is mass spectrometry. This method is not routinely used for environmental media because it is costly and time consuming. However, it is often used when it is necessary to know whether one of the interfering isotopes is present.

Gamma Spectrometry

Many radionuclides emit gamma rays immediately after undergoing decay by a primary decay mode, such as alpha or beta emission. Gamma spectrometry is a powerful analytical tool for such radionuclides. Each gamma emitter has a unique energy-abundance distribution of gamma rays that can be used to identify and quantify radionuclides. Even though many gamma rays have energies very close to one another, they can usually be resolved, and a sample containing a large number of radionuclides can be successfully analyzed. For some samples, processing is required to concentrate the radionuclides of interest into as small a volume as possible. This improves the limit of detection for the analysis. For most samples, though, the only processing is that required for homogeneity, such as crushing and blending soil. The sample is transferred to a closed container and placed in a gamma spectrometer, consisting of a detector and electronics capable of detecting and measuring the energy or energies of gamma rays and creating an energy spectrum. Computer software evaluates the spectra to identify and quantify the gamma-emitting radionuclides.

Analysis for Beta Emitters

Most beta emitters have a sufficient number of gamma rays to be analyzed by gamma spectrometry. Unfortunately, there are a few that do not. Betas are not emitted with discrete energies, so it is not possible to use techniques similar to alpha or gamma spectrometry except in some special cases. Three radionuclides of concern to the FEMP that require beta analysis are technetium-99, lead-210, and strontium-90. Radium-228 may also be analyzed using a beta technique. The samples are processed by separation and purification steps and counted for beta activity. The solution from the processing is then subjected to a series of chemical steps designed to remove all radionuclides except those of interest. The chemical separations may involve precipitations, solvent extractions, and ion exchange, or a combination of these. Once the sample is prepared, it is placed in a beta counter capable of detecting beta particles. The number of betas detected is related to the total activity in the sample. Accurate results are dependent upon the removal of all extraneous radionuclides from the final sample. This is necessary because the technique cannot distinguish between betas from different radionuclides. The presence of activity from other radionuclides could lead to an inaccurately high analytical result.

Total Uranium Analysis

In addition to alpha spectrometry, samples can be analyzed for total uranium content. It is possible to calculate the total uranium from isotopic data, but techniques based on chemical properties can also be used. The total uranium techniques used for FEMP samples include fluorometry and kinetic phosphorescence analysis (KPA). These techniques are similar in that both rely upon the use of an external source of high-energy light to excite uranium atoms, causing them to emit light of a characteristic wavelength. For both types of analysis, the uranium is separated from the processed samples. For fluorometry, the separated uranium is mixed with a fluoride salt to form a small pellet. For KPA, following its separation, the uranium is mixed with a solution containing a proprietary complexing agent. The pellet of solution is irradiated with high-energy light, and the light emitted is detected. The quantity of light is related to the amount of uranium in the solution or the pellet.

The results of total uranium analyses should agree with total uranium values calculated from alpha spectrometry data. Unfortunately, this is not always the case. Both total and isotopic uranium techniques are subject to interferences and errors that cannot be accurately characterized for every sample. When discrepancies are noted, it is often not possible to determine which results are valid. In such cases, the data may be rejected as unusable, or identified as being usable with qualification.

4.2 BACKGROUND DATA

This section summarizes background data for all media associated with Operable Unit 5. These background data provide points of comparison that aid in understanding the significance of data collected during the RI. The background data can be used to identify constituents present in Operable Unit 5 at levels statistically elevated above those levels which occur naturally in soil, surface water, sediment, and groundwater.

In general, the 95th percentile value calculated from the background concentration data is used in this section for comparison of contaminant concentrations. The measured levels of constituents detected in the Operable Unit 5 media are compared to these calculated values to identify the waste-related contaminants that occur at levels greater than would occur naturally. In some cases, because of a small number of samples, the maximum detected value of the background data is used to identify such contaminants.

The 95th percentile value is often used in statistical analysis (e.g., the 95th percentile test) to determine whether any sample measurement from a study area exceeds background. This value indicates that 95 percent of the background data set is less than or equal to that value. The use of the 95th percentile background value does not constitute a formal, statistical comparison to background (e.g., the T-test or the Wilcoxin Rank Sum Test), but is provided only as a point of reference. Other calculated values are used in Section 6.0 as reference values for assessing incremental risk due to contamination at the site. Further discussion of statistical methods used in this RI and the calculation of the 95th percentile background value is included in Appendix A.II.0.

Tables 4-1 through 4-8 present the background values of radiological and inorganic constituents in surface water and sediment, surface soil, subsurface soil, perched groundwater, and Great Miami Aquifer groundwater. The data used for surface and subsurface soils were derived from the 0- to 6-inch and the 36- to 54-inch sample set, respectively, in the Comprehensive Environmental Response, Compensation, and Liability Act/Resource Conservation and Recovery Act (CERCLA/RCRA) Background Soil Study (DOE 1993a). This study is summarized in Section 2.5.5.2. The data used for groundwater and surface water were taken from the Characterization of Background Water Quality for Streams and Groundwater (DOE 1994a).

This report compiles and evaluates data available through 1993, regarding background surface water and groundwater quality near the FEMP. One sampling point (W5) was selected for background water quality in Paddys Run (see Figure 2-16 for location). Background values for radiological inorganic and general water quality constituents are based on two sampling events in 1993. No organic background data are available. It has been conservatively assumed that the presence of any organics in Paddys Run is a result of FEMP operations.

One sampling point (W1) was selected for background water quality in the Great Miami River (see Figure 2-16 for location). Background values for radiological, inorganic, and general water quality constituents are based on five samples collected in 1988, 1989, and 1993. Indicator analyses for organic constituents (phenols), total organic carbon (TOC), total organic halogens (TOX), and total organic nitrogen (TON) were conducted but the identity of the compounds causing detects is unknown. It has also been conservatively assumed that the presence of any organics in the Great Miami River is a result of FEMP operations.

Twenty-three wells have been selected for background water quality in the Great Miami Aquifer (DOE 1994a). Four to 120 analyses were conducted for most constituents, except cesium-137, ruthenium-106, and uranium-235), with generally more analyses for most of the organics. Twenty-four samples were collected and analyzed for organics. Most of the detections are estimated values of common laboratory contaminants.

Five wells have been selected for background water quality in the glacial overburden (DOE 1994a). The majority of constituents, except cesium-137, ruthenium-106, and uranium-235, were analyzed between 10 and 26 times, although the number of validated values ranged from one to four.

It should be noted that four transuranic/fission products (i.e., synthetic radionuclides) were examined during the background soil study: cesium-137, ruthenium-106, strontium-90, and technetium-99. The presence of these isotopes in the background soil study area could only be the result of fallout from atmospheric releases of radiation, such as that resulting from weapons testing. Therefore, these radionuclides would be expected at detectable levels only in surface soil. In accordance with expectations, cesium-137 was detected only in the surface-soil sample set, as evidenced by the summary statistics provided. Strontium-90 was detected only once in the 81 soil samples collected. In all other cases, the surface soil background concentrations of the fission products were below levels

of detection used in the study (lower than RI/FS levels of detection) and were assumed to have concentrations of zero.

4.3 SOURCES

4.3.1 General Source Characterization

Contamination in Operable Unit 5 was characterized under the RI/FS sampling programs and other studies, as listed and described in Section 2.0.

This section provides a summary of the potential sources and associated expected contaminants in Operable Unit 5 as well as an overview of the approach that was used to characterize the contamination. General information is also provided regarding the history of the FEMP refining process as it relates to potential contamination. Further details regarding the refining process are provided in Section 1.0.

4.3.2 Historical Evidence of Contaminants

Section 1.0 of this report details the operational history of the FEMP. The site history was reviewed to develop an understanding of the origin, distribution, and identity of potential contaminants in Operable Unit 5.

Contamination within Operable Unit 5 media originated during processing and waste management operations at the FEMP. These operations resulted in releases of contaminants to the environment through routine releases/discharges, such as permitted air emissions, wastewater discharge, and storm-water discharges, as well as nonroutine events, such as spills and leaks. Some of these releases have resulted in the creation of secondary sources of contamination and release, which are the focus of Operable Unit 5.

The FEMP refining process was well documented in various reports and publications. The records provide an indication of the distribution of radiological and inorganic chemical constituents. Table 4-9 summarizes the potential sources of contamination and the expected contaminants applicable to Operable Unit 5, and Figure 4-4 shows the location of these potential sources within the FEMP site.

During its 38 years of operation, the FEMP produced more than 362,000 metric tons of uranium metal. The feed materials for this production primarily came from the following three sources:

- High tonnages of purified uranium in solid (uranium metal, black oxide - uranium oxide [U_3O_8]), brown oxide - uranium dioxide ([UO_2], orange oxide - uranium trioxide [UO_3], and green salt - uranium tetrafluoride [UF^4]), semi-solid (uranium hexafluoride [UF_5], and liquid (uranyl) nitrate [$UO_2(NO_3)_2$ solution) forms.

- Intermediate tonnages of uranium ores and ore concentrates containing primarily the isotopes of uranium and its progeny (thorium-230 and radium-226) as well as a wide variety of impurities (see Table 4-9 discussion of inorganic constituents below).

- Relatively low volumes of returned uranium residues and scraps containing fission products (strontium-90, technetium-99, ruthenium-106 and cesium-137) and activation products (neptunium-237, plutonium-238, and plutonium-239/240).

The FEMP also produced 369 metric tons of thorium-232 in the late 1960s and early 1970s. The feed materials for this production were thorium compounds and metal containing the progeny of thorium-232 (radium-228 and thorium-228).

Radiological Constituents

Consistent with the historical purpose of the FEMP, the predominant radiological contaminant in Operable Unit 5 is expected to be uranium (the FEMP processed more than 362,000,000 kilograms of this metal during its 38-year operation) and its more stable progeny (radium-226 and thorium-230). Thorium-232 was also refined at the FEMP; therefore, this radionuclide and its more stable progeny (radium-228 and thorium-228) are also expected. Thorium-230 was also an impurity in uranium ores and ore concentrates processed at the FEMP and a constituent of wastes from other DOE facilities that were disposed of at the FEMP. Several fission and activation by-products are also expected to be present, since the FEMP processed uranium that had been recycled from other DOE facilities.

Inorganic Chemical Constituents

Inorganic chemicals were integral to the manufacturing process at the FEMP. The predominant inorganic chemicals used in the uranium refining process at the FEMP were nitric acid, hydrochloric acid, hydrofluoric acid, magnesium metal, calcium hydroxide (lime), and calcium-magnesium carbonate (dolomite). Magnesium fluoride was also a major waste of the refining process. In addition, the ore concentrates processed at the FEMP contained elevated concentrations (greater than 1 percent) of impurities such as calcium, iron, magnesium, phosphorus (as phosphorous pentoxide -

P_2O_5), sodium, silicon (as silicon dioxide, SiO_2), and sulfur (as sulfate, SO_4), as well as minor concentrations of several other impurities, including arsenic, carbon (as carbonate, CO_3), molybdenum, phosphorus (as phosphate, PO_4), thorium, and vanadium (as vanadium pentoxide, V_2O_5).

Organic Chemical Constituents

Several historical uses of organic materials have been identified. A mixture of kerosene and tributyl phosphate was used as a solvent for the extraction of uranyl nitrate following the nitration of uranium ores and recoverable wastes. Other organic materials include oils (lubricating, cutting, cooling, and water-soluble), polychlorinated biphneyls (PCBs) from lubricants and electrical equipment, pesticides and herbicides, and solvents and cleaning fluids. In general, volatile organic compounds (VOCs) were used in support functions, such as maintenance activities, or were progeny of parent chemicals used at the site. Because many of the oils and oily materials were burned at the FEMP, chlorinated dibenzo p-dioxins/dibenzofurans (CDDs/CDFs), PAHs, and phenols could have been produced.

4.4 AIR AND DIRECT RADIATION

Routine airborne radon, airborne particulate, and direct radiation monitoring is conducted at the FEMP as part of the Environmental Monitoring Program. More details are available in the annual FEMP environmental monitoring reports.

4.4.1 Airborne Radon

Figure 4-5 shows the average annual radon levels for 21 fence-line locations (1-7 and A-P), two background locations (15-16), and nine other locations around the FEMP (see Figure 2-42) from 1988 through 1993. Each location has either two, three, or six alpha-track-type radon detectors for measuring radon concentrations in the air over long periods of time. The detectors are changed each calendar quarter and sent to the supplier for analysis.

The average quarterly radon level at each location was computed from the results of all detectors at that location. The annual average radon level at each location was then calculated from the quarterly averages. The average radon level at the fence line for each year was as follows:

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Year	Average Radon Level at Fence Line (pCi/L)
1988	1.16
1989	0.74
1990	0.74
1991	0.90
1992	0.57
1993	0.96

The maximum fence line radon level recorded during this period was 2.9 pCi/L in 1988 at location K, along the western perimeter immediately west of the southwest corner of the former production area. Since production ceased in 1989, the highest fence line radon level recorded was 1.7 in 1993 at location P, at the northwest corner of the site. None of the observed levels exceeded either the DOE guideline of 3.0 pCi/L above background (DOE Order 5400.5) or the EPA guidance of 4.0 pCi/L for indoor radon levels (EPA 1992).

4.4.2 Air Particulates

As indicated in Section 1.3.1.1, the end of the FEMP's production mission has resulted in a measurable reduction in the concentration of air particulates. At present, the largest sources of airborne emissions are the boiler plant cooling tower mists, fugitive dust from the waste pit area, and locations where environmental cleanup activities are under way.

The FEMP operates nine on-site air monitoring stations to measure the concentration of total suspended particulates (TSP), uranium, and other airborne radionuclides (Figure 2-41). Air monitoring stations 1 through 7 are located along the FEMP perimeter fence.

Figure 4-6 shows the average annual concentrations of airborne uranium for the years 1988 through 1993. Stations 8 and 9 recorded notably higher values than the other stations. These stations are located near the production area, in the prevailing wind direction (to the northeast). Consequently, higher concentrations of airborne uranium are anticipated at these locations. All of the average concentrations at the fence line are 2 to 3 orders of magnitude less than the DOE-Derived Concentration Guide of 1.0×10^{-13} μCi/ml ($100{,}000 \times 10^{-6}$ pCi/m^3 for comparison with data on

Figure 4-6) for natural uranium (DOE Order 5400.5 - Clearance Class Y). Even the highest average (at location 9 in 1991) was only 2 percent of the standard.

4.4.3 Direct Radiation

The FEMP periodically measures doses from direct radiation at a total of 32 locations. These measurements are normally made on a quarterly basis using thermoluminescent dosimeters (TLDs). Figure 4-7 shows the average dose for 14 representative locations measured in 1988 through 1993: 10 on-property locations (1 through 9) and 4 off-property locations (10 through 13).

The maximum incremental annual dose from all sources to the person living closest to the K-65 silos was estimated to be as follows (FEMP Environmental Monitoring Reports):

Year	Radiation Dose (m/Rem)
1988	19.3
1989	14.9
1990	10.0
1991	9.1
1992	1.0
1993	1.0

The reduction from 1991 to 1992 is the result of a bentonite layer added to the K-65 silos in late 1991, which effectively shields and reduces the levels of direct radiation from the silos. For comparison, the annual dose due to background radiation is approximately 100 mrem per year (excluding radon), and DOE's limit for exposure to all sources and all pathways is 100 mrem per year (DOE Order 5400.5).

4.5 SURFACE WATER AND SEDIMENT

This section presents a summary-level interpretation of total uranium data collected during 1993 for the Operable Unit 5 RI to describe the nature and extent of surface water and sediment contamination at the FEMP. The 1993 data are used because this is the most extensive data collected over a short time interval and the 1993 data most accurately represent current conditions. The two primary focuses of this section are Paddys Run and the uncontrolled drainages that flow into the creek

(Section 4.5.2) and the Great Miami River (Section 4.5.3). Appendix C provides a detailed discussion of the analytical data that were collected for several sampling programs since 1986.

For those instances where 1993 RI data are not available, the discussion in Section 4.5 includes surface water and sediment data collected from 1986 through 1993 to support the ongoing Environmental Monitoring (EM) Program. The EM surface water samples were collected weekly during those years. Sediment sampling, which was conducted annually, included the entire reach of the storm sewer outfall ditch (SSOD) and most of the length of Paddys Run. The RI/FS surface water and sediment sampling program was designed to build on the existing EM data.

It is important to note that several projects designed to control surface water runoff along the perimeter of the production area and the perimeter of the waste pit area have been completed since the RI/FS sampling began. Comparisons of data collected from sampling locations in these areas during various years must consider the date a sample was collected relative to the completion date for the projects and removal actions. (Surface water and sediment sampling for the controlled areas are discussed in Appendix C.)

The details of past and current wastewater and storm water practices which were presented in Section 1.3.1 help explain why projects were completed to control storm water runoff in certain areas of the FEMP. Based on data collected during the early sampling rounds of the RI/FS, the Best Management Practices sampling, and the EM Program, the FEMP began a phased, long-term strategy to better control storm water runoff. The strategy focused on collecting the most contaminated runoff first, then identifying remaining areas where surface water runoff contained high levels of contaminants. Section 1.3.4 includes information and completion dates on removal actions and other contamination abatement measures that reduced uncontrolled surface water runoff. Even with the completion of these projects, storm water runoff from much of the nonprocess areas of the FEMP remains uncontrolled.

Additional information is provided in Section 3.3 on surface water hydrology. Specific figures of relevance include 3-8, which illustrates areas of controlled storm water runoff at the FEMP, and Figure 3-9, which shows the locations of the uncontrolled drainages at the FEMP. Evaluating the nature and extent of surface water and sediment contamination in both Paddys Run and the SSOD is important because both streams lose water to the Great Miami Aquifer, and are major pathways by

which contaminants may reach the aquifer (see Figure 3-10). The relation of surface water at the FEMP to the Great Miami Aquifer is described in Section 3.3.2.

Section 5 also uses this information on surface water hydrology in the fate and transport discussion. In particular, infiltration modeling is discussed in Section 5.3.2. A figure showing the approximate size and location of the drainage areas used in the model is included in Section 4.5 because discussions of each drainage area reference this figure (Figure 4-8). For use in the model, the estimated total annual runoff from the areas shown on this figure is 2.267 x 10^7 ft^3/yr.

Section 4.5.2 presents information on the drainage areas and ditches that remain uncontrolled and flow into Paddys Run, concluding with a discussion of Paddys Run itself. The primary uncontrolled drainages are the north drainage ditch, which is just north of the railroad tracks that are parallel to the north boundary of the waste pit area; the pilot plant drainage ditch, which originates just west of the pilot plant and flows west into Paddys Run; and the south drainages of the FEMP, including the SSOD and its tributaries.

Section 4.5.3 presents information primarily about the Great Miami River and includes a brief discussion of the northeast drainage ditch which flows to the river. In addition, contaminants in the FEMP effluent are also discussed because of their potential impact on the river.

4.5.1 Data Presentation for Surface Water and Sediment

An examination of the Operable Unit 5 data set indicates that total uranium is the primary contaminant in surface water and sediment at the FEMP. Other contaminants are occasionally detected at concentrations greater than five times their background values, and volatiles and semivolatiles have also been detected. These occurrences are more common in sediment than in surface water. Section 4.2 presents information on the determination of background values.

Appendix C includes tables of descriptive statistics of all RI surface water and sediment data. Parameters analyzed for included radionuclides, inorganics, volatiles, semivolatiles, pesticides, and general water quality. These data, which summarize the range and extent of occurrence for each parameter, are grouped according to drainage area, year, and whether the data are filtered (45-micron) or unfiltered. Summary statistics for EM data from 1986 through 1993 are also included.

Appendix G contains tabulated analytical results for all surface water and sediment samples collected as part of the RI/FS investigation.

The discussion in Section 4.5 focuses on total uranium because it is the primary contaminant in surface water and sediment in the various study areas, as indicated in Tables 4-10, 4-11, 4-12, and 4-13. These tables provide an overview of the parameters that were found in surface water or sediment at maximum concentrations (for either filtered or unfiltered samples) greater than twice background but less than five times background, or greater than five times background. In some instances, a background value does not exist for a specific parameter or location, so other values were substituted. For example, a background value for filtered thorium-232 in Paddys Run did not exist, so the background value for thorium-232 in the Great Miami River was substituted. The same methodology was used when evaluating contaminant concentrations in sediment. Consequently, if a background value in sediment did not exist for either Paddys Run or the Great Miami River, the background concentration for soil was used.

Although the RI/FS samples for surface water included both unfiltered and filtered portions, unfiltered data are discussed in Section 4.5. The unfiltered data were used because unfiltered samples generally contain a significant quantity of fine silt- or clay-size material or sediment relative to filtered samples. The sediment in the unfiltered samples has inorganics and radionuclides within its matrix or adhered to its edges, thus generally resulting in higher concentrations of contaminants. This difference is more noticeable for metals on the inorganic analyte list than for radionuclides. Furthermore, because the EM data are unfiltered, the comparison of data between the RI and EM data will be more appropriate using unfiltered RI data.

Total uranium data collected for the RI during 1993, as presented on the maps in this section and discussed fully in Section 4.5 and Appendix C, represent the maximum unfiltered concentration. The EM data on the maps represent the upper confidence limit (UCL) on the median for 1993 total uranium. The discussion includes EM data from previous years, when appropriate. A contaminant other than total uranium, if detected above background at several locations in a drainage area, or detected at a maximum concentration greater than five times background, is discussed in Section 4.5 as well as in Appendix C.

Even though the EM data have not been validated to the same level as the RI/FS data, they are presented in this section to illustrate long-term trends of total uranium concentrations in surface water and sediment. The EM sampling program for surface water and sediment is discussed in Section 2.2.4.

4.5.2 Paddys Run and its Uncontrolled FEMP Tributary Drainages

Paddys Run is an intermittent stream that flows south through the FEMP near its west boundary, and empties into the Great Miami River approximately 1.5 miles south of the FEMP.

All uncontrolled drainages at the FEMP — except for the northeast drainage ditch, which flows to the Great Miami River — empty into Paddys Run or one of its tributaries. These uncontrolled drainage ditches continue to be potential pathways for contaminants to reach Paddys Run, the Great Miami River, or the Great Miami Aquifer.

Based on an examination of 1993 RI/FS data, the pilot plant drainage ditch had the highest concentration of total uranium for surface water in the uncontrolled drainages. Except for the samples collected near the inactive and active flyash piles (which had a maximum total uranium concentration of 840 μg/L), concentrations in all other uncontrolled drainages ranged from approximately 3 to 60 μg/L. The following paragraphs briefly describe the extent of the total uranium contamination detected in the uncontrolled drainage ditches leading to Paddys Run; detailed information on the extent of contamination for all parameters is provided in Appendix C.

4.5.2.1 The North Drainage Ditch

The north drainage ditch receives surface water runoff from an east-west strip north of the waste pit area and the former production area and drains to Paddys Run at a point immediately north of the railroad track. The north drainage ditch receives storm water runoff from Area 560, as shown in Figure 4-8. Area 560 includes a wood lot, jurisdictional wetland, and pine plantation. Potential sources of contamination located within the drainage area are the fire training area and the Solid Waste Landfill. Because much of the drainage area is in the predominant downwind direction from the waste pits and the production area and subject to deposition of airborne contaminants, particulates could be carried by surface water runoff into the drainage ditches. Leachate from deposited contaminants could also be found in the surface water.

The Operable Unit 2 RI investigation in 1993 sampled surface water and sediment along the drainage ditch at the locations shown in Figure 4-9 to determine whether suspected contaminant releases occurred from the Solid Waste Landfill.

As the surface water data included on Figure 4-9 show, the total uranium concentrations upstream and downstream of the Solid Waste Landfill are nearly the same (46.1 and 59.3 μg/L, respectively). The total uranium concentration in the downstream sediment sample was higher than in the upstream sample; both values were greater than five times background.

Operable Unit 5 collected a sediment sample in December 1992 as part of the Operable Unit 5 Work Plan Addendum. The total uranium concentration was 30.9 mg/kg. As shown in Table 4-13, several metals were detected at concentrations greater than five times background. Volatiles and semivolatiles were also detected in the sediment at FT-1, indicating that the fire training area could be releasing contaminants into the surface water.

4.5.2.2 The Pilot Plant Drainage Ditch

Surface water in the pilot plant drainage ditch had the highest concentration of total uranium of all uncontrolled drainage ditches located on the FEMP. This ditch originates approximately 400 feet west of the pilot plant and flows west into Paddys Run (Figure 4-10). Area 570, as shown in Figure 4-8, is drained by this ditch. At the head of the pilot plant drainage ditch is a former storm sewer pipe that, even though plugged at its entrance, discharges a continuous trickle flow. This discharge is a likely source of uranium contamination in the ditch. (See Section 1.3.4.10 for an explanation of the project to reduce the flow in the former storm sewer pipe by installing an interceptor sump.) The drainage ditch also collects surface water runoff from the open fields west of the pilot plant. In addition, a drain pipe empties storm water runoff, diverted from the eastern waste storage area as part of Removal Action No. 2 into the pilot plant drainage ditch.

In 1993, surface water samples were collected from three locations along the ditch, and one sample was collected from the drain pipe installed as part of Removal Action 2. Although sediment samples were not collected in 1993, sediment data from previous investigations are discussed in Appendix C.

Each of the three RI sampling locations had high concentrations of total uranium, with the highest concentration (2890 μg/L) detected at the head of the ditch. The RI data from the single sampling

event compare favorably with the EM data; samples were collected weekly for the EM Program when water was flowing in the ditch. The total uranium concentration at RI location PP-DD-01 was 703 μg/L, while the 34 EM samples collected during 1993 ranged from 17 to 1600 μg/L, and the UCL on the median was 580 μg/L. To further support the RI data, the 1991 and 1992 EM data had UCLs on the median of 630 and 730 μg/L, respectively.

There was one positive detection of plutonium-239/240 at a concentration of 0.81 pCi/L, which is greater than five times background. The sample was collected at end of the drain pipe, location PP-DD-02.

It is evident from the data that the surface water in the pilot plant drainage ditch continues to carry high concentrations of total uranium to Paddys Run. Water samples were also collected in 1993 from several seeps located in the pilot plant drainage ditch. The total uranium concentrations ranged from approximately 7 to 34 μg/L, which is much lower than the concentrations of total uranium found in the surface water in the ditch. Therefore the source of the contamination is near the head of the ditch.

4.5.2.3 South Drainage Area

Several drainages in the south area of the FEMP were sampled during 1993 by Operable Unit 2. The drainages are adjacent to or leading from the inactive flyash pile, the active flyash pile, and the South Field. For the Operable Unit 5 RI, only data from the Operable Unit 2 sampling points located on the downstream boundary between Operable Unit 2 and Operable Unit 5 are discussed and evaluated. The Operable Unit 2 RI includes a complete description and explanation of the nature and extent of surface water and sediment data for these source areas.

In general, the drainage ditches leading from Operable Unit 2 source areas mentioned above collect runoff from Areas 575 and 580, as shown in Figure 4-8. The storm sewer outfall ditch and its tributaries, which were not sampled by Operable Unit 2, drain Areas 581 and 582 and are included in this section. These drainage ditches are shown in Figure 4-11.

Because there are no perennial sources of surface water associated with the drainages in this area, surface water samples were collected after rain events. Some drainage ditches carry water for a few days following a significant rainfall.

Surface water samples were collected from the drainage ditch immediately west of the inactive flyash pile. As indicated in Figure 4-11, the sampling location discussed for Operable Unit 5 is IFP-SW-02, which had a total uranium concentration of 820 μg/L. The Operable Unit 2 RI stated that field observations indicate that recharge to the regional aquifer occurs by surface water from this drainage.

Furthermore, the Operable Unit 2 RI states that surface water samples were collected from the ditch that originates at the northeast corner of the South Field and flows south along its boundary. Sampling locations SF-SW-01 and -02 had total uranium concentrations of 340 and 487 μg/L, respectively. According to Operable Unit 2, the observed drainage represents perched groundwater at the east side of the South Field because these values are in approximate agreement with samples collected from the glacial overburden monitoring Well 1941 (388 to 547 μg/L) and Well 1942 (320 μg/L).

The Operable Unit 2 RI also states that a surface water sample was collected at location AFP-SW-02 in the drainage ditch leading from the active flyash pile. As a result of recent changes which were made to control surface water flow in the area, the surface water runoff is rapid at this location. The total uranium concentration at this location was 4.18 μg/L.

One drainage ditch not sampled in 1993 was the southwest drainage ditch. As described in Section 3.3.1.2, this ditch has eroded a gully that runs from a service road into Paddys Run, about halfway between the pilot plant drainage ditch and the inactive flyash pile. Total uranium concentrations in the two samples collected in 1989 were significantly above background (23 and 138 μg/L).

As shown in Figure 4-11, total uranium concentrations in the sediment samples collected in the drainages near the active flyash pile in 1993 ranged from 14.8 to 30.1 mg/kg. The summary statistics for the samples also showed multiple detections of all radionuclides except the plutonium isotopes (which were detected in one sample) and technetium-99 and ruthenium-106, which were not detected in any samples.

In addition, all metals analyzed were detected in sediment at concentrations above background with the exception of antimony and cadmium. Semivolatiles and toluene were also detected in several samples. These are discussed in greater detail in Appendix C.

The storm sewer outfall ditch, as described in Section 3.3, is a major drainage feature in the south area of the FEMP. During most of the FEMP's operation, the SSOD conveyed contaminated surface water runoff during heavy rainfall events from the production area to Paddys Run. Currently, the upper reach of the SSOD carries water only from the immediate area that it drains unless the SWRB overflows. The lower reaches of the SSOD continue to carry runoff from the east and south areas of the FEMP as well as from the agricultural land south of the property. The total drainage for the SSOD includes Areas 580, 581, and 582, as shown in Figure 4-8.

Surface water and sediment samples were collected at two locations along the SSOD in 1993 for the Operable Unit 5 RI (Figure 4-11). The first location was just below the SWRB along the upper reach of the SSOD. The total uranium concentration in the surface water was 3.2 μg/L. The second 1993 sampling location was near the confluence of the SSOD with Paddys Run, and the total uranium concentration was 34.7 μg/L. This indicates that total uranium is entering the lower reach of the SSOD. Possible sources include runoff from agricultural land east and south of the SSOD. The east tributary to the SSOD collects runoff from Area 581, which includes the former trap firing range (lead contamination of soil) and the sewage treatment plant and the former incinerator.

The sediment sample collected from the lower reach of the storm sewer outfall ditch for the 1993 RI sampling program had a total uranium concentration of 3.3 mg/kg, which is slightly above the background value determined for the RI samples (3 mg/kg). The sample collected at location ASIT-001 in May 1993 had a total uranium concentration of 11 mg/kg, which is about four times background.

Under the FEMP EM Program, sediment samples have been collected in the SSOD since 1977. As described in Section 2.2.4, the EM Program collects samples at 100-meter intervals along the SSOD, ending near the SWRB (Figure 4-12). The data from the eight samples collected in 1993 indicate that total uranium is present in elevated concentrations ranging from 2.1 to 16.1 mg/kg along the length of the SSOD. The EM Program collected four sediment samples near the W-5 EM surface water sampling location on Paddys Run north of the FEMP to determine an average background concentration for total uranium in sediment for the EM Program (1.1 mg/kg).

4.5.2.4 East Drainage Area

The eastern tributaries to the SSOD may be carrying contaminated surface water runoff from the area near the sewage treatment plant and the former incinerator. However, limited data exist to characterize the eastern tributaries to the SSOD. Two surface water samples were collected in May 1993 from drainage swales located immediately west of the sewage treatment plant (Figure 4-13). Contaminants from the sewage treatment plant and former incinerator, as well as from airborne releases, may be present in the runoff. Removal Action No. 14, described in Section 1.3.4.4 was being conducted at the time of the sampling to remove soil with high concentrations of uranium near the sewage treatment plant. The highest concentrations of total uranium in the surface soil in this area prior to the removal action were approximately 5000 mg/kg. Additional surface water samples have not been collected since the removal action was completed.

Total uranium concentrations in the two surface water samples near the sewage treatment plant were 37.3 and 55.6 μg/L; the maximum total uranium concentration in the sediment was 11.3 mg/kg. No other surface water data were collected along this tributary or the SSOD until near its confluence with Paddys Run. Therefore, it is not possible to evaluate the impact of this surface water runoff on Paddys Run.

4.5.2.5 Paddys Run

To determine possible impacts to Paddys Run by contaminants carried by surface water in the uncontrolled drainages, surface water and sediment samples were collected in 1993 for the RI/FS. The samples were collected along the creek from just south of the pilot plant drainage ditch to near State Route 128, which is just north of the confluence of Paddys Run with the Great Miami River (locations SWS-1 through SWS-9, as shown in Figure 4-14). The following paragraphs examine the overall impact to Paddys Run from the uncontrolled runoff.

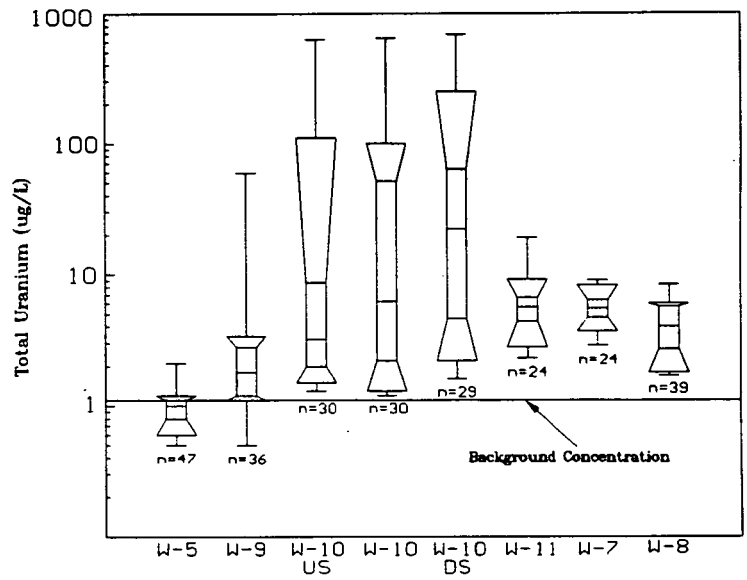
As presented in Section 4.2, the background value for total uranium in surface water for Paddys Run is 1.1 μg/L. By comparing total uranium concentrations along Paddys Run to the background value, impacts from the uncontrolled runoff can be assessed.

Because the first RI/FS sampling location in 1993 in Paddys Run is below the pilot plant drainage ditch, EM data collected at W-9 (the railroad bridge over Paddys Run) was used to evaluate any impact to Paddys Run from the north drainage ditch. The W-9 sample is collected downstream of the

north drainage ditch (Figure 4-9). In general, the total uranium data at W-9 reflect the contribution from the north drainage ditch, although some contamination could enter the creek through direct runoff.

The 8 years of EM data at W-9 show that the total uranium concentration is consistently about twice the background value for Paddys Run. For the 36 weekly samples collected during 1993, the UCL on the median was 2.3 μg/L. From the data, it appears that the overall impact on this section of Paddys Run from the north drainage ditch is minimal. The accompanying chart shows the 1993 concentration of total uranium for EM locations along Paddys Run.

BOX PLOT OF TOTAL URANIUM DATA, PADDYS RUN, 1993



An examination of the EM data collected in Paddys Run near the pilot plant drainage ditch does indicate that the ditch is adversely affecting Paddys Run. This seems to be the case even though the total uranium concentration of 3.6 μg/L for the 1993 RI surface water sample collected at location SWS-1 indicates little impact to the creek from the pilot plant drainage ditch.

The EM sampling location (W-10) is situated just north of the confluence of the pilot plant drainage ditch and Paddys Run, which is farther north than SWS-1 (Figure 4-10). The UCL on the median for the total uranium concentration at W-10 is 45 μg/L. Seventeen of the thirty samples collected during 1993 at W-10 did have total uranium concentrations below 10 μg/L, which is consistent with the RI

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data collected in 1993 at SWS-1. However, eight of the EM samples had total uranium concentrations above 50 μg/L, and the maximum value was 640 μg/L. This type of variability has been evident since sampling began at this location in mid-1985.

To determine whether the cause of the variability was the result of an incomplete mixing of the pilot plant drainage ditch water with Paddys Run, EM added a sampling location upstream of W-10 and the pilot plant drainage ditch. Since previous sampling of the pilot plant drainage ditch showed high concentrations of total uranium in the surface water, it was reasonable to expect that the W-10 data were influenced by the total uranium in the pilot plant drainage ditch surface water. A new sampling location (W-10 upstream [W-10 US]) was established approximately 15 feet upstream of the pilot plant drainage ditch to ensure that the sample collected at this location would not be impacted by contaminants from the ditch. At the same time, EM established a sampling location in the pilot plant drainage ditch, and sampling began in January 1991. Both locations are sampled on the same schedule and frequency as the other EM surface water locations.

In most cases, the data from W-10 US are similar to those from W-10: 22 of the 30 samples had total uranium concentrations less than 10 μg/L. Six samples had total uranium concentrations above 50 μg/L, and the maximum concentration was 630 μg/L in 1993 and approximately 1200 μg/L in both 1991 and 1992. The exception is the UCL on the median, which was 6.1 μg/L. This indicates that uranium may occasionally enter Paddys Run somewhere above the pilot plant drainage ditch but below the railroad bridge, where the W-9 sample is collected.

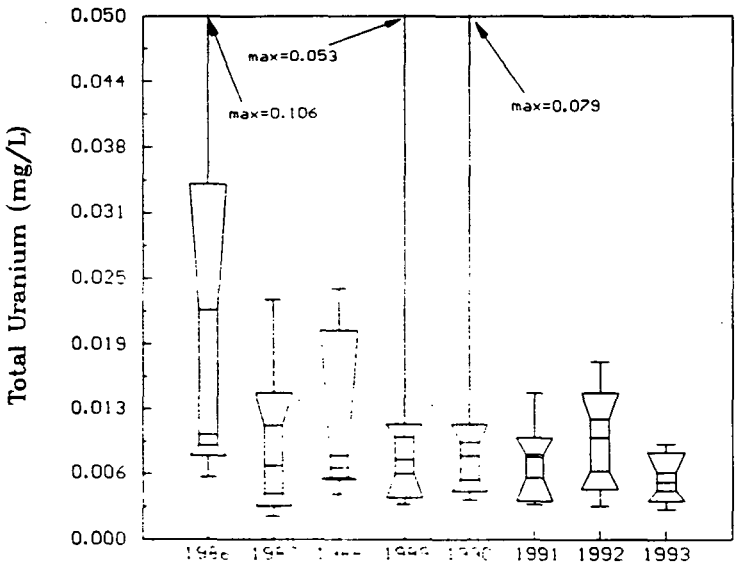
Data collected from EM location W-10 downstream (DS) are similar to data from the upstream locations, although the frequency of total uranium concentrations above 10 μg/L is greatest at this location. Even though W-10 DS was selected so the water from the pilot plant drainage ditch would mix thoroughly with Paddys Run before the sample was collected, the data may continue to reflect the impact from the high concentrations of total uranium entering Paddys Run from the pilot plant drainage ditch.

Farther downstream in Paddys Run, total uranium concentrations were fairly constant from RI sampling locations SWS-3 through SWS-7 (Figure 4-14). The samples were collected on two separate days in May 1993, within approximately 1 week of one another. The data show a continuing impact to Paddys Run, but the total uranium concentrations are much lower than at the reach near the pilot

plant drainage ditch. The impact may be from upstream sources. The 1993 UCL on the median for EM location W-11 is 6.4 μg/L, which is similar to the 1993 RI data at locations SWS-3, -4, and -5. Of the 24 samples collected at EM W-11 during 1993, only three had total uranium concentrations above 10 μg/L.

As discussed earlier, once the storm water retention basin became operational in 1986 and was expanded by the end of 1988, contaminated runoff from the production area was controlled with few exceptions. This reduction in contaminated storm water runoff reaching the SSOD and Paddys Run is illustrated in the following chart, which presents data collected at EM location W-7 both before and after the SWRB was placed in operation. The W-7 location is just south of where Paddys Run leaves the FEMP property.

EM TOTAL URANIUM DATA AT W-7
1986-1993



Total uranium concentrations in surface water samples collected at SWS-8 and SWS-9 were lower than in samples collected upstream, although they were still about 3.5 and 2.5 times background, respectively.

Sediment samples collected during 1993 show that total uranium is present in Paddys Run in concentrations ranging from 1.2 to 12 mg/kg, as shown in Figure 4-14. The 1993 RI sediment data show that, in addition to total uranium, beryllium, calcium, potassium, and zinc had maximum values

greater than five times background. Several volatiles and semivolatiles were present in Paddys Run sediment. The sediment data are discussed in detail in Appendix C.

In general though, sediment does not readily accumulate in the creek because of occasional high-flow conditions. Heavy rainfall events greatly increase the flow in Paddys Run, scouring the banks and carrying the sediment to the Great Miami River, thus precluding the buildup of sediment over the long term.

The lack of sediment accumulation can be shown by examining EM sediment data. As described in Section 2.2.4, Environmental Monitoring established a systematic sediment sampling program in Paddys Run to characterize contaminant concentrations in the stream. Samples were collected annually at the same locations during a 5-year period. A comparison of data from year to year did not show a trend in the accumulation or depletion of contaminated sediment. A high concentration of contaminant may have occurred in a location one year, but the sample taken at the same location the following year did not show the same contaminant at a similar concentration.

In 1991, EM modified the sampling program and began sampling in areas in which sediment was likely to accumulate. For 1993, total uranium concentrations ranged from 0.57 to 2.5 mg/kg in 12 samples collected in Paddys Run north of the SSOD, and from 0.5 to 3.8 mg/kg in the 12 samples collected in Paddys Run below the SSOD. In fact, the maximum concentration was from a sample collected about 100 feet south of the SSOD.

4.5.3 Great Miami River

As described in Section 3.3, the Great Miami River is the principal surface water feature near the FEMP. Two of the principal pathways by which FEMP discharges can enter the river are the permitted effluent from the outfall line and surface water flow from Paddys Run.

In this section, data collected to determine possible impacts from the FEMP to the Great Miami River are provided, along with data on the liquid effluent discharged through a permitted outfall to the river. Also discussed is the northeast drainage ditch, which is the only drainage on FEMP property that drains directly to the Great Miami River without first flowing to Paddys Run.

4.5.3.1 Northeast Drainage Area

The extreme northeast corner of the FEMP (an area of approximately 32 acres) does not drain toward Paddys Run (Area NE in Figure 4-8). This drainage ditch was sampled in 1993 because surrounding surface soil has slightly elevated levels of uranium as a result of the deposition of airborne contaminants. Location SWS-13, which is located off property as shown in Figure 4-15, was sampled to determine whether surface water runoff from the northeast corner of the FEMP and adjacent area was contaminated.

Approximately 165 acres drain to this sampling point, including the on-property area of the drainage basin. Surface water and sediment samples were collected from this drainage ditch. The total uranium concentration in the two RI surface water samples were 10.6 and 13.6 μg/L. As shown in Table 4-11, cyanide, manganese, and zinc were present in the surface water in concentrations greater than five times background.

For sediment, the total uranium concentration was about twice the background concentration. Beryllium and zinc were present in concentrations about six times greater than their respective background values, and several semivolatiles were present in high concentrations, as discussed in Appendix C.

A likely source of the uranium contamination in the surface water and sediment is historical air deposition and subsequent runoff carrying contaminated soil into the ditch. The source for the other contaminants is not clear, although the fire training area located to the west of this sampling location is a possible source because of deposition of airborne contaminants. Since the off-property area that drains to this point is five times greater than the on-property drainage area, runoff from farmland is another possible source.

4.5.3.2 FEMP Effluent

The primary impact of the FEMP on the Great Miami River is its liquid effluent. Section 1.3.1 describes the various sources of wastewater and collected storm water that comprise the effluent. The effluent is sampled on a continuous basis, and the data are compared to limits for nonradiological parameters, as stated in the National Pollutant Discharge Elimination System (NPDES) permit issued by the State of Ohio. Concentrations of radionuclides are compared to the Derived Concentration Guides, which are included in DOE Orders, and are reported in the Federal Facility Compliance

Agreement (FFCA). The parameters reported in the FFCA and for the NPDES permit have been negotiated with regulatory agencies, based on process knowledge and past sampling results.

During 1993, isotopic uranium, thorium, and radium, as well as actinium-228, were analyzed. The average concentrations are determined from monthly or quarterly composites of daily, 24-hour continuous samples. The only detectable concentrations of radionuclides in the effluent discharged to the Great Miami River in 1993 were isotopes of uranium and thorium-231. The average concentrations for the detected isotopes, as monitored at Manhole 175 and at the monitoring location for the groundwater pumped as part of the south plume removal action, were, respectively as follows:

Parameter	Manhole 175	South Plume Monitoring
Uranium-238	140 pCi/L	6.0 pCi/L
Uranium-234	96 pCi/L	3.1 pCi/L
Uranium-235	5.4 pCi/L	0.28 pCi/L
Uranium-236	3.7 pCi/L	Not Detected
Thorium-231	5.4 pCi/L	0.10 pCi/L

For NPDES, samples are analyzed for several parameters, including lead, cyanide, copper, and silver. The average daily monitoring results for 1993 at Manhole 175 were:

- Cyanide was <0.005 mg/L
- Copper was <14 μg/L
- Silver was <10 μg/L
- Lead was <3.3 μg/L

The only occurrences of noncompliance at Manhole 175 for the NPDES permit in 1993 were two pH 1 readings and one total suspended solids sample.

4.5.3.3 Great Miami River

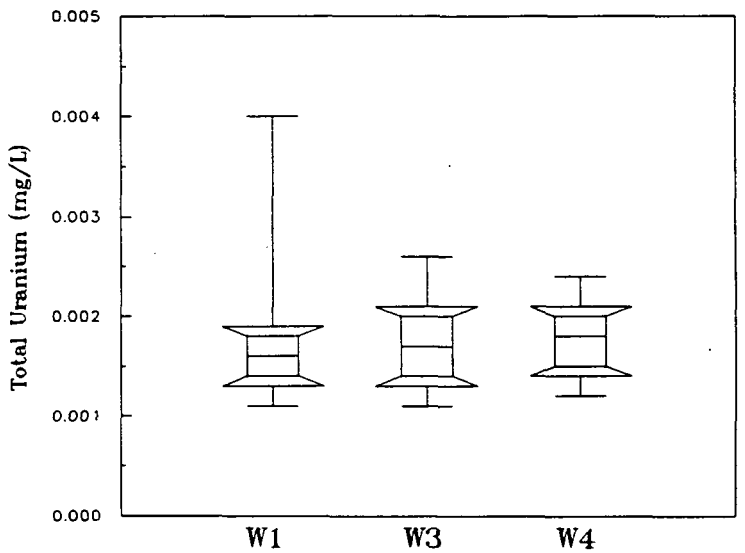
In addition to monitoring the effluent at Manhole 175, surface water and sediment samples were collected for the RI in 1993 from four locations in the river: just downriver of the FEMP outfall line; at the confluence and just downstream of the confluence of Paddys Run and the river; and downstream in Miamitown (Figure 4-16). As presented in Section 4.2, the background total uranium concentration for surface water in the river is presented as 1.4 μg/L.

Compared to the background concentration for total uranium in the Great Miami River, the 1993 RI data show a slight increase in total uranium concentrations in the river downstream of the FEMP outfall line. The maximum value was 2.1 μg/L near Paddys Run. Metals present in the river with maximum concentrations greater than five times background included aluminum, iron, manganese, and silicon.

Environmental Monitoring surface water data collected at locations W-1, W-3, and W-4 from 1986 through 1993 support the RI data (Figure 4-16). As shown in the following chart, there is a slight increase in total uranium concentrations detected downstream of the FEMP outfall line compared to the upstream location W-1.

For sediment sampling in 1993, the maximum total uranium concentration was 3.3 mg/kg, which is slightly above background. As shown in Tables 4-12 and 4-13, none of the radionuclides were detected at concentrations approaching five times background.

EM TOTAL URANIUM DATA
GREAT MIAMI RIVER, 1993



Aluminum, barium, and zinc were detected at concentrations greater than five times background. Some volatiles and semivolatiles were also detected.

Under the Environmental Monitoring Program, annual sediment samples are collected from nine locations along the Great Miami River. For the past several years, an analysis of total uranium

concentrations indicates that there is no difference between sediment samples collected above and below the FEMP outfall line to the river. In 1993, eight samples were collected along the Great Miami River for the EM Program. The maximum total uranium concentration in the two samples collected above the outfall line was 0.75 mg/kg. The maximum concentration in samples collected below the outfall line was 0.82 mg/kg.

4.5.4 Summary

Based on the examination of RI data collected during 1993, total uranium is the primary contaminant in surface water and sediment for Operable Unit 5. Although the most contaminated surface water runoff at the FEMP has been controlled, concentrations of total uranium are greater than five times background in all drainage areas examined by Operable Unit 5, as well as in Paddys Run. The maximum total uranium concentration in the Great Miami River downstream of the FEMP outfall line was greater than two times background. (The background value for total uranium is 1.1 μg/L in Paddys Run and 1.4 μg/L in the Great Miami River.)

4.5.4.1 On-property Drainages

For uncontrolled surface water runoff, the highest total uranium concentrations are found in the pilot plant drainage ditch, with the maximum concentration of 2890 μg/L detected at the head of the ditch (Figure 4-10). The source of the uranium appears to be in the area of the pilot plant, because contaminated water has been accumulating in a sump and is being slowly discharged to the ditch. (See Section 1.3.4.10 for a description of the project to repair the sump.) Samples collected from seeps along the ditch had total uranium concentrations in the range of approximately 7 to 34 μg/L, which is much lower than concentrations detected in the surface water in the ditch. The range of total uranium concentrations reported by the EM Program are similar to those reported for the Operable Unit 5 RI.

The ditches in the South Drainage Area associated with Operable Unit 2 have total uranium concentrations ranging to more than 800 μg/L at the inactive flyash pile, and nearly 500 μg/L at the southeast corner of the South Field. One possible source of contamination appears to be perched groundwater that enters the drainage ditch in the northeast corner of the South Field. The majority of data for this area was collected for and reported in the Operable Unit 2 RI report.

Total uranium concentrations in surface water for the other drainage areas discussed in Section 4.5 ranged from background to approximately 60 μg/L.

Sediment data showed that total uranium concentrations were also greater than five times background for all drainage areas with the exception of the Great Miami River. Sediment samples collected for the EM Program indicate that the range of total uranium concentrations in storm sewer outfall ditch sediment for 1993 was 1.4 to 11 mg/kg. The ditches in the South Drainage Area have several metals present in the sediment at maximum concentrations greater than five times background. These include aluminum (6x), barium (10x), beryllium (9x), copper (11x), potassium (6x), and zinc (9x).

4.5.4.2 Paddys Run

Uncontrolled surface water runoff continues to affect total uranium concentrations in Paddys Run, although the storm water runoff control projects completed during the past several years have greatly reduced the amount of contaminants reaching the creek. The 1993 RI data show that total uranium concentrations at on-property sampling locations along Paddys Run are greater than five times background. In contrast, total uranium concentrations south of the FEMP boundary are lower than concentrations from on-property locations, ranging from 9.1 μg/L at Willey Road to 2.6 μg/L at State Route 128.

The greatest impact to Paddys Run is near the point where the flow from the pilot plant drainage ditch enters the creek. The EM Program data from 1993 and previous years report total uranium concentrations to 1200 μg/L at the sampling locations in Paddys Run near the pilot plant drainage ditch. The UCL on the median for total uranium at EM location W-10 was 45 μg/L.

Sediment does not tend to accumulate over a period of years along Paddys Run because occasional high-flow conditions scour the banks and streambed, and the sediment and its associated contaminants are carried downstream. The maximum total uranium concentration of the RI sediment samples collected along Paddys Run was approximately four times background. Although some sediment data in any given year indicate uranium contamination at a specific location, data from the following year usually do not show similar levels of contamination. The EM Program collected samples at 100-meter intervals in Paddys Run for five years beginning in 1986. A comparison of data did not reveal any trends in the accumulation or depletion of contaminants in sediment in the creek. The maximum total uranium concentration in sediment in the 12 samples collected by the EM program in Paddys

Run upstream of the SSOD was 2.5 mg/kg; for the 12 samples collected downstream of the SSOD, the maximum concentration was 3.8 mg/kg.

4.5.4.3 Great Miami River

Surface water samples collected along the Great Miami River show a slight increase in total uranium concentrations downstream of the FEMP outfall line compared to background locations. The FEMP discharged more than 1000 pounds of uranium into the river in 1993, and the data show some impact from the FEMP on total uranium concentrations in surface water. The maximum total uranium concentration in the Great Miami River surface water was 2.1 μg/L. The range of total uranium concentration for the EM data is similar to the RI data.

Sediment samples collected during 1993 in the Great Miami River showed total uranium concentrations similar to the background value (3 mg/kg). Sediment samples collected for the EM Program had a maximum total uranium concentration of 0.82 mg/kg. The sample was collected just south of the confluence of Paddys Run and the river, and the concentration was similar to the concentration in the sample collected above the outfall line (0.75 mg/kg). Aluminum, beryllium, and zinc were detected at concentrations greater than 6, 5, and 13 times background, respectively; volatiles and semivolatiles were also detected in Great Miami River sediment.

4.5.4.4 Potential Data Limitations

The RI data collected during 1993, along with EM data, show that uncontrolled storm water runoff is carrying contaminants into Paddys Run, which is a pathway to the Great Miami Aquifer. For some areas at the FEMP, additional data could further quantify sources of contamination. Areas where data limitations exist are as follows:

- Northeast drainage area
- East drainage area

In the northeast drainage ditch, limited data exist to fully characterize surface water and sediment. The data indicate a continuing impact on surface water and sediment from historical deposition of airborne contaminants. The data could be influenced by contamination from farmland as well, since the off-property area that drains to the single sampling location is more than 130 acres.

As noted in the discussion, this is the only drainage ditch that does not flow to Paddys Run or one of its tributaries. Rather, it flows directly to the Great Miami River. Samples have not been collected along this ditch or in the river near where the ditch empties. However, the ditch is located, for the most part, on permeable flood plain deposits overlying the Great Miami Aquifer. Therefore, like Paddys Run, this ditch likely loses water to the underlying aquifer. This indicates the potential for contaminants in the ditch to effect water quality in the Great Miami Aquifer. Moreover, Well 2098 is adjacent to this ditch approximately 1400 feet downstream from the sampling location (SWS-13) shown on Figure 4-15. Validated total uranium results for 1988 through 1993 ranged from 1.5 to 5.1 μg/L. The average value for six validated samples (filtered and unfiltered) collected during this period is 3 μg/L. This is approximately two to four times background, depending on whether the filtered (0.8 μg/L) or unfiltered (1.2 μg/L) value for total uranium is used.

Based on sampling results at Well 2098, it does appear that contaminants migrating through the base of the ditch do have a slight impact on the water quality of the Great Miami Aquifer in the area of the ditch.

The second area where surface water and sediment data are limited is in the east drainage area. This area, as well as a large area south of the FEMP, drains into the SSOD. In 1993, an RI sample was collected near the confluence of the SSOD and Paddys Run, but no surface water data were collected along the SSOD or its tributaries in the east drainage area. Possible sources of contamination in this area include the sewage treatment plant and the former incinerator. Because the East Drainage Area is in the predominant wind direction, historical deposition of airborne contaminants occurred throughout the area. Surface water and sediment may be contaminated from uncontrolled runoff.

No additional characterization of these areas is necessary for the RI/FS. The need for additional evaluation of these areas will depend on the final remediation goals selected for the Operable Unit 5 Record of Decision (ROD). This is a remedy implementation issue that does not require resolution for the FS to proceed. Sufficient information is available to establish risk-based remedial goals, develop and compare remedial alternatives, and select a remedy for presentation in the ROD.

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4.5.4.5 Conclusions

The improvements in controlling storm water runoff at the FEMP have reduced the amount of contaminants reaching Paddys Run, which is a major pathway to the Great Miami Aquifer. Several drainage ditches remain uncontrolled, and data collected in those ditches during 1993 show total uranium concentrations greater than five times background for both surface water and sediment. In fact, the maximum total uranium concentration in the pilot plant drainage ditch was 2890 μg/L. Other contaminants were not detected with the frequency and consistency above background values as was total uranium. Additional data may need to be collected during remedy implementation for the northeast and the east drainage areas.

Sufficient surface water and sediment data have been collected and evaluated to determine the nature and extent of FEMP-related contamination. This determination is sufficient to perform a baseline risk assessment and select and evaluate remedial alternatives in surface water and sediment in the Operable Unit 5 Feasibility Study.

4.6 SOIL

This section describes the nature and extent of contamination in the surface and subsurface soils at the FEMP with regard to constituents detected and areas of significant contamination. A comprehensive soil sampling program was conducted at the FEMP from 1987 through 1993, with various phases described in Section 2.0. The objectives of this program include characterizing the nature and extent of surface and subsurface soils contamination, identifying probable sources of contamination, and examining the potential for migration of contamination to the groundwater. For site characterization, however, all data collected were combined and analyzed as a whole. Samples collected for the FEMP soil sampling program were analyzed for radionuclide, inorganic, and organic constituents.

Section 4.6.1 provides a site-wide overview of the constituents detected in the soil. Individual radionuclide and chemical parameters are discussed in relation to laboratory detection levels and naturally occurring background values. With the exception of uranium, Section 4.6.1 discusses various constituents in a summary fashion, whereas Appendix D (D.1) provides a more detailed discussion of the site-wide nature and extent of contamination by individual constituents. Uranium, however, is discussed in great detail in this section as well as in Appendix D because it is the major site contaminant in terms of volume released, frequency of detection, potential risk, and future remedial design considerations.

Sections 4.6.2 through 4.6.8 discuss soil contamination at the FEMP from the perspective of individual geographic areas of soil contamination. As in Section 4.6.1, describing the nature and extent of total uranium in the various areas will be the focus of these sections. When possible, the probable source of the observed contamination will be discussed. To facilitate the area discussion, site cross sections presenting vertical profiles of total uranium contamination are provided. These FEMP geographic areas, depicted in Figure 4-17, are as follows:

- Production area and other process areas (Section 4.6.2)
- Northeastern area of FEMP (Section 4.6.3)
- Southern area of FEMP (Section 4.6.4)
- Western area of FEMP (Section 4.6.5)
- Northwestern area of FEMP (Section 4.6.6)
- Area outside FEMP adjacent to boundary (Section 4.6.7)
- Area 2-5 miles outside FEMP boundary (Section 4.6.8)

Finally, Section 4.6.9 summarizes the nature and extent of soil contamination at the FEMP.

Appendix D.2 provides a more detailed discussion of the production area and other process areas at the FEMP. In this Appendix the FEMP area is divided into 25 subareas, as depicted in Plate D-1.

The 95th percentile value calculated for the background data set, as described in Section 4.2, is used in the following text as a benchmark for the comparison of contaminant values to background in the FEMP study area. Thus in the following discussions, when sampling results are described as "below background" or "five times above background," the background referred to is this 95th percentile value.

4.6.1 Overview of Site-Wide Contamination

The following discussion of the nature and extent of soil contamination at the FEMP is based on a detailed analysis of soil data, which is provided in Appendix D.1. The tabulated soil data used in the analysis are presented in Appendix H, according to geographic location of the sample. An index to Appendix H correlates the individual sample number and the corresponding geographic area.

The soil at the FEMP was segregated into surface (depths of 0 to 1.5 feet) or subsurface (depths greater than 1.5 feet) and subsequently subdivided into eight depth intervals, as follows:

Surface Soil	Subsurface Soil
• 0 to 0.5 foot	• 1.5 to 3.0 feet
• 0.5 to 1.0 foot	• 3.0 to 5.0 feet
• 1.0 to 1.5 feet	• 5.0 to 10.0 feet
	• 10.0 to 15.0 feet
	• 15.0 to 20.0 feet

Although use of these depth intervals allows for analysis of the vertical extent of soil contamination, the reader must be cautioned about misinterpretation of the results. For some of the parameters, the amount of data varies according to the depth interval. This factor must be considered in reviewing the maps or statistics used in analysis. Generally, the deeper the sampling interval, the more sparse the data.

In preparing Appendix D, various tools were used to analyze the data and support the discussions of nature and extent of contamination. These tools, as discussed below, include isoconcentration maps, statistical summaries, and summary tables by area and are used to indicate where significant levels of contaminants were detected.

Soil Isoconcentration Maps: Based on soil samples collected at the FEMP, soil isoconcentration maps were created for each parameter by sampling depth interval. These maps are located in the plate volume (Plates). Not all depths are included for each parameter. Because of the quantity of plates, not all maps are included. These plates are frequently referenced in the detailed parameter discussions in Appendix D.1. In Section 4.6.1, selected isoconcentration maps that are critical to the discussion are presented as reduced figures for the convenience of the reader. These figures do not contain the actual data, but rely on the isoconcentration lines derived from the plates to identify areas of contamination.

In reviewing the plates, the reader should understand how the lack of data at specific depths may affect the isoconcentration maps. For instance, a contour may appear on the 0- to 0.5-foot map of a given parameter. However, in the 0.5- to 1.0-foot interval, no samples may have been collected. If samples were subsequently collected in the 1.0- to 1.5-foot sampling interval and contamination was detected, the contour line would reappear. In such cases, interpolation of the data would suggest that contamination exists in the intermediate level, although no data were collected to verify its presence.

Statistical Summaries: Statistical summaries for analyzed constituents are presented throughout this section and in Appendix D. Tables 4-14 and 4-15 are typical examples. These tables provide statistical summaries of the constituents detected in surface and subsurface soils, respectively, site wide at the FEMP. The statistics present the number of positive detections for a parameter, the number of validated samples (see Section 2.12) in the data set, the range of sample concentrations detected, the average concentration for samples having a positive detection, the range of nondetected samples, and the 95th percentile background value.

Summary Tables: The summary tables used throughout this section and in Appendix D provide the reader with a quick reference to contamination by geographic area according to sampling depth intervals. The table indicates whether a sample from a geographic area was or was not analyzed in a depth interval, analyzed but not detected, detected at levels less than background, detected above but less than two times background, detected between two and five times background, or detected more than five times background. For parameters that were not detected or determined in the background study, positive detections are indicated with no reference to a background value.

The eight depth intervals are indicated in the summary tables. The reader can best understand the extent of vertical contamination of the soil by visualizing the table as a summarized cross section of the top 20 feet of soil. However, the reader must be cautioned that use of this table may exaggerate the degree or the impression of contamination, since contamination at five times background may be represented by a single sample rather than a preponderance of samples. Thus, to understand the frequency of occurrence for a detection at a specific depth, the statistical summaries should be used.

Table 4-16, a table of data collected from the entire site, is an example of a summary table. The radionuclides presented in all of the summary tables have been arranged by decay series to enhance the interpretation. With this arrangement, the reader should be able to determine quickly whether any unnatural relationships of radionuclides are observed in a given area. Note that total uranium and total thorium are not technically radionuclides but are metals, although all of their respective isotopes are radioactive. Since uranium-238 and thorium-232 are the major constituents of these metals, total uranium and total thorium have been placed after each of these radionuclides in the tables and in the discussions found in Appendix D. For a explanation of the decay series, refer to Section 4.1.

Analytical Data

The above-mentioned "tools" are used consistently throughout the soil discussion. It is important that the reader understand how the tables were generated and their meaning to fully understand the soil discussions in this section and in Appendix D. The analytical data-set for FEMP soil available for compilation of this report spans from 1987 to 1993. Tabulated validated data is located in Appendix H. Priority was given to validated data, since the validation process provides higher quality data. Where more than one analysis was performed on the same sample, all results are provided in Appendix H.

As environmental restoration occurred at the FEMP, soil has been removed and thus the most immediate environmental threats have been eliminated. Therefore, for an accurate portrayal of the current nature and extent of contamination, samples relating to excavated soil have been removed from this soil analysis. These samples are included, however, in Appendix H at the end of the geographic areas in which they were collected.

Soil samples collected during the 1987 to 1993 sampling program predominantly were analyzed for the full radiological, and HSL (TCL) inorganic and organic parameters. As one would expect, the majority of analyses were performed for radiological parameters, since these parameters are of most concern at the FEMP. Uranium was thought to be the principal contaminant in soil, and was therefore the primary contaminant investigated during the RI. The analytical data support this assumption. Total uranium was analyzed for in 2807 surface and 1898 subsurface soil samples. For inorganic parameters, approximately 450 surface and 380 subsurface soil samples were analyzed, whereas for organics approximately 380 surface and 425 subsurface soil samples were analyzed. The analyses were specified in accordance with expected contamination, based on historical operations as well as verification that unexpected constituents were not present in the surface and subsurface soils.

Uranium Envelope

As expected, uranium was identified as the principal contaminant in soil at the FEMP. The following discussion regarding the extent of uranium contamination at the FEMP provides a thorough description of the horizontal and vertical extent of uranium contamination. Where known, the probable sources of uranium contamination are discussed. The remaining parameters are discussed in less detail, either because their sources and distribution are generally governed by the same or similar

processes described for uranium, or because the levels and extent of contamination are minimal and contained within the area of uranium contamination.

From the review of the data, it appears that the areas of total uranium contamination encompass the other areas of site-related contamination. This boundary of uranium contamination will be referred to as the "uranium envelope." Therefore, all parameters will be discussed relative to uranium contamination or the uranium envelope. This phenomenon is attributable to the wide use of uranium at the FEMP.

Two values of total uranium are used in this discussion. The first value is 5 mg/kg for total uranium, which is slightly above background (3.73 mg/kg). The value of 5 mg/kg approximates the 10^{-6} risk level for total uranium (Appendix A.7). This value of 5 mg/kg is a summation of the background concentration for uranium and the 10^{-6} risk value. The second value is 20 mg/kg, approximately five times background, which approximates the 10^{-5} risk level for total uranium. This value of 20 mg/kg is a summation of the background for total uranium and the 10^{-5} risk value. The 20 mg/kg contour line will be used to determine whether a constituent is elevated above background outside this envelope. The 5 mg/kg contour line encompasses all of the FEMP property as well as some off-property areas. In this discussion the 20 mg/kg contour line will be presented on all of the soil plates (see Plates) to depict areas of contamination from other parameters in relation to the established uranium envelope. Figure 4-18 is a map showing the locations of the 5 mg/kg and 20 mg/kg isoconcentration contour lines. Note that these contour lines consider only risk associated with total uranium in the surface soil. Impacts from other constituents or additional media are not represented by these lines.

Source Areas

Table 4-9, presented in Section 4.3, summarizes the probable source areas within the FEMP and the contaminants expected to be found. This table is referenced throughout the discussions in this section and in Appendix D. The sources are divided into the geographic areas discussed within this section as well as Appendix D. The table will be used to distinguish between expected contamination and contamination that was not expected but was detected.

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4.6.1.1 Radiological Contamination

Radionuclide contamination presents the most serious problem at the FEMP. As expected, uranium is the most prevalent radionuclide as well as most prevalent contaminant present at the FEMP. During its 38 years of operation, the FEMP produced more than 362,000,000 kilograms of uranium metal. The majority of uranium and other radionuclides present at the FEMP resulted from the processing of four materials. These materials are listed below from highest to lowest volume processed:

1. Purified uranium and uranium compounds derived from uranium ores in solid, liquid, and gaseous forms. These materials would have contained only the first few members of the uranium decay chain, as depicted in Figure 4-1.

2. Purified uranium and uranium compounds derived from recycled reactor fuel, in solid, liquid, and gaseous forms. These materials would have contained the first few members of the uranium decay chain and trace quantities of fission products and uranium activation products.

3. Uranium ore residues containing some residual uranium and the long-lived members of the uranium chain and their progeny.

4. Purified thorium and its compounds. These materials would have contained thorium-232 and its progeny (see Figure 4-2 for a depiction of the thorium decay chain), although secular equilibrium may not have been achieved.

Section 1.0 provides a detailed description of the above four materials while Section 4.1 provides an explanation of additional radionuclides that may be present, based on the decay chains associated with the various materials.

Summary of Release Mechanisms

Given the importance of uranium in the environmental restoration of the FEMP, an understanding of the historical types of releases, types of deposition, form of uranium, and the geochemical conditions affecting uranium migration through the soil column is essential. Uranium releases from the process plants at the site have occurred in the past either as repetitive emissions or as singular, and in some instances, episodic, well-documented events. Releases were either airborne and on a site-wide scale or occurred as spills to the soil and can be characterized as point sources. An example of a singular, airborne release is the 1966 UF_6 tank leak at the pilot plant. Episodic UF_6 releases occurred at Plant 7 in the mid-1950s, and repetitive, airborne releases from the pilot plant and Plants 1, 2/3, 4, 5, and 8 (estimated to be 179,000 kg of uranium; Attachment 1 of Appendix F.3). Examples of former, repetitive, point-source releases to the soil are acid bath spills at Plants 2/3, 6, and 8 (estimated to be

1300 kg of uranium; RAC, 1994). Additionally, accidental spills resulted in concentrated, mobile point sources in the form of uranyl nitrate, ammonium uranyl, and other uranium solutions.

Historical releases of uranium in both soluble and relatively insoluble forms have occurred on a site-wide or point-source basis, as discussed in Section 1.0. Air emissions of uranium fluoride and oxide particles blanketed the entire production area, with the relatively insoluble uranium oxides comprising about 75 percent of the released mass. The highly soluble uranium fluoride solids and gases were also dispersed by the wind and deposited on the surface soil.

Site-wide, airborne deposition has resulted in a uranium source on the surface of the soil that contains both soluble and insoluble forms of uranium. On a site-wide basis, the air-deposited, soluble forms have leached and infiltrated the soil column through rainfall events that occurred shortly after deposition circa 1950s. The most leachable forms moved through the soil first, and the least leachable forms remain at or near the surface. The leachable forms will traverse the soil column to the groundwater, with minimal adsorption to the soil. Historical information on uranium releases supports the conceptual model of adsorption in areas of aqueous spills/leaks versus desorption in areas that received only uranium particles from air emissions.

In point-source releases, uranium is either moderately or highly leachable because of the presence of acid, which increases the mobility of the uranium. From a review of the analytical data, it is clear that uranium has penetrated to depths of at least 20 feet, and in some instances, it may have penetrated to greater depths in areas where point-source releases occurred. An understanding of these two release mechanisms is important, as these mechanisms govern the nature and extent of uranium contamination observed at the FEMP. Figure 4-19 depicts the resultant soil contamination from the two types of release mechanisms. As illustrated, airborne releases result in elevated levels of contamination within the top few inches of soil, whereas point-source releases are the likely source contamination to depths of 20 feet or greater. Attachment 1 to Appendix F.3, Historical Airborne Release of Uranium and Geochemical Concepts of the Subsurface Uranium Distribution at the Fernald Site, describes these concepts in greater detail and estimates a distribution coefficient for the soluble and insoluble forms of uranium.

The following summary of the extent of radiological contamination focuses on plant processes and operations responsible for the observed contamination at the FEMP. As previously stated, a detailed

discussion of total uranium will be presented in this section. Likewise, radium-226 and total thorium will be discussed in detail, since these radionuclides indicate contamination from K-65 refined material (radium-226) or waste from storage of thorium (total thorium). Other FEMP radionuclides are discussed in less detail, since the majority are within the uranium envelope and are less significant contaminants.

4.6.1.1.1 Uranium Decay Series

As discussed in Section 4.1, the principal radionuclides in the uranium decay series characterized at the FEMP are uranium-238, uranium-234, thorium-230, and radium-226. Of these, uranium-234 and uranium-238 are constituents of total uranium. For the depleted, natural, and slightly enriched uranium processed at the FEMP, the uranium-238 isotope accounts for greater than 95 percent of the total uranium on a mass basis; therefore, the nature and extent of contamination of uranium isotopes will be depicted and explained in the discussion on total uranium. Radium-226 and thorium-230, the other two primary radionuclides characterized at the FEMP, may be found at elevated levels as the result of processing uranium ore or yellowcake. Section 1.0 provides a discussion of each of these processes. Radium-226 is known to be present in both types of waste materials; thus, a discussion of radium-226 will describe the nature and extent of both radium-226 and thorium-230 contamination as a result of concentrate from processed materials. If radium-226 and thorium-230 are detected at elevated levels in FEMP soil, they are expected in the K-65 silos area from raffinate material or possibly in the process areas. Thus thorium-230 will not be discussed in this section; however, a discussion of thorium-230 contamination is provided in Appendix D. The following are discussions of both total uranium and radium-226.

Total Uranium

Uranium could have been released into the environment through a variety of pathways, such as spills, leaks from production processes or conveyance systems, gaseous/particulate emissions during production or incineration of wastes, improper storage/disposal of uranium-contaminated wastes, and so forth. Consequently, widespread uranium contamination of surface soil is expected.

Major aspects of the uranium distribution are as follows:

- Within the production area, 75 percent of the surface soil samples and 52 percent of the subsurface soil samples yielded above background concentrations of total uranium, whereas outside the production area, 77 percent of the surface soil and 39 percent of the

subsurface soil samples yielded above background concentrations of total uranium. The consistent percent of detections between the production area and outside the production area support the conclusion that the majority of the FEMP has a total uranium level of 4 mg/kg or higher.

- Uranium contamination in the surface soil at levels of five times background is widespread throughout the site, as indicated by the blackened squares in Table 4-17.

- Uranium contamination in the subsurface soil is present at levels greater than five times background from point-source releases underneath the process areas in the production area and areas where underground pipes and sumps may have leaked, as shown in Table 4-17.

- The majority of the production area and the other operable units have uranium surface soil concentrations greater than 20 mg/kg, whereas the uranium levels in the surface soil located elsewhere within the FEMP boundary are concentrations between 5 and 20 mg/kg (see Figure 4-18).

Following is a discussion of total uranium contamination in the surface and subsurface soil at the FEMP.

Total Uranium Contamination in Surface Soil

Total uranium was detected in 2216 of 2557 surface soil samples (constituting approximately 87 percent of detections) collected across the entire site. These samples do not include samples of waste materials that are considered to be part of other operable units. Of the 2216 detections, 1937 concentration values (approximately 87 percent of detections) exceeded the statistically calculated 95th percentile background concentration for surface soils of 3.73 mg/kg. There were 1,334 detections of total uranium with values greater than 20 mg/kg (52 percent), 880 detections of total uranium greater than 5 mg/kg but equal to or less than 20 (34 percent) and 343 detections of total uranium less than 5 mg/kg (14 percent). Therefore, a vast majority of the detected concentration values exceeded background levels.

Surface soil samples were taken from three depth intervals: 0 to 0.5, 0.5 to 1.0, and 1.0 to 1.5 feet. The areas of total uranium contamination, as determined within each depth interval, are discussed in the following subsections. The discussion provides an overview of uranium contamination using total uranium isoconcentration contours at the 10,000, 1000, 100, 20, and 10 mg/kg levels, as depicted in Figures 4-20, 4-21, and 4-22 corresponding to each of the three sampling intervals mentioned above. The figures reference corresponding plates, which contain the actual data and contours. The figures

depict the four areas of the site evidencing the highest surface soil contamination; shaded contours on the figures highlight areas where total uranium concentrations exceed 100 mg/kg.

FEMP Areas of Uranium Contamination Greater than 10,000 mg/kg: The highest concentrations of total uranium were detected in the top 6 inches of surface soil (0 to 0.5 foot), at levels that exceeded 10,000 mg/kg. The areas where total uranium concentrations exceeded 10,000 mg/kg (in order of soil study areas as listed in Table 4-17) were as follows: Plant 1 area; Plant 6 area; the laboratory area; and the scrap metal pile, decontamination building, and Buildings 64 and 65 area. In each of these areas, not more than two sample concentrations exceeded 10,000 mg/kg, and sample concentrations in the area of the immediate vicinity of the highest sample concentration were lower by at least an order of magnitude. For example, in the immediate vicinity of the location of the highest sample concentration of 12,337 mg/kg, the two nearest sample concentrations were 112 mg/kg (located 25 feet due west) and 715 mg/kg (located 1000 feet due east). This indicates that these locations of high concentrations were in fact isolated areas of major contamination. As depicted in Figure 4-20, each such an area is enclosed tightly (conceptually) by a contour of the 10,000 mg/kg concentration.

The concentrations of total uranium at depths of 0.5 to 1.0 foot and 1.0 to 1.5 feet were significantly less than the concentrations in the top 6 inches of soil. The sizes of the isoconcentration contours reflect this decrease in concentration, as seen by comparing Figure 4-21 (0.5- to 1.0-foot depth) and Figure 4-22 (1.0- to 1.5-foot depth) with Figure 4-20 (0- to 0.5-foot depth). The following discussion describes the main areas of contamination (as mentioned above) in each of the three sampling depths.

- Plant 1 Area: The main sources of contamination in the Plant 1 Area were spills or airborne releases from the following operations: the sampling of incoming ores/process material residues, crushing/milling of feed materials (uranium ores), reclamation of enriched uranium, and storage of milled ores and wastes. A review of activities performed on the Plant 1 pad during its nearly 38-year history indicates that spills of uranium-bearing material occurred.

  In the Plant 1 area, the range of all detected concentrations in the 0- to 0.5-foot sampling interval was 1.74 to 12336.9 mg/kg (Plate D-10A). At several isolated locations that were geographically separated from the location of the highest concentration and from

each other, the concentration range was on the order of 10 to 1000 mg/kg. The concentration range in samples from the 0.5- to 1.0-foot depth interval was 2.20 to 6140 mg/kg, whereas the range in samples from the 1.0- to 1.5-foot depth interval was 7.14 to 1050 mg/kg. Thus, the concentration ranges in the deeper surface soils were lower than the surficial interval by 50 percent to an order of magnitude.

- Plant 6 Area: The main sources of uranium contamination in the Plant 6 area were the following operations: the milling/machining operations (for uranium-rod manufacture), the nitric acid pickling baths (for metal briquetting/scrap-metal oxide removal), and the salt-oil heat treatment units for uranium billet preparation.

  In the Plant 6 area, the range of all detected concentrations in samples from the 0- to 0.5-foot depth intervals was 3.70 to 90,350 mg/kg. In addition to the highest detection of uranium in the Plant 6 area, only one other sample concentration exceeded 1000 mg/kg. At several locations the concentration range was on the order of 10 to 1000 mg/kg and, based on the uniformity of concentrations, the extent of contamination exceeding 100 mg/kg may be observed covering the entire Plant 6 area. The concentration range in the 0.5- to 1.0-foot depth samples was 3.25 to 1416 mg/kg, whereas the concentration range in the 1.0- to 1.5-foot depth samples was 2.30 to 8059 mg/kg. Thus, the concentration ranges in the deeper surface soils were lower than the surficial interval by 20 percent to an order of magnitude.

- Laboratory Area: The main source of contamination in the laboratory area may have been improper uranium sample storage/disposal practices and leaking drains.

  In the laboratory area, the range of all detected concentrations in samples from the 0- to 0.5-foot interval was 2.0 to 43,118 mg/kg. Three sample concentrations in the immediate vicinity of the highest sample concentration exceeded 1000 mg/kg; thus it appears that the contaminated soil in this area is widespread. In addition, the sample concentration at one other isolated location exceeded 1000 mg/kg. In several other locations the concentration range was on the order of 10 to 1000 mg/kg and, based on the uniformity soil concentrations exceeding 100 mg/kg, may be present in the surface soil across the western half of the laboratory area (see Figure 4-20). The concentration ranges in the deeper surface

soils were lower by a whole order of magnitude. The concentration range in the 0.5- to 1.0-foot depth samples was 125 to 1260 mg/kg, whereas the concentration range in the 1.0- to 1.5-foot depth samples was 3.20 to 3250 mg/kg.

- Scrap Metal Pile, Decontamination Building, and Buildings 64 and 65: The main source of contamination in the scrap metal pile is likely the uranium-laden wastes that might have been disposed along with the scrap metal. The main sources of contamination in Buildings 64 and 65 were the following operations that might have been conducted under uncontrolled conditions: storage of scrap drums and scrap metals/drummed uranium residue/contaminated equipment awaiting decontamination, decontamination operations, and related operations.

  In the scrap metal pile, decontamination building, and Buildings 64 and 65 area, the range of all detected concentrations in samples from the 0- to 0.5-foot interval was 12.0 to 21,424 mg/kg. The highest sample concentration was located in the scrap metal pile area. In all other locations the concentration range was on the order of 10 to 1000 mg/kg and, based on the uniformity of concentrations, the extent of contamination exceeding 100 mg/kg may be observed covering the entire area of the scrap metal pile, decontamination building, and Buildings 64 and 65. The concentration range in the 0.5- to 1.0-foot depth samples was 30 to 2270 mg/kg, whereas the concentration range in the 1.0- to 1.5-foot depth samples was 5.73 to 962 mg/kg. Thus, the concentration ranges in the deeper surface soils were lower than the shallow interval by an order of magnitude.

FEMP Areas of Uranium Contamination Ranging from 1,000 to 10,000 mg/kg: There are several other areas at the site where total uranium concentrations were elevated in the surface soil. Those areas where total uranium concentrations exceeded 1000 mg/kg but were less than 10,000 mg/kg in the 0- to 0.5-foot samples were as follows: Plant 2/3 area, Plant 9 area, sewage treatment plant area, D&D building and former drum baling area, fire training area, and the areas northeast and west of the FEMP. At the Plant 2/3 area, the sewage treatment plant area and the fire training area, the locations of the highest concentrations (exceeding 1000 mg/kg) were few and isolated. However, at the D&D building and former drum baling area, a significant extent of contamination exceeding 1000 mg/kg (with a maximum of 3890 mg/kg) was observed. The uniformity of sample

concentrations within the 100 to 1000 mg/kg range at the Plant 2/3 area, the sewage treatment plant area, the D&D building and drum baling area, and the area west of the FEMP indicates an extent of contamination exceeding 100 mg/kg in each area. At each of the above areas (with the exception of the Plant 9 area), the concentrations in the 0.5- to 1.0-foot depth and the 1.0- to 1.5-foot depth samples were lower than the concentrations in samples from the top 6 inches of soil by a significant factor, up to an order of magnitude. At the Plant 9 area, the maximum concentration in samples from depths of 1.0 to 1.5 feet was higher than the maximum concentration in samples from depths of the 0 to 0.5 foot and 0.5 to 1.0 feet by an order of magnitude. There was one detection of total uranium (5533 mg/kg) east of the production area that was not expected. The sample was collected in an area of depression near a drainage ditch which may explain the high uranium value.

FEMP Areas of Uranium Contamination Ranging from 10 to 1000 mg/kg: Aside from the areas discussed above, at all other areas outside the production area and within the FEMP boundary, sample concentrations in surface soil were typically in the range of 10 to 100 mg/kg. There was one detection of uranium the northeastern area (362 mg/kg) that was not expected. The source of this contamination is not known.

Total Uranium Contamination in Subsurface Soil

This section provides an overview of the total uranium contamination in FEMP subsurface soil (1.5- to 20.0-foot depth). The subsurface soil samples were collected from the following depths: 1.5 to 3.0 feet, 3.0 to 5.0 feet, 5.0 to 10.0 feet, 10.0 to 15.0 feet, and 15.0 to 20.0 feet.

Total uranium was detected in 1164 of 1829 subsurface soil samples (approximately 64 percent) collected at locations across the entire site. Of the 1164 detections, 878 concentrations (approximately 75 percent) exceeded background of 3.69 mg/kg. There were 325 detections of total uranium with values greater than 20 mg/kg (17 percent), 971 detections of total uranium greater than 5 mg/kg but equal to or less than 20 (53 percent), and 533 detections of total uranium less than 5 mg/kg (30 percent). Therefore, a majority of the detected concentrations exceeded background. However, a significant number of concentrations were less than background. Thus it appears that the vertical extent of contamination is confined in specific areas.

Figures 4-23 to 4-27 depict the isoconcentration contours in the following depth intervals: 1.5 to 3.0, 3.0 to 5.0, 5.0 to 10.0, 10.0 to 15.0, and 15.0 to 20.0 feet, respectively. In general, a reduction in

the areal extent of elevated concentrations depicted by the contours indicates a reduction in the extent of contamination with depth.

The following is a discussion of the main areas of subsurface contamination within each of the five depth intervals mentioned above. Plant 6 is discussed first because of the significance of the contamination in this area, followed by the other areas.

FEMP Areas of Uranium Contamination Greater than 10,000 mg/kg: The most significant uranium contamination was in the Plant 6 area, where total uranium concentrations exceeded 10,000 mg/kg. In this area, elevated concentrations were detected at all sampling depths to 20 feet. In the 1.5- to 3.0-foot depth, the highest concentrations were 54,000 and 16,877 mg/kg in samples from the northern and southern ends of Plant 6, respectively. The samples were taken from the same locations where the highest concentration in the surface soil in the 0- to 0.5-foot depth interval was 90,350 mg/kg (at the northern end) and the highest concentration in the 1.0- to 1.5-foot depth was 8059 mg/kg (at the southern end). Concentrations in the immediate vicinity of these locations were significantly lower (less by at least one order of magnitude), which indicates that these locations are isolated areas of major contamination. Similarly, in the 3.0- to 5.0-foot depth, the highest concentrations were in at least one of the two isolated areas in the 1.5- to 3.0-foot depth intervals, at levels of 39,100 and 69,300 mg/kg. As seen in Figures 4-23 and 4-24, these locations are tightly enclosed (conceptually) within contours of the 10,000 mg/kg level. The highest concentrations in the 5.0- to 10.0-, 10.0- to 15.0-, and 15.0- to 20.0-foot depths were significantly lower at 4763, 266, and 479 mg/kg, respectively. Few other sample concentrations were within the same order of magnitude as these maximum values. Most of the other detected concentrations at other locations in these depths were within the 10 to 100 mg/kg range, and consequently (as depicted in Figures 4-24, 4-25, 4-26, and 4-27), these locations are enclosed (conceptually) within the 10 mg/kg contour. Thus, the majority of the contaminated area in Plant 6 (with the exception of the isolated areas of major contamination) is within the order of magnitude ranges of 10 to 100 mg/kg.

FEMP Areas of Uranium Contamination Ranging from 10 to 10,000 mg/kg: Compared to the concentrations of total uranium in the Plant 6 area, the concentrations at all of the other areas were relatively less significant. These concentrations were less than 1000 mg/kg. Table 4-18 provides a summary of the minimum and maximum in each sampling interval by geographic areas.

Table 4-17, uranium summary table, indicates the areas where uranium contamination is present at levels of five times background. As expected, these areas are limited to process and waste storage areas as well as pipelines that carried process materials.

Appendix D.1 provides a more detailed description of uranium contamination. The analysis indicates that the concentrations greater than 100 mg/kg are typically limited to isolated areas in the subsurface soil. Generally, only 2 to 3 samples exceeded 100 mg/kg for a given depth interval in each area. Thus, the uranium contamination (7100 mg/kg) in the subsurface soil can be characterized as isolated occurrences underneath process and waste areas.

Radium-226

Radium-226 is a progeny of radioactive decay of uranium-234 isotopes. Therefore, uranium ores inevitably contain radium-226. Uranium ore (pitchblende) that was processed at the FEMP between 1953 and 1955 contained a range of radium levels. Results from a study by the United States Public Health Service (USPHS) (reported in Boback et al., 1987) indicate that the ratio of radium-226 activity to the mass of total uranium in pitchblende can be expected to be in the range of approximately 0.037-10.3 μCi/kg.

During the processing of the ore to extract uranium in a more concentrated form (called the "yellowcake"), most of the progeny is separated, with the exception of radium-226. Depending on the process of extraction (using sulphuric acid or carbonate solution), a wide range of concentrations of radium-226 may be expected in the yellowcake.

Thus contamination from radium-226 can be expected at locations where uranium ores or the yellowcake was processed or stored, because of spills/leaks from equipment, leaks/uncontrolled releases from pipes, leaks from storage facilities/drums, and so forth. Furthermore, radium-226 might also have been released into the atmosphere along with uranium, as a result of plant processes, incinerator operation, etc., and consequently deposited on surface soils. Table 4-19 presents the summary table for radium-226, while Table 4-20 presents the minimum and maximum detections of radium-226 by geographic area. Major aspects of the radium-226 contamination at the FEMP are as follows:

- Within the production area, 38 percent of the surface soil samples and 10 percent of the subsurface soil samples yielded above-background activities of radium-226, whereas

outside the production area (on- and off-property), 18 percent of the surface soil and 3 percent of the subsurface soil samples yielded above-background activities of radium-226.

- Radium-226 contamination at levels greater than five times background is primarily limited to the surface soil (see Table 4-19), and its presence at these levels is limited to the areas of expected contamination (see Table 4-9).

- Radium-226 is relatively insoluble; therefore, contamination at levels greater than five times background is not expected in the subsurface soil. The only exception to this is in the area west of K-65 silos. In this area, radium-226 was detected at levels greater than five times background as a result of leaks and spilling while filling the K-65 decant tank.

- All of the radium-226 activity detected at the FEMP is encompassed by the 20 mg/kg uranium envelope (described in Section 4.6.1).

Radium-226 Contamination in Surface Soil

The radium-226 contamination at the FEMP is limited to the process areas and storage areas where elevated levels were expected (see Table 4-9). Two areas of the FEMP evidenced radium-226 activities greater than 1000 pCi/g. These areas, the Plant 1 area and the scrap metal pile area, are discussed as follows.

FEMP Areas of Radium-226 Contamination Greater than 1000 pCi/g: The Plant 1 area and the scrap metal pile area were the only two areas at the FEMP where radium-226 detections exceeded 1000 pCi/g.

- Plant 1 area: The most significant radium-226 contamination in surface soil was observed in the Plant 1 area. The activity levels exceeded background by orders of magnitude. The concentration ranges in the surface soil depths were as noted below:

  - 0 to 0.5 foot: 0.42-2720 pCi/g
  - 0.5 to 1.0 foot: 0.69-2630 pCi/g
  - 1.0 to 1.5 feet: 0.60-383 pCi/g

- Scrap Metal Pile area: The highest activity in the 0- to 0.5-foot depth was 2950 pCi/g, which was detected at the scrap metal pile area. The activity levels in the 0.5- to 1.0-foot depth, however, barely exceeded the background level, and activity levels in the 1.0- to 1.5-foot depth samples were below the background level.

The activities in the immediate vicinity of these locations barely exceeded background even within the depth interval of the elevated detection. Thus these locations are actually isolated areas of major contamination of radium-226. These locations are tightly enclosed (conceptually) by the

isoconcentration contour of the 1000 pCi/g level, as depicted in Figures 4-28, 4-29, and 4-30, which show the isoconcentration contours at the 0- to 0.5-, 0.5- to 1.0-, and 1.0- to 1.5-foot depths, respectively.

FEMP Areas of Radium-226 Contamination Ranging from 10 to 1000 pCi/g: The other areas where activities exceeded background levels in surface soils were as follows: Plant 2/3 area, sewage treatment plant area, pilot plant area, D&D building and drum baling area, area west of the K-65 silos, K-65/Clearwell line west area, the southern area of the FEMP, and the western area of the FEMP. The range of concentrations in the 0- to 0.5-foot depth samples at these other areas was 0.30-220 pCi/g. The activity levels in the 0.5- to 1.0-foot depth and the 1.0- to 1.5-foot depth samples at these locations (with the exception of the area west of the K-65 silos and the K-65/Clearwell line west area) were less than 20.0 pCi/g. At the latter two areas, the maximum activity levels in the 0.5- to 1.0-foot samples were more elevated, to a maximum of 75.9 pCi/g.

In summary, the surface soil contamination from radium-226 is expected to have resulted from spills or leaks or deposition of air-dispersed particles. The contamination is limited to the top 6 inches of soil in most areas. Because of the low solubility of radium-226 and the absence of sources in the 1.0- to 1.5-foot depth, the contamination in the 0.5-to 1.5-foot depth is insignificant in all areas except the Plant 1 area. The significantly elevated contamination levels in one location at the Plant 1 area (in the 0.5 to 1.5 foot depth interval) might have resulted from earth moving operations at that location.

Radium-226 Contamination in Subsurface Soil

Radium-226 contamination in subsurface soil at most FEMP areas might be expected to be insignificant because of the absence of significant contamination in the 0.5- to 1.0-foot depths. As depicted in Figures 4-31 through 4-35, the sample activities exceeded background in isolated locations in the subsurface soil. A definite plume of radium-226 contamination exceeding background cannot be observed at the site unlike other more prevalent radionuclide contaminants such as uranium. However, a source under the K-65 silos is likely to have contributed to the contamination in the subsurface soil in the area west of the K-65 silos.

One source of subsurface soil contamination under the K-65 silos is expected to have been the sump and related piping below the silos. According to the RI report for Operable Unit 4, the sump might

have leaked or overflowed its contents into the surrounding soil (DOE 1993e) and caused the contamination in the subsurface soil. Leaks and spills associated with the filling of the silos is also a potential source for radium contamination in and around the Operable Unit 4 area.

One of the significant constituents of the slurry that was stored in the K-65 silos was radium-226, as noted in the analysis of the slurry for radionuclides (DOE 1992). Thus, contaminants in the supernatant from the silos would have consisted not only of the soluble constituents (such as sodium and potassium) of the slurry, but also a significant quantity of relatively insoluble constituents such as radium-226 as suspended particulates. Therefore, radium-226 contamination in the subsurface soil can be expected in the vicinity of the K-65 silos.

Accordingly, samples at the 3.0- to 5.0-foot depth and the 5.0- to 10.0-foot depth in the area west of the K-65 silos contained significantly elevated levels of radium-226, or ranges 0.30-137 pCi/g and 0.30-11.0 pCi/g, respectively.

It must be noted that the activities in the immediate vicinity of the highest detections were significantly lower, and mostly less than background. Thus, the locations of the highest activities were actually isolated areas of significant contamination. Furthermore, the activities in the 10.0- to 15.0-foot depth and the 15.0- to 20.0-foot depth samples in this area were less than background. The other areas where radium-226 activities exceeded background are shown in Table 4-19 and presented in Table 4-20.

4.6.1.1.2 Actinium Series

Uranium-235 is the only member of the actinium series routinely characterized at the FEMP. Uranium-235 is an alpha emitter with a 7.038×10^8 year half-life (Refer to Section 4.1 for a discussion of half-lives.). Natural uranium contains 0.72 percent (on an atom basis) of uranium-235; whereas enriched uranium contains the uranium-235 isotope in greater abundance (typically 0.95 percent to 1.25 percent at the FEMP); and depleted uranium contains less than 0.72 percent uranium-235 (typically, 0.14 percent to 0.20 percent for material processed at the FEMP). Approximately 54 percent of the shipments received at the FEMP were natural uranium, 20 percent were enriched uranium (some processing of 2 percent uranium-235 occurred in the 1960s), and 26 percent were depleted uranium.

Beginning in October 1962, the FEMP started processing recycled uranium, which is uranium that had been returned to the FEMP from other weapons materials processing facilities. The recycled materials had been irradiated in production reactors where finished uranium products were used. The recycled material contained trace amounts of uranium activation products and fission products. Uranium-236, an alpha emitter with a 2.3415 x 10^7 year half-life, is a neutron activation product of uranium-235. The factor of 30 less in half-life equates to uranium-236 activity being the same order as the uranium-235 activity. Its concentration in recycled material was on the order of 0.02 percent. (The isotopic level is a function of the neutron flux spectrum and irradiation time.) The alpha spectroscopy assay method used could not resolve the principal alpha from these two uranium isotopes. Thus the activity is reported as uranium-235/236 for this reason. (Some analyses were performed by thermal emission mass spectrometry, which did not have this limitation.)

The uranium-235 and uranium-236 released to the environment from FEMP activities were in the same chemical form as uranium-238. Thus the only difference in uranium-235/236 relative to uranium-238 or total uranium in contaminated soil can be explained by variable feed materials processed at the FEMP rather than by any intrinsic property of uranium-235 or uranium-236. Processes that released uranium-238 to the environment would have released uranium-235 and uranium-236 at their relative isotopic concentrations in the process stream at the time of release. Thus the total uranium discussion provided above applies to the uranium-235/236 contamination as well. A detailed discussion of uranium-235/236 is presented in Appendix D.1.

4.6.1.1.3 Thorium Decay Series

The thorium decay series is a natural alpha emission decay series. Members of the series include thorium-232, total thorium, radium-228, and thorium-228. The FEMP was the national repository for thorium. Thorium-232, the first member of a natural decay series, has a 1.405 x 10^{10} year half-life that decays by alpha emission. Thorium production occurred intermittently from 1954 through 1975 and then continued through 1980. Thorium was an impurity in uranium concentrates used as feed material and in uranium ore. The Canadian concentrates used as refinery feed from 1956 through 1960 contained sufficient thorium impurity to require blending so that the feed solutions did not exceed 0.5 percent thorium on a uranium basis (0.55 pCi thorium per kilogram of uranium). Thus both uranium production and thorium production processes provided release paths of thorium to the environment. However, thorium production provided the most significant releases to the environment. These releases are expected to be less than releases of uranium because uranium

production processes were the main mission of the FEMP. The past plant operations involved storage and processing of thorium materials in Plants 1, 4, 6, 8, and 9; the pilot plant; and the laboratory.

A detailed summary of total thorium contamination, as defined by sample activity relative to background levels in surface and subsurface soils, is presented below. A discussion of the nature and extent of total thorium will depict the contamination of the thorium decay chain, since thorium-232 comprises essentially all of the concentration of total thorium. Likewise the radium-228 will be present only from the decay chain of thorium-232; therefore, the total thorium contamination will depict radium-228 as well. A detailed discussion of each of these parameters is provided in Appendix D.1.

Total Thorium

Thorium was processed in ores, compounds, and metallic state at several plants at the FEMP. Thorium could have been released through a variety of pathways during various uncontrolled processing steps such as digestion, tetrafluoride production, solvent extraction, tetrafluoride reduction, dezincing operations, milling, etc. Further, thorium ores, compounds, and the metal were stored at various locations at the FEMP. Therefore leaks, spills, and other occurrences might have contributed to the contamination in these areas. Table 4-21 presents the summary of total thorium contamination, whereas Table 4-22 presents the minimum and maximum detected concentration ranges by study area.

The main aspects of the thorium distribution are as follows:

- Within the production area, 26 percent of the surface soil samples and 9 percent of the subsurface soil samples yielded above-background activities of radium-226, whereas outside the production area, 27 percent of the surface soil and 8 percent of the subsurface soil samples yielded above-background activities of radium-226.
- Total thorium contamination at levels greater than five times background is primarily limited to the surface soil (see Table 4-21), and its presence at these levels is limited to the areas of expected contamination (see Table 4-9).
- All of the total thorium concentrations detected at the FEMP are encompassed by the 20 mg/kg uranium envelope (described in Section 4.6.1).

Total Thorium Contamination in Surface Soil

This section provides an overview of the total thorium contamination in the surface soil at the FEMP. Total thorium was detected in 1417 of 1959 surface soil samples (constituting approximately

72 percent of detections) that were collected across the entire site. These samples do not include samples of waste materials that are considered to be part of other operable units. Of the 1417 detections, 511 concentration values (constituting approximately 36 percent of the detections) exceeded background for surface soils, or 12.4 mg/kg. Therefore a significant fraction of the detected concentrations exceeded background.

The discussion of the geographic areas of contamination is provided on a general basis using isoconcentration contours at the 1000, 100, and 10 mg/kg level. Figures 4-36, 4-37, and 4-38 depict the isoconcentration contours in samples from depths of 0 to 0.5 foot, 0.5 to 1.0 foot and 1.0 to 1.5 feet, respectively. The areas where the total thorium concentrations exceed 100 mg/kg are shaded to highlighted in these figures.

FEMP Areas of Thorium Contamination Greater than 1000 mg/kg: The highest concentrations of total thorium in the surface soils were detected at levels exceeding 1000 mg/kg at the scrap metal pile area and the laboratory area. The maximum concentrations exceeding for these areas in samples from the 0- to 0.5-foot interval were 1769.3 and 2581 mg/kg, respectively.

The absence of significant levels in the immediate vicinity of elevated sample concentration in the scrap metal pile area indicates that this location is an isolated area of major contamination. However, the locations of the elevated sample concentrations in the laboratory area may be part of a wider area of contamination at levels exceeding 50 mg/kg, as depicted in Figure 4-36, which shows the isoconcentration contours in the 0- to 0.5-foot depth. Improper disposal of thorium samples or wastes may have contributed to the contamination in these areas.

FEMP Area of Thorium Contamination Greater than 100 mg/kg: Significant concentrations of total thorium were also detected (at depths of 0 to 0.5 foot) at the following areas and at the maximum concentrations stated (see Table 4-22):

- Plant 1 area: 287 mg/kg
- Plant 9 area: 766 mg/kg
- Sewage treatment plant area: 564 mg/kg
- D&D building and drum baling area: 152 mg/kg
- Pilot plant area: 184 mg/kg
- K-65/Clearwell line west: 365 mg/kg
- Northeast area of FEMP: 954 mg/kg
- Western area of the FEMP: 347 mg/kg

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The concentrations of total thorium (in the 0.5- to 1.0-foot depth) at following areas continued to be elevated above the 100 mg/kg level although at relatively lower levels, as noticed by the maximum concentrations stated below:

- Laboratory area: 524 mg/kg
- Plant 1 area: 172 mg/kg
- K-65/Clearwell line west: 133 mg/kg

The concentrations (in the 1.0- to 1.5-foot depth) at the laboratory area continued to be elevated above the 100 mg/kg level, with a maximum concentration of 562 mg/kg. However, as depicted in Figure 4-38 (Plate D-48), several of the sample concentrations in the vicinity of the location of the maximum detection were below detection limits. Analysis of the data indicates that the extent of the contamination in this area had reduced significantly in size from its original extent in the 0- to 0.5-foot depth. Samples were not collected in this depth interval at the scrap metal pile area.

Four of the areas that were identified as having elevated sample concentrations in samples from the 0- to 0.5-foot depth or the 0.5- to 1.0-foot depth continued to have elevated sample concentrations in the 1.0- to 1.5-foot depth with maximum levels as noted below:

- Plant 9 area: 321 mg/kg
- Laboratory area: 562 mg/kg
- K-65/Clearwell line west area: 133 mg/kg
- Scrap metal pile area: 132 mg/kg

Thus, several areas had elevated sample concentrations of total thorium in the surface soil samples. The most significant area of contamination was in the laboratory area which had elevated levels of contamination in samples from each of the three sampling intervals throughout the entire 0- to 1.5-foot depth. Areas where elevated levels of contamination were detected in samples from the 0- to 0.5- and the 1.0- to 1.5-foot depth were the Plant 9 area, the K-65/Clearwell line west area, and the scrap metal pile area. Areas where the elevated levels of contamination were limited to the 0- to 0.5-foot and the 0.5- to 1.0-foot depth samples were the sewage treatment plant area, pilot plant area, D&D building and drum baling area, the northeast area of the FEMP, and the western area of the FEMP.

Total Thorium Contamination in Subsurface Soil

This section provides an overview of the total thorium contamination in the subsurface soil (1.5- to 20.0-foot depth) at the FEMP. Total thorium was detected in 777 of 1618 subsurface soil samples (constituting approximately 48 percent of detections) that were collected across the entire site. These samples do not include samples of waste materials that are considered to be part of other operable units. Of the 777 detections, only 144 concentration values (constituting approximately only 9 percent of the detections) exceeded the background concentration for subsurface soils of 11.1 mg/kg. Therefore a small fraction of the detected concentrations exceeded the background level.

A discussion of the areas of contamination is provided on a general basis using isoconcentration contours at the 100 and 10 mg/kg level. Figures 4-39 through 4-43 depict the isoconcentration contours in the 1.5- to 3.0-, 3.0- to 5.0-, 5.0- to 10.0-, 10.0- to 15.0-, and 15.0- to 20.0-foot depth, respectively.

The contamination in all of the areas in the surface soil identified at elevated levels was at significantly lower levels in the subsurface soil. As depicted in the figures, the isoconcentration contours are significantly smaller in size, indicating a reduced extent of contamination in the subsurface soil.

Most notably, the concentrations in all of the depth intervals from 1.5 to 20.0 feet in the laboratory area were less than 10 mg/kg. The data indicate that the elevated levels of contamination at this area were limited to the surface soil and that there were no subsurface sources in this area.

At the scrap metal pile area, concentrations in the 1.5- to 3.0-foot depth and the 3.0- to 5.0-foot depth were somewhat elevated at maximum levels of 69 and 72 mg/kg, respectively. However, the concentrations in the deeper samples were significantly lower and mostly less than 10 mg/kg.

At the pilot plant area, concentrations in the 3.0- to 5.0- and the 5.0- to 10.0-foot depth were significantly elevated at maximum levels of 83 and 290 mg/kg, respectively. However, the concentrations in the deeper samples were significantly lower. A possible subsurface source (the thorium sump) might have contributed the elevated levels at this area.

Some of the other areas where significant levels were observed in various depth intervals of subsurface soil were as follows: the Plant 1, 6, and 9 areas, the fire training area, and the southern area of the FEMP.

However, at all of the above areas (with the exception of the fire training area), the concentrations were less than 100 mg/kg. At the fire training area, however, the maximum concentration was 136 mg/kg in the 3.0- to 5.0-foot sample.

Typically, the elevated levels of subsurface soil contamination at the areas mentioned above were limited to a maximum of two depth intervals (of the five intervals sampled) in the entire 1.5- to 20.0-foot depth. However, the concentrations at most of the areas in the deeper subsurface soil (15.0- to 20.0-foot depth) were less than the background level. Thus, significant thorium contamination in the subsurface soil seems to be limited to a depth of less than 10.0 feet.

4.6.1.1.4 Uranium Activation and Fission Products

Beginning in October 1962, the FEMP started processing recycled uranium. The recycled materials had been irradiated in production reactors to produce weapons-grade materials. Products from the fissioning of uranium and plutonium accumulated in the irradiated uranium. The uranium was chemically processed to remove the fission products, but residual levels remained. The fission products in recycled materials processed at the FEMP were at low levels and some had long half-lives.

The activation products analyzed for in this investigation were neptunium-237, plutonium 239/240, and plutonium-238. Detections of these four radionuclides were generally isolated occurrences throughout the production area and waste storage areas. Approximately 5 percent or less of the samples analyzed for these activation products had detections (see Tables 4-13 and 4-14), thus contamination from these activation products is minimal. All detections in the soil were within the 20 mg/kg uranium envelope. A detailed discussion of each of these parameters is presented in Appendix D.1.

Uranium-236 is an additional uranium activation product that may be found in recycled material. However, the analytical methods used to quantify uranium isotopes for most FEMP samples cannot resolve between uranium-235 and uranium-236. However, it is likely that any elevated levels of

uranium-236 would be found in the same locations as the other activation products, that is, within the 20 mg/kg uranium envelope.

The fission products analyzed for in this investigation were strontium-90, technetium-99, ruthenium-106, and cesium-137. Detections of these four radionuclides were generally isolated occurrences throughout the site. A significant reduction from the surface soil to the subsurface soil (see Tables 4-14 and 4-15) in detections above background occurred in the soil at the FEMP. All detections in the soil were within the 20 mg/kg uranium envelope. A detailed discussion of each of these parameters is presented in Appendix D.1.

4.6.1.2 Inorganic Contamination

Similar to the radionuclide contamination, the majority of inorganic contamination is present within the uranium envelope. Thus a discussion is provided of those inorganics which have a high frequency of detection above background or which are important in the risk evaluation. Appendix D.1 provides a detailed discussion of all 26 inorganic parameters.

Isolated detections occurred outside the envelope at a level greater than five times background for cadmium, cyanide, and magnesium. Detections outside the uranium envelope also occurred for antimony, molybdenum, and silver, all of which have no background value. Table 4-42 summarizes the parameters and provides a general indication of sample location.

The following parameters have been designated as not as significant in the Appendix D discussion and are thus excluded from further discussion.

- Aluminum
- Antimony
- Barium
- Calcium
- Cobalt
- Cyanide
- Iron
- Manganese
- Potassium
- Selenium
- Silicon
- Sodium
- Thallium
- Vanadium
- Zinc

A summary-level discussion is provided for arsenic, beryllium, cadmium, lead, and mercury because they are viewed as the most significant inorganics, based on frequency of detection and levels. A detailed discussion of the inorganics chromium, copper, magnesium, molybdenum, nickel, and silver,

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which were determined to be contaminants of significance, as well as the 15 inorganics listed above, is provided in Appendix D.1.

Arsenic

Based on the data in the following discussion, arsenic is a significant contaminant at the FEMP. Except for isolated locations at the trap range and an area south of the K-65 silos, the elevated levels of arsenic are located within the 20 mg/kg envelope discussed in 4.6.1. Arsenic is a trace element in the earth's crust and is a trace constituent of coal and its resulting in flyash when burned. Arsenic is also a minor impurity in uranium ores and ore concentrates. Arsenic or its compounds were not reported to have been used in production activities at the FEMP.

A summary of arsenic contamination, as defined by sample concentration relative to the 95th percentile background values (background) in surface and subsurface soils, is presented in Table 4-23. Table 4-24 summarizes the geographic areas that exhibited arsenic concentrations and provides the range of concentrations for each depth interval in the surface and subsurface soils. Details for arsenic contamination in the geographic areas and in the surrounding areas of the former production plant are provided in Section D.2.

Surface Soil

Background concentrations for arsenic in the surface soil ranged from 3.40 to 9.2 mg/kg, based on 30 samples collected during the background study. Background was calculated as 8.2 mg/kg, as indicated in Table 4-5.

Arsenic concentrations were positively identified above background in 64 of 400 surface samples collected at depths of 0-1.5 feet. Arsenic concentrations ranged from 0.77 to 81.9. A statistical summary of sampling and analytical results for arsenic in the surface soil at the FEMP is presented in Table 4-14. Arsenic concentrations in surface soil across the FEMP are depicted in Figures 4-44 through 4-46 (Plates D-77, D-78, and D-79).

Arsenic concentrations in surface soil exceeded background in most areas of the FEMP. However, most of the arsenic contamination in FEMP surface soil was detected at levels of less than 16.4 mg/kg which is two times background. Arsenic concentration in surface soil across the FEMP is depicted in Figures 4-44 through 4-46 (Plates D-77, D-78, and D-79). The only location where arsenic

concentrations in surface soil exceeded five times backyard was in the 0.5- to 1.0-foot samples at the graphite furnace, oil burner, and coal pile area, where the range of all detected concentrations was 3.7 to 81.9 mg/kg. Other areas where arsenic exceeded twice background were the trap range and an area south of the K-65 silos where concentrations ranged from 2.0 to 25.3 mg/kg and 1.6 to 32.5 mg/kg, respectively.

Subsurface Soil

Background concentrations for arsenic in the subsurface soil ranged from 1.60 to 14.5 mg/kg, based on 51 samples collected during the background study. Background was calculated as 9.57 mg/kg, as indicated in Table 4-6.

Arsenic concentrations were positively identified above background in 36 of 312 subsurface samples collected at depths of 1.5 to greater than 10 feet. Arsenic concentrations ranged from 0.03 to 74.2 mg/kg. A statistical summary of sampling and analytical results for arsenic in subsurface soil at the FEMP is presented in Table 4-15.

The concentration of arsenic in subsurface soils at the FEMP exceeded background at a few locations. The majority of arsenic contamination was detected at concentrations that were less than twice background (19.14 mg/kg). The only location where arsenic concentrations exceeded twice background was in the 3.0- to 5.0-foot and 5.0- to 10.0-foot samples at the area west of the K-65 silos. The range of all detected concentration in these samples was 2.8 to 74.2 mg/kg.

The widespread occurrence of arsenic at concentrations that exceeded background may be attributed to the dispersion by air of particles from the coal and flyash piles, followed by surficial deposition.

Beryllium

Based on the data in the following discussion, it was determined that beryllium is a significant contaminant of the FEMP. Except for some isolated locations in the area northwest of the former production area and the active flyash pile, concentrations of beryllium are located within the 20 mg/kg uranium envelope as discussed in 4.6.1. Beryllium is a trace element in the earth's crust and is a trace constituent in coal and the resulting flyash when burned. Beryllium or its compounds were not reported to have been used in operations at the FEMP. Raw materials and products that were handled in Plant 1, Plant 8, the pilot plant, the laboratory, and the main maintenance building

could potentially have contributed to beryllium contamination in the surface soil. In addition, incineration residues from the contaminated oil/graphite burn pad and slag recycling building possibly were spread into the surrounding areas. Table 4-11 highlights the areas that may be potential sources of beryllium.

A summary of beryllium contamination, as defined by sample concentration relative to the 95th percentile background values (background) in surface and subsurface soil, is presented in Table 4-25. Table 4-26 summarizes the geographic areas that exhibited beryllium concentrations and provides the range of concentrations for each depth interval in the surface and subsurface soils. Details for beryllium contamination in the geographic areas and in the surrounding areas of the former production plant are provided in Section D.2.

Surface Soil

Background for beryllium in the surface soil was 0.60 mg/kg, based on one of 30 samples collected during the background study. Background was calculated as 0.60 mg/kg, as indicated in Table 4-5.

Beryllium concentrations were positively identified above background in 197 of 424 surface samples collected at depths of 0 to 1.5 feet. Beryllium concentrations ranged from 0.28 to 5.70. A statistical summary of sampling and analytical results for beryllium in the surface soil at the FEMP is presented in Table 4-14. Beryllium concentrations in the 0- to 0.5-foot interval of surface soil across the FEMP are depicted in Figure 4-47 and Plate D-84.

The majority of the FEMP had beryllium contamination in surface soil detected at levels exceeding background. About half of the geographic areas of the FEMP had detected levels greater than twice background. Beryllium concentrations exceeded five times background only at the following locations:

- Plant 2/3 area: 3.20 mg/kg
- Plant 8 area: 3.50 mg/kg
- Northeast area of FEMP: 5.70 mg/kg

Concentrations of beryllium in samples from the 1.0- to 1.5-foot depth interval from certain areas within the former production plant were higher than concentrations in the shallower samples. These areas include locations in the areas of Plant 2/3; Plant 8; the graphite furnace, oil burner, and coal pile; and Plant 9.

Subsurface Soil

Background concentrations for beryllium in the subsurface soil ranged from 0.48 to 0.68 mg/kg, based on 15 of 51 samples collected during the background study. Background was calculated as 0.62 mg/kg, as indicated in Table 4-6.

Beryllium concentrations were positively identified above background in 185 of 333 subsurface samples collected at depths of 1.5 to 15.0 feet below the ground surface. Beryllium concentrations ranged from 0.29 to 5.20 mg/kg. A statistical summary of sampling and analytical results for beryllium in the subsurface soil at the FEMP is presented in Table 4-15.

The majority of beryllium contamination in subsurface soil at the FEMP was detected at levels that exceeded background. Generally, there were detections greater than twice background throughout the farm production area to a depth of 3.0 feet. Beryllium concentrations exceeded five times background (3.10 mg/kg) only at the following locations:

- Plant 1 area: 3.50 mg/kg
- Plant 4/5/7 area: 3.90 mg/kg
- Area west of K-65 silos: 5.20 mg/kg

These levels were typically at depths of 5.0 to 10.0 feet.

Probable sources of beryllium contamination, as previously identified, were mainly the pilot plant; Plant 1; the graphite furnace, oil burner, and coal pile area; the laboratory, and the maintenance building. Low-level beryllium contamination is widespread at the FEMP, potentially because of dispersion from the coal and flyash piles. However, the concentrations of beryllium in the surface and subsurface soils at several locations exceeded five times background. The elevated levels of beryllium present in the soils at Plant 1 and the graphite furnace, oil burner, and coal pile area could be contributing to the perched groundwater plumes of beryllium as discussed in Appendix E. The soil contamination in other areas, such as Plant 2/3 and Plant 8, where beryllium concentrations exceeded background, could be contributing to the large perched groundwater plume that is also discussed in Appendix E.

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Cadmium

Based on the data in the following discussion, it was determined that cadmium is a significant contaminant in the FEMP. Except for isolated locations near the K-65 silos, all concentrations of cadmium were located within the 20 mg/kg uranium envelope as discussed in 4.6.1. Cadmium is a trace element in the earth's crust and is a trace constituent in coal and its resulting flyash when burned. Cadmium or its compounds were not reported to have been used in operations at the FEMP. However, cadmium was a minor imprinting in the uranium ore processed at the FEMP. Table 4-9 highlights the areas that may be potential sources of cadmium.

A summary of cadmium contamination, as defined by sample concentration relative to the 95th percentile background values (background) in surface and subsurface soils, is presented in Table 4-27. Table 4-28 summarizes the geographic areas that exhibited cadmium concentrations and provides the range of concentrations for each depth interval in the surface and subsurface soils. Details for cadmium contamination in the geographic areas and in the surrounding areas of the former production plant are provided in Section D.2.

Surface Soil

Background concentrations for cadmium in the surface soil ranged from 0.52 to 0.95 mg/kg, based on 30 samples collected during the background study. Background was calculated as 0.87 mg/kg, as indicated in Table 4-5.

Cadmium concentrations were positively identified above background in 154 of 442 surface samples collected at depths from 0 to 1.5 feet below the ground surface. Cadmium concentrations ranged from 0.49 to 12.40 mg/kg. A statistical summary of sampling and analytical results for cadmium in the surface soil at the FEMP is presented in Table 4-14. Cadmium concentrations in surface soil across the FEMP are depicted in Figures 4-49 through 4-51 (Plates D-85, -86, and -87).

Most of the cadmium contamination in surface soils at the FEMP was detected at levels exceeding background. The concentrations of cadmium in surface soils exceeded five times background (4.35 mg/kg) at the locations as listed below:

- Plant 1 area: 6.70 mg/kg
- Plant 2/3 area: 6.90 mg/kg
- Plant 6 area: 4.60 mg/kg
- Tank farm and boiler house: 5.40 mg/kg
- Graphite furnace, oil burner, and coal pile area: 12.40 mg/kg

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- Plant 9 area: 6.30 mg/kg
- Pilot plant area: 5.40 mg/kg
- Laboratory area: 4.90 mg/kg
- Maintenance building area: 8.00 mg/kg
- Fire training area: 7.60 mg/kg
- Area west of K-65 silos: 4.90 mg/kg
- Western area of FEMP: 6.70 mg/kg

Subsurface Soil

Background concentrations for cadmium in the subsurface soil ranged from 0.47 to 1.30 mg/kg, based on 51 samples collected during the background study. Background was calculated as 0.91 mg/kg, as indicated in Table 4-6.

Cadmium concentrations were positively identified above background in 172 of 320 subsurface samples collected at depths of 1.5 to greater than 10 feet below the ground surface. Cadmium concentrations ranged from 0.92 to 8.0. A statistical summary of sampling and analytical results for cadmium in the subsurface soil at the FEMP is presented in Table 4-15. Cadmium concentrations in subsurface soil across the FEMP are depicted in Figures 4-52 and 4-53 (Plates D-88 and D-89).

The majority of cadmium contamination in subsurface soil at the FEMP was detected at concentrations that exceeded background. Location where concentrations of cadmium exceeded five times its background and the maximum concentrations at each location are listed below:

- Plant 1 area: 6.40 mg/kg
- Plant 6 area: 7.0 mg/kg
- Pilot plant: 7.90 mg/kg
- Maintenance building area: 8.0 mg/kg
- Tank farm and boiler house: 7.60 mg/kg
- Graphite furnace, oil burner, and coal pile area: 7.70 mg/kg
- Western area of FEMP: 4.80 mg/kg

The probable sources of cadmium contamination at the FEMP are the coal and flyash piles and impurities in uranium ore. Air dispersion of cadmium, followed by surficial deposition, is a potential pathway for surface soil contamination. This is a possible explanation for the widespread presence of cadmium at the FEMP at concentrations exceeding background. Subsequent infiltration of cadmium by rainwater is a potential pathway for subsurface soil contamination.

Soil contamination in the areas of Plant 1; Plant 2/3; the pilot plant; and the graphite furnace, oil burner, and coal pile could be contributing to the cadmium concentrations in the perched groundwater at these locations, where cadmium was detected at levels that exceeded background for groundwater.

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Lead

Based on data in the following discussion, it was determined that lead is a significant contaminant of the FEMP. Except for the trap range and an isolated location in the northwestern area of the FEMP, concentrates of lead are located within the 20 mg/kg uranium envelope as discussed in D.1. Lead has been identified as a potential contaminant in operations of ore preparation and refinery (Plants 1 and 2), metal production and fabrication (Plants 5 and 6), decontamination (decontamination building), and maintenance (service building). Lead shot was used at the trap range. Lead concentrates in the K-65 silos were detected as high as 199,000 mg/kg. Table 4.6.1 highlights the areas that may be potential sources of lead contamination.

A summary of lead contamination, as defined by sample concentrations relative to the 95th percentile background values (background) in surface and subsurface soils, is presented in Table 4-29. Table 4-30 summarizes the geographic areas that exhibited lead concentrations and provides the range of concentrations for each depth interval in the surface and subsurface soils. Details for lead contamination in the geographic areas and in the surrounding areas of the former production plant are provided in Section D.2.

Surface Soil

Background concentrations for lead in the surface soil ranged from 11.00 to 36.40 mg/kg, based on a total of 30 samples collected during the background study. Background was calculated as 26.40 mg/kg, as indicated in Table 4-5.

Lead concentrations were positively detected above background in 114 of 415 surface soil samples at concentrations ranging from 2.88 to 2180.00 mg/kg. A statistical summary of the analytical results for lead in the surface soil at the FEMP is presented in Table 4-14.

As depicted in Figures 4-54 through 4-56 (Plates D-99, D-100, and D-101), the majority of lead contamination in FEMP surface soil was found in the 0- to 0.5-foot interval in areas throughout the FEMP. Lead concentrations were detected at levels of at least 132 mg/kg in these areas. The level of 132 mg/kg is five times background. These areas include:

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- Plant 2/3 area
- Plant 6 area
- Sewage treatment plant area
- Electrical substation area
- Maintenance building area
- D&D building and drum baling area
- Scrap metal pile, decontamination building, and Buildings 64 and 65
- KC-2 warehouse area
- Trap range
- K-65/Clearwell line west area

As expected, the highest level of lead (2180 mg/kg) was detected at the trap range.

Subsurface Soil

Background concentrations for lead in the subsurface soil ranged from 3.00 to 18.40 mg/kg, based on a total of 51 samples collected during the background study. Background was calculated as 15.60 mg/kg, as indicated in Table 4-6.

Lead concentrations were positively detected above background in 85 of 339 subsurface soil samples at lead concentrations ranging from 0.47 to 139 mg/kg. A statistical summary of the analytical results for lead in the subsurface soil at the FEMP is presented in Table 4-15.

The majority of lead contamination in FEMP subsurface soil was detected in the area west of K-65 silos. Lead concentrations were detected at levels of at least 78.00 mg/kg in this area. The level of 78.00 mg/kg is five times background. Lead was detected in the area west of K-65 silos at concentrations ranging from 8.90 to 139.00 mg/kg. Lead was detected in the fire training area with concentrations as high as 71.00 mg/kg and may be attributable to the use of waste solvents and oils in that area. The probable sources for lead are lead shot at the trap range and impurities in uranium ores.

Mercury

Based on the data in the following discussion, it was determined that mercury is a significant contaminant in the surface soil of the FEMP. Except for an isolated detection at the trap range, concentrations of mercury were located within the 20 mg/kg uranium envelope as discussed in 4.6.1. Mercury is a trace constituent in the earth's crust and is a minor trace element in flyash. Mercury and its compounds were reported as sources of potential contaminants in Plant 4 (hydrofluorination and vaporization processes), Plant 5 (metal reduction), Plant 8 (primary calciner and oxidation furnace), the boiler plant (steam production), the maintenance building (maintenance activities), and

the pilot plant (general sump). Table 4-11 highlights the areas that may be potential sources of mercury.

A summary of mercury contamination, as defined by sample concentration relative to the 95th percentile background values (background) in surface and subsurface soils, is presented in Table 4-31. Table 4-32 summarizes the geographic areas that exhibited mercury concentrations and provides the range of concentrations for each depth interval in the surface and subsurface soils. Details for mercury contamination in the geographic areas and in the areas surrounding the former production plant are provided in Section D.2.

Surface Soil

Background concentrations for mercury in the surface soil were detected in 1 of 30 samples collected during the background study. Background for mercury in the surface soil was calculated as 0.30 mg/kg, as indicated in Table 4-5.

Mercury concentrations were positively detected background in 21 of 447 surface soil samples at concentrations ranging from 0.06 to 6.30 mg/kg. A statistical summary of the analytical results for mercury in the surface soil at the FEMP is presented in Table 4-14. Mercury concentration in surface soil across the FEMP is depicted in Figures 4-58 through 4-60 (Plates D-104, 105, and 106).

Most of the mercury in FEMP surface soil was detected in the 0.0- to 0.5-foot interval, as depicted in Plate D-104. Mercury concentrations were detected at levels above 1.50 mg/kg in the following areas: Plant 1 area, Plant 2/3 area, and the trap range. The level of 1.50 mg/kg is five times background.

Mercury was found at concentrations ranging from 0.14 to 4.60 mg/kg, 0.08 to 2.10 mg/kg, and 0.06 to 6.30 mg/kg in the construction rubble mound (Plant 1 area), central portion of Plant 2/3, and northern portion of the trap range, respectively. No known processes in the FEMP production would contribute to the mercury contamination in these areas. The mercury contamination in the construction rubble mound may have resulted from past storage activities. In addition, mercury was detected above two times background in the areas of the pilot plant, maintenance building, and tank farm and boiler house. The mercury contamination in these areas is expected based on processes used in the areas.

Subsurface Soil

Background concentration for mercury in the subsurface soil was detected in one of 51 samples collected during the background study. Background for mercury in the subsurface soil was determined to be 0.29 mg/kg, as indicated in Table 4-6.

Mercury concentrations were positively detected above background in 1 of 342 subsurface soil samples at concentrations ranging from 0.04 to 2.30 mg/kg. A statistical summary of the analytical results for mercury in the subsurface soil at the FEMP is presented in Table 4-15.

The only mercury contamination in subsurface soil at the FEMP was detected in the Plant 2/3 area. Mercury contamination in the 1.5- to 3.0-foot interval of subsurface soil is depicted in Plate D-107. Mercury was detected at a level of 2.3 mg/kg, which is greater five times background near the incinerator building. The mercury contamination in this location may have resulted from releases from past plant operations.

4.6.1.3 Organic Contamination

Numerous surface and subsurface soil samples were collected throughout the FEMP and adjacent areas, and analyzed for volatile and semivolatile organic analytes. As evidenced from the analytical results for organics, volatile organic compounds (VOCs) and semivolatile organic compounds are not significant contaminants at the FEMP. Except for isolated locations near the K-65 silos, northwest of the waste pits (Operable Unit 1), and southwest of the South Field, all concentrations of VOCs were found at sampling locations within the 20 mg/kg uranium envelope as discussed in Section 4.6.1. Similarly, all detections of semivolatiles were located within the 20 mg/kg uranium envelope as well. The majority of the detected VOCs and semivolatiles were present at relatively low levels in the top surface soil intervals of 0- to 0.5- and 0.5- to 1.0-foot. Although the levels of organic contamination generally decreased with depth, and within the same sampling interval, higher levels of VOCs and semivolatiles were detected in the 1.5- to 3.0- and 3.0- to 5.0-foot intervals in the subsurface soil than in the surface soil.

VOCs are common constituents of solvents, degreasers, and fuels that have been used at the FEMP. Semivolatiles are present in a variety of materials associated with industrial applications. The semivolatiles that were particularly associated with the production processes at the FEMP include PAHs and phthalates. PAHs are present in petroleum products and are also formed as a result of

incomplete combustion of hydrocarbon fuels, which were used at the FEMP. Phthalates are present in polymers and resins used in equipment and protective coatings. Table D-1 highlights the areas that are identified as potential sources of VOCs and semivolatiles.

Since VOCs do not occur naturally in the environment, no background concentrations for VOCs exist. Any positive detection of VOCs is considered to be above background. Similarly, any positive detection of semivolatiles is treated as exceeding background. The summary of VOC and semivolatile detections in and around the FEMP is provided below.

Volatile Organic Compounds: Twenty-four of thirty-six VOCs that were analyzed for were detected more than once in the surface soil intervals in the FEMP. Of these, toluene, methylene chloride, trichloroethene, acetone, 1,1,1-trichloroethane, and tetrachloroethene were the most frequently detected VOCs in the surface soil samples (as many as 73 detections in a total of 386 samples) as shown in Table 4-14. These VOCs primarily were detected in the top surface soil intervals of 0 to 0.5 and 0.5 to 1.0 foot in the production area. Total concentrations of VOCs in the 0- to 0.5-foot interval of the surface soil are illustrated in Figure 4-61. The majority of the VOC detections in the FEMP were present in the following areas:

- East of Plant 1 pad
- North of Plant 2/3 area
- Southwest of Plant 4
- Southeast of Plant 9
- West of pilot plant area
- Central of electrical substation area
- Northwest and northeast of maintenance building
- Southeast of maintenance building
- South and north of scrap metal pile
- North of graphite furnace, oil burner, and coal pile area
- South of coal pile (runoff basin) area
- South of KC-2 warehouse
- Southern portion of fire training area

Note that several of the above areas were detected with high levels of total VOC concentration in the surface soil: north of the maintenance building (92,860 μg/kg at 0 to 0.5, 58,110 and 6248 μg/kg at 0.5 to 1.0 foot), east of the Plant 1 pad (51,380 μg/kg at 0 to 0.5 foot), south of the scrap metal pile (2135 μg/kg at 0 to 0.5 foot), and north of the graphite furnace and oil burner (16,764 μg/kg at 0.5 to 1.0 foot).

In the subsurface soil, similar VOCs were detected as in the surface soil within the FEMP. Carbon disulfide, acetone, 4-methyl-2-pentanone, 1,1,1-trichloroethane, 1,2-dichloroethene, tetrachloroethene, trichloroethene, methylene chloride, and toluene were the most widely detected VOCs in the

subsurface soil (as many as 94 detections in a total of 382 samples). The VOCs primarily were detected in the intervals of 1.5 to 3.0 feet and 3.0 to 5.0 feet in areas within the production area, similar to those in the surface soil. High levels of total VOC concentrations were detected in subsurface soil in several areas: northwest (near the north pad) of the maintenance building (ranging to 121,600 μg/kg at 1.5 to 3.0 feet and 150,310 μg/kg at 3.0 to 5.0 feet), north of the graphite furnace and oil burner (11,775 μg/kg at 3.0 to 5.0 feet), southeast of Plant 9 (4465 μg/kg at 3.0 to 5.0 feet), west of the Pilot Plant (7463 μg/kg at 3.0 to 5.0 feet, 22,669 μg/kg at 5.0 to 10.0 feet, and 112,980 μg/kg at 10.0 to 15.0 feet), and in the southern portion of the Plant 1 area (15,181 μg/kg at 10.0 to 15.0 feet).

The sources of high levels of VOCs in the surface soil of the production area may be attributable to isolated spills of solvent material or leaks from storage containers (e.g., drums). The common laboratory and field decontamination solvents, such as methylene chloride and acetone, were among the most widely detected VOCs in the surface soil of the FEMP. Detections of these solvents in the samples may not be truly representative of actual site contaminants. The VOCs contamination in the shallow depths (1.5 to 5.0 feet) of the subsurface soil may be attributable to vertical contaminant migration from spills and leaking drums occurring at the surface. At greater depths (below 5.0 feet), the potential sources of VOCs contamination are leaks from subgrade piping and sumps (i.e., the pilot plant) or lateral migration of contaminated material by the perched groundwater, which is typically approximately 5 feet below the ground surface in most areas of the production area.

Semivolatile Organic Compounds: Semivolatiles, particularly the PAHs and phthalates, originated from the materials associated with the production processes at the FEMP. Forty-five semivolatiles and thirty-seven semivolatiles were positively identified in more than 300 samples that were collected at depths of 0 to 1.5 feet and below 1.5 feet, respectively, throughout the FEMP. Because of the number of semivolatile organic compounds detected in the soil samples, summation of all semivolatiles at each sampling location was used to depict the semivolatiles contamination.

The primary compounds in the semivolatiles detected in surface soil at the FEMP were PAHs and phthalates. A variety of PAHs were detected not only frequently, but also at high concentrations. The three most frequently detected PAHs were bis(2-ethylhexyl)phthalate (99 of 341 samples), fluoranthene (114 of 345 samples), and pyrene (115 of 345 samples) in a range of 36 to 11,000 μg/kg, 1 to 33,000 μg/kg, and 1 to 22,000 μg/kg, respectively. The majority of semivolatiles

in the surface soil at the FEMP was detected in the following areas, where total semivolatiles were detected at levels of 10,000 μg/kg or greater:

- West of Plant 6
- South and west of pilot plant
- Engine garage area
- North and southeast of maintenance building
- South of scrap metal pile
- South of KC-2 warehouse area

The highest concentrations of total semivolatiles detected in the surface soil of the FEMP were present near the scrap metal pile (362,220 μg/kg), south of the KC-2 warehouse area (121,950 and 119,470 μg/kg), and in the western portion of the pilot plant area (90,758 and 71,040 μg/kg).

Similar semivolatiles, particularly the PAHs, that were detected in surface soil were also detected in subsurface soil at the FEMP. A number of PAHs were detected frequently and at high concentrations. The majority of semivolatile contamination in subsurface soil at the FEMP was detected in the same areas as for surface soil. The highest concentrations of total semivolatile organic compounds detected in the subsurface soil were present in the northern portion of the maintenance building area (53,770 μg/kg), the northern portion of the Plant 1 pad (8898 μg/kg), and near the graphite furnace (8100 μg/kg).

The semivolatiles contamination detected in the surface soil in the FEMP may be attributable to spills of contaminated materials in the areas. The detection of semivolatiles in the subsurface soil, especially in the maintenance building area, is likely the result of leaks from subsurface structures, such as underground storage tanks and pipelines, in those areas. Bis(2-ethylhexyl)phthalate was the most commonly detected semivolatile organic. It is noted that bis(2-ethylhexyl)phthalate is a common laboratory contaminant, and its presence may be the result of cross-contamination in the samples.

Polychlorinated Biphenyls: Polychlorinated biphenyls (PCBs) were detected in the surface soil (0 to 1.5 feet) across the FEMP. Aroclor-1254 was the most predominant PCBs constituent, which was detected in 81 of 337 surface soil samples with concentrations ranging from 11 to 14,000 μg/kg (Table 4-14). Aroclor-1260 was detected in only 17 of 338 surface soil samples at much lower levels. The highest concentrations of total PCBs in the surface soil were detected in the southern portion of Plant 2/3 area (14,000 μg/kg), near the graphite furnace (150 to 11,000 μg/kg), north of the maintenance building (59 to 10,000 μg/kg), near the drum baling area (710 to 6200 μg/kg), and south of the KC-2 warehouse (1100 to 2100 μg/kg).

Four constituents of PCBs were positively detected in the subsurface soil samples (below 1.5 feet) collected from the FEMP. Aroclor-1254 and aroclor-1260 were the most predominant PCBs, having been detected in 23 of 254 samples with a range of 9.9 to 1700 μg/kg and 5 of 254 samples with a range of 10 to 2700 μg/kg subsurface soil samples, respectively. In addition, aroclor-1242 and aroclor-1248 were detected in a limited number of subsurface samples. The PCBs contamination in the FEMP subsurface soil was found in areas similar to those for the surface soil contamination. The areas exhibiting concentrations of total PCBs in the subsurface soil include the graphite furnace (450 to 3100 μg/kg), north of the maintenance building (26 to 1200 μg/kg), the fire training area, near the burn trough (2700 μg/kg), the southern portion of the Plant 2/3 area (350 to 740 μg/kg), the western portion of the pilot plant area (485 μg/kg), the western portion of the Plant 1 area (120 μg/kg), the laboratory area (76 μg/kg), and the eastern part of the Plant 8 area (40 μg/kg).

The most likely sources of PCBs contamination in the surface soil are miscellaneous spills of PCBs-contaminated waste oils from aboveground storage containers or leaks in dielectric transformers present in the substation area. The PCB contamination present in the fire training area may be attributable to the use of PCBs-contaminated waste oils burned during fire training exercises in the area. The probable source of PCBs in the subsurface soil is surface soil contamination, which has migrated vertically over time into the subsurface soil.

Dioxins and Furans: Dioxins were detected only in the surface soil within the FEMP. Six surface soil samples collected within the FEMP area revealed detections of the dioxin octachlorodipenzo-p-dioxin, with a concentration range of 240 to 1100 ng/g. Two of these samples were collected near the graphite furnace burn pad, located in the graphite furnace, oil burner and coal pile area. Two of the detected concentrations (610 and 1100 ng/g) of dioxins were located in the 0- to 0.5-foot depth interval. Only one sample collected within the 0.5- to 1.0-foot depth interval detected concentrations of dioxins. This sample, located west of the Operable Unit 1 waste pit area, had a concentration of 240 ng/g. Two other surface soil samples collected south of the waste pit area revealed total dioxin concentrations of 310 and 900 ng/g. The dioxins present in this area could possibly be linked to the burn pit present in this area. No samples collected deeper than 1 foot from the surface exhibited detections of dioxins. The detections of dioxins in the surface soil located near the graphite furnace burn pad are not unexpected, since dioxins are by-products of the incomplete combustion of oils and petroleum products burned in this area.

In addition, dioxins were detected in the surface soil south of the fire training area, at 270 ng/g. This occurrence may have been caused from airborne deposition of burned material combusted during fire training activities in the area.

Only two detections of total furans occurred in the soils of the FEMP. One detection of total furans was in the top surface soil interval (0 to 0.5 foot) near the graphite furnace burn pad, with a total furan concentration of 1620 ng/g (heptachlorodibenzofurans [320 ng/g] and octachlorodibenzofuran [1300 ng/g]). This finding is expected because of the presence of dioxins in this area, since the source and cause of each is very similar. Another detection of total furans was present in the subsurface soil in the vicinity of the burn pond in the fire training area. Octachlorodibenzofuran, with a concentration of 1500 ng/g, was detected at the 1.5- to 3.0-foot depth interval in this area. This occurrence is most likely attributable to the combustion of waste oils in the subgrade fire pond and the migration of contamination through the bottom of the pond into the subsurface soil of the area.

4.6.2 Production Area and Other Process Areas

This section provides a summary of the contamination in surface and subsurface soils at the production area. The first part of this section lists contaminants in the order of predominance, based on concentrations/activity levels and the depth of occurrence. The second section focuses on the distribution of uranium (the most predominant contaminant) across the production area and at various depths throughout the soil.

Table 4-33 provides a summary of the production area contamination. The process plants and storage facilities at various locations in the production area are known to be the primary cause of contamination as a result of operations over the past 38 years. The main contaminant is uranium, although other radionuclides, inorganic constituents, and organic constituents were detected at levels that exceeded their 95th percentile background values (background). As is expected, and shown in Table 4-33, uranium was detected at depths as great as 20 feet in the production area. Uranium contamination at this depth was concentrated underneath the process area (Section 4.6.1.1).

Primary among radionuclide contaminants was uranium. Uranium and its isotopes occurred at all depths of surface and subsurface soils at levels that exceeded five times their respective background levels. As shown in Figure 4-18, the 20-mg/kg contour for total uranium encompasses the entire

production area. Thus, the other contaminants present in the production area are within the uranium envelope. The highest concentration of total uranium in surface soil was 90,350 mg/kg, which occurred in the 0- to 0.5-foot depth interval; the highest concentration in subsurface soil was 69,300 mg/kg, which occurred in the 3.0- to 5.0-foot depth interval. Both of these were detected in the same boring underneath the northern portion of Plant 6. Secondary among radionuclides were thorium and radium.

Thorium, radium, and their isotopes were detected at all depths in surface soils at levels that exceeded five times background. However, thorium and radium levels in subsurface soil did not exceed five times background at all depth intervals. As Table 4-33 indicates, contamination from thorium and radium of five times background did not exceed the 5- to 10-foot depth interval. Among the other radionuclides, only strontium-90 was present at all depth intervals of surface and subsurface soils at levels that exceeded five times background; however its maximum activity levels were relatively low at 26.3 pCi/g in surface soil and 47.6 pCi/g in subsurface soil. For the other radionuclides, cesium-137, technetium-99 and, to a lesser extent plutonium, neptunium-237, and ruthenium-106, were detected in surface soil and subsurface soil.

Primary among inorganic RCRA constituents was cadmium, which was detected in all depths of surface as well as subsurface soils at concentrations that exceeded five times background (Section 4.6.1.2). Primary among inorganic non-RCRA constituents were calcium, magnesium, sodium, and zinc. Although these non-RCRA constituents occurred at far higher concentrations than cadmium, their concentrations exceeded five times background in all depth intervals of surface soil, but in fewer sampling intervals in subsurface soil. A notable exception was zinc, whose concentrations exceeded background by a factor of five in all but two depth intervals of subsurface soil. It must be noted that (as discussed in detail in Section 2.0) the "surface soil" in some of the areas may actually be subsurface soil transported from elsewhere at the FEMP as part of the initial site grading. The background levels of calcium, magnesium, and sodium in subsurface soil exceed those in surface soil by factors of 5 to 35, as a comparison of Tables 4-14 and 4-15 indicate. Therefore, the elevated levels observed in "surface soil" may be within the range of background concentrations of subsurface soil, and may not be the result of artificial sources.

Secondary among inorganic RCRA constituents were arsenic, barium, chromium, lead, mercury, and silver, whose concentrations exceeded their respective background levels (where applicable) by factors

of one to five, especially in the surface soil. The concentrations of arsenic, barium, and chromium were below their respective background levels in the 15.0- to 20.0-foot depth. Mercury was detected at concentrations that were less than its background level in the 3.0- to 15.0-foot depth intervals and is expected to have continued to remain below its background level in the 15.0- to 20.0-foot depth although not analyzed for in this interval. Silver was detected at all depth intervals in surface and subsurface soils. Secondary among inorganic, non-RCRA constituents were aluminum, antimony, beryllium, cobalt, copper, manganese, potassium, and selenium, which were detected at concentrations that exceeded their respective background levels mostly by factors of one to five. Among other inorganic non-RCRA constituents, thallium and vanadium were detected at concentrations that were either below background levels (especially in the 10.0- to 15.0-foot depth) or barely exceeded background levels in most other depth intervals. Appendix D.1 provides a detailed discussion of all of these inorganic constituents.

Primary among VOCs were the following constituents (typical constituents of industrial solvents and fuels), which were detected at all depths of surface and subsurface soils: trichloroethane, 4-methyl-2-pentanone, methylene chloride, tetrachloroethene, toluene, xylenes, and trichloroethene. Secondary among VOCs were the following, which were less prevalent: dichlorinated alkanes and alkenes, chloroform, 2-butanone, 2-hexanone, benzene and ethyl benzene. Vinyl chloride was detected only in the subsurface soil. Several other VOCs, such as chlorinated and brominated alkanes, alkenes, and aryl compounds, were also sporadically detected.

Primary among semivolatile organic contaminants was bis(2-ethylhexyl)phthalate, which was detected at all depths in surface and subsurface soils. Secondary semivolatiles were several polynucleated aromatic hydrocarbons, such as pyrene and anthracene and certain phthalates that were typically detected in all depths of surface soil and most depths of subsurface soil. Unlike the primary VOCs, none of the semivolatiles (with the exception of bis(2-ethylhexyl)phthalate) were detected in the 15.0- to 20.0-foot depth.

Primary among pesticides/PCBs were aroclors, which were the only compounds in this category that were detected at significant concentrations in both the surface and subsurface soils. The only pesticide that was detected in subsurface soils deeper than 10.0 feet was methoxychlor. Dioxins/ furans were detected primarily in surface soils at relatively low levels. Only octachlorodibenzofurans

were detected in the 1.5- to 3.0-foot depth. Dioxins/furans were not analyzed for in samples from subsurface soils deeper than 3.0 feet.

Profile of Total Uranium Contamination with Depth

Profiles of total uranium contamination with depth at various locations in the production area can be assessed using the cross sections (Figures 4-63 to 4-70). Figure 4-62 is an index of the cross section locations at the FEMP. The following is a summary of the profiles.

Figure 4-63 shows Section KK-KK', which is a cross section from the west to the east beginning at the biodenitrification tower and ending east of Plant 6. From the biodenitrification tower to the incinerator building, concentrations of total uranium are less than 50 mg/kg in the surface soil. At the incinerator building area, concentrations exceed 500 mg/kg in the surface soil and reduce significantly to a maximum of 259 mg/kg in the 15.0-foot depth. The groundwater concentrations are elevated (maximum of 25,100 μg/L). Concentrations of uranium continued to be elevated in subsurface soil east of the incinerator with a maximum of 467 mg/kg at 10.0 feet. The maximum groundwater concentration increases to 77,600 μg/L. Further east, in the area east of the Plant 2/3 maintenance building, and at Plant 4, concentrations exceed 100 mg/kg in the surface, but are less than 50 mg/kg in the subsurface soil. Maximum groundwater concentrations east of the Plant 2/3 maintenance building exceed 1000 μg/L. Concentrations in surface soil were approximately 100 mg/kg west of Plant 5, and increased to a maximum of 652 mg/kg to the east of Plant 5. However, concentrations reduced by an order of magnitude in the subsurface soil east of Plant 5 at depths of 15.0 to 20.0 feet. At Plant 6, in the area of the slug pickling bath and water treatment area, concentrations exceeded 1000 mg/kg in surface and 100 mg/kg in subsurface soil. The maximum concentration in the groundwater at Plant 6 was 172,000 μg/L. Further east, concentrations were lower in the range of 10 to 100 mg/kg in surface and subsurface soils.

Figure 4-67 shows Section II-II', which is a cross section from west to east spanning Well/Boring Locations 1351 to 1320, through the in-process warehouse, the tank farm, the maintenance building, Plant 9, and the special products plant. West of the in-process warehouse, concentrations were less than 29 mg/kg in surface and subsurface soils. Concentrations in the surface soil west of the maintenance building in the area of the storage pad were elevated, with a maximum level of 137 mg/kg. Further east, the concentrations in the soils at the special products plant were at low levels, but the maximum concentration in the groundwater was 15,600 μg/L.

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Figure 4-70 shows Section HH-HH', which is a cross section from west to east spanning Well/Boring Locations 11073 to 1302, from Plant 1 through the coal pile runoff basin to the area of the D&D building. In the Plant 1 Area, concentrations exceeded 10 mg/kg to a maximum of 49 mg/kg. Further east, in the area of the pump station and the cooling tower, surface soil concentrations marginally exceeded 10 mg/kg. In the entire east of the coal pile runoff basin, surface soil concentrations exceeded 10 mg/kg up to a maximum of 76 mg/kg.

Figure 4-69 shows Section FF-FF', which is a cross section from west to east spanning Well/Boring Locations 2010 to 4013. Concentrations were generally less than 100 mg/kg in the shallow surface soil. Concentrations reduced significantly within 10.0 feet of the surface at these locations. At the extreme east end in the former drum bailing area, at Location 4013, the maximum concentration in the surface soil increased to 662 mg/kg. Surface soil concentrations were elevated above 100 mg/kg at the graphite furnace and oil burner.

Figure 4-68 shows Section EE-EE', which is a cross section from west to east spanning Well/Boring Locations 1333 to 1505, through the decontamination pad and drum baling area. From Location 1333 to west of the decontamination pad, concentrations in the surface soils ranged from 10 to 100 mg/kg. Concentrations were elevated to greater than 1000 mg/kg with a maximum of 1,637 mg/kg in the drum baling area.

Figure 4-64 shows Section V-V', which is a cross section from south to north spanning Well/Boring Locations 1269 to 1330, from the area south of the laboratory, through the western portions of Plants 2/3 and Plant 8, through Plant 1, and ending at the quonset huts. In the southern section from Locations 1269 to 1255, concentrations in surface and subsurface soils exceeded 10 mg/kg, with a maximum of 30 mg/kg. Further north at 1262, the maximum surface concentration was 251 mg/kg. In the area of Plants 8 and 3 (1234-1221), concentrations in surface as well as subsurface soils exceeded 100 mg/kg, with a maximum concentration in surface soil of 373 mg/kg. The maximum concentration in groundwater was 24,300 μg/L. At the ore refinery plant, surface and subsurface soil concentrations were elevated, with maximums exceeding 1000 mg/kg and 100 mg/kg, respectively. The maximum groundwater concentration was 74,700 mg/L. Further north, through the Plant 1 area, the concentrations were less than 10 mg/kg in surface soils. At the northern end of Plant 1 pad, concentrations in surface and subsurface soils were elevated; the maximum level in surface soil exceeded 100 mg/kg. The subsurface soil concentrations were in the 10 to 100 mg/kg range.

Figure 4-65 shows Section Y-Y', which is a cross section from south to north spanning Well/Boring Locations 1841 to 1272, along "C" street through the maintenance building, the boiler plant, and the KC-2 warehouse. Concentrations were less than 100 mg/kg in surface and subsurface soils south of the maintenance building. Concentrations exceeded 100 mg/kg in surface soil in the area of the maintenance building, where the maximum groundwater concentration was 2180 μg/L. Further north, concentrations were in the 10 to 100 mg/kg range in the surface soil in between the boiler plant and the KC-2 warehouse. The highest concentration in this region was in the area west of the graphite burner, where the maximum groundwater concentration was 205 μg/L.

Figure 4-66 shows Section AA-AA', which is a cross section from south to north spanning Well/ Boring Locations 1174 to 1086, through Plant 6, Plant 9, the magnesium storage building and decontamination building and ending at the area south of the drum baling area. Concentrations exceeded 100 mg/kg in the surface soil at 1174, which is south of Plant 6. Concentrations were elevated in the surface soil in the southern half of Plant 6. In the northern half of Plant 6, concentrations in the surface soil exceeded 10,000 mg/kg and the maximum was approximately 100,000 mg/kg. The concentrations in the subsurface soil exceeded 100 mg/kg in the northern half. The maximum groundwater concentration was 62,300 μg/L. Further north, in the area south of Plant 9, concentrations exceeded 1000 mg/kg in surface soil in the vicinity of the above-ground storage tank. The maximum groundwater concentration was 15,600 μg/L. Concentrations in the surface soil between Plant 9 and the magnesium storage building were about 10 mg/kg. Further north, the maximum concentration in the surface soil exceeded 100 mg/kg at Location 1294. At the decontamination building, concentrations in surface and subsurface soils did not exceed 10 mg/kg.

In summary, total uranium concentrations in the shallow surface soil in a majority of cross sections exceeded 10 mg/kg. Concentrations exceeded 100 mg/kg mainly in areas of known sources, such as Plant 4, Plant 5, Plant 6, the maintenance building. Elevated concentrations in subsurface soil were detected in conjunction with elevated concentrations in groundwater, although the converse was not necessarily true.

4.6.3 Northeastern Area of FEMP

The northeastern area of the FEMP property consists mainly of a densely wooded area of pine trees in the far northern section and open fields close to the former production area boundary. The area is located north and east of the former production area, to the fenced boundary of the FEMP in each

direction, and surrounds the sewage treatment plant area. No known disposal or plant-related activities were associated with this area of the FEMP. This area is located in the primary downwind direction of the former production area. Approximately 65 soil samples were collected from this area under the site-wide RI/FS Work Plan and the RI/FS Work Plan Addendum investigations.

Surface Soil: The most significant radionuclide contamination in the surface soil is mainly attributable to total uranium and uranium isotopes. Elevated uranium activities were primarily detected approximately 200 feet north of the sewage treatment plant. The highest level of total uranium in surface soil was 5533.31 mg/kg. The majority of the surface soil samples were collected at the 0- to 0.5-foot depth interval. As the depth increased total uranium and uranium isotope concentrations decreased significantly. Other radionuclides were primarily detected in a few samples and also decreased significantly at increased depths.

Elevated levels of total thorium and thorium isotopes were detected in only a few samples approximately 200 feet north of the sewage treatment plant. The highest concentration of total thorium found in the surface soil was 954.35 mg/kg.

Within the 0- to 0.5-foot depth interval, 10 inorganic constituents were at levels at least two times background. Of these constituents, only beryllium, calcium, and magnesium concentrations were elevated above five times background. All three of these compounds decreased significantly in concentration within the 1.0- to 1.5-foot depth, however. Molybdenum and silver were detected, but no background levels were recorded.

The only volatile organic compounds detected in the surface soil were acetone and methylene chloride, both common laboratory contaminants. Each was detected in the 0- to 0.5-foot depth interval only.

Ten semivolatile organic compounds, mainly PAHs, were detected in a maximum of 4 samples out of 22 samples collected from the 0- to 0.5-foot interval. These detections of semivolatile organic compounds ranged from 31 μg/kg to 100 μg/kg. None of these compounds were detected in the 1.0- to 1.5-foot depth interval. The pesticide endrin aldehyde was detected at 15 μg/kg in the 0- to 0.5-foot depth interval only. No PCBs were detected in the surface soil of this area.

Subsurface Soil: Radionuclide levels in the northeastern area of the FEMP decreased significantly within the subsurface soil. In sporadic boring locations, total uranium exhibited elevated concentrations to a depth of 20 feet. Most of the elevated total uranium concentrations were, in the range of 5 mg/kg to 7 mg/kg, but 16 mg/kg was reported as the maximum detection in the 2- to 2.5-foot depth sample collected from Boring 1160 and 11 mg/kg was in the 19.5- to 20.0-foot depth of Boring 1498. Both borings are located east of Plant 6. Strontium-90 was detected at significantly elevated concentrations, 9.40 pCi/g and 2.16 pCi/g, in the 1.5- to 3.0-foot (Boring 3120) and 10.0- to 15.0-foot (Boring 1737) intervals, respectively, as depicted by the cross section.

The only inorganic constituent to show significantly elevated concentrations within the subsurface soil zone was molybdenum at the 1.5- to 3.0-foot and 5.0- to 10.0-foot depth intervals. Silver was detected at these depth intervals, as well, but no background level was recorded.

Three volatile organic compounds, 1,1,1-trichloroethane, acetone, and carbon disulfide, were detected at concentration ranging from 2 μg/kg to 25 μg/kg only in the 12.0- to 12.5-foot interval at Boring 11086. These were the only volatiles detected in the subsurface soil samples in this area. The common laboratory contaminant, bis(2-ethylhexyl)phthalate, was the only semivolatile organic compound detected in three samples collected in the 5.0- to 10.0-foot and 10- to 15-foot intervals throughout the subsurface soil in this area. No pesticides or PCBs were detected in the subsurface soils of the northeastern area of the FEMP.

Conclusion: The majority of the soil contamination present in this area is located within surface soil. Figures 4-72 and 4-73 are cross sections depicting total uranium pads of this area. Figure 4-72 shows Section A-A; which is a cross section from south to north. Well 1741 to 2731 is located in the northern region. Figure 4-73 shows Section C-C; which is a cross section from west to east. Well 1736 to 1738 depicts total uranium contamination in the northeastern region. As indicated, both of these cross sections uranium contamination is limited to the surface soil in this area.

Most of the high levels of total uranium in the surface soil were detected in areas within short distance east of Plant 9, north of sewage treatment plant, and north of the northeast production area. Elevated levels of total uranium in the subsurface soil were relatively low and concentrated in the area east of Plant 6.

The probable source of uranium contamination in this area, at levels of 10 to 70 mg/kg, is airborne deposition from emissions, since the area is located immediately downwind of the production area. These emissions may have resulted from past activities in the production area and from operation of the incinerator located at the sewage treatment plant. No processes or routes are knowing to levels of radionuclides attributed to the high detected in the surface soil east of Plant 9 and in the subsurface soil east of Plant 6.

4.6.4 Southern Area of FEMP

The southern area of the FEMP property consists mainly of open, grass-covered fields and pine woodlots. The area is located south of the production area. However, the trap range, southwest field area, the active flyash pile, inactive flyash pile, and South Field are located within the overall boundary of the area but excluded from this discussion. Access roads to these disposal areas pass through the southern area. There were no known disposal activities conducted in this area of the FEMP. More than 110 soil sample locations, mainly for surface soil samples, were collected from this area under the CIS, litigation study, the site-wide RI/FS Work Plan and the RI/FS Work Plan Addendum investigations.

Surface Soil: The most significant radionuclide contamination in the surface soil of the southern area of the FEMP, is mainly attributable to the presence of uranium and thorium isotopes. As represented by levels of total uranium, elevated uranium activities were primarily detected at sampling locations in the area immediately south of the laboratory and pilot plant, in the vicinity of the Operable Unit 2 area, and at scattered locations in the eastern half of the area. Concentrations of total uranium that were observed in the surface soil depth intervals ranged from 1.50 mg/kg to 443.58 mg/kg. The majority of the surface samples were collected in the 0- to 0.5-foot depth interval. Radiological results in the boring locations indicated that in general the levels of radionuclides decrease significantly as the depths increase.

Elevated levels of thorium isotopes and total thorium were also found in the same general areas as the elevated uranium, but at much fewer locations and relatively lower levels. Concentrations of total thorium in the surface soil ranged from 1.64 mg/kg to 54.72 mg/kg, with a few detections exceeding background (12.4 mg/kg).

Only the 0- to 0.5-foot depth interval was analyzed for inorganic constituents. Those inorganics to show significantly elevated concentrations at this depth were beryllium, cadmium, calcium, cyanide, lead, magnesium, and sodium. Molybdenum and silver were detected, but no background levels were recorded. These elevated detections were primarily observed in the vicinity of the Operable Unit 2 area.

As with the inorganic data, only the top 6 inches of soil were analyzed for volatile organic and semivolatile organic compounds. The only volatile organics that were detected in three samples out of 20 samples collected in the 0- to 0.5-foot depth interval include 2-butanone, acetone, chlorobenzene, tetrachloroethene, toluene, and trichloroethene. The detected concentrations of total volatile organics ranged from 2 μg/kg to 22 μg/kg.

Eighteen semivolatile organic compounds were detected in the surface soil samples in this area, most of which are common PAH compounds. These detections were obtained in a maximum of 5 samples out of 21 samples analyzed and the ranges were 7 μg/kg to 700 μg/kg. No pesticides or PCBs were detected in the surface soil of the southern area of the FEMP.

Subsurface Soil: Similar to the surface soil, the radiological contamination in the subsurface soil primarily consisted of uranium and thorium isotopes. The levels of these isotopes were relatively low and, except for total uranium, most of the detections were only slightly above background. As depicted by the cross-sections I-I' in Figure 4-76, the cross-section H-H' in Figure 4-75 and cross-section F-F' in Figure 4-71, the total uranium concentrations present in the subsurface soil of the southern area of the FEMP are relatively low.

No analyses were conducted for inorganic constituents on the subsurface soil samples collected from the southern area of the FEMP. No volatile organics, semivolatile organics, pesticides, or PCBs were detected in the subsurface soil in this area.

Conclusion: The majority of the radiological and chemical contamination in this area is present in the surface soil depth intervals, primarily in areas immediately south of the laboratory and pilot plant and south of the Active Flyash Pile in Operable Unit 2. Uranium isotopes and total uranium were the primary radiological contaminants in this area. Only a few locations exhibited highly elevated concentration of total uranium (50 mg/kg or higher). In addition, a few inorganic analytes in

particular beryllium, cadmium, cyanide, lead, molybdenum, and silver were detected at elevated levels in samples collected in the vicinity of the Operable Unit 2 study area. Radiological results in the boring locations throughout the area indicated that in general the levels of radionuclides decrease significantly as the depths increase.

The contamination present in the surface soil of the southern area of the FEMP was most likely caused by airborne deposition of past plant emissions in the former production area and the disposal of flyash in the Operable Unit 2 area. Spills or airborne releases during flyash disposal may be the possible sources of the highly elevated levels of uranium and thorium levels that were observed in the lower depth intervals in the surface soil. The sources of contamination in the subsurface soil, especially in the depth below the perched groundwater table, are unknown. Possible sources for the elevated levels are vertical migration of contaminated perched water. This pathway of contaminants is supported by some detections of elevated activities of radionuclides in the subsurface soil at depths up to 75 feet.

4.6.5 Western Area of FEMP

The western area of the FEMP property consists mainly of an open area that surrounds the waste pit area (Operable Unit 1), the solid waste landfill and lime sludge ponds (Operable Unit 2), and the silo area (Operable Unit 4). The area is located immediately west of the production area and extends west to the fenced property boundary, west of Paddys Run. No known disposal or plant-related activities were conducted in this region of the FEMP, although access roads to Operable Units 1, 2 and 4 pass through this area.

Surface Soil: All 17 of the radionuclides for which analyses were performed in the 0- to 0.5-foot depth interval exhibited levels that were elevated at least two times background. Most of these radionuclides decreased in levels with depth; the exceptions were uranium-238, total uranium, uranium-234, uranium-235/236, radium-228, thorium-228, strontium-90, and technetium-99. The maximum total uranium concentration in the surface soil in this area was 2115 mg/kg, located within the 0- to 0.5-foot depth. The highest concentrations of total uranium were detected in an isolated area west of Plant 1, south of the solid waste landfill and east of waste pits 4 and 6.

The majority of inorganic constituents were detected at elevated concentrations above background in the 0- to 0.5-foot depth interval in this area. However, only beryllium, calcium, magnesium,

molybdenum, potassium, selenium, sodium, and zinc concentrations were still significantly elevated above two times background at the 1.0- to 1.5-foot depth. Molybdenum and silver were detected, but no background levels were recorded.

Ten volatile organic compounds were detected in the 0- to 0.5-foot surface soil samples collected from the western area of the FEMP with detected concentrations ranging from 2 to 10 μg/kg, mainly located in isolated locations surrounding the waste pit area.

Twenty semivolatile organic compounds were detected in the surface soil samples. With concentrations ranging from 26 to 1300 μg/kg, the highest detections were located in isolated spots along the road north of the waste pit area. The majority of these compounds were PAHs commonly found at industrial sites. Only nine of these compounds, mainly PAHs, were detected at the 1.0- to 1.5-foot depth in concentrations ranging from 42 μg/kg to 140 μg/kg.

The pesticides 4,4'-DDE (detected in 1 of 40 samples) and dieldrin (1 of 41 samples) were detected in the 0- to 0.5-foot depth samples only in concentrations of 20 μg/kg each. Similarly, the PCBs Aroclor-1254 (5 of 41 samples) and Aroclor-1260 (2 of 41 samples) were detected solely in the 0- to 0.5-foot depth interval in concentration ranges of 11 to 590 μg/kg and 130 to 240 μg/kg, respectively. The highest isolated spots of PCB concentrations were located immediately west of the Plant 1 pad area. Octachlorodibenzo-p-dioxin was detected solely in the 0- to 0.5-foot depth interval in 4 of 11 samples ranging in concentrations from 240 to 900 ng/g.

Subsurface Soil: Radionuclide levels decreased significantly within the subsurface soil intervals within the western area of the FEMP. The radionuclides that exhibited continuous elevated activities throughout the 1.5- to 20-foot depth of subsurface soil include uranium-238, total uranium, and total thorium. Total uranium, the predominant radiological contaminant in the subsurface soil, was present in up to 9 samples from a maximum of 22 samples in depths of 1.5 feet to 15.0 feet at concentrations ranging from 2 mg/kg to 27.71 mg/kg. The high levels of total uranium were detected primarily in samples collected from the area immediately west of Plant 1 area. Several samples collected from the 15- to 20-foot interval also detected total uranium to a maximum of 11 mg/kg, which was the typical detection limit for other samples in the same sampling program. In addition, a highly elevated total uranium concentration of 132,000 mg/kg was present in the 38.5- to 40.0-foot depth sample collected at Boring 2009, located approximately 700 feet southwest of the K-65 silos. Activities of

uranium-238 were present slightly above background in most of the subsurface soil depth intervals, except in the interval of 5.0 to 10.0 feet where uranium-238 was detected at 7.78 pCi/g. Total thorium was present in the subsurface soil at levels slightly above background, and the maximum level of 18 mg/kg for total thorium was the typical detection limit for other samples in the same sampling program.

Strontium-90 was detected at significantly elevated activities (2.53-6.65 pCi/g) in a limited number of locations at depths from 3.0 to 15.0 feet located southwest of K-65 silos, north of Plant 1 drum storage area (northwest of Plant 1 area), and central-south of K-65 slurry line. Radium-226 was detected immediately north of the solid waste landfill (Operable Unit 2), with activity greater than two times background in the 1.5- to 3.0-foot depth but decreased significantly at greater depth. Uranium-235/236 was detected in two samples collected from the 5.0- to 10.0-foot depth at concentrations of 0.819 pCi/g and 0.875 pCi/g. Activities of plutonium-239/240 were detected in one sample each from the 10.0- to 15.0-foot and 15.0- to 20.0-foot intervals, and plutonium-238 activities were present in the 10.0- to 15.0-foot depth interval only. The plutonium activities were also present in the subsurface soil samples collected from the area north of the Plant 1 drum storage area.

The majority of inorganic constituents detected at elevated concentrations in the surface soil were detected at significantly decreased concentrations within the subsurface zone. Only cadmium and silver were still significantly elevated within the greater depth intervals, mainly in the area north of the solid waste landfill.

Ten volatile organic compounds were detected at low concentrations in the subsurface soil samples. The majority of these compounds were detected primarily within the 1.5- to 3.0-foot depth interval in a limited number of samples (e.g., maximum of 2 of 18), in low concentrations ranging from 1 to 12 μg/kg. Toluene, however, was detected continuously from 1.5 to 20.0 feet in concentrations ranging from 1 to 14 μg/kg in 5 of 25 samples. Trichloroethene was detected in the 20.0-foot depth interval only at 7 μg/kg.

The majority of the VOA detections in the subsurface soil were in isolated locations surrounding the waste pit area.

Seventeen semivolatile organic compounds, mainly PAHs, were detected in the subsurface soil samples in a limited number of samples (i.e., maximum 5 of 24 samples), with concentrations ranging from 44 to 34,000 μg/kg. The majority of these compounds were confined to the 1.5- to 3.0-foot interval. The majority of the semivolatile contamination in the subsurface soil appears to be located in isolated spots near the Operable Unit 4 study area.

No pesticides or PCBs were detected in the subsurface soils collected from the western area of the FEMP.

Conclusion: The majority of the soil contamination present in the western area of the FEMP is located within the top 1.5 feet. Total uranium concentrations are elevated sporadically throughout this area and appear to be the most predominant radionuclide constituent detected in this area. The highest concentrations of radionuclides in the surface soil appear to be located surrounding the Operable Unit 1 waste pit area. The majority of the radionuclide contamination in the subsurface soil in this area is located in the area west of the Plant 1 area.

The majority of the inorganic contamination is localized within the surface soil, mainly within the area located north of the Operable Unit 2 sanitary landfill. Low concentrations of the volatile organic compounds and semivolatile organic compounds, mainly PAHs, were detected primarily in the surface soils located in isolated locations surrounding the waste pit area.

The radiological and chemical contamination appear to occur in immediate areas surrounding the Operable Unit 1 waste pit area, west of the Plant 1 area, north of Operable Unit 2 solid waste landfill, and south of K-65 slurry line. These areas contain known sources of contamination and the contaminants may have been transported to the western area of the FEMP via spills, air deposition, surface water runoff, and groundwater migration. In addition, vertical migration may be potential routes for subsurface soil contamination.

4.6.6 Northwestern Area of FEMP

This area is located northwest of the production area, but still within the FEMP property boundary. It consists mainly of a wooded area, interspersed with dirt roads. This area is located north of the waste pit area (Operable Unit 1) and a railroad track and south of an off-property, privately owned farm. No known disposal or plant related-activities were associated with this region of the FEMP.

Approximately 65 soil samples, mostly surface soil, were collected from this area as part of the site-wide RI/FS program. Table 4-37 presents the distribution of constituents above the background values for each sample depth interval.

Surface Soil: Within the 0- to 0.5-foot depth interval, several radionuclides were detected which exhibited elevated concentrations. Of these, uranium-238, total uranium, uranium-234, uranium-235/236, strontium-90 and cesium-137 concentrations were the most significantly elevated by greater than two times to greater than five times background levels. As depicted by the cross section C-C[1] in Figure 4-73, the total uranium concentrations in this area are relatively low and limited to the surface (O- to 0.5-foot). Total uranium concentrations were highest in the 0- to 0.5-foot depth interval and decreased with depth. One isolated total uranium sample had a concentration of 52 mg/kg in the surface soil, within the 0- to 0.5-foot depth. This sample was located just north of the waste pit area. This was the only area that exceeded five times the background concentration for total uranium.

The majority of inorganic compounds detected in the surface soil were at least slightly elevated above background levels. The inorganics that exhibited the most significantly elevated concentrations (by at least two times background) were beryllium, cadmium, calcium, cyanide, magnesium, molybdenum, silver, sodium, and zinc. The majority of the highest concentrations of these inorganic constituents were present within the 0- to 0.5-foot depth interval in an area located northeast of the waste pit area.

Three volatile organic compounds were detected in low concentrations within the surface soil. These were 4-methyl-2-pentanone (detected in 1 of 18 samples at 14 μg/kg), toluene (5 of 18 samples at 1 to 4 μg/kg), and trichloroethene (1 of 18 samples at 4 μg/kg). All of which were analyzed and detected in the 0.0- to 0.5-foot depth interval only in an area located northwest of the fire training area.

Nine semivolatile organic compounds, mainly, PAHs, were detected in the surface soil, in concentrations ranging from 45 to 160 μg/kg, mainly in an area located north of waste pit area.

The pesticide 4,4'-DDT was detected in the 0.0- to 0.5 foot depth interval in 1 of 14 samples at 15 μg/kg. No PCBs were detected in the surface soil.

Subsurface Soil: The maximum sample concentration was compared to the 95th percentile background value (background) for each constituent to determine whether the constituent was considered a contamination problem in the area. The only radiological parameter to be analyzed continuously in the subsurface soil in the northwestern area of the FEMP was total uranium. It was detected at slightly elevated concentrations above background from 1.5 to 20 feet, mainly located in the area north of the waste pit area. The only radionuclide to exhibit activities elevated above five times background levels was strontium-90, within the 10.0- to 15.0-foot depth. in an isolated location north of the fire training area.

Inorganic constituents were not analyzed in the subsurface soil samples collected from the northwestern area of the FEMP.

The only volatile organic compounds detected in the subsurface soil were 1,1,1-trichloroethane (1 detection in 2 samples at 1 μg/kg) and methylene chloride (1 detection in 2 samples at 25 μg/kg), both at the 5.0- to 10.0-foot depth only. Both samples were located southwest of the fire training area.

Semivolatile organic compounds, pesticides, and PCBs were not analyzed in the subsurface soil samples collected from the northwestern area of the FEMP.

4.6.7 Area Outside FEMP Adjacent to Boundary

Soil outside the FEMP property boundary has been investigated since early 1986, when two law suits were filed against the operators of the former Feed Materials Production Center (FMPC) of releasing potentially hazardous amounts of uranium to off-site areas. Soil samples were collected and analyzed for isotopic uranium activities during the 1986 soil assessment to support the litigation. Additional studies of off-site soil contamination were conducted in subsequent years for radionuclides and chemical compounds.

The area outside the FEMP adjacent boundary, as shown in Figure 4-77, is selected on the basis of the 1986 soil assessment results. This area encompasses an oval area of approximately 3 square miles, excluding the area of the FEMP site itself, extending 1.3 miles both northeast and southwest of the FEMP. Soil samples in the area outside the FEMP adjacent boundary were collected and analyzed under four major soil sampling programs, including the 1986 soil assessment and others, and

two sampling programs that contain a few sampling locations in this area. Descriptions of the sampling programs and a detailed discussion on the FEMP adjacent property are provided in Section D.2.30.

Table 4-38 presents the distribution of radiological and chemical constituents in the surface and subsurface soils of the area outside the FEMP adjacent boundary. The maximum detection of each constituent is compared to the 95th percentile background value (background), if available, to determine whether the constituent was elevated above background. When background was not available, any detection of these constituents was reported.

Surface Soil: A total of 182 soil samples were taken at various surface soil sampling locations in adjacent areas outside the FEMP property boundary. The majority of the surface soil samples were analyzed for activities of total uranium and isotopic uranium, whereas some were also analyzed for activities of other radionuclides.

Surface soil samples within the 0- to 0.5-foot depth interval in this area consisted primarily of samples from the top 0- to 2.0-inch depth, with the remainder from the depth intervals of 2.0 to 4.0 inches and 4.0 to 6.0 inches. Within the 0- to 0.5-foot depth interval, a few samples were detected containing levels of isotopic uranium (i.e., U-238, U-234, and U-235/236) and total uranium at levels in excess of five times background. The highest levels of isotopic uranium and total uranium were observed at locations immediately northeast of the FEMP property. The second highest level of total uranium (approximately 46 mg/kg) was detected at a sampling location located south of Manhole 177 and immediately east of FEMP property boundary. The remainder of the sampling locations where surface soil samples were collected from the 0- to 0.5-foot depth interval, levels of total uranium ranged from 1.2 to 39.7 mg/kg. Note that the majority of total uranium levels were present in the lower end of this range and that the average of all positive detections of total uranium was determined to be 7.61 mg/kg.

In addition, thorium and radium isotopes and total thorium were present in samples from the 0- to 0.5-foot depth interval at levels only slightly above background. Strontium-90 and cesium-137 were detected in a few samples at levels slightly above background. Plutonium-239/240 and technetium-99 were each observed in one of a total of 12 samples collected from this depth interval.

Other decay products, including neptunium-237, plutonium-238, and ruthenium-106, were analyzed but not detected in samples from this depth interval.

No samples were actually collected from the 0.5- to 1.0-foot depth interval in this area. However, a number of samples were collected at depths of 0 to 1.5 feet and reported as 1.0- to 1.5-foot depth interval samples in the area outside the FEMP boundary.

Within the 1.0- to 1.5-foot depth interval, the highest activities of uranium-238 and uranium-234 were located approximately three-fourths of a mile south of the FEMP property. However, for the other sampling locations in the 1.0- to 1.5-foot depth interval, relatively low levels of isotopic uranium and total uranium were detected. Thorium isotopes (Th-230, Th-232, and Th-228) and total thorium were detected at levels slightly above background.

Several inorganic analytes were detected in the samples from the 0- to 0.5-foot depth interval. Of these, barium, beryllium, cadmium, and cobalt were detected at concentrations slightly above two times background. Other inorganic analytes were either detected at insignificant levels or analyzed for but not detected.

Three volatile organic compounds (VOCs), including acetone, tetrachloroethene, and toluene, were detected in samples from depths of 0 to 0.5 feet. These VOCs are basic ingredients in common solvents and petroleum products. No VOCs were analyzed in other depth intervals.

Various semivolatile organic compounds, primarily polynuclear aromatic hydrocarbons (PAHs), were detected in the 0- to 0.5-foot depth interval samples collected from sampling locations located northeast of the FEMP. In addition, three pesticides (4,4'-DDT, alpha-chlordane, and gamma-chlordane) were detected at sampling locations in the same area.

Subsurface Soil: Subsurface soil samples were collected at boring locations during the groundwater monitoring well program under the site-wide RI/FS Work Plan. A total of 28 locations were developed within the area outside the FEMP adjacent boundary. A number of subsurface soil samples, ranging from four to nine samples, were collected from the borings in various depth intervals and analyzed for radiological parameters. Only one sample was also analyzed for VOCs.

The following discussion focuses on the contamination of radiological and chemical constituents in the subsurface soil at depths of 1.5 to 20.0 feet.

Values of isotopic uranium (U-238 and U-234) and total uranium were detected in all subsurface soil depth intervals throughout 15.0 to 20.0 feet in this area. The highest levels of these constituents were detected in the 3.0- to 5.0-foot depth interval at above background. Within the depth intervals of 10.0 to 15.0 feet and 15.0 to 20.0 feet, these uranium constituents (U-238, U-234, and total uranium) were observed at levels between two times and five times background values. Uranium-235/236 was detected in only one sample collected from the depth interval of 3.0 to 5.0 feet with activity levels between two times and five times background. Thorium-230 was detected at levels slightly above background in depth intervals of 1.5 to 3.0 feet, 3.0 to 5.0 feet, and 15.0 to 20.0 feet. Thorium-232 and total thorium were detected only in the 15.0- to 20.0-foot depth interval at levels between two times and five times background values. Radium isotopes and thorium-228 were present in some of the depth intervals at levels slightly greater background.

Strontium-90 was detected in a few samples collected from depths of 1.5 to 3.0 feet and 5.0 to 10.0 feet with activity levels greater than five times background. Activities of technetium-99 and cesium-137 were observed in the depth intervals of 5.0 to 10.0 feet and 1.5 to 3.0 feet, respectively. No other radionuclides were observed in the subsurface soil samples.

In addition, a few VOCs were detected in samples collected from a location southwest of the FEMP at a depth of 16.0 feet. These VOCs are ingredients of petroleum products, including ethylbenzene, toluene, and total xylenes.

Conclusions: Most of the radiological contamination detected in the area outside the FEMP adjacent boundary was present in the 0- to 2-inch samples of the 0- to 0.5-foot surface soil depth interval. The main radiological contaminants detected in this area were isotopic uranium and total uranium. A few samples collected from the 0- to 0.5-foot depth interval evidenced isotopic uranium (i.e., U-238, U-234, and U-235/236) and total uranium at levels in excess of five times background. These sampling locations were located immediately northeast of FEMP and south of Manhole 177 east of FEMP). At other sampling locations in the 0- to 0.5-foot depth interval, levels of total uranium were detected in the range of 1.2 to 39.7 mg/kg, with most of the results in the lower end of this range as shown on Figure 4-77.

Within the 1.0- to 1.5-foot depth interval, the highest activities of uranium-238 and uranium-234 were detected about three-fourths of a mile south of the FEMP. At the other sampling locations in the 1.0- to 1.5-foot depth intervals, relatively low levels of isotopic uranium and total uranium were detected.

In the subsurface soil samples, levels of isotopic uranium (U-238 and U-234) and total uranium were detected throughout depths of 15.0 to 20.0 feet. The highest levels of these constituents were detected in the 3.0- to 5.0-foot depth interval at values above background.

In addition, some chemical contaminants, including inorganics analytes, VOCs, semivolatile organics, and pesticides, were detected in samples collected from the depth intervals of 0 to 0.5 feet and 15.0 to 20.0 feet.

The potential pathway for migration of constituents into surface soil outside the FEMP is deposition of airborne contaminants from sources within the FEMP. The predominant wind directions in the area tend to support the evidence for air dispersion in the east of the FEMP. The potential pathways for migration of constituents into subsurface soil also include the contaminated groundwater flowing south and the past releases from the outfall pipeline in the east. Other potential sources of contamination in this area (e.g., industrial factories located south of the FEMP) may have contributed to the chemical and radiological contamination that was observed in the subsurface soil in the southern FEMP adjacent property area.

4.6.8 Area 2 to 5 Miles Outside FEMP Boundary

In 1986, the FEMP conducted an investigation for potential surface soil contamination in an area between 2 and 5 miles outside of the FEMP boundary. This study was limited to the top 6 inches of soil. The investigation was conducted in support of litigation filed against National Lead of Ohio (NLO), the previous operators of the Feed Materials Production Center (renamed Fernald Environmental Management Project). In this investigation, 180 surface soil samples were collected; most were collected from within the top 2 inches of soil. All of the samples were analyzed for total uranium and several were also analyzed for the individual uranium isotopes. Figure 4-77 provides the sampling locations and total uranium results from this area. The boundary (shown by a dashed line) approximates the area where no results were obtained above background. A few isolated detections are present within this area.

A small number of samples contained uranium at concentrations exceeding the representative background concentrations. The frequency of elevated samples and the activity ranges are summarized below. The representative background is shown in parentheses.

- Uranium-238: 5 of 52 Samples, or 9.6 percent
  Range: 1.41-1.83 pCi/g (1.24 pCi/g)
- Uranium-235: 0 of 51 Samples, or 0 percent
- Uranium-234: 8 of 52 Samples, or 15 percent
  Range: 1.24-1.68 pCi/g (1.24 pCi/g)
- Total Uranium: 16 of 180 Samples, or 8.9 percent
  Range: 3.76-5.13 mg/kg (3.73 mg/kg)

These elevated samples were collected primarily in the areas east, northeast, and southwest of the FEMP. These locations are downwind of the FEMP, and the elevated concentrations could conceivably be a consequence of airborne releases. However, these concentrations are not necessarily representative of contamination. The uranium concentrations identified as elevated are all very close to the representative background value. The highest value was less than a factor of two greater than background, for total uranium, while the highest isotopic concentration was less than 50 percent higher than the background value. Background is not an absolute number. Instead, whenever a background value for any radionuclide is stated, it is actually a representation of a distribution of measurements. Variability such as seen in the data summarized above is not unusual for background distributions.

In 1983. Myrick, et al. (Determination of Concentrations of Selected Radionuclides in Surface Soil in the U.S.; T.E. Myrick, B.A. Berven and F.F. Haywood; Health Physics, Vol. 45, No. 3, pp 631; September 1983) conducted a study of background concentrations of uranium-238, thorium-232, and radium-226 in the United States. In this study, 355 samples were collected and analyzed, with the background concentrations ranging between 0.12 and 3.8 pCi/g. Twelve samples were collected in Ohio. The Ohio background samples ranged between 0.77-2.2 pCi/g. All of the uranium-238 measurements that have been identified as above background are within the range of backgrounds identified by Myrick, et al.

An additional consideration is the statistical uncertainty associated with measurements of radionuclides. Radioactive decay is best described as a random process. We can only discuss the probability that a decay will take place within a given time period. Since the measurement of radionuclides depends on measuring radiation given off during decay, the measurement will always be somewhat uncertain. For many decays, or high activity concentrations, the uncertainty is a small fraction of the measured activity. However, when there are few decays such as when activities are near background levels, the uncertainty can be a large fraction of the stated value.

At low activity levels, other laboratory random uncertainties can also be significant. Total random uncertainties exceeding 50 percent are not unusual for low activity data. Systematic uncertainties can also contribute to the overall uncertainty associated with radionuclide measurements. However, because systematic uncertainties are difficult to quantify, most laboratories do not attempt to measure or quantify them. Considering all sources of random and systematic uncertainty, total uncertainties could even exceed 100 percent of the stated measurement value at near-background activities. As an example, if we were to assume that both the background and the sample data had uncertainties of only 20 percent, the activities of the samples mentioned above as exceeding the representative concentration would be statistically indistinguishable from background. Therefore, although we have stated that for the purposes of the point-to-point comparison in Section 4, some values in the 2-5 mile area appear to be elevated, a more rigorous statistical evaluation would probably show that these values are not elevated.

4.6.9 Summary of FEMP Soil Contamination

Extensive sampling of surface and subsurface soils has been conducted within the boundaries of the FEMP and at nearby locations outside the FEMP property. The sampling was conducted as part of the RI site investigation and other programs. These investigations were designed to characterize the nature and extent of soil contamination resulting from past FEMP activities and to permit quantification of baseline risks associated with the contamination. The nature and extent of soil contamination has been sufficiently characterized to perform a viable baseline risk assessment for Operable Unit 5 and evaluate and select remedial alternative(s).

Nature and Extent of Contamination Within the FEMP Boundaries

Within the boundaries of the FEMP, much of the soil sampling was conducted in areas where contamination would most likely be present because of activities known to have been conducted. This

was supplemented with systematic sampling designed to evaluate potential contamination from airborne releases and point-source releases. Tables 4-40 and 4-41 summarize the results of this investigation. These tables list the areas evidencing detections of parameters at levels greater than five times background as well as indicating the geographic areas where these parameters were expected to be found, based on process history. The contamination at the FEMP is discussed by radiological parameters as well as inorganic and organic parameters.

Radiological Parameters

Radiological contamination is predominantly characterized by total uranium, radium-226, and total thorium, based on decay chains and historic operations at the FEMP. Other radiological parameters are found within the bounds of these three parameters. As Tables 4-40 and 4-41 indicate, the radiological contamination is widespread in surface soil throughout the production and waste storage areas as well as the areas adjacent to the production area, whereas the subsurface soil contamination is limited to certain areas and parameters. Of the radiological contamination detected, uranium and its progeny were generally the only radionuclides found at significantly elevated levels at the FEMP. The uranium contamination, as expected, is widespread, whereas the occurrence of the other radiological constituents is localized and generally limited to the surface soil. Radiological contamination at the FEMP is located within the 20 mg/kg contour for total uranium with a few exceptions.

Table 4-42 provides a listing of the parameters and their approximate location at the FEMP outside the uranium envelope (Section 4.6.1). Parameter occurrences at the trap range typically fall within an extensive "lead envelope" that covers that area. Parameter occurrences at the sewage treatment plant and near the K-65 silos were generally just outside the uranium envelope. Strontium-90, beryllium, selenium, cyanide, magnesium, zinc, and volatile organics fall outside the uranium envelope. However, a review of the data and locations indicates that these detections are isolated occurrences. There appears to be no systematic relationship between these occurrences and known source areas. In some instances an apparent relationship does exist between the detected value and the sampling program under which the sample was collected. This suggest that a slight sampling bias was introduced by either the sample collection procedures and equipment or the laboratory procedure which may have resulted in falsely elevated readings in some parameters.

One example of this bias is that strontium-90 is found along the southeast boundary, the area north of the waste storage and production areas, and at scattered sample locations west of Paddys Run in samples that were collected in the initial soil sampling program included in the March 1988 RI/FS work plan (Plate 2-7). Numerous additional samples were collected in subsequent sampling programs; however, they did not detect Strontium-90 in above-background concentrations in areas close to the location of the earlier samples. A second example is the samples collected under the EWMF field program (Section 2.5.5) which contain slightly elevated levels of molybdenum and thorium 228, whether the sample was collected in the southeast corner of the FEMP at Borings 1733 and 1747 or in the northern part of the FEMP in Borings 1728 through 1738.

Total Uranium: Surface soil concentrations of uranium in excess of five times background are found consistently throughout the former production process areas and in portions of the administrative and laboratory areas. The pervasive uranium contamination is a result of processing uranium for the nation's nuclear weapons program, which was the original charter of the FEMP. It has been estimated that during the 38-year production life of the FEMP, more than 179,000 kilograms of uranium and nearly 6500 kilograms of thorium were released to the atmosphere from the production facilities.

Uranium contamination in surface and subsurface soils is summarized in Tables 4-17 and 4-18, Figures 4-62 through 4-75, and Plates 4-1 through 4-7. Together, the figures, tables, and plates represent the contaminated areas and the depth of contamination by uranium. Above-background levels of uranium are found in some areas of the FEMP at depths as great as 20 feet. The highest concentrations of uranium in the surface soil, greater than 10,000 mg/kg, were found in the Plant 1 area, Plant 6 area, laboratory area, and scrap metal pile area. Total uranium contamination in the subsurface soil can be characterized as isolated occurrences underneath process and waste areas. The areas of highest subsurface uranium contamination, those with concentrations greater than 100 mg/kg, were found localized near former processing facilities and in-ground sumps where acid-solutions of uranium and liquid wastes were handled in large volumes. Total uranium concentrations in surface soil within the FEMP boundary typically ranged from 10 to 100 mg/kg.

Radium-226: Radium-226 contamination in FEMP soil is summarized in Tables 4-19 and 4-20 and Figures 4.6-12 through 4.6-19. Radium-226 contamination is limited to process areas and storage areas where elevated levels were expected. The Plant 1 area and scrap metal pile are the two areas

evidencing radium-226 activity greater than 1000 pCi/g. The only area of significant radium-226 contamination in the subsurface soil is the area west of the K-65 silos. The source of this contamination is likely the K-65 decant tank or spills associated with the filling of the silos.

Total Thorium: Total thorium contamination in FEMP soil is summarized in Tables 4-21 and 4-22 and Figures 4.6-20 through 4.6-27. Elevated levels of thorium and its decay products were generally found in localized areas near former processing and storage locations. All thorium detections were within the uranium envelope. The highest concentrations of total thorium, exceeding 1000 mg/kg, were within the scrap metal pile and laboratory areas. These occurrences were not pervasive, but isolated areas of major contamination. Thorium contamination was detected primarily in the surface soil and was limited to a depth of less than 10.0 feet in the subsurface soil.

Fission and Uranium Activation Products: Fission and uranium activation products present are associated with recycled uranium that was processed at the FEMP. This is uranium that has been irradiated in a nuclear reactor for the production of energy, weapons material, or man-made radionuclides. Irradiated uranium was chemically processes to remove fission and activation products prior to its shipment to the FEMP, but some residual levels remained. These fission and activation products are found sporadically and are generally located within the uranium envelope (see Table 4-42).

Inorganic and Organic Parameters

Inorganic constituents were detected at above-background concentrations in surface and subsurface soil as summarized in Tables 4-40 and 4-41. As illustrated in the tables the majority of inorganic contamination is located in the surface soil. The primary inorganic contaminants at the FEMP are beryllium and cadmium. The only known source of cadmium is as an impurity in the uranium ore feed material, while the primary source of beryllium is not known (see Table 4-9). Silver, for which no background value exists, was detected in both the surface and subsurface soil at low levels across the site. Table 4-41 indicates that selenium was found in the subsurface soil; however, no background level is available, and detections in the subsurface soil are low.

Volatile organic and semivolatile organic compounds and PCBs were detected in select samples in the vicinity of all of the major processing and supporting facilities (Table 4-9). Generally, all of the

organic detections were located within the uranium envelope, with the exception of a few isolated detections of volatile organics.

Nature and Extent of Contamination Outside the FEMP Property

Total uranium concentrations were observed at levels slightly above background on the property surrounding the FEMP. The locations where uranium detections exceeded background were mainly in the areas east, northeast, and southwest of the FEMP. The levels generally ranged from 5 to 6 mg/kg in these areas. The probable source of the elevated levels of uranium is airborne releases from areas within the FEMP. However, it must be noted that such low analyte levels (as those stated above) might be considered to be typically minor variations in analytical results (or limitations on the accuracy of analysis). Therefore, if the levels of uranium and its isotopes do exceed background, the exceedance is minor and may be attributable to the accuracy of analytical measurement. There were also isolated areas of significant contamination located along the outfall line and along the east boundary adjacent to the sewage treatment plant.

4.7 PERCHED GROUNDWATER

This section describes the nature and extent of contamination in perched groundwater at the FEMP. Section 4.7.1 discusses the nature and extent of individual parameters or parameter groups that occur in perched groundwater at concentrations greater than background. Uranium is discussed in great detail here and in Appendix F because it is the major site contaminant in terms of volume released, potential risk, and future remedial design considerations. Section 4.7.1 provides summary information, and is based on detailed discussions of FEMP groundwater analytical data presented in Section E.1 of Appendix E.

The groundwater data presented in Section 4.7.1 and E.1 reveal three general patterns of contamination in perched groundwater: first, the FEMP has a general site-wide elevation of uranium concentrations due to air deposition and miscellaneous spills; second, distinct contaminant plumes exist that are attributable to specific source areas; and third, there are isolated and localized occurrences of uranium and other contaminants which can or cannot be attributed to a well-defined source area. Section 4.7.2 illustrates that there are seven geographically distinct groundwater contamination areas at the FEMP and addresses the characteristics of the seven areas.

The following text routinely compares site data to a background value. The background value used here is the 95th percentile of the background data set. Section 4.2 contains a complete discussion of how background values were calculated.

4.7.1 Overview of Perched Groundwater Contamination

This summary discussion of the nature and extent of groundwater contamination is based on detailed analyses of groundwater data presented in Appendix E.1. A number of data presentation formats were used to analyze groundwater data during preparation of Appendix E.1. First, groundwater isoconcentration maps were created for each parameter based on groundwater samples collected primarily during 1993; the maps are presented as plates in this report (see plate volume). Selected isoconcentration maps (plates) that are important in understanding groundwater contamination are included in Section 4.7.1 as reduced-size figures. This section and Appendix E.1 contain tables of descriptive statistics that summarize the range and extent of occurrence for each parameter in FEMP monitoring wells. In addition, to illustrate temporal trends of analytical results, Appendix M contains graphs of parameter concentrations versus time. Appendix I contains tabulated analytical results for all groundwater samples collected to determine nature and extent. Finally, Appendix F contains a detailed discussion of the vertical distribution of uranium and processes responsible for mobilizing the uranium.

Groundwater Analytical Data

The FEMP groundwater analytical data set available for compilation of this report spans from 1988 to 1994. However, only during the 1993 field programs were a majority of the FEMP wells sampled within a relatively short period. Section 2.0 describes the individual sampling programs that were conducted at the FEMP. For purposes of site characterization, all data are evaluated together as a whole, and data are only distinguished by date of collection. The 1993 data set is functionally a snapshot of contaminant distribution, whereas the 1988-1992 data set cannot be sorted to effectively describe site-wide contaminant distribution in one distinct period. Because the 1993 data set is the most complete site-wide data set that is constrained to a distinct period, it was the prime data set used to create the groundwater isoconcentration maps presented in this report (plate volume). (See Section E.1 for a discussion of the process used to select data for the isoconcentration maps.)

The 1988-1994 RI/FS sampling programs predominantly focused on collecting groundwater samples for analysis of the full radiological, HSL inorganics, and general water quality parameters.

Groundwater samples from specific wells were additionally analyzed for HSL organics, including pesticides and PCBs. RCRA sampling programs during this period focused on a similar suite of analytes, with the addition of volatile organic compounds (VOCs). Under the 1993 sampling programs, samples were collected from a majority of the FEMP Type 1 wells and analyzed for uranium, thorium, radium, technetium-99 HSL inorganics, HSL VOCs, and general water quality parameters.

Filtered versus Unfiltered Samples

During many of the FEMP groundwater investigations, each radiological and inorganic groundwater sample was divided into unfiltered and filtered (45-micron) portions for analysis. Statistical summaries, discussed throughout Appendix E.1, show that unfiltered analytical results typically had higher reported concentrations than filtered analytical results, except in the case of relatively soluble compounds such as sodium and technetium-99. Higher concentrations typically result because unfiltered samples generally contain a significant quantity of fine silt-or clay-size material relative to filtered samples, and the silt- or clay-size material has inorganics and radionuclides within its matrix or adhered to its edges. Sodium and technetium-99 are relatively more soluble and therefore are not as prevalent in or on solid particles as are less soluble elements.

The difference between analytical results for unfiltered and filtered samples is most noticeable for metals on the inorganic analyte lists. The differences between results for radionuclides in unfiltered and filtered samples is still apparent although less pronounced. This report assumes that filtered and unfiltered samples are approximately equivalent for describing the nature and extent of radionuclide contamination, but only filtered groundwater samples are considered representative of actual dissolved concentrations of metals.

Chemical Speciation

A summary of chemical species present in perched groundwater is provided in Table 4-43 and is referred to in Sections 4.7.1.1 and 4.7.1.2 in discussing the relative mobility of individual contaminants in the glacial overburden. The table was generated with the EQ3NR geochemical code (Version 7.1; Wolery 1992) using the 95th percentile values reported in Tables 5-1, 5-2, 5-4, and 5-5 of the draft report "Characterization of Background Water Quality for Streams and Groundwater" (DOE 1994a). A speciation block, which is provided for each individual contaminant, summarizes the abundance of each specie as a percent of the total contaminant concentration (e.g., perched

groundwater with 1 part of dissolved silver will have 0.64 part as $AgCl^o$, 0.27 part as Ag^+, and 0.09 part as $AgCl_2^-$).

The speciation summary in Table 4-43 provides information regarding the form and the charge of chemical species in groundwater and can be used to evaluate and contrast the mobility of contaminants in the glacial overburden. A general hierarchy of mobility is built upon the charge of the aqueous specie as follows:

negative species > neutral species > positive species

Within individual charge groups, larger complexes will migrate slower than individual ions of the same charge (e.g., $AgCl_2^-$is slower than Cl^-). The magnitude of charge on the complex will have an effect on the mobility of the ion (e.g., Cu^+ versus Cu^{+2}), with higher charged species moving relatively slower. In some cases (e.g., $CuOH^+$ versus Cu^{+2}), an ion of greater size and lower charge may move at the same rate as a small ion with higher charge. These principles will be applied to the species in Table 4-43 to discuss the relative mobility of the primary constituents of concern in Sections 4.7.1.1 and 4.7.1.2.

The speciation data in Table 4-43 has been used in Table 4-44 to describe FEMP parameters according to their solubility in groundwater and tendency to adsorb to soil. Table 4-44 also describes the major potential sources for each parameter and summarizes their extent of contamination in perched groundwater at the FEMP.

Uranium as the Primary Contaminant

Uranium is the principal FEMP contaminant in perched groundwater. The following discussion regarding the extent of uranium contamination will focus on describing how uranium entered perched groundwater as well as the hydrogeologic factors that are responsible for the observed uranium distribution in perched groundwater. Uranium is the focus of this discussion because it is the prime contaminant that is dominant in the risk assessment (Section 6.0) and is consequently the prime contaminant controlling selection of remedial options in the feasibility study (FS). The sources and distribution of the remaining FEMP contaminants, discussed in less detail, are generally governed by the same processes described for uranium.

4.7.1.1 Radiological Contamination

Based on process knowledge, the relative volumes of materials processed through the FEMP can be ranked from high to low: uranium ore materials, purified uranium materials, thorium feed materials, and returned uranium fuel materials (see Section 4.1).

The relative volumes of isotopes processed through the FEMP can be ranked as follows:

U-238 > > U-235 > U-234 > > Th-232 > uranium series progeny > Th-232 progeny, and activation and fission products

The above ranking for volumes of isotopes is also observed in the site-wide extent of contamination. A qualitative review of the plate volume shows that uranium isotopes are present as widespread plumes, whereas activation and fission products occur in isolated wells at low values. The following summary of the extent of uranium contamination focuses on describing the plant processes responsible for the observed distribution of uranium as well as the hydrogeological factors that have resulted in the plume shapes observed today. A detailed discussion of the vertical distribution and mobility of uranium is provided in Appendix F. Other FEMP radionuclides are discussed in less detail, since plant processes and hydrogeologic processes described for uranium largely apply.

4.7.1.1.1 Total Uranium

The FEMP processed primarily depleted and natural uranium, and smaller quantities of slightly enriched uranium (see Section 4.1). For such uranium, the uranium-238 isotope constitutes greater than 95 percent of the uranium on a mass basis, while the other two natural isotopes of uranium, uranium-235 and uranium-234, constitute less than 5 percent by mass.

A fourth isotope of uranium, uranium-236, can be found at the FEMP in extremely small quantities. Uranium-236 does not occur naturally. It is produced in a nuclear reactor through successive neutron captures and subsequent decay. Uranium-236 entered the FEMP as part of recycled uranium materials received from Hanford. Uranium-235 and uranium-236 both decay through emission of an alpha particle. Because the alpha particles emitted by uranium-235 are very close in energy to the alpha particles emitted by uranium-236, alpha spectrometry, the uranium isotope analysis technique used by the RI/FS, cannot distinguish uranium-235 from uranium-236. Consequently, activity

concentrations of the two isotopes are reported together as uranium-235/236. (Refer to Section 4.1 for a discussion of isotopic analysis.)

The RI sampling programs generally analyzed samples for both total uranium and isotopes of uranium. The following discussion will focus on results of total uranium analyses. Note that all isotopes of uranium have identical chemical behavior in soil and groundwater.

The status of uranium as the principal contaminant in perched groundwater is evident in the summary statistics (Table 4-45). Total uranium in filtered samples was detected at above-background concentrations in 174 of 181 wells, and had a maximum detected concentration of 129,000 μg/L. The background concentration of total uranium is approximately 1 μg/L. The summary statistics for unfiltered samples yield somewhat higher results (Table 4-45). Figures 4-78 and 4-79 are contour maps of total uranium concentrations based on filtered and unfiltered samples of perched groundwater, respectively. Major aspects of the uranium distribution are as follows:

- All samples of perched groundwater obtained from wells in the production area yielded above-background concentrations of uranium.
- Perched groundwater outside the production area indicates the presence of uranium plumes near the sewage treatment plant, the fire training area, the Solid Waste Landfill, the waste pit area, the K-65 silos, and the South Field/flyash pile area.
- Areas with high uranium concentrations (i.e., greater than 20 μg/L) are generally confined to locations under and immediately adjacent to process buildings and waste storage areas.
- A large portion of the site area is interpreted to have uranium concentrations above 5 μg/L in the groundwater.

Site-wide, most uranium is believed to have entered the perched groundwater through three pathways:

- Infiltration of rainwater carrying soluble uranium derived from particles deposited via air onto soils and on the roofs of buildings.
- Contaminated fluids that were spilled on the floors of production buildings and subsequently infiltrated through floors or leaked from sumps, subfloor piping, and process equipment into underlying soil.
- Leachates that migrated from above-grade and below-grade waste storage units.

The unsaturated surface horizon of soil is weathered as a result of natural processes. The weathered horizon allows rapid infiltration of surface water from the ground surface to the top of the perched water table. However, migration of groundwater in the saturated zone is relatively slow because of the low hydraulic conductivity of the glacial overburden (see Section 3.6.1.1). As a result, uranium plumes in perched groundwater are localized near their sources.

The location numbers shown on Figure 4-4 and listed in the key of Figure 4-4 indicate the major known and suspected contaminant sources investigated during the RI field investigation. Potential major sources were identified through process knowledge and site history. Several of the major plumes and their sources are discussed below.

Major Uranium Plumes and Sources

Uranium in perched groundwater beneath and adjacent to the Plant 1 pad (74T, Figure 4-4) was detected at concentrations ranging from less than background (1.3 μg/L) to 670 μg/L. Historically, the Plant 1 pad was used for storing and sampling incoming ore materials and process waste. A review of activities performed on the Plant 1 pad during its nearly 40-year history indicates that numerous spills of uranium-bearing material occurred, although most spills prior to 1988 were not documented. Therefore, contamination beneath and adjacent to the pad is likely to have entered the groundwater as surface water runoff that infiltrated into the soil through cracks in the concrete pad or flowed north and west off the pad onto the adjacent ground surface. The Plant 1 pad removal action instituted measures in 1992 to repair the storage pad and to capture surface water runoff that was previously free to run uncontrolled off the north and west sides of the pad.

The entire area containing Plants 2, 3, and 8 is underlain by perched groundwater containing total uranium concentrations in excess of 100 μg/L (Figures 4-78 and 4-79). Isolated areas within this sector have uranium concentrations as high as 77,600 μg/L in perched groundwater. This sector of the production area was distinguished by acid-based chemical processing operations, so most uranium was handled in a soluble form. Prepared ores and uranium-bearing residues were dissolved in nitric acid in the ore refinery plant (2A) and metals dissolver building (2D). It is believed that significant quantities of uranium entered the subsurface here as a dissolved component of acid solutions that were spilled on floors or leaked from sumps and subgrade piping. The general sump (2B) and refinery sump (3H) were used to treat aqueous effluent from Plant 2/3 to remove dissolved uranium. Both treatment processes are suspected of having leaked significant quantities of uranium-bearing fluids.

Other suspected sources in this sector include ore digestion in the hot raffinate building (3E), the scrap recovery plant (8A), aboveground uranyl nitrate storage tanks, miscellaneous spills, and soils that were contaminated through air deposition.

Uranium concentrations as high as 58,200 μg/L were found in perched groundwater in the vicinity of the pilot plant. The pilot plant was originally used for pilot testing of new or proposed plant operations and later for other processes, including acid digestion, which resulted in aqueous uranium-bearing solutions. All sumps in the building were connected to a main sump and water treatment system located adjacent to the southwest corner of the plant. It is believed that sumps and subgrade piping of the pilot plant are the source of the observed perched groundwater contamination in this area. The main pilot plant sump was removed in 1993 because it was suspected to be leaking.

Perched groundwater in the vicinity of Plant 6 yielded uranium concentrations as high as 142,000 μg/L. Plant 6 was used primarily for milling and machining solid uranium. The uranium contamination in the groundwater is believed to have entered the subsurface as a result of leaking subsurface pipes and sumps associated with two nitric acid pickling operations (6J and 6I in Figure 4-4), a salt-oil heat treating process (6E), and a water treatment unit (6H) that was used to remove machining oil and uranium from process water. Removal Action 1 removes contaminated perched groundwater from beneath Plant 6 where it accumulates in the inactive scrap metal pickling clarifier pit (6I) and is removed via two extraction wells. Extracted groundwater is treated in Plant 8 to remove uranium and organic contaminants.

In the vicinity of Plant 9, groundwater was encountered beneath only the south portion of the building. Uranium contamination was detected at levels as high as 436,000 μg/L. Plant 9 was used for casting and milling of uranium metal and for Zirnlo decladding of non-irradiated fuel cores. Suspected sources of uranium contamination in perched groundwater include the Zirnlo baths, sumps, a nitric acid pickling bath, and a water treatment unit. The area of contamination beneath the southeast corner of the plant is believed to be partially the result of former leaks and overflow from a 4700-gallon sump located adjacent to the building.

Uranium concentrations in perched groundwater near the northeast corner of the production area were detected at levels as high as 5466 μg/L. The three suspected sources for this contamination are contaminated surface water runoff from the scrap metal pile, the outside equipment storage areas

(P007 in Figure 4-4) used to store contaminated, excess equipment, and the decontamination building (69). The scrap metal pile was used to store contaminated metal from the FEMP and other DOE sites. The scrap metal pile was removed from the decontamination pad in 1993 as part of Removal Action 15. The equipment storage area northeast of the decontamination building is used to store contaminated equipment. Additionally, it was once used as a drum baling and storage area. The decontamination building is a suspected source because it contains acid and caustic soak vats, which may have leaked.

Uranium occurs in perched groundwater in the vicinity of the sewage treatment plant, located on the east side of the FEMP, in concentrations ranging to 289 μg/L. Suspected sources at the sewage treatment plant are the two clarifier basins (25G), the sludge drying beds (25F), and the trickling filters (25H). An additional suspect source is the outdoor incinerator (39D) and contaminated soil adjacent to the incinerator. Groundwater elevation gradients show that the sewage treatment plant area is a source of groundwater recharge (see Section 3.6.1.2). The recharge is believed to come from leaks in the aqueous waste stream handled by the sewage treatment plant. Removal Action 14 was implemented in 1992 to remove soils containing high concentrations of uranium. This removal action is ongoing.

Elevated concentrations of uranium ranging to 168 μg/L were detected in perched groundwater in the vicinity of the fire training area. Activities performed at the fire training area included burning of combustible liquids in the fire training pond (73B) and burn trough (74D), and burning of solid material in the training center building. The pond is a 45-foot-diameter, shallow pond where combustible liquids were ignited to practice fire fighting. Interviews with site personnel indicated that contaminated oils and solvents from the production area were used to create training fires. The pond drained to an open pit located approximately 150 feet to the southeast. Fire training activities are suspected of introducing uranium to soil, which would have subsequently infiltrated to groundwater.

The Operable Unit 4 RI reported that uranium is present in perched groundwater beneath the K-65 silos at concentrations as high as 9240 μg/L. The RI report indicated that the suspected sources are releases of leachate from silos 1 and 2 and the subsurface decant tank. Perched groundwater beneath the silos flows west toward Paddys Run. A line of lysimeters (1894, 1895, and 1896) was completed between the Operable Unit 4 contaminant plume and Paddys Run to determine the westward extent of

groundwater contamination. Analytical results from the three lysimeters indicate that perched groundwater contamination has not migrated to Paddys Run.

The RI report for Operable Unit 1 revealed that uranium was detected at above-background concentrations in all perched groundwater wells located within the Operable Unit 1 area. Perched groundwater within Operable Unit 1 flows radially away from the center of the pit area. The Operable Unit 1 RI reported that perched groundwater adjacent to the burn pit and pit 4 appears to contain the highest uranium concentrations in the Operable Unit 1 area, ranging to 11,482 μg/L.

Other Uranium Plumes and Sources

The highest concentrations of uranium contamination in perched groundwater are encountered in three areas: beneath buildings, such as Plant 2/3, where acids were used to dissolve or pickle solid uranium; adjacent to sumps or water treatment areas in process buildings; and beneath or adjacent to waste units that released leachate. The common theme linking these three types of areas is that significant quantities of uranium-bearing solutions were (or continue to be, in the case of subgrade waste units) available to leak into subsurface soil.

In addition to the major sources discussed above, uranium was detected at above-background concentrations in perched groundwater throughout the production area. Potential sources of elevated uranium concentrations in the production area include infiltration of surface water through uranium contaminated surface soil, undocumented spills, and leaking storm sewers and process lines. Storm sewers are found throughout the production area. The Best Management Practices storm sewer investigation conducted in 1988 showed that numerous pipe breaks existed in the storm sewer system and that there were sections of the storm sewer system that either gained water from or lost water to perched groundwater. The storm sewer potentially acts as a pathway for lateral migration. Disturbed soil in backfilled utility trenches is also a potential lateral migration route that may have contributed to the site-wide distribution of elevated uranium concentrations in groundwater.

Large areas of elevated uranium concentrations are present in the groundwater under open land outside the waste storage and production areas (Figures 4-78 and 4-79). Uranium in these fringe areas of the site property was deposited by air fallout from production stack emissions and unintentional air releases. Sections 4.6.3 to 4.6.6 describe how on-property fringe area surface soil has total uranium concentrations of 5 to 50 mg/kg (relative to a background concentration of

3.73 mg/kg). Solubilized surface soil contamination is the source of the observed groundwater contamination.

Fewer groundwater monitoring locations were installed in the fringe areas of the FEMP than in the production and waste storage areas. The fringe area monitoring locations detected total uranium concentrations elevated above background (1.3 μg/L) but generally below 20 μg/L. The elevated concentrations are a result of surface soil contamination that has solubilized and been transported downward into the perched groundwater. Because the source of contamination is air fallout, the distribution of soil and groundwater contamination is predicted to be relatively homogeneous across the area when compared to the patterns seen where sources are localized. Consequently, it is assumed that concentrations do not vary more than approximately one order of magnitude in the fringe areas, and the sparse well spacing of the fringe areas adequately represents the range of concentrations in perched groundwater. The 5 μg/L total uranium contours shown on Figures 4-78 and 4-79 are based on the assumption that most air fallout is confined to on-property areas. However, the actual extent of above-background total uranium concentrations in groundwater may extend to off-property areas. Figure 4-18 shows the maximum lateral extent of above-background surface soil concentrations. Potentially, perched groundwater within the area has slightly elevated total uranium concentrations.

Geochemistry of Uranium Transport

Appendix F contains a detailed discussion of the geochemistry of uranium transport in the glacial overburden. This discussion is a summary of the material presented in Appendix F.

Uranium solids present in near-surface soil are leached by rainwater to form a portion of the dissolved constituents delivered to perched groundwater. Uranium particles in the soil are oxidized (e.g., uranium IV and uranium V oxidation states in UO_2 and U_3O_8 are converted to uranium VI, which destabilizes the bonding in the mineral structure) and leached to release the uranyl ion (UO_2^{+2}). The uranyl ion readily forms anionic complexes with the carbonate ion (Table 4-43) present in porewater and groundwater. This results in uranium forms are moderately to highly mobile in the glacial overburden. There is a large reservoir of bicarbonate and carbonate ions in the perched groundwater with a 95th percentile background concentration of (525 mg/L). This is sufficient to complex all uranium in the highest observed uranium concentration in perched groundwater. All isotopes of uranium will be speciated into the uranyl carbonate complexes in

proportion to their abundance in the source; that is, isotopes of heavy elements are not fractionated by the physicochemical processes of dissolution, aqueous speciation, and adsorption/desorption. Details regarding the geochemical processes responsible for mobilizing uranium, and the resulting uranium distributions, are provided in Appendix F.

Initial Uranium Distribution at Time of Release

Figure 4-82a is a schematic cross-section of FEMP glacial overburden showing a conceptual view of the initial uranium distribution in the production area. Although the release events occurred over a 30-year period (1955 to 1985), the conceptual view in Figure 4-82a depicts all releases as occurring simultaneously at one point in time. In the illustrated scenario on Figure 4-82a, aqueous acid spills released mobile forms of uranium that immediately began to percolate into and react with the glacial overburden. If uranium concentrations in the aqueous spills exceeded mineral solubilities after reactions with the glacial overburden, precipitation of $(UO_2)_3(PO_4)_2 \cdot 4H_2O$, $CaUO_4$, $Mg(UO_2)_2(PO_4)_2$, $UO_3 \cdot 2H_2O$, and/or other uranium solids may have occurred. The initial distribution of solids released by air emissions is restricted to the top few centimeters of the soil.

Figure 4-83a illustrates the initial conditions for uranium releases in areas outside of the production area. In these areas, aqueous forms of uranium are absent during the initial deposition, since uranium is deposited as particles derived from air emissions. The more soluble form of these uranium particles (e.g., UF_6) is rapidly dissolved upon the first storm event.

Uranium Distribution at the Present Time

The present-day scenario under the production area is conceptualized in Figure 4-82b, which shows uranium distributed throughout most of the glacial overburden. Soluble uranium forms have been removed by leaching, leaving the less soluble forms (U_3O_8, UO_2, and UO_3). The primary uranium phases may be mixed with alteration products such as $UO_3 \cdot 2H_2O$ and precipitates of $CaUO_4$ and $(UO_2)_3(PO_4)_2 \cdot 4H_2O$ throughout the upper portion of the brown glacial overburden. The uranium plume generated from the dissolution of soluble $UO_2(NO_3)_2 \cdot 6H_2O$, UF_6, UF_4, and $Na_2U_2O_7$ particles commingles with the plume derived from spills of aqueous uranium solutions. Principal aqueous species in the migrating plumes are predicted to be $UO_2(CO_3)_2^{-2}$ and $UO_2(CO_3)_3^{-4}$, with minor formation of $(UO_2)_2CO_3(OH)_3^-$, $UO_2(OH)_2^\circ$, and $UO_2PO_4^-$. Adsorption of uranium on soil particles may be accompanied by precipitation of $(UO_2)_3(PO_4)_2 \cdot 4H_2O$, $CaUO_4$, $Mg(UO_2)_2(PO_4)_2$, and/or $UO_3 \cdot 2H_2O$.

Figure 4-83b summarizes the present conceptual model for uranium distribution in areas affected solely by uranium particles derived from past atmospheric releases. The uranium plume generated from the dissolution of soluble UF_6, UF_4, and $Na_2U_2O_7$ particles has reached the lower section of the glacial overburden in some areas. Principal aqueous species in the migrating plume are predicted to be $UO_2(CO_3)_2^{-2}$ and $UO_2(CO_3)_3^{-4}$, with minor formation of $(UO_2)_2CO_3(OH)_3^-$, $UO_2(OH)_2°$, and $UO_2PO_4^-$. Adsorption of uranium on soil particles may be accompanied by precipitation of $(UO_2)_3(PO_4)_2 \cdot 4H_2O$, $CaUO_4$, $Mg(UO_2)_2(PO_4)_2$, and/or $UO_3 \cdot 2H_2O$ if a large mass of soluble uranium particles was present initially.

Across most of the FEMP, the released uranium is concentrated in the upper 1.5 feet of the glacial overburden and may reach uranium concentrations of greater than 1,000 mg/kg of soil. The uranium forms in the upper 15 feet of weathered and fractured soil are expected to be dominated by the less soluble oxides U_3O_8, UO_2, and UO_3, possibly mixed with precipitates of $CaUO_4$ and $(UO_2)_3(PO_4)_2 \cdot 4H_2O$. $CaUO_4$ and $(UO_2)_3(PO_4)_2 \cdot 4H_2O$ are predicted to be present based on EQ3/6 modeling results using solution analyses obtained from a 70-day leach of surface soil contaminated with uranium oxide particles (Lee et al., 1993). Much of the uranium in the upper 15 feet of the glacial overburden may have been distributed by mechanical processes after deposition. For example, air emission particles may have been reworked into the upper portion of the overburden by construction activities, or fluid transport of fine particles through fractures may have been facilitated by infiltration of rainwater through fractures. However, neutralization of acidic uranyl nitrate spills by carbonate minerals may have produced local areas of intense uranium precipitation in the upper few feet of soil. The persistence of uranium in these areas through time is dependent on the solubility of the precipitated solid and the volume of percolating water that contacts the precipitate.

Analytical data collected from subsurface soil samples indicate that uranium is distributed throughout the glacial overburden to a depth of 20 feet in the area surrounding the pilot plant, Plant 2/3, and Plants 6 and 9. Uranium concentrations in the 15- to 20-foot interval of unfractured, gray, glacial overburden reach values greater than 100 mg/kg of soil. The presence of uranium in this interval implies that geochemical, rather than mechanical, processes are responsible for the distribution. Aqueous spills, rainwater dissolution of $UO_2(NO_3)_2 \cdot 6H_20$, UF_6, UF_4, and $Na_2U_2O_7$ particles, and reactions with carbonate minerals in the glacial overburden mobilize the uranium primarily as the aqueous species $UO_2(CO_3)_2^{-2}$, $UO_2(CO_3)_3^{-4}$, and to a lesser extent as $(UO_2)_2CO_3(OH)_3^-$, $UO_2(OH)_2°$, and $UO_2PO_4^-$. Percolating rainwater transports the species into the subsurface where

adsorption and possibly precipitation occur to redistribute the uranium in the subsurface soil. Solids predicted to precipitate in the subsurface include $(UO_2)_3(PO_4)_2 \cdot 4H_2O$, $CaUO_4$, $Mg(UO_2)_2(PO_4)_2$, and/or $UO_3 \cdot 2H_2O$.

Uranium concentrations range from 0.29 to 129,000 μg/L in groundwater perched within the glacial overburden. Groundwater or pore water containing high uranium concentrations will partition some of the uranium into and onto the soil by precipitation and adsorption processes. A uranium concentration of 129,000 μg/L is in close agreement with the predicted solubility limits for $(UO_2)_3(PO_4)_2 \cdot 4H_2O$, $Mg(UO_2)_2(PO_4)_2$, and $CaUO_4$ in perched groundwater having high bicarbonate activity, implying $(UO_2)_3(PO_4)_2 \cdot 4H_2O$, $Mg(UO_2)_2(PO_4)_2$, and/or $CaUO_4$ have precipitated in some of the perched water zones. Scanning electron microscope studies conducted on FEMP soil by the Oak Ridge National Laboratory noted the association of calcium and phosphate with uranium particles (Lee and Marsh 1992), supporting the presence of $CaUO_4$, $(UO_2)_3(PO_4)_2 \cdot 4H_2O$ or other calcium/phosphate uranium phases in the soils.

Nested lysimeters were installed at three on-property locations. All three nests were designed similarly having a lysimeter in the base of the grey glacial overburden, and a deep lysimeter within the unsaturated sand and gravel below the glacial overburden but above the saturated portion of the Great Miami Aquifer. Groundwater samples from lysimeter pair 11129/11130 illustrate results typical of all three locations. Groundwater from the lysimeter at the base of the glacial overburden (11130) had total uranium concentrations of 2.8 to 13.0 μg/L; and groundwater from the lysimeter below the glacial overburden had concentrations of 15.0 to 28.0 μg/L. This indicates uranium mobilized on the surface of the glacial overburden is capable of infiltrating to the base of the glacial overburden in less than 40 years. Results of the EQ3/6 run indicate all uranium minerals are undersaturated in the pore water implying that the uranium distribution in soil at the base of the unweathered glacial overburden (i.e., in excess of background) is controlled by adsorption

Section 4.8.1 includes a discussion on total uranium contamination in the Great Miami Aquifer. The discussion documents how vertical infiltration through the glacial overburden has resulted in uranium concentrations ranging from less than background (1.2 μg/L) to 7.3 μg/L in the saturated portion of the Great Miami Aquifer beneath the lysimeters. The concentrations observed in the Great Miami Aquifer are less than those observed in the perched groundwater, because the perched groundwater is diluted when it enters into the Great Miami Aquifer.

Section 3.6.1.2 presents predicted horizontal and vertical perched groundwater flow velocities, based on field and laboratory data. The calculations assumed that most horizontal flow occurs in the brown clay or brown clay sand above the gray glacial overburden and predicted horizontal velocities range from 2.1 feet/year for brown clay, to 58.8 feet/year for brown clay sand. Vertical seepage velocities were predicted to range from 0.85 to 1.42 feet/year. It is important to note that dissolved uranium does not travel horizontally or vertically at the speed of groundwater, rather uranium travels at 1/20 to 1/80 the velocity of groundwater (see Section 5 and Appendix F).

Uranium Distribution at Some Future Time

Most of the present source of U_3O_8, UO_2, and $UO_3 \cdot 2H_2O$, and possibly $CaUO_4$ and $(UO_2)_3(PO_4)_2 \cdot 4H_20$, in the upper 1.5 feet of glacial overburden may be remediated in the future by soil washing and/or removal for solidification (final remedial options are chosen after the completion of the FS). Therefore, the future distribution of uranium in the glacial overburden may be controlled by desorption of physically adsorbed uranium and dissolution of $(UO_2)_3(PO_4)_2 \cdot 4H_2O$, $Mg(UO_2)_2(PO_4)_2$, $CaUO_4$, $UO_3 \cdot 2H_2O$, and/or other uranium particles in the subsurface. This scenario is depicted in Figures 4-82c and 4-83c. Semiquantification of this future uranium distribution will be addressed in the FS. Section 5.0 of this report uses computer fate and transport modeling to predict the distribution of uranium assuming no future remedial action.

4.7.1.1.2 Radionuclides from Uranium Raffinates

Thorium-230 and radium-226 are progeny of uranium-228, and were left in the raffinate that remained after extraction of uranium from uranium ores and ore concentrates. Thus, thorium-230 and radium-226 are anticipated constituents in those areas used to handle, process or store raffinates from the FEMP refinery. Thorium-230 and radium-226 also occur naturally in perched groundwater. Thorium-230 and radium-226 are not considered major contaminants in terms of volumes released to groundwater. The pattern of above-background detections of these radionuclides indicates only isolated occurrences, and not extensive plumes.

Thorium-230 was detected in unfiltered samples at above-background values in 38 of 192 (20 percent) wells tested, and had a maximum value of 28 pCi/L, relative to a background value of 1.3 pCi/L (Table 4-45). Elevated concentrations of thorium-230 were detected in three principal areas around the production area and several areas outside the production area. Plant 2/3 had the maximum concentration of thorium-230 (28 pCi/L in Well 1784). Groundwater below Plant 6 and Plant 1 also

had elevated concentrations of thorium-230. These were areas at the FEMP where ores and uranium concentrates were handled and processed. Thorium-230 was also detected in isolated wells from outside the production area: the solid waste landfill area, the waste pit area, the South Field area, the fire training area, the sewage lift station area, and the drum bailing area. Thorium-230 concentrations in these areas typically did not exceed two times background. Thorium-230 is not considered a major contaminant at the FEMP because contamination of thorium-230 is only found in isolated wells.

Radium-226 was detected in unfiltered samples at above-background activity concentrations in 86 of 195 wells tested, and had a maximum concentration of 35.8 pCi/L, relative to a background concentration of 0.9 pCi/L (Table 4-45). Radium-226 is generally found in the same areas as thorium-230, and was found most frequently in the Plant 2/3 area. Additionally, Plant 6 also had elevated concentrations of radium-226. The maximum observed concentration of radium-226, 35.8 pCi/L, was near the K-65 Silos. Radium-226 was also detected above background near the fire training area, the sewage treatment plant, the South Field, and the Solid Waste Landfill. Radium-226 is not considered a major contaminant at the FEMP because radium-226, like thorium-230, was only detected in isolated wells.

4.7.1.1.3 Total Thorium

Total thorium is a measure of the quantity of thorium in a sample without distinguishing between thorium's three principal isotopes: thorium-232, thorium-230, and thorium-228. The thorium-232 isotope decays to radium-228 and thorium-228 whereas thorium-230 is a progeny of uranium-238 and is unrelated to the decay of thorium-232. Thorium-230 and thorium-228 have very high specific activities (rates of radioactive decay) relative to thorium-232. Therefore, total thorium is largely a measure of thorium-232 because thorium-230 and thorium-228 are only a small fraction by weight of total thorium at the FEMP.

Figure 4-81 shows the distribution of total thorium in perched groundwater at the FEMP based on filtered samples. Total thorium concentrations generally ranged from nondetectable (usually less than 1.0 μg/L) to approximately 2 μg/L. One isolated result as high as 10.4 μg/L was observed in the fire training area. Figure 4-81 illustrates that dissolved concentrations are low, and detectable results are generally in isolated wells.

Geochemistry of Thorium Transport

Thorium mobility in the glacial overburden is in sharp contrast to the observed uranium behavior. Like uranium, thorium is most commonly present as an oxide particle (i.e., ThO_2). However, thorium oxide is nearly insoluble under ambient environmental conditions because thorium exists in a single oxidation state (thorium IV), as opposed to the three oxidation states for uranium. The stability of ThO_2 cannot be weakened by the oxidation process that mobilizes uranium. Therefore, perched groundwater will have thorium concentrations orders of magnitude lower than uranium concentrations because the solubility of ThO_2 is unaffected by oxidizing conditions. This statement is supported by observed perched groundwater concentrations for thorium and uranium in the Plant 2/3 area (Figures 4-78 through 4-81) and other areas known to process both thorium and uranium (e.g., Plant 6). Table 4-43 predicts that the small fraction of thorium that is dissolved in perched groundwater (true dissolved thorium has a concentration near 10^{-13} moles/L) will be moderately mobile in the glacial overburden as a neutral hydroxide complex and a negatively charged phosphate complex. However, the very low predicted solubility limit for ThO_2 indicates that detected thorium in perched groundwater is most likely derived from the migration of colloid particles.

4.7.1.1.4 Radionuclides from Thorium Ore Raffinates

Radium-228 and thorium-228 are progeny of thorium-232 and are found as a natural constituent of thorium ores processed at the site. Radium-228 and thorium-228 were left in the raffinate after the extraction of thorium from ores. Thus, radium-228 and thorium-228 are anticipated constituents in those areas used to handle, process or store raffinates from the FEMP thorium refining. Radium-228 and thorium-228 are not considered major contaminants in terms of volumes released to groundwater. The pattern of above-background detections of these radionuclides indicates only isolated occurrences, and not extensive plumes.

Radium-228 was detected in unfiltered samples at above-background values in 32 of 190 wells (17 percent) tested, and had a maximum value of 219 pCi/L, relative to a background value of 3 pCi/L (4.7-1). Elevated concentrations of radium-228 were detected below Plant 6, northeast of the Plant 1 pad, near the Plant 9 sump, near the K-65 Silos, and near the waste pits. Radium-228 is not considered a major contaminant at the FEMP because contamination of radium-228 is only found in isolated wells.

Thorium-228 was detected at above-background values in 19 of 192 wells (10 percent) tested, and had a maximum concentration of 14 pCi/L, relative to a background value of 1.6 pCi/L (Table 4-45). Thorium-228 was detected in the following areas: near the solid waste landfill, near Plant 2/3, below Plant 6, and near the waste pits. Thorium-228, like radium-228, is not considered a major contaminant at the FEMP because contamination of thorium-228 is only found in isolated wells.

4.7.1.1.5 Activation and Fission Products from Returned Uranium Fuels

Strontium-90, technetium-99, cesium-137 and ruthenium-106 are fission products which entered the FEMP as part of the feed materials from reactor returns. Activation products such as plutonium and neptunium were also introduced to the FEMP as contaminants in uranium recycle materials. The pattern of above-background detections of these parameters indicates that extensive plumes generally do not exist and that only small volumes of these radionuclides were released to groundwater. Technetium-99 is an exception; it is detected in multiple adjacent wells in the production area, but is still considered to have been released only in small quantity.

Strontium-90 was detected in unfiltered samples at above-background concentrations in 7 of 112 wells and had a maximum concentration of 7.68 pCi/L, relative to a background of 2.0 pCi/L (Table 4-45). Strontium-90 was detected in perched groundwater in the following areas: near the waste pits, below Plant 6, near the lime sludge ponds, near Plant 7, near the K-65 silos, and in the South Field area.

Technetium-99 was detected in unfiltered samples at above-background concentrations in 55 of 170 wells and had a maximum concentration of 6130 pCi/L, relative to a background concentration of 30 pCi/L (Table 4-45). Technetium-99 was detected in multiple adjacent wells in the following areas: Plant 2/3, below Waste Pit (W6), and near the biodenitrification surge lagoon (BSL). Technetium-99 was also detected in isolated wells below Plant 6, below Plant 9, near the fire training area, and near the northern end of the Plant 1 storage pad. Because of the high specific activity of technetium-99, even the highest activities indicate a low weight concentration in groundwater. For instance, the highest detected value for technetium-99, 6130 pCi/L, corresponds to a weight concentration of 0.36 μg/L (0.36 parts-per-billion). Thus, only a very small volume of technetium-99 has been released to the perched groundwater.

Cesium-137 was detected in unfiltered samples in 4 of 114 wells and had a maximum concentration of 20 pCi/L (Table 4-45). Cesium-137 was detected in isolated wells near Plant 2/3, below Plant 6, near the fire training area, and near the sewage treatment plant.

Ruthenium-106 was not detected in perched groundwater samples from the 109 Type 1 wells sampled (Table 4-45).

Plutonium-239/240 was detected in groundwater samples from six wells. Plutonium-238 was detected in seven wells. The plutonium concentrations were all so low that they were near the analytical detection limit (Table 4-45). All of the data were qualified as estimated or could not be validated. Consequently, the data may be inaccurate and are not necessarily indicative of plutonium contamination.

Neptunium-237 was detected in unfiltered samples at an above-background concentration in 1 of 106 wells, a well near the fire training area, with a concentration of 0.625 pCi/L, relative to a background concentration of 0.25 pCi/L (Table 4-45).

4.7.1.2 Inorganic Contamination

Production at the FEMP involved refining of ores through various metallurgical processes. Many of the processes used to solubilize uranium in process material also solubilized inorganics that were present in ores. Additionally, acid refining and pickling processes likely released metals from metal reaction vessels and associated equipment. The processes generated wastes that contained assorted inorganic chemical constituents, including metals. Perched groundwater monitoring was conducted from 1988 to 1992; however, the analytical parameters often varied. In 1993, a site-wide groundwater sampling program was conducted to perform analyses of a comprehensive suite of 26 inorganic analytes that included 25 metals. In addition, some perched groundwater wells were sampled through the RCRA monitoring program; analytical parameters included those same 26 inorganics. Analyses were performed on both filtered and unfiltered samples from each well in the program. The analysis of extent of contamination in the RI is based on filtered samples from Type 1 wells.

Filtered versus Unfiltered Samples

Wells that are completed in the glacial overburden to monitor perched groundwater typically yield very turbid water samples. The turbidity is a direct result of the high clay and silt content of the formation. Detailed discussions of the nature and extent of individual metals (Appendix E, Section E.1.2) show that unfiltered samples routinely have higher concentrations than filtered samples. This is because clay- and silt-size material are included in unfiltered samples, and laboratory analyses of the unfiltered groundwater detects dissolved metal portions, insoluble metal portions that are naturally part of the clay- and silt-size particles, and insoluble contamination that is adhered or bound to the surface of soil particles. Using routine analytical methods, it is not possible to determine, in an unfiltered analytical result, the individual contributions of soluble and insoluble components. Consequently, elevated concentrations in unfiltered samples are not conclusive indicators of elevated dissolved concentrations. Filtered groundwater samples are the best indicator of groundwater conditions for metals. Hence, the analysis of FEMP perched groundwater relies on filtered data to draw conclusions regarding the nature and extent of metal contamination. The following is a summary of the encyclopedic descriptions for 26 inorganic parameters presented in Appendix E (Section E.1.2).

Isolated Minor Contaminants

Nineteen inorganics were present at above-background concentrations, but without trends indicative of plumes or widespread contamination. Either the potential volumes released to the environment are minimal or releases to the environment have not been transported sufficient distance from a source to result in plume dimensions that can be identified with the distribution of monitoring wells at the FEMP. The 19 inorganics are aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, cyanide, lead, mercury, molybdenum, nickel, potassium, selenium, silicon, silver, and thallium (Table 4-44). These constituents are generally not detected at concentrations greater than one- and two-times background. Detection of these constituents at above-background concentrations are minimal or tend to be isolated from known contamination areas or sources. Many above-background occurrences of these constituents may represent detection of naturally occurring concentrations.

Characteristic Patterns of Contamination

Characteristic patterns of contamination in unfiltered samples were observed for the following six metals: calcium, iron, magnesium, manganese, sodium, and zinc. Typical of these patterns are

increased concentrations in the vicinity of waste sources and detection of above-background concentrations in multiple adjacent wells implying the presence of plumes (Table 4-44). Some of the areas where these trends are observed include the southwest quadrant of the production area, the Plant 6 area, the Plant 9 area, the waste pits, the Solid Waste Landfill, the Operable Unit 4 K-65 silos, and the fire training area.

Individual Inorganics

Chromium, copper, molybdenum, nickel, selenium, vanadium, and zinc were commonly detected in perched groundwater below the production area and/or Operable Unit 1 and 4 areas (Figures 4-84 through 4-90, respectively). The mobility of these metals in the glacial overburden is dependent on the form of the metal in the source and the speciation of the dissolved metal in perched groundwater. Possible sources for the metals are discussed below, and the aqueous speciation is summarized in Table 4-43.

Chromium was principally detected in perched groundwater at above-background concentrations below Plant 2/3, Plant 6, and Plant 9 (Figure 4-84). Chromium is associated with uranium ores and uranium ore concentrates, and is therefore a component of raffinate. The predicted aqueous speciation for chromium (Table 4-43) indicates that most chromium is likely present in the chromium III oxidation state as $Cr(OH)_2^+$, which will have relatively low mobility in the glacial overburden. Based on Eh measurements for perched groundwater (Appendix F), it is unlikely that chromium will be oxidized to the more mobile chromium VI oxyanion form (i.e., CrO_4^{-2}). Therefore, chromium mobility is predicted to be low when chromium III cation species are present.

Copper was primarily detected in perched groundwater below Plants 2/3, 6, and 9 (Figure 4-85). Copper is a minor component of uranium ores and ore concentrates. Additionally, copper was used as cladding on uranium fuel recycled at the FEMP. The predicted aqueous speciation for copper (Table 4-43) indicates that about 94 percent of the dissolved copper is present as the neutral $CuCO_3^o$ complex, which suggests moderate mobility for copper in the glacial overburden.

Molybdenum was primarily detected in perched water at above-background concentrations below Plant 5 and Operable Units 1 and 4 (Figure 4-86). Molybdenum is a minor component of uranium ores and ore concentrates. The predicted aqueous speciation for molybdenum (Table 4-43) indicates

that all dissolved molybdenum will move as the oxyanion MoO_4^{-2}, which implies that molybdenum will be very mobile in the glacial overburden when a leaching source is present.

Nickel was primarily detected at above-background concentrations in perched groundwater below Plants 5 and 9 and Operable Units 1 and 4 (Figure 4-87). Nickel is a minor component of uranium ores and ore concentrates, and was a component of cladding on uranium fuel recycled at the FEMP. The predicted aqueous speciation for nickel (Table 4-43) shows 95 percent of the dissolved nickel present as Ni^{+2}, which suggests that nickel will have relatively low mobility in the glacial overburden. Therefore, the presence of nickel in perched groundwater indicates that significant sources of nickel exist.

Selenium was primarily detected at above-background concentrations in perched water below the Operable Unit 4 K-65 silos (Figure 4-88), which reflects the association of selenium with uranium ore deposits and the raffinate residue. Selenium forms oxyanion species SeO_3^{-2} and $HSeO_3^-$in groundwater (Table 4-43), and these species are predicted to be quite mobile in the glacial overburden when a leaching source is present.

Vanadium was detected in perched groundwater below Plants 2/3, 6, and 9 and Operable Units 1 and 4 (Figure 4-89). Its close association with high-concentration uranium plumes in these areas reflects the similar geochemical behavior of vanadium and uranium oxide compounds, as these compounds are commingled in uranium ore deposits. Vanadium is predicted to form a variety of anion complexes in groundwater (Table 4-43), with the potential for considerable mobility when a leaching source is available.

Zinc is found in perched groundwater below Plant 5 and Operable Units 1 and 4 (Figure 4-90), suggesting that zinc is present in the Plant 5 reduction operations and the uranium raffinate. The predicted aqueous speciation for zinc (Table 4-43) indicates that zinc forms a variety of cation complexes, which will have low mobility in the glacial overburden. Therefore, the presence of zinc in perched groundwater indicates that significant sources of zinc exist.

Of special note here is the absence of any lead plume below the Operable Units 1 and 4 waste storage areas, which contain significant sources of lead associated with uranium raffinate. Lead mobility in perched groundwater is controlled by the solubility of cerussite ($PbCO_3$), which is predicted to be

about 3 μg/L in perched groundwater containing 450 mg/L of bicarbonate. The measurement of lead concentrations in perched groundwater throughout the FEMP indicates concentrations very near the predicted solubility limit, supporting the statement that the lack of lead mobility results from the low cerussite solubility.

4.7.1.3 Organic Contamination

Organic chemicals were used at the FEMP for a variety of functions, including metallurgical processes, machinery operation and maintenance, power generation and distribution, dry cleaning, fire training, and other industrial operations. These processes also generated wastes that contained organic chemical constituents.

Volatile Organic Compounds

Thirty-seven VOCs were analyzed for in unfiltered perched groundwater samples, 25 of those VOCs were detected at least once in Type 1 wells. Figure 4-91 shows the extent of total VOC contamination (total VOC is equal to the summed concentrations of all VOCs detected in a single sample). Of 222 Type 1 wells sampled, only eight of the VOCs analyzed for were detected in six or more wells: 1,1-dichloroethane (1,1-DCE), 1,1,1-trichloroethane (1,1,1-TCA), 1,2-dichloroethene (1,2-DCE), 1,2-dichloroethane (1,2-DCA), tetrachloroethane (PCE), and trichloroethene (TCE). These VOCs are all common degreasers or degradation products of degreasers.

Based on the 1993 data set, VOC contamination in the perched groundwater occurs at several areas of the FEMP (Figure 4-91). The main origins of VOC contamination include (1) processes that use solvents, (2) storage, treatment, and incineration of waste oils, and (3) environmental degradation of chlorinated aliphatic hydrocarbons. The highest concentrations of VOCs are present as small isolated plumes beneath the areas of Plant 6, Plant 9, the Plant 2/3, and the pilot plant. The largest VOC plumes are present in the perched groundwater at the fire training area, and at the sewage treatment plant.

Other Organics

A single pesticide, 4,4'-DDT, was observed as an isolated above-detection in perched groundwater at Well 1324 (3.0 μg/L).

Furans were observed in one well, Well 1080. The furans detected were hexachlorodibenzofurans, pentachlorodibenzofurans, and tetrachlorodibenzofurans.

Herbicides and organophosphorus pesticides were not detected in perched groundwater samples collected from FEMP Type 1 wells.

4.7.1.4 General Water Quality Parameters

Waste waters from chemical processes at the FEMP impacted perched groundwater quality in several areas. General water quality parameters are typically not important contributors to risk calculations; however, water quality parameters are indicators of impacted groundwater quality.

An impact on water quality was observed in the perched groundwater for the following parameters: alkalinity, chloride, nitrate, sulfate, total organic carbon, total organic halogens, and total organic nitrogen. Other parameters such as ammonia, fluoride, pH, total phenols, and specific conductivity were measured; however, results indicated that the natural background conditions for these parameters were not greatly affected by site activities.

Table 4-44 lists major groundwater quality parameters that have been affected in the groundwater to a sufficient degree to be detected as plumes. The plumes are typically found in the following areas of the FEMP: Plants 1, 2/3, 6, and 9; the waste pits; the lime sludge ponds; the K-65 silos; the Solid Waste Landfill; the sewage treatment plant; the fire training area; and the South Field. Detailed discussions of each parameter are presented in Appendix E.1. The plate volume contains isoconcentration maps for those general water quality parameters which aid in understanding perched groundwater contamination.

4.7.2 Descriptions of Composite Plumes in Perched Groundwater

Contamination that is present as definable plumes (versus isolated, above-background occurrences) is typically observed in seven geographically separate areas of the FEMP. This section is a discussion of the nature and extent of contamination in the seven areas.

Section 4.7.1 and Appendix E.1, together with the plate volume, provide depictions of the nature and extent of individual parameters based on the 1993 data set. When viewed in composite, the individual

constituent patterns reveal the presence of seven broadly contaminated areas where multiple contaminants are present above background in perched groundwater:

1. Production Area: Area I Plume
2. Sewage Treatment Plant Area: Area II Plume
3. Operable Unit 2 South Field/Flyash Pile Area: Area III Plume
4. Operable Unit 4 K-65 Silos Area: Area IV Plume
5. Operable Unit 1 Waste Pits/Operable Unit 2 Solid Waste Landfill Areas: Area V Plume
6. Fire Training Area: Area VI Plume
7. Operable Unit 2 Lime Sludge Ponds Area: Area VII Plume

Figure 4-92 shows the borders of the seven broadly contaminated areas. Also shown are the 5 and 20 μg/L contours for total uranium based on unfiltered samples. The areas all have total uranium concentrations greater than 20 μg/L in portions, but are distinct from each other because they are geographically separated by areas of low or background total uranium concentrations. Figure 4-92 also indicates the general directions of groundwater flow in the vicinity of the seven affected areas, based on the horizontal flow directions described in Section 3.6.1.2.

Several of the perched groundwater contamination areas result from Operable Units 1, 2, 3, and 4 sources. Detailed source-area investigations have been conducted on Operable Units 1, 2 and 4 that focused on the nature of the sources and documented whether actual or potential releases have occurred from these units. The results of these investigations have been reported in the respective RI reports for Operable Units 1, 2 and 4. The releases resulting from sources within Operable Unit 3 are being characterized here as part of Operable Unit 5.

The comprehensive site-wide investigations conducted under the Operable Unit 5 RI provide the link between Operable Units 1, 2, 3 and 4 source investigations and the site-wide extent of contaminated media. This section summarizes the relationships observed between the source areas and the extent of perched groundwater contamination revealed by the Operable Unit 5 investigations. Summary descriptions of the other operable unit sources are provided in Sections 1.0 and 4.3.

Table 4-46 presents the maximum concentrations observed for each parameter in each contamination area. Shading patterns are used to rank the maximum observed concentrations according to their elevation above background. The summary illustrates only maximum concentrations in perched groundwater and does not include data from wells in the waste units.

Tables 4-47 to 4-53 (based on Tables E.1-2 to E.1-8 in Appendix E) provide statistical summaries of the number, frequency of detection, concentration ranges, and background levels of radionuclides, inorganics, and major general chemistry parameters in each of the seven affected areas. Note that the tables list statistics for perched groundwater only, and analytical results for Operable Unit 1 and 2 waste unit leachate are not included in calculation of the statistics. As the tables illustrate, the greatest number of constituents and the highest reported above-background concentrations occur in Contamination Area I beneath the production area.

4.7.2.1 Area I: Production Area

The contaminants detected in Contamination Area I resulted from a variety of process-area spills and leaks that occurred over the 38-year operating history of the FEMP. Other probable mechanisms by which the perched groundwater in Area I became contaminated are infiltration of surface water through contaminated, production-area surface soil, and leaks from the storm sewer network and subgrade piping. At the outer fringes of the Area I plume, where concentrations grade to background levels, uranium is generally present as a result of air deposition onto surface soils and subsequent infiltration to the perched groundwater.

A total of 48 constituents (16 radionuclides, 25 inorganics, VOCs, semivolatiles, and 5 general chemistry parameters) were detected at above-background concentrations in Area I. Table 4-47 summarizes analytical results for radionuclides, inorganics, and general chemistry parameters in production area Type 1 wells. Seven inorganics have been released to groundwater in sufficient quantity to be discernable as plumes in the monitor well network: calcium, iron, magnesium, manganese, sodium, vanadium, and zinc. Organic compounds were detected infrequently in perched groundwater and are generally minor contaminants relative to the volume of uranium and inorganics released to perched groundwater. Twenty-four VOCs were detected in perched groundwater (Table E.1-2, Appendix E). Seven VOCs were detected in six or more wells: 1,1,1-trichloroethane (maximum 310 μg/L), 1,1-dichloroethane (maximum 800 μg/L), 1,2-dichloroethene (maximum 270 μg/L), 1,2-dichloroethane (maximum 72 μg/L), 1,2-dichloroethene (maximum 1000 μg/L), tetrachloroethene (maximum 10000 μg/L), and trichloroethene (maximum 10000 μg/L). The VOCs listed above are all degreasers or degradation products of degreasers. Semivolatile organic compounds were only rarely detected, and then only at low concentrations. The most frequently detected SVOC was tributyl phosphate, which was detected in 5 of 28 wells tested (maximum

410 μg/L). Note that tributyl phosphate was used at the FEMP in the uranium refining process. Dioxins, pesticides, PCBs, and furans were not detected in groundwater samples.

On the basis of Figures 4-78 to 4-91 and individual isoconcentration maps in the plate volume, plumes of locally higher concentrations are clearly evident beneath discrete plant process areas. The distribution of contamination indicates that lateral migration of contaminants from their initial points of entry has not been extensive. The maps clearly show that uranium is the major contaminant, and other contaminants have smaller plume dimensions or only isolated, above-background occurrences relative to uranium. The constituents comprising Contamination Area I are generally commingled as a result of releases from multiple production area sources and the migration of contaminants away from their initial point of entry over the 38 years of plant operation. The major areas where contaminants are typically detected well above background are located beneath Plants 2/3, 8, 6, and 9.

4.7.2.2 Area II: Sewage Treatment Plant

The plume in the vicinity of the sewage treatment plant and incinerator complex clearly has its point of origin at the incinerator complex (Figures 4-78, 4-79, and 4-91). The individual parameter plumes that originate from the sewage treatment plant do not overlap with Contamination Area I, except for low-level uranium contamination which is present throughout most of the east side of the site. Air deposition onto the surrounding surface soil from incinerator air emissions, and leaks from the sewage treatment plant are the likely means by which the perched groundwater became affected in this area.

A total of 24 constituents or constituent groups (11 radionuclides, 8 inorganics, VOCs, semivolatiles, and 3 general chemistry parameters) were detected at above-background concentrations in the Area II Plume. Table 4-48 summarizes analytical results for radionuclides, inorganics, and general chemistry parameters in the sewage treatment plant area Type 1 wells. Second to uranium, VOCs were the most frequently detected parameter above background. Four VOCs were detected in perched groundwater (Table E.1-3, Appendix E): 1,1-dichloroethane (maximum 3 μg/L), 1,2-dichloroethene (maximum 89 μg/L), tetrachloroethene (maximum 39 μg/L), and trichloroethene (maximum 13 μg/L). Two semivolatile organic compounds were detected at concentrations only slightly above the method detection limit: diethyl phthalate and phenol. Diethyl phthalate is a common laboratory and sampling cross-contaminant. Pesticides and PCBs were not detected in any groundwater samples.

4.7.2.3 Area III: Operable Unit 2 South Field/Flyash Pile Area

Plumes of individual parameters in Area III are commingled releases from sources within the Operable Unit 2 South Field and active and inactive flyash pile areas. This is evident from the individual contaminant concentration contour maps (plates) described in E.1 and summarized in Figures 4-78 to 4-91. At the outer fringes of the plume, where uranium and other parameter concentrations approach background levels (Figures 4-78 and 4-79), the contaminants may be present as a result of air deposition onto the surrounding surface soil and subsequent infiltration to the perched groundwater, rather than resulting from releases from the South Field/flyash pile source areas. Along the northern fringe of the plume, where uranium levels approach background, the Area III and Area I plumes may grade into each other at levels approaching background. This is evident from the concentration maps of unfiltered total uranium in Figures 4-78 and 4-79.

A total of 22 constituents or constituent groups (12 radionuclides, 8 inorganics, VOCs, semivolatiles, and 2 general chemistry parameters) were detected at above-background concentrations in Contamination Area III. Table 4-49 summarizes analytical results for radionuclides, inorganics, and general chemistry parameters in Type 1 monitor locations.

The principal contaminant detected in Area III was uranium, which occurs as a distinct plume in the area. Other radionuclides occur as isolated detections. Two VOCs, 2-butanone and acetone, were detected in one sample each at concentrations of 1 μg/L and 6 μg/L, respectively (Table E.1-4, Appendix E). Two semivolatiles, diethyl phthalate and tributyl phosphate, were detected in one sample each at a concentration of 1 μg/L. Acetone and diethyl phthalate are both common laboratory contaminants. Pesticides and PCBs were not detected in any groundwater samples. The eight inorganics were only detected at above-background concentrations in isolated wells. The two general chemistry parameters, nitrate and sulfate, were only isolated, low-concentration detections.

4.7.2.4 Area IV: Operable Unit 4 K-65 Silos Area

The Area IV plumes are a result of contaminant migration from the Operable Unit 4 K-65 silos area. To the north of the K-65 silos, as uranium levels grade to background, the Area IV plumes and the southern margin of the Area V plumes may be commingled at levels approaching background (Figures 4-78 and 4-79). As discussed below in Section 4.7.2.5, the Area V plume extends into the northern boundaries of the Operable Unit 4 area as far south as Silos 3 and 4.

A total of 29 constituents or constituent groups (7 radionuclides, 17 inorganics, VOCs, SVOCs, and 3 general chemistry parameters) were detected at above-background concentrations in Contamination Area IV. Table 4-50 summarizes analytical results for radionuclides, inorganics, and general chemistry parameters in K-65 area Type 1 monitor locations. The principal contaminant detected was uranium, which occurs as a distinct plume in the area. Other radionuclides occurred as isolated detections. Seven inorganics have been released to groundwater in sufficient quantity to be discernable as plumes in the monitor well network: calcium, magnesium, manganese, sodium, vanadium, and zinc. Contamination by organic compounds is minor relative to the suspected volume of uranium and inorganics released to groundwater. VOCs were detected very infrequently and at low concentrations: 1,1,2,2-tetrachloroethane (maximum 5 μg/L), 1,1,2-trichloroethane (maximum 2 μg/L), 2-hexanone (maximum 6 μg/L), 4-methyl-2-pentanone (maximum 7 μg/L), acetone (maximum 41 μg/L), bromoform (maximum 2 μg/L), carbon disulfide (maximum 9 μg/L), methylene chloride (maximum 2 μg/L), and toluene (maximum 1 μg/L). Three isolated detections of semivolatiles were observed: bis(2-ethylhexyl)phthalate (maximum 350 μg/L), diethyl phthalate (maximum 3 μg/L), and n-nitroso-di-n-propylamine (maximum 8 μg/L). PCBs were not detected in groundwater; however, there was a single detection of 4,4-DDT at a concentration of 8 μg/L.

Based on the 5 μg/L total uranium contour, the Area IV plume extends to within 50 feet of the eastern bank of the Paddys Run channel. Three lysimeters (1894, 1895, and 1896) were installed in the summer of 1993 to assess whether contaminants had reached the bank of Paddys Run, and all three lysimeters showed uranium concentrations near background. The line of lysimeters is located approximately 200 feet downgradient of the Operable Unit 4 K-65 silos and immediately adjacent to the Paddys Run channel. The information from the lysimeters indicates that while the line of contamination originating from the Operable Unit 4 sources lies close to Paddys Run, contaminants are not measurably discharging to the channel bank at this time.

In the Operable Unit 4 area, Paddys Run has eroded through the glacial overburden, and the streambed is in contact with the sands and gravels of the Great Miami Aquifer. Paddys Run thus serves as the point of discharge for the perched groundwater migrating laterally in the Operable Unit 4 area. Contaminants eventually reaching Paddys Run will discharge to the creek and will not migrate further westward across the creek. However, contaminants that reach Paddys Run under these conditions can infiltrate directly to the Great Miami Aquifer through the streambed, or through the weathered portions of the streambank along the eastern side of the creek. As discussed below in

Sections 4.8.1.1 and 4.8.2, the infiltrating sections of Paddys Run are a major pathway by which the Great Miami Aquifer has become contaminated.

4.7.2.5 Area V Plume: Operable Unit 1 Waste Pits and Operable Unit 2 Solid Waste Landfill Areas

The Area V plumes envelop the Operable Unit 1 waste pits and the Operable Unit 2 Solid Waste Landfill (Figures 4-78, 4-79 and 4-92). Based on the individual constituent contour maps presented in the plate volume and Figures 4-78 to 4-91, the waste pits appear to be the major contributor to the Area V plumes. In the northeast portion, however, contributions from the Solid Waste Landfill may be present, and these plumes become commingled with plumes originating from the waste pits. This is apparent from the concentration maps of unfiltered total uranium presented in Figures 4-78 and 4-79.

A total of 43 constituents or constituent groups (12 radionuclides, 24 inorganics, VOCs, semivolatiles, and 5 general chemistry parameters) were detected at above-background concentrations in Contamination Area V. Table 4-51 summarizes analytical results for radionuclides, inorganics, and general chemistry parameters in Type 1 monitoring locations. Similar to the other contamination areas, uranium is the principal groundwater contaminant. Other radionuclides were detected in isolated wells. Five inorganics have been released to groundwater in sufficient quantity to be discernable as plumes in the monitor well network: calcium, iron, magnesium, manganese, and sodium. Contamination by organic compounds is minor relative to the suspected volume of uranium and inorganics released to groundwater. Sixteen volatile organic compounds were detected in perched groundwater. Seven VOCs were detected in multiple wells: 1,1,1-trichloroethane (maximum 8 μg/L), 1,1-dichloroethane (maximum 48 μg/L), 1,1-dichloroethene (maximum 5 μg/L), 1,2-dichloroethene (maximum 60 μg/L), 4-methyl-2-pentanone (maximum 18 μg/L), benzene (maximum 4 μg/L), and trichloroethene (maximum 290 μg/L). Eight semivolatile organic compounds were detected in perched groundwater. Three of the compounds were phthalates, a common laboratory and sampling cross-contaminant. The other five semivolatile organic compounds were each detected once: 2,3,4,6-tetrachlorophenol (4.2 μg/L), 4-nitrophenol (4 μg/L), benzoic acid (4 μg/L), pentachlorophenol (7 μg/L), and tributyl phosphate (320 μg/L). No PCBs were detected in groundwater. Three furans were each detected once: hexachlorodibenzofurans (0.32 μg/L), pentachlorodibenzofurans (0.32 μg/L), and tetrachlorodibenzofurans (0.12 μg/L).

The five general chemistry parameters occur as discernable plumes over Area V. The general chemistry parameters with the highest concentrations and greatest number of detections above background were chloride and nitrate. Chloride was detected at above-background concentrations in 15 of 34 wells tested, with a maximum concentration 140 times background (6300 mg/L). Sulfate was detected at above-background concentrations in 21 of 34 wells tested. Elevated concentrations of fluoride were detected in 5 of 34 wells and elevated concentrations of ammonia were detected in 3 of 33 wells.

To the south, the Area V plumes extend into the Operable Unit 4 area approximately as far south as Silos 3 and 4, where uranium concentrations approaching background are observed. Silo 4 is empty and thus is not a contributing source to the Area V plumes. The degree to which Silo 3 contributes to the above-background levels observed in this portion of the Area V cannot be distinguished from the contour maps; however, the Operable Unit 4 RI concluded that, based on process knowledge, potential contributions from Silo 3 would be expected to be considerably less than those anticipated from the K-65 Silos (Silos 1 and 2). Infiltration of rainwater through uranium-contaminated soil (air fallout) is the likely source of perched groundwater contamination in this overlapping area.

4.7.2.6 Area VI: Fire Training Area

The fire training area includes the training building, burn pond and drain pit, and the burn trough. The Area VI plumes in the vicinity of the fire training area clearly originate at the training complex. The bulk of the contamination appears to originate at the burn pond, drain pit, and burn trough, rather than from the burnhouse. Because the activities that took place in the burn areas included the ignition of radiologically contaminated combustible organic liquids, the mix of groundwater contaminants includes a mix of organic and radiological constituents. As shown on the parameter concentration contour maps (plates) and Figures 4-78 to 4-91, the plume is not commingled with any of the other perched groundwater plumes, with the exception of low-level total uranium concentrations.

A total of 23 constituents or constituent groups (15 radionuclides, 7 inorganics, VOCs, and semivolatiles) were detected at above-background concentrations in Contamination Area VI. Table 4-52 summarizes the analytical results for radionuclides, inorganics, and general chemistry parameters in Type 1 monitor locations. Uranium and volatile organic compounds are the primary contaminants in the fire training area groundwater data. Other radionuclides and inorganic parameters

were generally detected in isolated wells. Thirteen VOCs were detected in perched groundwater. Seven VOCs were detected in multiple wells: 1,1,1-trichloroethane (maximum 82 μg/L), 1,1-dichloroethane (maximum 520 μg/L), 1,1-dichloroethene (maximum 14 μg/L), 1,2-dichloroethene (maximum 150 μg/L), chloroethane (maximum 24 μg/L), methylene chloride (maximum 19 μg/L), and trichloroethene (maximum 1 μg/L). With respect to semivolatile organic compounds, only three were detected; and all three were phthalates, which are common laboratory and sampling cross-contaminants.

4.7.2.7 Area VII: Operable Unit 2 Lime Sludge Ponds Area

Figures 4-78 and 4-79 show that the pattern of total uranium contamination does not distinctly separate the Lime Sludge Ponds area from the production area. The Lime Sludge Ponds area and production area do not appear to be separated by an area with less-than-20 μg/L total uranium contamination. However, the Lime Sludge Ponds are physically separated from the production area by open space, and they are administratively separated from the production area contamination by the site division into Operable Units. Source area investigations, conducted as part of the Operable Unit 2 RI, concluded that perched groundwater contaminants detected in the vicinity of the Lime Sludge Ponds may be attributed to the K-65 trench that traverses through this area, rather than releases from the ponds.

A total of 18 constituents or constituent groups (11 radionuclides, 4 inorganics, semivolatiles and 2 general chemistry parameters) were detected at above-background concentrations in Contamination Area VI. Table 4-53 summarizes the analytical results for radionuclides, inorganics, and general chemistry parameters in Type 1 well locations. Uranium is the most extensive contaminant in groundwater. Other radionuclides and inorganics occur at above-background concentrations only in isolated wells. No organic constituents were detected at above-background concentrations.

4.7.3 Summary of Nature and Extent of Contamination in Perched Groundwater

As part of the area-wide Operable Unit 5 RI studies, perched groundwater was sampled from 336 Type 1 groundwater monitoring locations situated throughout the FEMP. The period of record for sampling activities extends from 1988 to 1993, during which time more than 2000 samples have been collected. The encyclopedic descriptions of groundwater contamination, presented in Appendix E.1 and summarized in Section 4.7.1, show that uranium is the principal groundwater contaminant and that contamination of other radionuclide, inorganic, organic, and general chemistry parameters falls

within the extent of uranium contamination as defined by the 5 μg/L contour line of total uranium based on unfiltered samples. Table 4-44 summarized the extent of contamination for major radionuclides, inorganics, and general chemistry parameters.

The principal contaminants associated with site operations have been detected in seven geographically distinct areas (Figure 4-92), and each area has multiple sources to which contamination is attributed. Tables 4-47 to 4-53 are statistical summaries that list the major contaminants occurring in each respective contamination area, whereas Table 4-46 is a visual representation of the maximum contaminant values observed in each plume. Based on the 5 μg/L total (unfiltered) uranium contour identified in the 1993 data set (Figure 4-79), the land area occupied by the seven broadly contaminated areas is approximately 525 acres, which is approximately one-half of the on-property glacial overburden area.

Each of the seven groundwater contamination areas contains multiple contaminants in addition to uranium. The total number of constituents and constituent groups detected above background within each area is as follows (based on Tables E.1-2 to E.1-8, Appendix E):

I Production Area: 48 constituents and constituent groups

- 16 radionuclides
- 25 inorganics
- volatile organic compounds
- semivolatile organic compounds
- 5 general chemistry parameters

II Sewage Treatment Plant Area: 24 constituents and constituent groups

- 11 radionuclides
- 8 inorganics
- volatile organic compounds
- semivolatile organic compounds
- 3 general chemistry parameters

III South Field/flyash Pile Area: 22 constituents and constituent groups

- 12 radionuclides
- 8 inorganics
- volatile organic compounds
- semivolatile organic compounds
- 2 general chemistry parameters

IV K-65 Silos Area: 29 constituents and constituent groups

- 7 radionuclides
- 17 inorganics
- volatile organic compounds
- semivolatile organic compounds
- 3 general chemistry parameters

V Waste Pits and Solid Waste Landfill Areas: 43 constituents and constituent groups

- 12 radionuclides
- 24 inorganics
- volatile organic compounds
- semivolatile organic compounds
- 5 general chemistry parameters

VI Fire Training Area: 23 constituents and constituent groups

- 15 radionuclides
- 7 inorganics
- volatile organic compounds
- semivolatile organic compounds

VII Lime Sludge Ponds Area: 18 constituents and constituent groups

- 11 radionuclides
- 4 inorganics
- semivolatile organic compounds
- 2 general chemistry parameters

Uranium contamination exists outside the seven areas primarily as a result of air-deposition of plant air emissions, resulting in uranium deposition on surface soils both on-property and off-property. The surface soil contamination has (and continues to be) leached by infiltrating rain water, resulting in slightly elevated concentrations of uranium in perched groundwater. Outside the seven areas and within the bounds of the U.S. DOE property, perched groundwater has total uranium concentrations greater than background (1.3 μg/L) but generally less than 20 μg/L. Figure 4-18 shows the extent of surface soil contamination in the FEMP area. The uppermost saturated horizon in this area potentially has elevated concentrations of total uranium resulting from leaching from contaminated surface soil. However, total uranium concentrations are predicted to be less than 5 μg/L (relative to a background concentration of 1.3 μg/L), based on trends seen in on-property glacial overburden monitor wells (Figure 4-79).

The characterization of contaminant nature and extent developed here is used in Section 5.0 to establish baseline conditions in contaminant fate and transport modeling. In Section 6.0, the current and future conditions are evaluated to determine the human health and environmental risks associated with the affected perched groundwater. The results of the risk assessment will then be used to develop candidate, risk-based, remediation areas in the FS.

The results of the RI characterization activities for perched groundwater provide sufficient information from which to characterize risk and to determine appropriate response actions in the feasibility study. Both the 1993 data set and the earlier (pre-1993) data will be carried forward to the feasibility study for use in developing candidate remediation areas and assessing performance-based remedial technologies. No further information is needed at this juncture to begin to properly execute the feasibility study process. The potential off-site uranium contamination of perched groundwater is not a significant data limitation of the RI. Potentially contaminated areas outside the site property may still require additional evaluation and confirmation on a case-by-case basis to determine whether land areas represented by the isolated detections require remediation. The need for additional evaluation will be dependent on the final remediation goals selected for the Record of Decision (ROD). This, however, is a remedy implementation issue that does not require resolution for the feasibility study to proceed. Sufficient information is available to establish risk-based remedial goals, develop and compare remedial alternatives, and select a remedy for presentation in the ROD.

4.8 GREAT MIAMI AQUIFER

This section describes the nature and extent of contamination in the Great Miami Aquifer at the FEMP. Section 4.8.1 discusses the nature and extent of individual parameters or parameter groups that occur in groundwater at concentrations greater than background. Uranium is discussed in great detail here because it is the major site contaminant in terms of volume released, potential risk, and future remedial design considerations. Section 4.8.1 provides summary information, and is based on detailed discussions of FEMP groundwater analytical data presented in Section E.2 of Appendix E.

The groundwater data presented in Section 4.8.1 and Appendix E.2 reveal that the majority of contamination in the Great Miami Aquifer entered the groundwater system through distinct point sources or line sources. Section 4.8.2 illustrates the individual characteristics of the six distinct plumes. The FEMP groundwater contamination plume that extends south of the FEMP is commingled with a groundwater contamination plume that originates from a neighboring industrial

facility, the Paddys Run Road Site (PRRS), which is unrelated to the FEMP. The PRRS is currently undergoing an independent CERCLA RI/FS. Section 4.8.2 describes the commingling of the FEMP and PRRS plumes.

The following text routinely compares site data to a background value. The background value used here is the 95th percentile of the background data set. Section 4.2 contains a complete discussion of how background values were calculated.

4.8.1 Contamination in the Great Miami Aquifer

This summary discussion of the nature and extent of groundwater contamination is based on detailed analyses of groundwater data presented in Appendix E.2. A number of data presentation formats were used to analyze groundwater data during preparation of Appendix E.2. First, groundwater isoconcentration maps were created for each parameter based on groundwater samples collected primarily during 1993; the maps are presented as plates in this report (see plate volume). Selected isoconcentration maps (plates) that are important in understanding groundwater contamination are included in Section 4.7.1 as reduced-size figures. This section and Appendix E.2 contain tables of descriptive statistics that summarize the range and extent of occurrence for each parameter in FEMP monitor wells. In addition, for illustrating temporal trends of analytical results in monitor wells, Appendix M contains graphs of parameter concentrations versus time. Appendix I contains tabulated analytical results for all groundwater samples collected to determine nature and extent.

Groundwater Analytical Data

The FEMP groundwater analytical data set available for compilation of this report spans from 1988 to 1994. However, only during the 1993 field programs were a majority of the FEMP wells sampled within a relatively short period. Section 2.0 describes the individual sampling programs that were conducted at the FEMP. For purposes of site characterization, all data are evaluated together as a whole, and data are only distinguished by date of collection. The 1993 data set is functionally a snapshot of contaminant distribution, whereas the 1988 to 1992 data set cannot be sorted to effectively describe site-wide contaminant distribution in one distinct period. Because the 1993 data set is the most complete site-wide data set that is constrained to a distinct period, it was the prime data set used to create groundwater isoconcentration maps presented in this report (plate volume). See Appendix E.0 for a discussion of the process used to select data for the isoconcentration maps.

The 1988 to 1994 RI/FS sampling program predominantly focused on collecting groundwater samples for analysis of full radiological, HSL inorganic, and general water quality parameters. Groundwater samples from specific wells were additionally analyzed for HSL organics, including pesticides and PCBs. RCRA sampling programs during this period focused on a similar suite of analytes, with the addition of VOCs. Under the 1993 sampling programs, samples were collected from a majority of the FEMP wells and analyzed for uranium, thorium, radium, HSL inorganics, HSL VOCs, and general water quality parameters.

Filtered vs. Unfiltered Samples

During many of the FEMP groundwater investigations, samples for radiological and inorganic analysis were commonly divided into unfiltered and filtered (45-micron) portions for analysis. Statistical summaries, discussed throughout Appendix E.2, show that unfiltered analytical results typically had higher reported concentrations than filtered analytical results, except in the case of relatively soluble compounds such as sodium and technetium-99. Higher concentrations typically result because unfiltered samples generally contain a variable quantity of fine silt- or clay-size material relative to filtered samples, and the silt- or clay-size material has inorganics and radionuclides within its matrix or adhered to its edges. Sodium and technetium-99 are relatively more soluble and therefore are not as prevalent in or on solid particles as are less soluble elements.

As in Section 4.7.1, discussed above, the difference between unfiltered and filtered samples is dramatic in perched groundwater samples, because perched groundwater wells are completed in a clay-and-silt-dominated formation which typically yields very turbid groundwater samples. However, for the Great Miami Aquifer, the differences between filtered and unfiltered sample results are less dramatic, because the Great Miami Aquifer formation is predominantly sand and gravel deposits which yield groundwater samples of relatively low turbidity. Consequently, the following text and the text of Appendix E.2 relies primarily on data from unfiltered samples to describe the nature and extent of contamination.

Chemical Speciation

Section 4.7.1 provided a description of chemical speciation and relative mobilities for FEMP parameters in perched groundwater. The chemical speciation for the perched groundwater system, presented in Table 4.43 and discussed in Section 4.7.1, can be applied to the Great Miami Aquifer system, because the soil and groundwater chemistry of the two systems are very similar.

Consequently, the relative rankings of parameters according to solubility and tendency to adsorb, or adhere, to soil (discussion of chemical speciation in Section 4.7.1, and solubility/absorption rankings in Table 4-44) are used here in Section 4.8.1 to describe the relative solubility and absorption potential of parameters in the Great Miami Aquifer system.

Uranium as the Primary Contaminant

Uranium is the principal FEMP contaminant in Great Miami Aquifer, and was the primary contaminant that was investigated during the RI. The following discussion regarding the extent of uranium contamination will focus on describing how uranium entered the Great Miami Aquifer as well as the hydrogeologic factors that are responsible for the observed uranium distribution in groundwater. The remaining FEMP contaminants will be discussed in less detail, because their sources and distribution are generally governed by the same processes described for uranium.

In the perched groundwater discussion (Section 4.7), it was shown that all nonuranium contamination occurs within the area of uranium contamination. Such an observation generally holds true in the Great Miami Aquifer. However, in the Great Miami Aquifer, one case exists where contamination is detected outside the maximum extent of uranium contamination in plumes. The contaminant detected outside the uranium plume areas, sulfate, is relatively more mobile than uranium and is a minor contributor to the risk assessment presented in Section 6. Uranium is the focus of this discussion because it is the prime contaminant that is dominant in the risk assessment (Section 6) and is consequently the prime contaminant controlling selection of remedial options in the Feasibility Study.

4.8.1.1 Radiological Contamination

4.8.1.1.1 Total Uranium

The FEMP processed primarily depleted and natural uranium and lessor quantities of slightly enriched uranium (see Section 4.1). For such uranium, the uranium-238 isotope constitutes greater than 95 percent of the uranium on a mass basis, whereas the other two natural isotopes of uranium, uranium-235, and uranium-234, constitute approximately 5 percent by mass.

A fourth isotope of uranium, uranium-236, can be found at the FEMP in extremely small quantities. Uranium-236 does not occur naturally. It is produced in a nuclear reactor from the alpha decay of plutonium-240 or through electron capture by neptunium-236. Uranium-236 entered the FEMP as part of recycled uranium materials received from Hanford. Uranium-235 and uranium-236 both

decay through emission of an alpha particle. Because the alpha particles emitted by uranium-235 are very close in energy to the alpha particles emitted by uranium-236, alpha spectrometry, the uranium isotopic analysis technique used by the RI/FS, cannot distinguish uranium-235 from uranium-236. Consequently, activity concentrations of the two isotopes are reported together as uranium-235/236. (Refer to Section 4.1 for a discussion of isotopic analysis.).

The RI sampling programs generally analyzed samples for both total uranium and isotopes of uranium. The following discussion will focus on results of total uranium analyses. Note that all isotopes of uranium have identical chemical behavior in the soil or groundwater environment.

Uranium was the principal FEMP contaminant investigated during the RI. The monitoring well network installed in the Great Miami Aquifer was principally designed for three purposes: to determine the nature and extent of individual uranium plumes and other constituents, to establish the natural background concentrations of uranium and other constituents, and to monitor RCRA waste management units for potential releases. All uranium contamination has entered the aquifer from sources above, resulting in plumes that are most extensive and concentrated at the Type 2 well depth and successively less extensive and concentrated at the Type 3 and 4 well depths.

Figures 4-93 and 4-94 are maps showing total uranium concentrations in Type 2 wells, based on analytical results for unfiltered and filtered samples, respectively. The maps show a uranium distribution that is markedly different from the uranium distribution seen in soils (e.g., Figure 4-18) or perched groundwater (e.g., Figure 4-93); areas of high-concentration uranium contamination in the glacial overburden are in most cases not underlain by high-concentration uranium contamination in the Great Miami Aquifer. The contamination observed in the Great Miami Aquifer entered the aquifer primarily at areas where the glacial overburden is thin or absent. Areas with a significant thickness of glacial overburden have acted as aquitards to migration of contaminants from surface soil and shallow perched groundwater to the underlying Great Miami Aquifer.

Major Uranium Plumes and Sources

The uranium contamination observed in the Great Miami Aquifer can be divided into six separate plumes, which have six distinctly different point or line sources (Figure 4-95):

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Plume Name	Source of Plume
Waste Storage Area A	Leachate that leaks from waste pits which are separated from the Great Miami Aquifer by only a liner and/or minimal thickness of glacial overburden strata.
Waste Storage Area B	Contaminated surface water runoff from the waste storage area that flows into Paddys Run and subsequently infiltrates into the Great Miami Aquifer through the bed of Paddys Run, where the glacial overburden is absent.
Plant 6	Contaminated perched groundwater is transmitted to the Great Miami Aquifer, where the Plant 6 basement and sewage lift station are underlain by less than 5 feet of glacial overburden.
South Plume A	Leachate and surface water runoff from the flyash piles and South Field that infiltrates into the Great Miami Aquifer where the glacial overburden is thin or absent.
South Plume B	Contaminated surface water runoff from the production area that formerly flowed into the storm sewer outfall ditch and Paddys Run, where it infiltrated through the stream bed into the Great Miami Aquifer.
South Plume C	Contaminated surface water flow of Paddys Run that infiltrated through the streambed into the Great Miami Aquifer.

Samples from Type 2 wells define the maximum lateral extent for the uranium component of the six plumes (Figure 4-93). The data for Type 3 and 4 wells (Figures 4-96 and 4-97) show that each of the distinct plumes described above is present as less concentrated and arealy extensive plumes at depth.

The approximate edge of each uranium plume is defined by the 5 μg/L contour line shown on the total uranium isoconcentration maps for Type 2 wells (Figures 4-93 and 4-94). It is reasonable to assume that each plume began forming by the middle-1950s; therefore, the extent of each plume outlined in Figures 4-93 and 4-94 represents uranium's distribution after approximately 38 years of travel time.

Waste Storage Area A Plume

The waste storage area A plume originates primarily as waste pit leachate that enters the Great Miami Aquifer as a result of leaks from one or more waste pits (Figures 4-93 and 4-95). In the waste storage area, the glacial overburden is up to 30 feet thick. However, all of the waste pits, with the

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exception of Pit 5, are excavated deeply into the glacial overburden. Each of these pits can potentially leak to the Great Miami Aquifer because they are underlain by only a thin, protective barrier. Waste Pit 3, the Burn Pit, and the Clearwell were excavated to such a depth that in places little or no glacial overburden separates their liners from the underlying sand and gravel of the Great Miami Aquifer.

Waste Pits 1, 2, 4, 5, and 6 and the solid waste landfill are underlain by approximately 30 feet of glacial overburden. The Operable Unit 1 RI report (DOE 1994h) contains a detailed description of waste pit construction details, and the RI report for Operable Unit 2 (DOE, 1994) contains a detailed description of the solid waste landfill. The Operable Unit 1 RI report concluded that uranium and other contaminants have entered the Great Miami Aquifer as a result of vertical leaks from the waste pits to the Great Miami Aquifer; however, the report did not conclude which pits are specifically responsible for observed contamination in the Great Miami Aquifer. The Operable Unit 2 RI report concluded that the solid waste landfill has not yielded a detectable release to the Great Miami Aquifer. Consequently, Waste Pit 3, the Clearwell, and the burn pit may be the largest contributors of contamination to the waste storage area A plume, because they are the only pits not underlain by glacial overburden.

Isoconcentration maps of unfiltered total uranium in Type 2, 3, and 4 wells illustrate the depth distribution of uranium in the Great Miami Aquifer. Concentrations of total uranium greater than 5 μg/L in the waste storage area A plume extend laterally across the entire waste pit area in Type 2 wells (Figure 4-93). The highest total uranium value at this interval was 64.7 μg/L in Well 2822. Deeper in the aquifer at the level of the Type 3 wells, the 5 μg/L contour for total uranium extends laterally across an area of similar size (Figure 4-96), as was observed in Type 2 wells (Figure 4-93); however, the area of greater-than-20 μg/L contamination is smaller at the Type 3 well depth (Figure 4-96) than is observed at the Type 2 well depth (Figure 4-93). The highest total uranium value at the Type 3 depth interval was 28.4 μg/L in Well 3001. No detections above background were noted in Type 4 wells (Figure 4-97). This is to be expected, since the waste pit area is underlain by the blue clay layer, between the Type 3 and Type 4 well depth interval, which act as an aquitard to downward plume migration.

Cross sections shown in Figures 4-98 through 4-107 depict the vertical distribution of total uranium concentrations in the Great Miami Aquifer. Cross Section H-H' (Figure 4-106) shows the vertical

distribution of total uranium beneath the Operable Unit 1 waste pits and Operable Unit 2 solid waste landfill. The cross section includes analytical results from monitor wells and Hydropunch samples. Within the area of the cross section, water flows approximately from WSW to ENE (left to right in Figure 4-106). The concentration trends support the conclusion that the highest concentrations of total uranium are located in the upper portion of the aquifer immediately beneath the waste pits. Concentrations downgradient of the source are lower as a result of dilution that occurs (via advection, dispersion, and absorption) as groundwater moves away from the point source.

Waste Storage Area B Plume

The waste storage area B plume originates as contaminated surface water in Paddys Run that infiltrates into the Great Miami Aquifer, where Paddys Run flows directly on top of the sand and gravel of the Great Miami Aquifer (Figure 4-95). Surface water from the waste storage area and north buffer zone has historically drained directly to Paddys Run by way of several unnamed drainages and the pilot plant drainage ditch. Surface water that enters Paddys Run can potentially infiltrate into the Great Miami Aquifer, because the glacial overburden is absent in the bottom of the stream channel, and the stream flows directly on top of the sand and gravel of the Great Miami Aquifer (Figure 4-95). High concentrations of uranium have been documented in the surface water flow that leaves the waste storage area (see Section 4.5). Surface water flow in the waste storage area has been controlled since 1992 as a result of a removal action to control storm water runoff in the waste pit area. Consequently, the waste storage area is no longer a contributing source to the waste storage area B plume. However, potentially contaminated surface water flow continues to enter the Paddys Run drainage by way of the pilot plant drainage ditch and drainage from the north buffer zone.

Isoconcentration maps of unfiltered total uranium in Type 2, 3 and 4 wells illustrate the depth distribution of uranium in the Great Miami Aquifer. Concentrations of total uranium greater than 5 μg/L in the waste storage area B plume extend laterally away from the line source (Figure 4-93). The highest total uranium value at this interval was 27.2 μg/L in Well 2009. Deeper in the aquifer at the level of the Type 3 wells, the 5 μg/L contour for total uranium extends laterally over a smaller area (Figure 4-96) than was observed in Type 2 wells (Figure 4-93); and the area of greater-than-20 μg/L contamination is smaller at the Type 3 well depth (Figure 4-96) than is observed at the Type 2 well depth (Figure 4-93). The highest total uranium value at the Type 3 depth interval was 31.5 μg/L in Well 3108. No detections above background were noted in Type 4 wells (Figure 4-97).

This is to be expected, since the area is underlain by the blue clay layer between the Type 3 and Type 4 well depth interval.

Plant 6 Plume

The Plant 6 plume is believed to originate as perched groundwater that infiltrates into the Great Miami Aquifer, where a deep basement underlies the west half of Plant 6, and where the sewage lift station is excavated deeply into the glacial overburden. The west portion of Plant 6 is a rolling mill, which has a basement extending greater than 20 feet below grade. The glacial overburden in the Plant 6 area is approximately 25 feet thick. Total uranium occurs in perched groundwater beneath Plant 6 at concentrations ranging to 146,000 μg/L (see Section 4.7.1.1.1). Concentration contours of total uranium indicate that the highest concentrations in the Plant 6 plume directly underlie the Plant 6 area (Figure 4-93). It is believed that the Great Miami Aquifer contamination is primarily the result of contaminated, perched groundwater that migrated downward along the Plant 6 basement walls or migrated downward within backfill adjacent to the walls.

Isoconcentration maps of unfiltered total uranium in Type 2, 3 and 4 wells illustrate the depth distribution of uranium in the Great Miami Aquifer. Concentrations of total uranium greater than 5 μg/L in the Plant 6 plume extend laterally downgradient from the Plant 6 source area. The highest total uranium value at this interval was 37 μg/L in Well 2054. Deeper in the aquifer at the level of the Type 3 wells, the 5 μg/L contour for total uranium extends laterally over a much smaller area (Figure 4-96) than was observed in Type 2 wells (Figure 4-93). The highest total uranium value at the Type 3 depth interval was 13.1 μg/L in Well 3054. No detections above background were noted in Type 4 wells (Figure 4-97).

South Plume

Contaminated groundwater in the southern portion of the FEMP has historically been referred to as the south plume. Monitor wells installed in 1992 and 1993 provide data that show the south plume is be a composite of three separate plumes: South Plume A, South Plume B, and South Plume C (Figure 4-95). Each plume has a distinctly different source of contamination.

South Plume A

South Plume A originates as infiltration that occurs where the glacial overburden is thin or absent adjacent to and beneath the southern Operable Unit 2 waste units (Inactive Flyash Pile, South Field,

and Active Flyash Pile). The stretch of Paddys Run adjacent to the southern Operable Unit 2 waste units is a source of infiltration to the Great Miami Aquifer, just as was described above for the waste storage area B plume; however, the maximum concentrations in South Plume A are two orders of magnitude greater than in the waste storage area B plume. The RI report for Operable Unit 2 (DOE 1994h) concluded that the Inactive Flyash Pile, South Field, and Active Flyash Pile were all sources of uranium contamination in the Great Miami Aquifer. Each of these units is constructed such that they lie partly on glacial overburden and partly on sand and gravel of the Great Miami Aquifer. Releases from these units may potentially reach the Great Miami Aquifer by (1) leachate leaking downward from the waste unit to sand and gravel of the Great Miami Aquifer that underlies the unit, (2) leachate leaking to perched groundwater, which in turn is transmitted through the glacial overburden to the Great Miami Aquifer, and (3) surface water runoff that flows southward from the waste units onto areas where the glacial overburden is absent and infiltration into the Great Miami Aquifer can readily occur.

Isoconcentration maps of unfiltered total uranium in Type 2, 3 and 4 wells illustrate the depth distribution of uranium in the Great Miami Aquifer. Concentrations of total uranium greater than 5 μg/L in the waste storage area A plume extend laterally to the east where they commingle with South Plume B. The isoconcentration map of total uranium in Type 2 wells shows that a large portion of the plume has concentrations over 100 μg/L. The highest total uranium value at this interval was 2070 μg/L in Well 2945. Deeper in the aquifer at the level of the Type 3 wells, the 5 μg/L contour for total uranium extends laterally over a smaller area (Figure 4-96) than as was observed in Type 2 wells (Figure 4-93). The highest total uranium value at the Type 3 depth interval was 3.0 μg/L in Well 3016. No detections above background were noted in Type 4 wells (Figure 4-97).

South Plume B

South Plume B originated as contaminated surface water runoff that infiltrated into the Great Miami Aquifer through the bed of the storm sewer outfall ditch (SSOD), Paddys Run, and the area immediately southeast of the South Field (Figure 4-95). Prior to 1986 a significant portion of the storm water runoff from the production area flowed down the SSOD to Paddys Run and eventually to the Great Miami River. Surface water in the SSOD and Paddys Run can potentially infiltrate into the sand and gravel of the Great Miami Aquifer because no glacial overburden underlies the streambed. Surface water can potentially infiltrate at any point between the head of the SSOD and Willey Road

not underlain by impermeable material, because the groundwater table is in general, along this section, lower than the elevation of the stream bottom; the stream is said to be losing water. South of Willey Road, infiltration is sometimes limited or entirely prevented (Figure 4-95) if the groundwater table is higher than the elevation of the stream bottom. When the water table elevation exceeds the elevation of the stream bottom, the stream potentially gains water from the aquifer; the stream is said to be gaining. The source of the north portion of South Plume B is a section of drainage that is always losing. The source of the south portion of South Plume B is a section of Paddys Run that is alternately gaining or losing dependent on the water table elevation, which varies seasonally.

Like the aforementioned plumes, isoconcentration maps of unfiltered total uranium in Type 2, 3 and 4 wells illustrate the depth distribution of uranium in the Great Miami Aquifer. Figures 4-93, 4-96 and 4-97 show uranium-depth-distribution trends in South Plume B that are similar to South Plume A; that is, highest concentrations are seen in Type 2 wells, and deeper portions of the aquifer have lower concentrations. Seven cross sections (Figures 4-104 to 4-109 and 4-111) were constructed based on analytical results of unfiltered samples from monitor wells and Hydropunch sampling.

Cross section B-B' (Figure 4-104) is oriented approximately perpendicular to, or at a right angle to, the direction of plume migration. The groundwater flow direction is out of the page toward the viewer. The cross section demonstrates that the plume front is lobate in shape, such as is seen on Figure 4-93. The lobate shape of the plume front indicates that the Great Miami Aquifer does not have homogeneous groundwater flow, and lobes that extend in advance of the main body of the plume are indicators of areas where groundwater (and uranium) transport is relatively more rapid than surrounding areas.

Like cross section B-B', cross sections C-C' and D-D' (Figures 4-105 and 4-106) are oriented approximately perpendicular to the direction of groundwater flow. Cross section C-C' is located immediately north of the South Plume extraction wells (Figure 4-93), whereas cross section D-D' is located south of the extraction wells. The south plume extraction wells are a west-east-oriented line of five wells that were brought online in 1993 to prevent further southward migration of South Plume B.

The southern edge of South Plume B is co-mingled with inorganic and organic plumes that originate from the Paddys Run Road Site (PRRS). The maps of total uranium distribution shown here

(Figures 4-93 and 4-94) indicate that uranium exists in groundwater at above-background concentrations beneath and downgradient of the PRRS. Uranium is commonly associated with phosphorous/phosphate ores (Nash, Granger, and Adams 1991) and, therefore, could be a byproduct of manufacturing processes at the Albright & Wilson/Mobil Mining and Minerals Companies phosphoric acid and sodium tripolyphosphate manufacturing plant. It is possible that a portion of the uranium beneath and downgradient of the PRRS is attributable to the PRRS.

The draft PRRS remedial investigation (ERM, 1992) tested for uranium in its groundwater investigation. However, the PRRS eliminated uranium as a contaminant of concern by comparing its groundwater samples to a total uranium background value of 647.3 pCi/L (sic). Based on the available data, there are three possible sources of above-background uranium concentrations in the Great Miami Aquifer beneath and downgradient of the PRRS: (1) the uranium contamination originated entirely from the FEMP, (2) the uranium contamination originated entirely from the PRRS, or (3) the uranium contamination originated from both the FEMP and the PRRS. This RI report does not have sufficient data to conclude whether or not any of the South Plume B uranium contamination is attributable to the PRRS.

South Plume C

South Plume C originated as contaminated surface water flow in Paddys Run that infiltrated into the Great Miami Aquifer through the bed of Paddys Run along the losing stretch of stream between New Haven Road and the Great Miami River (Figures 4-95 and 4-93).

South Plume C has relatively low total uranium concentrations relative to South Plumes A and B. The maximum value detected in the 1993 data set was 11.4 μg/L in well 2127. No Type 4 wells were completed in the South Plume C area.

Other Uranium Plumes and Sources

Slightly elevated total uranium concentrations are observed in wells outside of the plume edges defined by the 5 μg/L isoconcentration contours (Figures 4-93 and 4-94). The concentrations ranged from approximately 2 to 5 μg/L with isolated concentrations as high as 14 μg/L. Section 4.7.1.1.1 illustrated how uranium contamination on the surface of the glacial overburden has in places been transported through the glacial overburden to result in slightly elevated uranium concentrations in the unsaturated sand and gravel above the Great Miami Aquifer. It is believed that this process of slow

transport through the glacial overburden is responsible for many of the isolated, above-background, total uranium detections in wells outside the six well-defined plumes of the Great Miami Aquifer.

Figure 4-18 shows the extent of surface soil contamination in the FEMP area. The upper portion of the Great Miami Aquifer (i.e., Type 2 well depth) within this area potentially has slightly elevated uranium concentrations resulting from leaching of surface soil contamination (see discussion on uranium transport within the glacial overburden, Section 4.7.1.1.1).

Cross section A-A' (Figure 4-103) illustrates the extent of contamination in the Great Miami Aquifer that is due to migration of leachate from surface soil, through the glacial overburden, to the upper portion of the aquifer. Migration of leachate from surface soil contamination on the eastern FEMP property boundary has resulted in a thin horizon at the top of the aquifer that has total uranium concentrations above background (1.2 μg/L) but below approximately 5 μg/L. Note that the uranium contamination is not seen at deeper depths in the aquifer.

Low levels of uranium contamination also exist in groundwater along the east bank of the Great Miami River, south of the confluence of Paddys Run (Figure 4-108). The low levels of uranium contamination in the area were identified through sampling of private wells; results up to 9.9 μg/L total uranium were observed. The contamination is believed to have resulted from infiltration of Great Miami River water into the bank of the river. It is believed that uranium-bearing surface water flowed down Paddys Run and entered the Great Miami River; subsequently, the Paddys Run water may have flowed along the west bank of the Great Miami River without mixing completely with the Great Miami River water, and thus allowed migration of river water into the soil of the bank. The extent of uranium contamination that would result from such a scenario is unknown; however, the local groundwater gradient is generally eastward toward the river. Consequently, it can be stated that westward migration of total uranium is likely less than 200 feet.

Geochemistry of Uranium Transport

Uranium that was delivered to the Great Miami Aquifer as infiltrating surface water along Paddys Run and the storm water outfall ditch may be present in a variety of aqueous forms (e.g., UO_2^{+2}, $UO_2(OH)_2^{o}$, $UO_2PO_4^{-}$, $UO_2(CO_3)_2^{-2}$, which are complexes of the uranyl ion with hydroxyl, phosphate, and carbonate ions) or as colloid particles. However, once the infiltrating water mixes with the carbonate-rich groundwater in the Great Miami Aquifer (see analyses in Appendix F), greater

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than 99 percent of the dissolved uranium is predicted to be transported as $UO_2(CO_3)_2^{-2}$ and $UO_2(CO_3)_3^{-4}$. In contrast to the variety of uranium forms in surface water, uranium dripping into the Great Miami Aquifer from the base of the glacial overburden will be present as $UO_2(CO_3)_2^{-2}$ and $UO_2(CO_3)_3^{-4}$ because of the similarity in the bicarbonate concentration of Great Miami Aquifer and perched groundwaters.

4.8.1.1.2 Radionuclides from Uranium Raffinates

Thorium-230 and radium-226 are progenies of uranium-238 and are found as a natural constituent in uranium ores. (Refer to Figure 4-1 for a depiction of the uranium decay chain.) Because large quantities of ore were processed through the site and raffinate was disposed of in the on-site waste units, thorium-230 and radium-226 are potential contaminants in the Great Miami Aquifer. Thorium-230 and radium-226 are considered minor groundwater contaminants because they are detected only in isolated wells (i.e., their pattern of occurrence does not define a plume), and the above-background concentrations are typically elevated only slightly above background.

Based on unfiltered samples from Type 2 wells, thorium-230 was detected at above-background concentrations in only 10 of 158 wells sampled (Table 4-54). Concentrations of thorium-230 ranged to a maximum of 2.5 μg/L, relative to a background concentration of 0.89 μg/L.

Based on unfiltered samples from Type 2 wells, radium-226 was detected at above-background concentrations in only 22 of 158 wells sampled (Table 4-54). Concentrations of radium-226 ranged to a maximum of 14.9 μg/L, relative to a background concentration of 1.5 μg/L.

4.8.1.1.3 Total Thorium and Thorium-232

Analysis for total thorium is a measurement of the quantity of thorium in a sample without distinguishing between thorium's three principal isotopes, thorium-232, thorium-230, and thorium-228. Thorium-232 was processed at the FEMP briefly. The decay progeny of thorium-232 are radium-228 and thorium-228. (Refer to Figure 4-2 for a depiction of the thorium decay chain.) Thorium-230 is unrelated to thorium-232 and thorium-228 because it is a progeny of uranium-238 (Figure 4-1). Thorium-232 is much more prevalent in nature, by weight, than are thorium-230 and thorium-228. Additionally, activities of the three thorium isotopes observed at the site, when converted to weight percent, show that thorium-232 is always the most abundant isotope in total

thorium results. Consequently, measurement of total thorium in samples is largely a measurement of thorium-232.

Figure 4-98 shows the observed distribution of thorium-232 in the Great Miami Aquifer, based on unfiltered samples. Two important points should be stressed regarding the figure: most above-background detections of thorium-232 are found immediately next to a source of infiltration to the Great Miami Aquifer (either the storm sewer outfall ditch or Paddys Run), and several above-background detections are located long distances from the six major FEMP plumes identified in the Great Miami Aquifer. Thorium-232 was detected at above background concentrations in 13 of 185 wells, ranging from 0.3 to 2.7 μg/L, relative to a background concentration of 0.23 (unfiltered statistics from Table 4-54).

There is no mechanism that can easily explain the above-background detections of thorium-232 at distances far removed from known sources; consequently, the above-background detections are thought to represent natural variations in the thorium-232 concentration of groundwater.

Geochemistry of Thorium Transport

Because the principal solid form of thorium (ThO_2) is nearly insoluble in the carbonate-rich neutral pH groundwater of the Great Miami Aquifer, detected levels of thorium are likely the result of the presence of colloid particles and not dissolved thorium. Colloid particles may be delivered to the Great Miami Aquifer were surface water flows over the unsaturated portion of the sand and gravel sediments, but colloids are not commonly transported through unfractured, clay-rich sediments similar to those found in the base of the glacial overburden.

Regardless of the thorium form delivered to the Great Miami Aquifer in the past, its future concentration in the Great Miami Aquifer is limited to a value below that observed today because of emplacement of surface water runoff controls that shut off the colloid source and the very low solubility of ThO_2.

4.8.1.1.4 Radionuclides from Thorium Raffinates

Radium-228 and thorium-228 are progeny of thorium-232 and are found as a natural constituent in thorium materials brought to the site for refining. Thus, radium-228 and thorium-228 are potential contaminants to the Great Miami Aquifer. Radium-228 and thorium-228 are considered minor

groundwater contaminants because they are only detected in isolated wells (i.e., their pattern of occurrence does not define a plume), and the above-background concentrations are typically only slightly elevated above background.

Based on unfiltered samples from Type 2 wells, thorium-228 was detected at above-background concentrations in only 18 of 158 wells sampled (Table 4-54). Concentrations of thorium-228 ranged to a maximum of 1.97 μg/L, relative to a background concentration of 0.77 μg/L.

Based on unfiltered samples from Type 2 wells, radium-228 was detected at above-background concentrations in only 8 of 158 wells sampled (Table 4-54). Concentrations of radium-226 ranged to a maximum of 5.3 μg/L, relative to a background concentration of 3.6 μg/L.

4.8.1.1.5 Activation and Fission Product from Returned Uranium Fuels

Fission products and activation products are isotopes that are created in controlled nuclear reactors (activation products: neptunium-237, plutonium-239/240, and plutonium-238; fission products: strontium-90, technetium-99, ruthenium-106, and cesium-137). They can be found in minor quantities in uranium fuel rods that have been used as reactor fuel. Fission products and activation products entered the FEMP as constituents in uranium fuel rods returned to the FEMP for recovery and recycling of uranium. All fission and activation products are considered minor groundwater contaminants because they are generally detected only in isolated wells (i.e., their pattern of occurrence does not define a plume), and the above-background concentrations are typically only slightly elevated above background. Technetium-99 is an exception--it is detected in multiple adjacent wells in the waste storage area A plume (i.e., it can be defined as a plume).

Table 4-54 lists summary statistics for the fission and activation products tested for in Type 2 wells. The most important information to gain from the table is that the frequencies of detection are low, as are the reported values. Note that ruthenium-107 was not detected at all, and the highest frequency of detection is that for technetium-99, which was detected in 12 of 140 wells tested (unfiltered samples).

Though technetium-99 can be defined as a plume on the basis of analytical results, it is important to note that the volume of technetium released is very minimal. For instance, the maximum detected activity of technetium-99 (34.3 pCi/L) corresponds to a weight concentration of 0.0022 μg/L (i.e., 2.2 parts-per-trillion).

4.8.1.2 Inorganic Contamination

The descriptions of soil and perched groundwater contamination illustrated that inorganic parameters are significant contaminants in the glacial overburden and waste storage units. Consequently, some degree of inorganic contamination is expected in the Great Miami Aquifer. FEMP groundwater investigations typically tested for a suite of 26 inorganic parameters. The following is a summary of the encyclopedic descriptions for 26 inorganic parameters presented in Appendix E.2.2. Table 4-54 summarizes the occurrence of inorganic parameters in FEMP Type 2 wells through statistics. The reader must be aware that the summary statistics include data from wells completed in the PRRS plumes.

Fourteen inorganics were present at above-background concentrations, but they were not found with trends indicative of plumes or widespread contamination; that is, the potential volume released to the environment is minimal, or potential releases to the environment have not been solubilized and transported a sufficient distance from a source to result in plume dimensions that can be resolved with the distribution of monitor wells at the FEMP. The 14 inorganics are potentially attributable to FEMP site activities: aluminum, antimony, copper, cyanide, lead, manganese, molybdenum, nickel, selenium, silicon, silver, thallium, vanadium, and zinc. Table 4-54 summarizes the analytical results for inorganics as they occur in Type 2 wells. Detection of these constituents at above-background concentrations are minimal. Many above-background occurrences may represent detection of naturally occurring concentrations.

Characteristic patterns of contamination that are attributable to FEMP site activities were observed for the following eight metals: cadmium, calcium, chromium, cobalt, iron, magnesium, potassium, and sodium. Typical of these patterns are increased concentrations in the vicinity of waste sources and detection of above-background concentrations in multiple adjacent wells; that is, the data and contours imply the presence of plumes. Of the 8 metals, only cadmium, cobalt, and chromium are potentially significant contributors to risk calculations presented in Section 6.0.

Cadmium and cobalt were detected at above-background concentrations only in the Plant 6 plume. The lateral extent of the identified plumes is small, localized beneath the Plant 6 source, and limited to the confines of the total uranium component of the Plant 6 plume. On the basis of unfiltered samples from Type 2 wells in the Plant 6 plume, cadmium was detected at a maximum concentration of 0.0459 mg/L, relative to a background concentration of 0.0135 mg/L. On the basis of unfiltered

samples from Type 2 wells, cobalt was detected at a maximum concentration of 0.0114 mg/L, relative to a background concentration of 0.0086 mg/L.

Chromium was detected in patterns indicative of a plume only within South Plume A. The lateral extent of the identified plumes is small, localized immediately downgradient of the Operable Unit 2 source, and limited to the confines of the total uranium component of South Plume A. On the basis of unfiltered samples from Type 2 wells in the South Plume A, chromium was detected at a maximum concentration of 0.0436 mg/L, relative to a background concentration of 0.0211 mg/L.

Inorganic Data Collected from the Vicinity of the PRRS

The RI report for the PRRS (ERM 1992) identified a defined list of inorganic groundwater contaminants as being attributable to the PRRS; however, this RI investigation for the FEMP identified a different list of potential PRRS contaminants. The RI investigation for the FEMP independently sampled FEMP and PRRS monitor wells, and therefore uses a data set that is different from the data set used by the PRRS to write its RI (ERM 1992). Additionally, the FEMP and PRRS RI investigations have each used independent background values to determine the presence or absence of contamination. For instance, the RI investigation for Operable Unit 5, based on the 1993 data set, did not identify above-background concentrations of aluminum within the PRRS plume, despite the fact that aluminum is identified as a contaminant of the PRRS in the PRRS RI report (ERM 1992). Reviews of groundwater isoconcentration maps (Appendix E.2) identified above-background concentrations of the following parameters in the vicinity of the PRRS that are potentially attributable to the PRRS: arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, selenium, silicon, silver, sodium, thallium, vanadium, and zinc.

4.8.1.3 Organic Contamination

Volatile Organic Compounds

The summary of VOCs in Appendix E.2 described the extent of VOC contamination in the Great Miami Aquifer. That discussion is summarized here. Detections of VOCs were noted in each of the six FEMP plumes; however, the detections of individual VOCs were in every case isolated and of low concentration. VOCs were noted at their highest concentrations beneath and downgradient of the PRRS. The PRRS has extensive organic contamination in groundwater that is attributable only to the PRRS (ERM, 1992).

The extent of VOC contamination in the waste storage area A plume is a good example of the minimal VOC contamination present in FEMP plumes. Based on Type 2 wells in the waste storage area A plume, nine individual VOCs were detected. No individual VOC was detected in more than one well. The nine VOCs and their observed concentrations were 1,1,1-trichloroethane (10 μg/L), 1,1-dichloroethane (5 μg/L), 1,2-dichloroethene (5 μg/L), 2-butanone (34 μg/L), acetone (2 μg/L), chloroform (1 μg/L), toluene (0.8 μg/L), trichloroethene (120 μg/L), and trichlorofluoromethane (66 μg/L). Note that the VOC with the highest concentration was trichloroethene, which is a solvent/degreaser that was one of the most frequently detected VOCs within perched groundwater.

Semivolatile Organic Compounds

Detections of semivolatile organic compounds (SVOCs) were noted in each of the six FEMP plumes; however, the detections of individual SVOCs were in every case isolated and of low concentration. The only semivolatiles detected in the Great Miami Aquifer were phthalates and phenols. Phthalates are common laboratory and/or sampling contaminants, and most detections of phthalates are attributed to sample cross-contamination. Phenols were detected in the waste storage area A plume only, where the maximum detected concentration was 50 μg/L.

Other Organics

Pesticides were detected in three wells in the waste storage area A plume and in one well in South Plume B. All detections of pesticides were in isolated wells, and detectable concentrations were low. Pesticides detected in the waste storage area A plume were endosulfan-II (0,15 μg/L), endosulfan sulfate (2.6 μg/L), and heptachlor (0.07 μg/L). Pesticides detected in South Plume A were dieldrin (0.016 μg/L) and endosulfan-I (0.025 μg/L).

Isolated detections of dioxins and furans were detected in two isolated wells in the waste storage area A plume and one well in South Plume C. Constituents detected in the waste storage area A plume were hexachlorodibenzofurans (0.38 ng/L), octachlorodibenzo-p-dioxins (0.7 ng/L), pentachlorodibenzofurans (0.31 ng/L), and tetrachlorodibenzofurans (0.22 ng/L). Constituents detected in South Plume C were 2,3,7,8-tetrachlorodibenzo-p-dioxin (1.7 ng/L) and 2,3,7,8-tetrachlorodibenzofuran (1.2 ng/L). The constituents detected in South Plume C were detected in well 2094, located in a farm field. The positive detections are not attributed to site activities.

Herbicides and organophosphorus pesticides were not detected in groundwater samples collected from FEMP Type 2, 3, and 4 wells.

4.8.1.4 General Water Quality Parameters in the Great Miami Aquifer

General water-quality parameters are typically not important contributors to risk calculations presented in Section 6.0; however, water quality parameters are indicators of areas of affected groundwater. Appendix E.2 contains detailed discussions of individual parameters, which show that site activities have adversely affected the Great Miami aquifer in the form of plumes of ammonia, chloride, nitrate, sulfate, and TOC. Isolated, above-background detections were observed for alkalinity, fluoride, pH, total phenols, phosphorus, specific conductivity, TOX, TON, and TKN. Next to uranium, sulfate and nitrate form the most arealy extensive FEMP contaminant plumes in the Great Miami Aquifer.

Figure 4-109 is an isoconcentration map that portrays the extent of nitrate contamination in the Great Miami Aquifer, based on groundwater samples from Type 2 wells. The map indicates that above-background concentrations of nitrate are pervasive beneath the waste pits, such that the data define a plume. Note that above-background concentrations are present in isolated wells adjacent to sources of infiltration to the aquifer, such as Paddys Run and the SSOD. The occurrence of above-background concentrations indicates that the Waste Pits have been the major source of nitrate to the Great Miami Aquifer, and infiltration of nitrate along the loosing stretches of Paddys Run and the SSOD has resulted in only isolated, above-background concentrations in the Great Miami Aquifer.

Figure 4-110 is an isoconcentration map that portrays the extent of sulfate contamination in the Great Miami Aquifer, based on groundwater samples from Type 2 wells. The map indicates that above-background concentrations of sulfate are pervasive beneath the waste pits and the south portion of the production area, such that the data in each area define the plumes. The sulfate plume beneath the waste storage area is attributed to leaks of leachate from the waste pits. The sulfate plume beneath the production area has its highest concentration beneath the Plant 6 area, suggesting that the source of contamination is the same as the uranium, which defines the Plant 6 plume. However, the sulfate plume beneath the production area extends upgradient (west) from the Plant 6 source. The westward extension of the sulfate plume is anomalous relative to all other parameters that occur above-background in the Plant 6 Plume, suggesting that there may be a source of sulfate in the Plant 2/3 area. No other parameters show concentration trends that would indicate the Plant 2/3 area as a source of contamination to the Great Miami Aquifer.

4.8.2 Descriptions of Individual Plumes in the Great Miami Aquifer

Section 4.8.1 discussed total uranium and other individual constituents, and illustrated how the majority of contamination entered the Great Miami Aquifer from six sources. This section does not focus on specific constituents; rather, it focuses on describing the particular sets of above-background constituents that are characteristic of each of the six plumes in the Great Miami Aquifer. Particular attention is focused on data from Type 2 wells because data from Type 2 wells best depict the extent of contamination. Data from the Type 3 and Type 4 levels of the aquifer are sparsely spaced relative to that from Type 2 wells. And the maximum concentrations of contaminants are in most every case observed in Type 2 wells.

The following discussions of individual plumes are summarized in Table 4-55. The table lists major FEMP parameters and categorizes their occurrence in each FEMP plume. Each parameter is categorized with respect to its presence in Type 2 wells as to whether it occurs in a characteristic pattern of contamination, or whether it occurs as above-background detections in isolated wells. If a parameter occurs as a plume, it has been released to the aquifer in sufficient quantity to result in a plume, and it is sufficiently mobile to be transported and dispersed to form a detectable plume.

If a parameter occurs only as above-background detections in isolated wells, then it may have been released in such small quantity that advection and dispersion, attendant with groundwater transport through the aquifer, have resulted in dilution to such a degree that contamination can no longer be detected at points downgradient from the release. Alternatively, if a constituent has a low solubility in groundwater and a high tendency to adsorb to soil, then releases of contaminant to groundwater may not result in a dissolved plume of detectable concentrations. In the latter case, transport of an appreciable volume of dissolved contamination cannot occur because of solubility limit constraints. Table 4-55 presents, for each parameter, the predicted solubility and the predicted tendency to adsorb to soil. An explanation of how to use the solubility and absorption rankings is provided in the chemical speciation discussion of Section 4.8.1.

It is important to note that the occurrence of above-background detections in isolated wells is not always indicative of actual contamination of groundwater by site activities. Many isolated, above-background detections do in fact indicate release to groundwater; however, many of the isolated, above-background detections probably represent natural variations of groundwater concentrations above the background reference value.

Waste Storage Area A Plume

The contaminants in the waste storage area A plume likely entered the Great Miami Aquifer as leachate that leaked from the Operable Unit 1 waste pits. The Operable Unit 1 RI report (DOE 1994g) documented that observed contamination in the Great Miami Aquifer below and downgradient of the waste pits area is a result of releases from the waste pits, but the report did not determine specifically which pits leak to the Great Miami Aquifer, nor did it document the extent of contamination in the Great Miami Aquifer resulting from releases from the waste pits.

The extent of total uranium and sulfate contamination effectively describes the maximum extent of above-background constituents in the waste storage area A plume (Figures 4-93, 4-95, and 4-100). Groundwater flows east from the waste storage area, and the sulfate component of the waste storage area A plume extends up to 1600 feet downgradient of the source area (Figure 4-110). Note that the extent of sulfate contamination extends approximately 800 feet further downgradient than the maximum extent of uranium contamination represented by the 5 μg/L isoconcentration contour. The greater extent of sulfate is due to its relatively greater mobility in groundwater (higher solubility and lower tendency to adsorb to soil).

Elevated concentrations of nonuranium constituents are generally limited to the confines of the total uranium plume shown in Figure 4-93. Table 4-56 contains a graphical representation of the maximum concentrations observed for each parameter in the waste storage area A plume. Table 4-57 summarizes the occurrence of each parameter in Type 2 wells in terms of frequency of detection in wells, frequency of detection above background, and range of detectable results. Characteristic patterns of contamination are observed for uranium, technetium-99, calcium, iron, magnesium, potassium, sodium, total VOCs, ammonia, chloride, nitrate, and sulfate. Table 4-55 lists 25 parameters that occur as above-background detections in isolated wells only.

Waste Storage Area B Plume

The contaminants in the waste storage area B plume entered the Great Miami Aquifer as surface water in Paddys Run, which infiltrated into the Great Miami Aquifer. The source of contaminated surface water to Paddys Run is surface water runoff from north of the production area, contaminated surface soils in the waste storage area, Operable Unit 1, Operable Unit 4, and the pilot plant drainage ditch. The extent of total uranium contamination in the waste storage area B plume is portrayed on

Figure 4-93. Groundwater flows east from the source of infiltration at Paddys Run, and the waste storage area B plume extends up to 1000 feet downgradient of the source area (Figure 4-93).

Elevated concentrations of non-uranium constituents are generally limited to the confines of the total uranium plume shown in Figure 4-93. Table 4-58 summarizes the occurrence of each parameter in Type 2 wells in terms of frequency of detection in wells, frequency of detection above background, and range of detectable results. Characteristic patterns of contamination are observed for uranium and calcium only. Table 4-55 lists 24 parameters that occur as only above-background detections in isolated wells. Table 4-56 contains a graphical representation of the maximum concentrations observed for each parameter in the waste storage area B plume.

Plant 6 Plume

The contaminants in the Plant 6 plume are believed to have entered the Great Miami Aquifer at two locations where the glacial overburden is thin or absent: the west basement of Plant 6 and the sewage lift station. Each of these structures was emplaced deeply in the glacial overburden such that there is little to no barrier of glacial overburden between the structures and the Great Miami Aquifer. At each of these structures, contaminated fluids can potentially leak from the structure to the Great Miami Aquifer. Disturbed backfill against the structures is a potential route for relatively rapid migration of shallow contaminated perched groundwater to the Great Miami Aquifer. The extent of total uranium and sulfate contamination effectively describes the maximum extent of the Plant 6 plume (Figures 4-93, 4-95, and 4-100). Groundwater flows east from the source area, and the Plant 6 sulfate plume extends up to 1600 feet downgradient of the source area (Figure 4-100). Note that the sulfate plume extends upgradient (westward) from Plant 6. This westward lobe of the plume is potential evidence that sulfate may have migrated through the glacial overburden from the Plant 2/3 area. Corresponding plumes of other contaminants are not observed beneath Plant 2/3 that would infer significant release of other contaminants from the Plant 2/3 area glacial overburden to the Great Miami Aquifer.

Elevated concentrations of nonuranium constituents are generally limited to the confines of the total uranium plume shown in Figure 4-93. Table 4-59 summarizes the occurrence of each parameter in Type 2 wells in terms of frequency of detection in wells, frequency of detection above background, and range of detectable results. Characteristic patterns of contamination are observed for uranium, cadmium, calcium, cobalt, and sulfate. Uranium, cadmium, and cobalt are potentially significant

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contributors to risk assessment calculations presented in Section 6.0. Whereas the uranium plume has a lateral extent up to 1200 feet downgradient of the Plant 6 source, the cadmium and cobalt plumes are limited in lateral extent to no more than 500 hundred feet across. The cadmium and cobalt plumes are limited in extent to the most concentrated portions of the uranium plume. Table 4-55 lists 14 parameters that occur as above-background detections in isolated wells only based on sampling of the waste storage area B Plume wells. Table 4-56 contains a graphical representation of the maximum concentrations observed for each parameter in the Plant 6 plume.

South Plume A

South Plume A originates as infiltration that occurs where the glacial overburden is thin or absent adjacent to and beneath the Operable Unit 2 waste units. The RI report for Operable Unit 2 (DOE 1994h) concluded that the Inactive Flyash Pile, South Field, and Active Flyash Pile are all sources of contamination in the Great Miami Aquifer. Each of these waste units is constructed such that it lies partially upon the glacial overburden and partially on sand and gravel of the Great Miami Aquifer. Contaminant releases probably occur as leachate releases from the bottom of the waste units directly to the aquifer and as surface water flow from the waste units onto Paddys Run alluvium or Great Miami Aquifer sediments where infiltration into the aquifer may occur. Groundwater flows east from the source area, and South Plume A extends eastward to a point where it is commingled with South Plume B.

Elevated concentrations of nonuranium constituents are generally limited to the confines of the total uranium plume shown in Figure 4-93. Table 4-60 summarizes the occurrence of each parameter in Type 2 wells in terms of frequency of detection in wells, frequency of detection above background, and range of detectable results. Characteristic patterns of contamination are observed for uranium, calcium, chromium, magnesium, and potassium. Table 4-55 lists 17 parameters that occur as above-background detections in isolated wells only, based on sampling of South Plume A wells. Table 4-56 contains a graphical representation of the maximum concentrations observed for each parameter in South Plume A.

South Plume B

The contaminants in South Plume B entered the Great Miami Aquifer as surface water in the SSOD (SSOD) and Paddys Run, which infiltrated into the Great Miami Aquifer. The source of contaminated surface water is storm water runoff from the production area. Prior to 1986,

stormwater runoff was not controlled and was free to flow down the SSOD and Paddys Run. Discharge of stormwater runoff from the production area has been controlled since 1986, when the first of two stormwater retention basins was constructed. The extent of total uranium contamination in South Plume B is portrayed on Figure 4-93. All other parameters which occur above-background and are attributable to the FEMP site activities generally have extends which fall within the confines of the total uranium plume. Groundwater of South Plume B flows eastward in the northern portion of the plume and southward in the southern portion of the plume (Figure 4-95). Consequently, the northern portion of the plume has been transported eastward, whereas the southern portion of the plume has been transported southward.

Figure 4-95 depicts how the southern edge of uranium contamination in South Plume B is commingled with the Paddys Run Road Site (PRRS) plume. The PRRS lies south of and adjacent to the FEMP along Paddys Run Road. The PRRS consists of two facilities, Albright & Wilson Americas, Inc. (A&W), and the Ruetgers-Nease Chemical Company, Inc. (RNCC). A formal RI was initiated at the site by the companies and the Ohio EPA in 1989, and a draft RI was published in September 1992 (ERM, 1992). The A&W company occupies the northern portion of the property and manufactures phosphoric acid and phosphates. The RNCC is located south of the A&W facility at the intersection of Paddys Run Road and New Haven Road and manufactures aromatic sulfonated compounds. The PRRS RI report documented releases to the Great Miami Aquifer of inorganics, VOCs, semivolatile organic compounds, pesticides, and general water chemistry parameters.

Elevated concentrations of nonuranium constituents attributable to the FEMP are generally limited to the confines of the total uranium plume shown in Figure 4-93. Table 4-61 summarizes the occurrence of each parameter in Type 2 wells in terms of frequency of detection in wells, frequency of detection above background, and range of detectable results. Table 4-55 identifies 24 constituents that were detected at above-background concentrations in FEMP sampling of South Plume B, and attributed to the PRRS. Note that some above-background constituents were attributed to both the FEMP and the PRRS. With respect to contamination that is attributable to the FEMP, characteristic patterns of contamination are observed for uranium, calcium, magnesium, and potassium. With respect to contamination that is potentially attributable to the FEMP, Table 4-55 lists 24 parameters that occur only above-background detections in isolated wells only, based on sampling of South Plume B wells. Table 4-56 contains a graphical representation of the maximum concentrations observed for each parameter in South Plume B.

South Plume C

South Plume C originated as contaminated surface water flow of Paddys Run that infiltrated into the Great Miami Aquifer along a losing section of Paddys Run. The outline of uranium contamination on Figure 4-93 defines a plume that appears to have spread laterally away from the source of infiltration along Paddys Run. Regionally, groundwater flows southeastward parallel to Paddys Run. Figure 4-95 depicts how the uranium contamination in South Plume C is commingled with the PRRS plume.

Elevated concentrations of nonuranium constituents attributable to the FEMP are generally limited to the confines of the total uranium plume shown in Figure 4-93. Table 4-62 summarizes the occurrence of each parameter in Type 2 wells in terms of frequency of detection in wells, frequency of detection above background, and range of detectable results. Table 4-55 identifies 11 constituents that were detected at above-background concentrations in FEMP sampling of South Plume C, and attributed to the PRRS. Note that some above-background constituents were attributed to both the FEMP and the PRRS. With respect to contamination that is attributable to the FEMP, characteristic patterns of contamination are observed for uranium only. With respect to contamination that is potentially attributable to the FEMP, Table 4-55 lists 13 parameters that occur as only above-background detections in isolated wells. Table 4-56 contains a graphical representation of the maximum concentrations observed for each parameter in South Plume C.

4.8.3 Summary of the Nature and Extent of Contamination in the Great Miami Aquifer

The above presentation of nature and extent of contamination in the Great Miami Aquifer was prepared using groundwater analytical data from 323 wells. The period of record for Operable Unit 5 sampling activities extends from 1988 to 1994, and the Operable Unit 5 data base compiled for this report consists of more than 2900 groundwater samples collected between 1988 and 1994 (Appendix I). The comprehensive data set was culled, as described in Appendix E.0, to select a set of data confined to one distinct period. The selection process focused on data collected in 1993, because 1993 was the year during which the most wells were sampled in the shortest period. This data set, referred to as the 1993 data set, was used to analyze the extent of contaminant occurrence.

The encyclopedic descriptions of groundwater contamination, presented in Appendix E.2 and summarized in Section 4.8.1, show that uranium is the principal groundwater contaminant and that contamination of virtually every other radionuclide, inorganic, organic, and general chemistry

parameter falls within the extent of uranium contamination as defined by the 5 μg/L contour line of total uranium based on unfiltered samples (Figure 4-93). One general chemistry parameter, sulfate, has a plume (Figure 4-100) which extends further than the maximum extent of uranium contamination defined by the 5 μg/L isoconcentration contour (Figure 4-93).

The majority of contamination observed in the Great Miami Aquifer is attributed to six point or line sources (Figures 4-95 and 4-93). Each source has resulted in a distinct plume:

- The waste storage area A plume which is a result of leaks from the Operable Unit 1 waste pits
- The waste storage area B plume which is a result of surface water infiltration along the northern stretch of Paddys Run
- The Plant 6 plume which is a result of leaks through the glacial overburden where the overburden has been thinned beneath Plant 6 and the sewage lift station
- South Plume A which is a result of leachate and surface water that infiltrates in the vicinity of the Operable Unit 2 Inactive Flyash Pile, Active Flyash Pile and South Field
- South Plume B which is a result of surface water infiltration along the Storm sewer outfall ditch and Paddys Run
- South Plume C which is a result of surface water infiltration along the southern stretch of Paddys Run south of New Haven Road.

Two of the six FEMP plumes, South Plumes A and B, are commingled with contaminant plumes that originate from an independent industrial facility located south of the FEMP, the Paddys Run Road Site (Figure 4-95).

Each plume is distinct in terms of the list of above-background constituents which comprise the plumes. Table 4-55 summarizes the extent of contamination for each parameter in each plume. Tables 457 through 4-62 are statistical summaries that list the major contaminants occurring in each respective plume, whereas Table 4-56 is a visual representation of the maximum contaminant values observed in each plume.

Contamination of the Great Miami Aquifer is largely confined to the uppermost portion of the aquifer. Based on the 5 μg/L total uranium contour identified for Type 2 wells (Figure 4-93), the areal extent of uranium contamination at the top of the Great Miami aquifer is 340 acres. Similarly, the areal

extent of uranium contamination at the Type 3 well depth (Figure 4-96) is 120 acres. Uranium contamination occurs as isolated above-background detections at the bottom of the aquifer, in Type 4 wells (Figure 4-97).

Low levels of uranium contamination exist outside of the six FEMP plumes primarily as a result of deposition of airborne emissions on surface soils both on-property and off-property. The surface soil contamination has (and continues to be) leached by infiltrating rainwater, resulting in slightly elevated uranium concentrations in both perched groundwater (see also Section 4.7.1.1.1) and the uppermost horizon of the Great Miami Aquifer. Figure 4-18 shows the extent of surface soil contamination in the FEMP area. The uppermost portion of the Great Miami Aquifer in this area potentially has elevated concentrations of total uranium resulting from leaching of contaminated surface soil. However, total uranium concentrations are estimated to be less than 10 μg/L (relative to a background concentration of 1.2 μg/L), based on trends seen in the groundwater samples from the existing monitor well network.

Low levels of uranium contamination also exist in groundwater along the west bank of the Great Miami River, south of the confluence of Paddys Run (Figure 4-108). The low levels of uranium contamination in the area were identified through sampling of private wells. The contamination is believed to have resulted from infiltration of Great Miami River water into the bank of the river. The maximum concentration observed in the area was 9.9 μg/L (relative to a background concentration of 1.2 μg/L).

The 1993 data set used to describe nature and extent of contamination shows that there are isolated low-level above-background detections of radionuclides and inorganics outside the maximum extent of uranium contamination as defined by the 5 μg/L contour line for total uranium based on unfiltered samples (Figure 4-93). In most cases there is no strong evidence that the low-level above-background detections are site related, and there is strong possibility that the occurrences are due to natural variation of the constituents in nature, agricultural activities, sample cross contamination, or analytical error. The data are carried forward for consideration in risk assessment calculations, despite the possibility that the low-level above-background detections may not be site related.

The characterization of contaminant nature and extent developed here is used in Section 5.0 to establish baseline conditions for contaminant fate and transport modeling. In Section 6.0, the current

and future conditions are evaluated to determine the human health and environmental risks associated with the affected groundwater of the Great Miami Aquifer. The results of the risk assessment will then be used to develop candidate, risk-based, remediation areas in the FS.

The results for the RI characterization for the Great Miami Aquifer provide sufficient information from which to characterize risk and to determine appropriate response actions in the FS. Both the 1993 data set and the earlier (pre-1993) data will be carried forward to the FS for use in developing candidate remediation areas and assessing performance-based remedial technologies. No further information is needed at this juncture to begin to properly execute the FS process. The potential contamination that is detected outside the bounds of the six major FEMP plumes is not a significant data limitation of the RI. Potentially contaminated areas outside the major plumes may still require additional evaluation and confirmation on a case-by-case basis to determine whether the land areas represented by the isolated detections require remediation. The need for additional evaluation will be dependant on the final remediation goals selected for the Record of Decision (ROD). This however, is a remedy implementation issue that does not require resolution for the FS to proceed.

4.9 BIOTA

4.9.1 Radiological Analyses of Biological Samples

Biological samples from the FEMP site and reference sites were analyzed for radionuclides in 1987 and 1988. Radionuclide concentrations were measured in soil, aquatic and terrestrial vegetation, benthic macroinvertebrates, fish, and small mammals from the FEMP site. Radionuclide concentrations were also determined in soil, field crops, garden produce, benthic macroinvertebrates, and fish from areas outside the boundaries of the FEMP.

4.9.1.1 Garden Produce and Agricultural Crops

4.9.1.1.1 Indiana Control Area

Agricultural crops (alfalfa, corn, and soybeans), garden produce (green peppers, okra, potatoes, tomatoes), and soil samples were obtained from three locations near Brookville, Indiana, and analyzed for concentrations of five radionuclides (cesium-137, strontium-90, uranium-234, uranium-235/236, and uranium-238). Results of these analyses are presented in Table 4-63.

The Brookville area, which is a rural area approximately 20 miles (32 km) northwest of the FEMP, was assumed to be outside the direct influence of airborne and waterborne contamination from the

FEMP site. Any radionuclides found in Brookville samples were assumed to be from natural (geological) sources (the three isotopes of uranium) or atmospheric weapons testing (cesium-137 and strontium-90).

None of the crop and vegetable samples from the Indiana control area had detectable concentrations of cesium-137, and only two samples (alfalfa and soybean hulls) had detectable concentrations of strontium-90.

Soil samples from the Indiana control area contained detectable concentrations of cesium-137 (0.3 pCi/g), strontium-90 (1.2 pCi/g), uranium-234 (2.4 pCi/g), and uranium-238 (3.2 pCi/g). Detectable concentrations of the three uranium isotopes were found in alfalfa (uranium-234, uranium-235/236, and uranium-238), potato peels (uranium-234 only), soybean hulls (uranium-234 only), and tomatoes (uranium-234 and uranium-238).

4.9.1.1.2 FEMP and Vicinity

Results of soil, crop, and vegetable analyses from Sampling Sites G2, G3, G4, and G5 (all northeast of FEMP) are presented in Table 4-63. Radionuclide concentrations in soil from this area, which (depending on the garden or field sampled) is approximately 1.0 to 1.3 miles from the FEMP, were lower than those from the Indiana control area. Three of the five radionuclides were found in higher concentrations in soil at the Indiana sampling locations. Radionuclide concentrations in crops and produce from the two areas appear to be essentially the same. However, in the absence of more intensive studies and larger sample sizes, it is impossible to determine whether the apparent difference in soil radionuclide concentrations between the Indiana locations and Sampling Sites G2-G5 is statistically significant, or whether the apparent similarities in radionuclide concentrations in crops and vegetables from the two areas are real.

Concentrations of radionuclides in soil from Sampling Site G6, which is approximately 0.7 mile southeast of FEMP, were higher than those of the Indiana control area in two of five analyses (strontium-90 and uranium-234) and essentially the same in cesium-137 and uranium-235/236. Radionuclide levels in garden produce from this site were low, below detection limits in all cases except for pumpkins (1.5 pCi/g of uranium-234 and 0.8 pCi/g of uranium-238) and tomatoes (1.9 pCi/g of uranium-234 and 0.7 pCi/g of uranium-238).

Soil concentrations of radionuclides from Sampling Site G1, approximately 0.6 mile (1.0 km) northwest of FEMP, were detectable in three instances—cesium-137, uranium-234, and uranium-238—but were consistently lower than those observed at the Indiana control area. Garden produce from this site contained levels of radionuclides below detection limits in most cases (green pepper, okra, squash), but cucumber from this location contained the highest concentrations of cesium-137 (1.1 pCi/g), uranium-234 (3.0 pCi/g), and uranium-238 (1.8 pCi/g) observed in produce from any sample location. The reason for the relatively high concentrations of radionuclides in cucumber is unknown, but it should be noted that these measurements are from a single sample that may or may not be representative of the larger "population" of cucumber in the area.

4.9.1.2 Vegetation

Results of analyses of vegetation from a number of locations within Operable Unit 5, the relatively undeveloped area that surrounds the source operable units (Units 1-4), are presented in Table 4-64.

Forb leaves from Study Area A (see Figure B.1-1 in Appendix B), an area of mixed woodland and wetland in the northwest corner of FEMP, contained detectable concentrations of uranium-234 (2.5 pCi/g) and uranium-238 (2.4 pCi/g), but did not contain detectable concentrations of uranium-235/236 (Table 4-64). Forb roots from the same site contained detectable, but slightly lower, concentrations of uranium-234 (1.9 pCi/g) and uranium-238 (1.0 pCi/g), and did not contain detectable concentrations of uranium-235/236. Grass leaves from this study area also contained detectable concentrations of uranium-234 (3.2 pCi/g) and uranium-238 (0.9 pCi/g), as did grass roots (2.2 pCi/g of uranium-234 and 2.0 pCi/g of uranium-238).

Leaves and roots of forbs and grasses from Study Area B, an area north-northeast of the former FEMP production area that is predominantly planted pines, had higher concentrations of uranium-234 (2.5 pCi/g forb leaves and 3.4 pCi/g forb roots; 4.0 pCi/g grass leaves and 10.7 pCi/g grass roots) and uranium-238 (1.4 pCi/g forb leaves and 5.0 pCi/g forb roots; 1.7 pCi/g grass leaves and 6.6 pCi/g grass roots) than forbs and grasses from Study Area A (see Table 4-64). Cattail samples from a wetland in Study Area B contained radionuclide concentrations below detection limits in all cases but uranium-238, which measured 0.8 pCi/g in cattail leaves. Sedge leaves and roots from this site contained no detectable levels of any of the five radionuclides of concern.

Forbs and grasses from Study Area C, a grassland directly east of the former production area, had detectable levels of all five radionuclides (Table 4-64), with the highest reported for uranium-234 (13.7 pCi/g in forb roots) and the second highest reported for uranium-238 (14.3 pCi/g in forb roots). Uranium-234 and uranium-238 concentrations were high in all samples from Study Area C.

A grass sample from Study Area E, the grassland south of the former production area, contained a low, but detectable, concentration of cesium-137 (0.6 pCi/g in roots), but contained no detectable concentrations of strontium-90 or the three uranium isotopes in leaves or roots.

A soil sample from Study Area F, the riparian corridor of Paddys Run, contained above-background concentrations of uranium-234 (3.9 pCi/g) and uranium-238 (12.4 pCi/g). Given these concentrations, it is not surprising that detectable concentrations of the same two uranium isotopes were found in onion leaves, cattail leaves and roots, forb leaves and roots, and grass leaves and roots from the same area (Table 4-64). The highest concentrations of these two uranium isotopes at this location were found in grass roots, which contained 7.7 pCi/g of uranium-234 and 22.3 pCi/g of uranium-238 (the highest reported concentration from all vegetation samples).

Forb leaves and forb roots from Study Area G, a pine plantation south of the main waste storage area, contained detectable concentrations of uranium-234 (3.1 pCi/g and 10.4 pCi/g, respectively) and uranium-238 (3.3 pCi/g and 12 pCi/g, respectively). Grass roots showed relatively high levels of uranium-234 (8.4 pCi/g) and uranium-238 (9.5 pCi/g), but grass shoots and stems had markedly lower concentrations of both uranium-234 (0.8 pCi/g) and uranium-238 (below detection limits). The results of these analyses were incorporated, where applicable, into models used to predict total radiological dose received by terrestrial ecological receptors (see Appendix B).

4.9.1.3 Mammals

Results of radionuclide bioassays of small mammals from Study Areas A, B, E, and F (all parts of Operable Unit 5) are presented in Table 4-65.

Muscle and skeletal tissue, as well as viscera, from all small mammals collected from Study Areas A and E were composited to form a single sample.

Analysis of muscle and skeletal tissues indicated that radionuclides were not present in concentrations above detection limits. A sample of viscera from the same animal had detectable concentrations of the three uranium isotopes: 8.3 pCi/g of uranium-234; 1.1 pCi/g of uranium-235/236; and 9.6 pCi/g of uranium-238.

An opossum from Study Area B was dissected, and samples of muscle tissue and internal organs were analyzed separately for the presence of radionuclides. None of the five radionuclides of concern were present in a detectable concentration. A cottontail rabbit carcass and a small mammal composite sample from Study Area E were also analyzed for radionuclides. None of the radionuclides were present in a detectable concentration in either animal. A sample of opossum muscle tissue from Study Area F also contained no detectable radionuclide concentrations.

4.9.1.4 Benthic Macroinvertebrates

Benthic macroinvertebrates were collected from Paddys Run (Study Area F) and two locations in the Great Miami River and analyzed for radionuclides. Results of these analyses are presented in Tables 4-65 and 4-66.

4.9.1.4.1 Paddys Run

Two composite benthic macroinvertebrate samples and a crayfish sample from Study Area F (Paddys Run, adjacent to and downstream of the main waste storage area) contained detectable concentrations of uranium-234 and uranium-238. The uranium-234 concentration was 3.6 pCi/g for the benthic macroinvertebrate samples and 3.5 pCi/g for crayfish from this section of Paddys Run. The uranium-238 concentration was 2.8 pCi/g in benthic macroinvertebrates and 0.9 pCi/g in crayfish.

4.9.1.4.2 Great Miami River

A composite sample of benthic macroinvertebrates from a portion of the Great Miami River southeast and downstream of the FEMP (at the confluence of Paddys Run and the Great Miami River) contained detectable concentrations of three uranium isotopes, but cesium-137 and strontium-90 concentrations were below the limit of detection (Table 4-65).

A composite benthic macroinvertebrate sample from the Great Miami River southwest and downstream of the FEMP (approximately 7 miles downriver from the FEMP) did not have detectable concentrations of cesium-137 and strontium-90. Although analyses for the three isotopes of uranium

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were performed, the results of these analyses were rejected during data validation. A crayfish sample from the same portion of the Great Miami River had a uranium-234 concentration of 1.5 pCi/g. The other radionuclides were not detectable.

The results of these analyses were incorporated, where applicable, into models used to predict total dose received by aquatic receptors (see Appendix B).

4.9.1.5 Fish

Results of radionuclide analyses of fish from Paddys Run and the Great Miami River are presented in Tables 4-65 and 4-66.

4.9.1.5.1 Paddys Run

Whole-body samples of creek chub and sucker (presumably the white sucker, *Catostomus commersoni*) from Study Area A (Paddys Run, upstream of FEMP) had no detectable concentrations of radionuclides (Table 4-65). Whole-body samples of bluegill had no detectable concentrations of cesium-137, strontium-90, or uranium-235/236, but had detectable concentrations of uranium-234 and uranium-238 (0.7 and 1.00 pCi/g, respectively). Because sample sizes were small and ages of fish were unknown, no attempt was made to draw inferences about differential rates of radionuclide uptake and assimilation in these fish or the relative vulnerability of these species with respect to radionuclides.

Whole-body samples of sucker, bluegill, and an unidentified species of fish from Study Area F (Paddys Run, adjacent to or downstream of the main waste storage area of FEMP) were below detection limits for all five radionuclides, but creek chub contained low, but detectable, concentrations of uranium-234 and uranium-238 (1.0 and 0.7 pCi/g, respectively). Because sample sizes were small, it would be unwise to ascribe small differences in radionuclide body burdens to species-specific differences in food habits, habitat preferences, or differential rates of metabolism/assimilation of radionuclides.

4.9.1.5.2 Great Miami River

No detectable concentrations of radionuclides were found in samples of shad (presumably gizzard shad, *Dorosoma cepedianum*), channel catfish, or composited fish from the Great Miami River northeast and upstream of the FEMP (Table 4-66). Channel catfish muscle tissue (fillets) from fish

from the same section of the Great Miami River showed low, but detectable (0.35 pCi/g) concentrations of cesium-137, but did not contain detectable levels of the other four radionuclides of concern. Sample sizes were too small to permit statistical comparisons, so it is unknown whether the slightly elevated concentration of cesium-137 in channel catfish muscle tissue is significant.

No detectable concentrations of radionuclides were found in whole-body samples of bass freshwater drum, shad, or composited fish from the Great Miami River southeast of FEMP (Table 4-66).

No detectable concentrations of radionuclides were found in samples of creek chub, shad, green sunfish, or longear sunfish from a section of the Great Miami River southwest and downstream of the FEMP. Bluegill from the same section of the river contained detectable concentrations of uranium-234 (2.4 pCi/g), uranium-235/236 (0.55 pCi/g), and uranium-238 (1.3 pCi/g). The sucker sample had 0.6 pCi/g of uranium-234.

4.9.2 Hazardous Substance List (HSL) Analyses of Biological Samples

Grass leaves and roots from four study areas (A, C, E, and F) were analyzed for the presence of metals and organic pollutants. A rabbit and a small mammal from Study Area E and a composite minnow sample from Study Area F were analyzed for the same contaminants. Results of these analyses are presented in Table 4-67.

4.9.2.1 Organic Contaminants

The results of the analyses for volatile or semivolatile organic compounds and two polycyclic aromatic hydrocarbons on grass and roots in Study Area C are also presented in Table 4-67. The sewage treatment plant is located in this study area.

4.9.2.2 Metals/Inorganic Contaminants

Aluminum concentrations in grass varied widely, ranging from 25 mg/kg in leaves at Study Area F to 10,600 mg/kg in roots at Study Area A. Aluminum concentrations in animals were typically lower, ranging from 4 mg/kg (a rabbit carcass from Study Area E) to 42 mg/kg (a small mammal from Study Area E).

Arsenic concentrations in grass roots ranged from below detection limit (Study Area F) to 11 mg/kg (Study Area G). Arsenic concentrations in grass leaves were essentially the same, ranging from 7.0

to 13.0 mg/kg at the four study areas. Arsenic concentrations in the animals ranged from 6 mg/kg in the minnow composite to 13 mg/kg in the small mammal composite.

Barium concentrations were consistently higher in grass roots (17.5 to 59.8 mg/kg) than in grass leaves (2.8 to 12.5 mg/kg). Barium concentrations in animals were lower, ranging from 0.2 mg/kg (a rabbit from Study Area E) to 1.0 mg/kg (a small mammal from Study Area E and minnows from Study Area F).

Cadmium concentrations were below detection limits or low in most instances, with only one sample exceeding 1.0 mg/kg. The highest concentration of cadmium in vegetation was observed at Study Area C, where samples of grass roots contained 0.9 mg/kg of cadmium. A concentration of 4.2 mgCd/kg was measured in the minnow sample collected from Study Area F. Lead levels were low in all samples from all sites except one, grass roots from Study Area C, which contained 12 mg/kg of lead. Silver levels were also low at all sites. Vanadium showed a similar trend, with the highest concentration occurring in grass roots from Study Area C. The highest concentration of zinc was also found in grass roots from Study Area C, but the between-station differences were not as pronounced as they were with a number of other metals.

Fluoride concentrations ranged from 210 to 720 mg/kg in grass leaves, and below detection limit (<50 mg/kg) to 620 mg/kg in grass roots. Fluoride concentrations in animal samples were generally higher, ranging from 540 mg/kg (rabbit carcass from Study Area A) to 1400 mg/kg (minnow sample from Study Area F).

Sulfates were present in measurable quantities in all vegetation and animal samples from Study Areas A, C, E, F, and G. Sulfate concentrations ranged from 320 to 2400 mg/kg in leaves of grass and 67 to 1300 mg/kg in grass roots. Sulfate concentrations in animal tissue were found in roughly the same range, from 160 to 1700 mg/kg.

4.10 ASSESSMENT OF HAZARDOUS WASTE MANAGEMENT UNIT (HWMU) CONTRIBUTIONS TO SOIL AND PERCHED GROUNDWATER CONTAMINATION

There are 53 RCRA-regulated hazardous waste management units (HWMUs) at the FEMP, 22 of which are proposed to be addressed as part of an integrated RCRA/CERCLA closure process.

As part of the FEMP's negotiated RCRA/CERCLA integration strategy with Ohio EPA, the RI for Operable Unit 5 is expected to report the locations of the RCRA-regulated HWMUs to be closed under CERCLA; identify the RCRA constituents managed in the units; and provide information on the nature and extent of contamination in the environmental media affected at the site. Section 1.0 provides an overview of the waste management characteristics of the 22 HWMUs that are to be addressed through the FEMP's RCRA/CERCLA closure process, including a listing of the hazardous wastes that were managed in the units. Section 4.6 provides an overview of the nature and extent of soil contamination, while more detailed discussions by area and by parameter are included in Appendix D. Section 4.7 provides a similar overview of the nature and extent of perched groundwater contamination, while detailed discussions by parameter are included in Appendix E.

The locations of the 22 HWMUs to be addressed under the RCRA/CERCLA closure process and their proximity to areas of total uranium contamination in surface soil and to the seven perched groundwater areas of contamination are displayed in Figure 4-112. As is shown in this figure, all 22 units are located within areas of elevated surface soil contamination, defined by the 20 mg/kg isoconcentration contour for total uranium. As presented in Section 4.6, the majority of other contaminants in soil are within the uranium envelope defined by the 20 mg/kg total uranium contour (see 4.6.1). Thus remediation of soil will likely be driven by uranium concentrations and therefore will likely include the soil under each of the HWMUs with known media contamination.

Of the 22 HWMUs, 21 units directly overlie one of the seven perched groundwater plumes identified through the Operable Unit 5 RI. The exception is the biodentrification surge lagoon, which is partially underlain by the 5 ppb total (unfiltered) uranium contour.

Sixteen of the twenty-one HWMUs that overlie perched groundwater plumes are located in the production area, which is completely surrounded by the 20 mg/kg surface soil total uranium contour and overlies the broad Area I plume. The majority of these units are found in the southwest quadrant of the production area in the Plant 2/3 and Plant 8 areas where soil and perched groundwater are contaminated with numerous chemical and radiological constituents. Three of the twenty-one units (Waste Pit 4, Waste Pit 5, and the experimental treatment facility) overlie the Area V plume originating in the Operable Unit 1 waste pit area. One unit (the fire training facility) overlies the Area VI plume in the fire training area, and the remaining unit (the sludge drying beds) overlies the Area II plume in the sewage treatment plant area.

Tables 4-68 and 4-69 summarize the RCRA waste types that were managed in the 22 HWMUs and denotes whether constituents derived from the wastes were detected in the respective underlying perched groundwater plumes. As this table indicates, for all cases other than the biodentrification surge lagoon, the constituents that were the basis for the individual HWMU listings were found in the underlying perched groundwater. In general, however, these same constituents were detected throughout the broadly contaminated areas, indicating their presence can be attributed to releases from a variety of sources, of which the individual HWMUs are just one possible subset. The exception is the fire training area HWMU, which is the primary contributor to the fire training area plume. In this case, the HWMU can be directly linked to all of the contaminants detected in the Area VI plume.

The biodentrification surge lagoon does not appear to be contributing RCRA constituents to the perched groundwater underlying the unit. The lagoon is located on the fringe of the Area V plume, where it straddles the 5 ppb total uranium contour interval identified in the 1993 sampling program. The Area V plume originates upgradient of the biodentrification surge lagoon within the Operable Unit 1 waste pit area. The presence of the constituents comprising the Area V plume is attributed to releases from potential sources within the waste pit area, of which three other HWMUs (Waste Pit 4, Waste Pit 5, and the experimental treatment facility) are a subset. The fringes of the Area V plume appear to result from contaminant migration from the waste pit area and are not affiliated with the biodentrification surge lagoon.

Section 4.2 identified the major suspected sources that may have contributed to the observed distribution of contaminants in the perched groundwater. Approximately 100 major sources were identified, and the 22 HWMUs to be closed in concert with the CERCLA response actions are a subset of these 100 potential sources. The broad, area-wide investigation provided by the Operable Unit 5 RI has demonstrated that the perched groundwater contaminants are widely distributed, are often commingled, and rarely can be attributed to a single, unique source. Because of the widespread distributions, it is not possible to conclusively link the presence of a particular constituent in the perched groundwater to a particular HWMU (with the exception of the fire training area, where one primary source is present). The contaminants are typically present both upgradient and downgradient of the individual HWMUs; relative to the contributions by the other suspected sources, the 22 HWMUs cannot be singled out as contributing more or less of the constituents to the affected perched groundwater. The CERCLA response actions for perched groundwater (to be identified and

developed in the FS) will thus need to address the area-wide perched groundwater contamination in an integrated, cohesive manner that considers the releases from all potential sources.

TABLE 4-1

BACKGROUND DATA FOR RADIONUCLIDES AND CHEMICALS IN SURFACE WATER - PADDYS RUN

Constituents	Frequency of Detection		Range of Detection		95th Percentile[a]	
	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered
Radionuclides (pCi/L)						
Cesium-137	1/1	1/1	3.1	3.9	3.1	3.9
Neptunium-237	NA	1/1	NA	0.42	NA	0.42
Plutonium-238	0/1	0/1	ND	ND	ND	ND
Plutonium-239/240	1/1	1/1	0.093	0.29	0.093	0.29
Radium-226	1/2	0/2	0.35	ND	0.35	ND
Radium-228	1/2	0/2	2.1	ND	2.1	ND
Ruthenium-106	0/1	0/1	ND	ND	ND	ND
Strontium-90	1/1	1/1	0.96	0.86	0.96	0.86
Technetium-99	0/2	0/2	ND	ND	ND	ND
Thorium-228	0/2	0/2	ND	ND	ND	ND
Thorium-230	0/2	1/2	ND	0.28	ND	0.28
Thorium-232	0/2	0/2	ND	ND	ND	ND
Uranium-234	1/1	2/2	0.7	0.45 - 0.7	0.7	0.7
Uranium-235/236	0/2	0/2	ND	ND	ND	ND
Uranium-238	2/2	2/2	0.6 - 0.73	0.48 - 0.5	0.73	0.5
Radionuclides (μg/L)						
Thorium, Total	0/1	0/1	ND	ND	ND	ND
Uranium, Total	2/2	2/2	0.90 - 1.1	0.81 - 1.1	1.1	1.1
Inorganics (mg/L)						
Aluminum	2/2	1/2	0.195 - 0.64	0.132	0.64	0.132
Antimony	0/2	0/2	ND	ND	ND	ND
Arsenic	0/2	0/2	ND	ND	ND	ND
Barium	2/2	2/2	0.034 - 0.0534	0.0304 - 0.0526	0.0534	0.0526
Beryllium	0/1	0/1	ND	ND	ND	ND
Cadmium	0/2	0/2	ND	ND	ND	ND
Calcium	2/2	2/2	86.6 - 107	85.3 - 107	107	107
Chromium	0/2	0/2	ND	ND	ND	ND
Cobalt	0/1	0/1	ND	ND	ND	ND
Copper	0/1	0/1	ND	ND	ND	ND
Cyanide	0/2	0/1	ND	ND	ND	ND
Iron	2/2	0/2	0.129 - 0.513	ND	0.513	ND
Lead	0/2	0/2	ND	ND	ND	ND
Magnesium	2/2	2/2	20.7 - 27.8	20.4 - 27.7	27.8	27.7

TABLE 4-1 (Continued)

Constituents	Frequency of Detection		Range of Detection		95th Percentile[a]	
	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered
Manganese	1/1	1/1	0.035	0.0257	0.035	0.0257
Mercury	0/2	0/2	ND	ND	ND	ND
Molybdenum	0/2	0/2	ND	ND	ND	ND
Nickel	0/1	0/1	ND	ND	ND	ND
Potassium	2/2	2/2	2.12 - 3.58	1.96 - 3.5	3.58	3.5
Selenium	0/2	0/2	ND	ND	ND	ND
Silicon	2/2	2/2	2.95 - 3.36	2.43 - 3.01	3.36	3.01
Silver	0/2	0/2	ND	ND	ND	ND
Sodium	2/2	2/2	13 - 18.2	12.9 - 18.3	18.2	18.3
Thallium	0/1	0/1	ND	ND	ND	ND
Vanadium	0/1	0/1	ND	ND	ND	ND
Zinc	0/1	0/1	ND	ND	ND	ND
General Water Quality Parameters (mg/L)						
Alkalinity	2/2	NA	235 - 342	NA	342	NA
Ammonia	1/2	NA	0.0387	NA	0.0387	NA
Chloride	2/2	NA	27.8 - 31.6	NA	31.6	NA
Fluoride	2/2	NA	0.022 - 0.22	NA	0.22	NA
Nitrate	1/2	NA	1.66	NA	1.66	NA
Phenols	0/2	NA	ND	NA	ND	NA
Phosphorous	1/1	NA	0.228	NA	0.228	NA
Sulfate	2/2	NA	46.8 - 55.7	NA	55.7	NA
Sulfide	0/2	NA	ND	NA	ND	NA
TKN	1/2	NA	0.288	NA	0.288	NA
TOC	2/2	NA	1.68 - 5.35	NA	5.35	NA
TOX	1/2	NA	0.011	NA	0.011	NA
TON	1/2	NA	0.288	NA	0.288	NA

[a]For small data sets (≤ 7 samples) the distribution is undefined and the maximum detected concentration is used as the 95th percentile.

ND - Not Detected
NA - Not Analyzed

TABLE 4-2

BACKGROUND DATA FOR RADIONUCLIDES AND CHEMICALS IN SEDIMENT - PADDYS RUN

Constituents	Frequency of Detection	Range of Detection[a]	95th Percentile
Radionuclides (pCi/g)			
Radium-226	3/3	0.4 - 0.5	0.5
Radium-228	0/3	ND	ND
Radionuclides (mg/kg)			
Uranium, Total	3/3	1 - 3	3
Inorganics (mg/Kg)			
Aluminum	1/1	1970	1970
Arsenic	1/1	7	7
Barium	1/1	21	21
Beryllium	1/1	0.5	0.5
Cadmium	1/1	3.7	3.7
Calcium	1/1	25,900	25,900
Chromium	1/1	18.3	18.3
Cobalt	1/1	4.9	4.9
Copper	1/1	10.8	10.8
Iron	1/1	6700	6700
Magnesium	1/1	18,300	18,300
Manganese	1/1	411	411
Mercury	0/1	ND	ND
Molybdenum	0/1	ND	ND
Nickel	1/1	13.7	13.7
Potassium	1/1	307	307
Selenium	0/1	ND	NA
Silver	0/1	ND	NA
Sodium	1/1	197	197
Thallium	0/1	ND	NA
Vanadium	1/1	12.4	12.4
Zinc	1/1	13.5	13.5

[a]For small data sets (≤ 7 samples) the frequency is undefined and the maximum detected concentration is used as the 95th percentile.

ND - Not Detected
NA - Not Analyzed

TABLE 4-3

BACKGROUND DATA FOR RADIONUCLIDES AND CHEMICALS IN SURFACE WATER - GREAT MIAMI RIVER

Constituents	Frequency of Detection		Range of Detection		95th Percentile[a]	
	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered
Radionuclides (pCi/L)						
Cesium-137	0/4	0/2	ND	ND	ND	ND
Neptunium-237	0/5	0/3	ND	ND	ND	ND
Plutonium-238	0/5	0/3	ND	ND	ND	ND
Plutonium-239/240	0/5	0/3	ND	ND	ND	ND
Radium-226	1/4	0/3	0.12 - 0.41	ND	0.41	ND
Radium-228	1/5	0/3	2.2	ND	2.2	ND
Ruthenium-106	0/4	0/2	ND	ND	ND	ND
Strontium-90	0/5	0/3	ND	ND	ND	ND
Technetium-99	0/5	0/2	ND	ND	ND	ND
Thorium-228	3/5	2/3	0.54 - 0.62	0.79 - 0.86	0.62	0.86
Thorium-230	4/5	2/3	0.26 - 0.36	0.38 - 0.62	0.36	0.62
Thorium-232	0/5	1/3	ND	0.27	ND	0.27
Uranium-234	5/5	3/3	0.3 - 1.1	0.44 - 0.5	1.1	0.5
Uranium-235/236	1/5	0/3	0.25	ND	0.25	ND
Uranium-238	3/5	3/3	0.59 - 0.76	0.44 - 0.5	0.76	0.5
Radionuclides (µg/L)						
Thorium, Total	NA	NA	NA	NA	NA	NA
Uranium, Total	5/5	3/3	0.74 - 1.4	0.52 - 1.1	1.4	1.1
Inorganics (mg/L)						
Aluminum	2/2	2/2	1.30 - 1.89	0.086 - 0.115	1.89	0.115
Antimony	0/2	0.2	ND	ND	ND	ND
Arsenic	2/4	2/3	0.0018 - 0.0036	0.0016 - 0.0024	0.0036	0.0024
Barium	5/5	4/4	0.049 - 0.1	0.075 - 0.1	0.1	0.1
Beryllium	0/2	0/2	ND	ND	ND	ND
Cadmium	2/5	0/4	0.006 - 0.0098	ND	0.0098	ND
Calcium	5/5	4/4	61.2 - 77	66 - 79.3	77	79.3
Chromium	0/5	0/4	ND	ND	ND	ND
Cobalt	0/2	0/2	ND	ND	ND	ND
Copper	1/5	0/4	0.0118	ND	0.0118	ND
Cyanide	2/2	2/2	0.0030 - 0.0052	0.0022 - 0.0041	0.0052	0.0041
Iron	5/5	0/4	0.164 - 2.23	ND	2.23	ND
Lead	1/4	0.3	0.010	ND	0.010	ND
Magnesium	5/5	4/4	21.5 - 33.9	27.2 - 34.9	33.9	34.9

TABLE 4-3 (Continued)

Constituents	Frequency of Detection		Range of Detection		95th Percentile[a]	
	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered
Manganese	5/5	0/4	0.009 - 0.082	ND	0.082	ND
Mercury	0/4	0/4	ND	ND	ND	ND
Molybdenum	1/5	0/4	0.02	ND	0.02	ND
Nickel	2/5	0/4	0.11 - 0.023	ND	0.023	ND
Potassium	5/5	4/4	2.3 - 6.08	3.4 - 6.2	6.08	6.2
Selenium	0/4	0/3	ND	ND	ND	ND
Silicon	2/2	2/2	4.47 - 5.90	2.5 - 3.04	5.9	3.04
Silver	0/5	0/3	ND	ND	ND	ND
Sodium	5/5	4/4	12.9 - 75.8	27.1 - 77.2	75.8	77.2
Thallium	0/2	0/2	ND	ND	ND	ND
Vanadium	0/2	0/2	ND	ND	ND	ND
Zinc	1/2	0/2	0.0446	ND	0.0446	ND
General Water Quality Parameters (mg/L)						
Alkalinity	2/2	NA	232 - 245	NA	245	NA
Ammonia	2/4	NA	0.1 - 0.11	NA	0.11	NA
Chloride	5/5	NA	18 - 325	NA	325	NA
Fluoride	5/5	NA	0.27 - 0.9	NA	0.9	NA
Nitrate	5/5	NA	0.4 - 6.58	NA	6.58	NA
Phenols	1/4	NA	0.01	NA	0.01	NA
Phosphorous	5/5	NA	0.12 - 1.1	NA	1.1	NA
Sulfate	4/4	NA	45.6 - 138	NA	138	NA
Sulfide	0/1	NA	ND	NA	ND	NA
TKN[b]	2/2	NA	1.11 - 1.84	NA	1.84	NA
TOC[a]	2/2	NA	1.97 - 3.06	NA	3.06	NA
TOX[d]	4/5	NA	0.019 - 0.25	NA	0.25	NA
TON[c]	5/5	NA	0.2 - 1.73	NA	1.73	NA

[a]For small data sets (≤ 7 samples) the frequency is undefined and the maximum detected concentration is used as the 95th percentile.
[b] Total Kjeldahl nitrogen
[c] Total Organic Carbon
[d] Total Organic Halogens
[e] Total Organic Nitrogen
ND - Not Detected
NA - Not Analyzed

TABLE 4-4

BACKGROUND DATA FOR RADIONUCLIDES IN SEDIMENT - GREAT MIAMI RIVER

Constituents	Frequency of Detection	Range of Detection	95th Percentile[a]
Radionuclides (pCi/g)			
Cesium-137	0/3	ND	ND
Neptunium-237	0/4	ND	ND
Plutonium-238	0/4	ND	ND
Plutonium-239/240	0/4	ND	ND
Radium-226	3/3	0.4 - 0.57	0.57
Radium-228	0/3	ND	ND
Ruthenium-106	0/3	ND	ND
Strontium-90	0/3	ND	ND
Technetium-99	0/4	ND	ND
Thorium-228	0/4	ND	ND
Thorium-230	2/4	0.7 - 0.72	0.72
Thorium-232	1/3	0.8	0.8
Uranium-234	2/4	0.6 - 0.88	0.88
Uranium 235/236	0/4	ND	ND
Uranium-238	1/4	1.0	1.0
Radionuclides (mg/kg)			
Uranium, Total	2/3	1.3 - 3	3
Thorium, Total	1/1	3	3

[a]For small data sets (≤ 7 samples) the frequency is undefined and the maximum detected concentration is used as the 95th percentile.

ND - Not Detected
NA - Not Analyzed

TABLE 4-5

BACKGROUND DATA FOR RADIONUCLIDES AND CHEMICALS IN SURFACE SOIL (0 - 1.5 FEET)

Constituents	Frequency of Detection	Range of Detection	Distribution	95th Percentile
Radionuclides (pCi/g)				
Actinium-227	1/30	0.09	Undefined	0.09
Cesium-137	30/30	0.16 - 0.71	Lognormal	0.71
Lead-210	30/30	0.53 - 1.30	Lognormal	1.30
Neptunium-237	NA	NA	NA	NA
Plutonium-238	NA	NA	NA	NA
Plutonium-239/240	NA	NA	NA	NA
Protactinium-231	0/30	ND	Undefined	ND
Radium-224	30/30	0.54 - 0.93	Undefined	0.90
Radium-226	30/30	0.85 - 1.48	Normal	1.42
Radium-228	30/30	0.80 - 1.27	Normal	1.25
Ruthenium-106	0/30	ND	Undefined	NA
Strontium-90	4/30	0.30 - 0.46	Undefined	0.42
Technetium-99	0/30	ND	Undefined	NA
Thorium-228	29/30	0.68 - 1.43	Normal	1.43
Thorium-230	29/30	0.90 - 2.01	Normal	1.97
Thorium-232	30/30	0.64 - 1.52	Lognormal	1.36
Uranium-234	30/30	0.67 - 1.31	Lognormal	1.24
Uranium-235/236	27/30	0.03 - 0.20	Lognormal	0.16
Uranium-238	30/30	0.85 - 1.33	Lognormal	1.24
Radionuclides (mg/kg)				
Thorium, Total	30/30	5.84 - 13.9	Lognormal	12.4
Uranium, Total	30/30	2.56 - 4.03	Lognormal	3.73

TABLE 4-5 (Continued)

Constituents	Frequency of Detection	Range of Detection	Distribution	95th Percentile
Inorganics (mg/kg)				
Aluminum	30/30	5350 - 15,000	Lognormal	11,900
Antimony	0/22	ND	Undefined	NA
Arsenic	26/30	3.40 - 9.20	Normal	8.20
Barium	29/29	31.0 - 94.1	Lognormal	94.1[a]
Beryllium	1/30	0.60	Undefined	0.60
Cadmium	6/30	0.52 - 0.95	Undefined	0.87
Calcium	30/30	856 - 5340	Lognormal	4340
Chromium	30/30	6.70 - 17.7	Lognormal	15.5
Cobalt	30/30	4.30 - 16.5	Normal	14.2
Copper	27/30	3.20 - 17.3	Normal	14.1
Cyanide	12/30	0.14 - 0.29	Undefined	0.27
Iron	30/30	9370 - 24,900	Normal	21,700
Lead	28/30	0.53 - 1.3	Lognormal	26.4
Magnesium	30/30	1020 - 3590	Lognormal	2780
Manganese	29/29	189 - 1500	Lognormal	1350
Mercury	1/30	0.30	Undefined	0.30
Molybdenum	0/30	ND	Undefined	NA
Nickel	29/30	5.80 - 22.7	Lognormal	20.9
Potassium	29/30	374 - 1590	Normal	1230
Selenium	1/30	0.72	Undefined	0.72
Silicon	29/29	480 - 2230	Lognormal	1800
Silver	0/30	ND	Undefined	NA
Sodium	27/30	26.9 - 54.7	Normal	51.1
Thallium	1/30	0.58	Undefined	0.58
Vanadium	30/30	11.3 - 32.7	Lognormal	30.4
Zinc	30/30	29.4 - 70.0	Lognormal	59.6

[a]Maximum detect since 95th percentile exceeds the maximum positive detect.

ND - Not Detected
NA - Not Analyzed/Not Applicable

TABLE 4-6

BACKGROUND DATA FOR RADIONUCLIDES AND CHEMICALS IN SUBSURFACE SOIL (BELOW 1.5 FEET)

Constituents	Frequency of Detection	Range of Detection	Distribution	95th Percentile
Radionuclides (pCi/g)				
Actinium-227	3/51	0.06 - 0.10	Undefined	0.10
Cesium-137	0/51	ND	Undefined	ND
Lead-210	43/51	0.31 - 0.97	Normal	0.85
Neptunium-237	NA	NA	NA	NA
Plutonium-238	NA	NA	NA	NA
Plutonium-239/240	NA	NA	NA	NA
Protactinium-231	0/51	ND	Undefined	ND
Radium-224	51/51	0.28 - 1.07	Lognormal	1.01
Radium-226	51/51	0.59 - 1.61	Undefined	1.47
Radium-228	51/51	0.36 - 1.37	Lognormal	1.31
Ruthenium-106	0/51	ND	Undefined	ND
Strontium-90	2/51	0.44 - 0.56	Undefined	0.44
Technetium-99	0/51	ND	Undefined	ND
Thorium-228	49/50	0.47 - 1.39	Lognormal	1.38
Thorium-230	48/51	0.07 - 2.34	Normal	1.91
Thorium-232	44/50	0.35 - 1.35	Undefined	1.26
Uranium-234	48/51	0.48 - 1.30	Undefined	1.04
Uranium-235/236	46/51	0.03 - 0.20	Undefined	0.15
Uranium-238	48/51	0.60 - 1.23	Normal	1.12
Radionuclides (mg/kg)				
Thorium, total	50/50	2.83 - 12.3	Normal	11.1
Uranium, total	48/51	1.81 - 3.69	Lognormal	3.69

TABLE 4-6 (Continued)

Constituents	Frequency of Detection	Range of Detection	Distribution	95th Percentile
Inorganics (mg/kg)				
Aluminum	51/51	3250 - 16,100	Lognormal	16,100
Antimony	0/37	ND	Undefined	ND
Arsenic	44/51	1.60 - 14.5	Lognormal	9.57
Barium	51/51	13.7 - 134	Lognormal	119
Beryllium	15/50	0.48 - 0.68	Undefined	0.62
Cadmium	6/51	0.47 - 1.30	Undefined	0.91
Calcium	51/51	3310 - 335,000	Undefined	150,000
Chromium	51/51	4.50 - 22.4	Lognormal	20.7
Cobalt	51/51	3.60 - 17.9	Lognormal	15.7
Copper	50/51	6.80 - 24.3	Lognormal	20.0
Cyanide	1/51	0.17	Undefined	0.17
Iron	51/51	8970 - 30,700	Lognormal	30,700[a]
Lead	47/51	3.00 - 18.4	Lognormal	15.6
Magnesium	51/51	2930 - 54,100	Normal	42,600
Manganese	51/51	251 - 1750	Undefined	1300
Mercury	1/51	0.29	Undefined	0.29
Molybdenum	1/51	2.70	Undefined	2.70
Nickel	51/51	8.50 - 41.9	Lognormal	34.3
Potassium	51/51	340 - 2180	Lognormal	1980
Selenium	0/51	ND	Undefined	ND
Silicon	51/51	449 - 1850	Lognormal	1590
Silver	0/51	ND	Undefined	ND
Sodium	51/51	53.8 - 345	Undefined	285
Thallium	3/51	0.49 - 0.55	Undefined	0.49
Vanadium	51/51	8.40 - 44.5	Undefined	37.8
Zinc	51/51	27.3 - 101	Lognormal	82.0

[a]Maximum detect since 95 percent UCL on median exceeds the maximum positive detect.

ND - Not Detected
NA - Not Analyzed/Not Applicable

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TABLE 4-7

BACKGROUND DATA FOR RADIONUCLIDES AND CHEMICALS IN PERCHED WATER

Constituents	Frequency of Detection		Range of Detection		Distribution		95th Percentile	
	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered
Radionuclides (pCi/L)								
Cesium-137	NA	0/13	NA	ND	NA	Undefined	NA	ND
Neptunium-237	NA	3/10	NA	0.043 - 0.25	NA	Undefined	NA	0.25
Plutonium-238	NA	1/13	NA	0.075	NA	Undefined	NA	0.075
Plutonium-239/240	NA	0/19	NA	ND	NA	Undefined	NA	ND
Radium-226	1/4	9/22	0.9	0.14 - 0.9	Undefined	Lognormal	0.9	0.9
Radium-228	1/4	4/22	2.2	1.9 - 5.2	Undefined	Undefined	2.2	3
Ruthenium-106	NA	0/13	NA	ND	NA	Undefined	NA	ND
Strontium-90	NA	1/16	NA	2.0	NA	Undefined	NA	2.0
Technetium-99	1/4	2/26	30	30 - 49.3	Undefined	Undefined	30	30
Thorium-228	1/2	11/24	0.1	0.23 - 1.62	Undefined	Lognormal	0.1	1.6
Thorium-230	0/4	11/25	ND	0.14 - 2.0	Undefined	Lognormal	ND	1.3
Thorium-232	0/3	3/14	ND	0.2 - 0.34	Undefined	Undefined	ND	0.34
Uranium-234	1/1	9/13	0.6	0.25 - 1.1	Undefined	Normal	0.6	0.9
Uranium-235/236	0/2	0/13	ND	ND	Undefined	Undefined	ND	ND
Uranium-238	A	9/13	A	0.23 - 0.99	A	Normal	A	0.8
Radionuclides (μg/L)								
Thorium, Total	NA	1/10	NA	3.1	NA	Undefined	NA	3.1
Uranium, Total	2/3	8/15	1.0 - 1.4	0.48 - 1.5	Undefined	Normal	1.4	1.3

TABLE 4-7 (Continued)

Constituents	Frequency of Detection		Range of Detection		Distribution		95th Percentile	
	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered
Inorganics (mg/L)								
Aluminum	3/7	2/5	0.0375 - 0.123	0.774 - 2.29	Undefined	Undefined	0.123	2.29
Antimony	2/4	0/2	0.0141 - 0.0272	ND	Undefined	Undefined	0.0272	ND
Arsenic	5/17	3/5	0.0042 - 0.122	0.0031 - 0.0194	Undefined	Undefined	0.122	0.0194
Barium	22/23	5/5	0.034 - 0.452	0.0486 - 0.454	Undefined	Undefined	0.451	0.454
Beryllium	2/6	0/4	0.001 - 0.0018	ND	Undefined	Undefined	0.0018	ND
Cadmium	2/22	0/4	0.006 - 0.007	ND	Undefined	Undefined	0.006	ND
Calcium	25/25	5/5	74.4 - 155	81.1 - 172	Lognormal	Undefined	131	172
Chromium	8/24	1/5	0.006 - 0.0345	0.0046	Undefined	Undefined	0.034	0.0046
Cobalt	0/7	0/5	ND	ND	Undefined	Undefined	ND	ND
Copper	4/23	3/5	0.013 - 0.03	0.0053 - 0.0294	Undefined	Undefined	0.019	0.0294
Cyanide	0/4	0/5	ND	ND	Undefined	Undefined	ND	ND
Iron	18/25	5/5	0.0467 - 4.9	0.249 - 6.35	Undefined	Undefined	3.58	5.5
Lead	6/17	3/4	0.0014 - 0.0087	0.0013 - 0.0016	Undefined	Undefined	0.0087	0.0016
Magnesium	25/25	5/5	20.4 - 47.8	23.1 - 50.7	Lognormal	Undefined	47.8	50.7
Manganese	19/23	4/5	0.0025 - 0.22	0.0035 - 0.205	Lognormal	Undefined	0.18	0.205
Mercury	1/22	0/5	0.0004	ND	Undefined	Undefined	0.0004	ND
Molybdenum	2/20	0/4	0.017 - 0.028	ND	Undefined	Undefined	0.017	ND
Nickel	4/24	1/5	0.021 - 0.026	0.0072	Undefined	Undefined	0.022	0.0072
Potassium	21/23	4/5	0.891 - 31.5	0.963 - 17.2	Lognormal	Undefined	29.3	17.2
Selenium	0/16	0/5	ND	ND	Undefined	Undefined	ND	ND
Silicon	4/4	4/4	5.62 - 7.43	5.6 - 10.7	Undefined	Undefined	7.43	10.7
Silver	5/25	1/5	0.0105 - 0.052	0.0031	Undefined	Undefined	0.04	0.0031

TABLE 4-7 (Continued)

Constituents	Frequency of Detection		Range of Detection		Distribution		95th Percentile	
	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered
Sodium	23/23	5/5	5.71 - 56.3	8.81 - 50	Lognormal	Undefined	56.3	50
Thallium	0/5	0/5	ND	ND	Undefined	Undefined	ND	ND
Vanadium	2/7	1/5	0.018 - 0.0195	0.0051	Undefined	Undefined	0.0195	0.0051
Zinc	5/7	4/5	0.0104 - 0.0443	0.0192 - 0.352	Undefined	Undefined	0.0443	0.352
General Water Quality Parameters (mg/L)								
Alkalinity	NA	5/5	NA	313 - 430	NA	Undefined	NA	430
Ammonia	NA	11/22	NA	0.1 - 4.5	NA	Undefined	NA	4.3
Chloride	NA	20/25	NA	1.4 - 50	NA	Undefined	NA	45
Fluoride	NA	25/25	NA	0.2 - 1.3	NA	Lognormal	NA	1.3
Nitrate	NA	9/11	NA	0.012 - 0.3	NA	Normal	NA	0.29
Nitrate/Nitrite	NA	1/4	NA	0.07	NA	Undefined	NA	0.07
Phenols	NA	11/21	NA	0.007 - 0.03	NA	Lognormal	NA	0.03
Phosphate	NA	1/1	NA	0.191	NA	Undefined	NA	0.191
Phosphorous	NA	12/20	NA	0.026 - 0.18	NA	Lognormal	NA	0.18
Sulfate	NA	22/25	NA	3 - 175	NA	Normal	NA	136
Sulfide	NA	0/4	NA	ND	NA	Undefined	NA	ND
TKN[a]	NA	10/14	NA	0.178 - 4.34	NA	Undefined	NA	4.34
TOC[b]	NA	4/7	NA	1.15 - 9	NA	Undefined	NA	9
TOX[c]	NA	3/16	NA	0.011 - 0.126	NA	Undefined	NA	0.126
TON[d]	NA	10/20	NA	0.1 - 1.35	NA	Undefined	NA	0.34
Total Solids	NA	1/1	NA	452	NA	Undefined	NA	452
Total Dissolved Solids	1/1	NA	433	NA	Undefined	NA	433	NA

TABLE 4-7 (Continued)

Constituents	Frequency of Detection		Range of Detection		Distribution		95th Percentile	
	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered
Field Parameters								
Dissolved Oxygen	NA	22/22	NA	1 - 9.2	NA	Lognormal	NA	9.2
pH (Standard Units)	NA	29/20	NA	6.9 - 7.7	NA	Lognormal	NA	7.5
Specific Conductivity (μmhos/cm)	NA	30/30	NA	470 - 1170	NA	Lognormal	NA	955

[a]Total Kjeldahl Nitrogen
[b]Total Organic Carbon
[c]Total Organic Halogens
[d]Total Organic Nitrogen
A Analyzed but data not useable. See DOE, 1994a "Characterization of Background Water Quality for Streams and Groundwater," Appendix C for description of data quality.
ND Not Detected
NA Not Analyzed

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TABLE 4-8

BACKGROUND DATA FOR RADIONUCLIDES AND CHEMICALS IN GROUNDWATER - GREAT MIAMI AQUIFER

	Frequency of Detection		Range of Detection		Distribution		95th Percentile	
Constituents	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered
Radionuclides (pCi/L)								
Cesium-137	0/1	2/70	ND	5.8 - 6.7	Undefined	Undefined	ND	5.8
Neptunium-237	1/1	4/81	0.12	0.25 - 0.62	Undefined	Undefined	0.120	0.25
Plutonium-238	0/1	6/62	ND	0.022 - 0.089	Undefined	Undefined	ND	0.048
Plutonium-239/240	1/1	5/59	0.042	0.016-0.083	Undefined	Undefined	0.042	0.05
Radium-226	10/11	56/105	0.20 - 2	0.071 - 2	Normal	Lognormal	1.90	1.5
Radium-228	0/13	23/106	ND	1.0 - 52	Undefined	Undefined	ND	3.6
Ruthenium-106	1/1	0/76	ND	ND	Undefined	Undefined	ND	ND
Strontium-90	0/1	4/87	ND	0.65 - 4.8	Undefined	Undefined	ND	0.65
Technetium-99	0/1	2/99	ND	22 - 26	Undefined	Undefined	ND	22
Thorium-228	4/10	37/101	0.2 - 0.4	0.075 - 2.9	Undefined	Undefined	0.4	0.77
Thorium-230	2/11	44/98	0.1 - 0.29	0.18 - 2.5	Undefined	Lognormal	0.29	0.89
Thorium-232	3/11	9/71	0.1 - 0.3	0.1 - 0.77	Undefined	Undefined	0.3	0.23
Uranium-234	9/11	65/98	0.23 - 0.9	0.14 - 1.3	Normal	Lognormal	0.9	0.8
Uranium-235/236	0/10	5/97	ND	0.094 - 0.26	Undefined	Undefined	ND	0.094
Uranium-238	9/11	42/104	0.23 - 0.9	0.14 - 0.93	Normal	Lognormal	0.9	0.64

TABLE 4-8 (Continued)

Constituents	Frequency of Detection		Range of Detection		Distribution		95th Percentile	
	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered
Radionuclides (μg/L)								
Thorium, Total	NA	3/50	NA	0.97 - 2.1	NA	Undefined	NA	0.97
Uranium, Total	10/12	69/115	0.1 - 0.8	0.1 - 3.1	Normal	Undefined	0.8	1.2
Inorganics (mg/L)								
Aluminum	11/27	4/15	0.062 - 0.175	0.06 - 0.225	Lognormal	Undefined	0.175	0.225
Antimony	0/10	0/11	ND	ND	Undefined	Undefined	ND	ND
Arsenic	27/89	7/16	0.002 - 0.55	0.0011 - 0.0294	Undefined	Undefined	0.26	0.0294
Barium	97/110	14/16	0.021 - 0.82	0.0368 - 0.768	Undefined	Lognormal	0.669	0.768
Beryllium	6/23	0/16	0.001 - 0.0023	ND	Undefined	Undefined	0.0022	ND
Cadmium	16/106	3/16	0.002 - 0.01	0.0022 - 0.0135	Undefined	Undefined	0.006	0.0135
Calcium	110/111	16/16	63.6 - 181	78 - 162	Lognormal	Lognormal	136	159
Chromium	35/111	2/16	0.008 - 0.0441	0.0067 - 0.0211	Undefined	Undefined	0.03	0.0211
Cobalt	0/23	1/15	ND	0.0086	Undefined	Undefined	ND	0.0086
Copper	31/110	2/16	0.01 - 0.176	0.011 - 0.035	Undefined	Undefined	0.083	0.0354
Cyanide	01/12	0/16	ND	ND	Undefined	Undefined	ND	ND
Iron	74/111	14/15	0.007 - 5.42	0.312 - 5.5	Undefined	Normal	4.14	5.72
Lead	13/79	1/15	0.0016 - 0.029	0.002	Undefined	Undefined	0.009	0.002
Magnesium	111/111	16/16	15.7 - 46	20.1 - 39	Lognormal	Normal	37.8	38.5
Manganese	83/106	16/16	0.002 - 0.916	0.0043 - 0.904	Undefilned	Lognormal	0.78	0.904
Mercury	10/104	0/15	0.0002 - 0.001	ND	Undefined	Undefined	0.0004	ND
Molybdenum	21/90	0/8	0.004 - 0.04	ND	Undefined	Undefned	0.025	ND

TABLE 4-8 (Continued)

Constituents	Frequency of Detection		Range of Detection		Distribution		95th Percentile	
	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered
Nickel	14/111	1/16	0.012 - 0.0279	0.0514	Undefined	Undefined	0.023	0.0514
Potassium	94/101	13/16	0.664 - 4.03	0.648 - 1.96	Lognormal	Lognormal	3.32	1.96
Selenium	6/79	1/15	0.00105 - 0.006	0.00075	Undefined	Undefined	0.004	0.00075
Silicon	4/4	1/1	2.6 - 3.46	5.81	Undefined	Undefined	3.46	5.81
Silver	13/110	1/16	0.0031 - 0.034	0.0117	Undefined	Undefined	0.0138	0.0117
Sodium	106/106	16/16	1.96 - 101	3.08 - 50.4	Lognormal	Normal	55.0	47.2
Thallium	0/16	0/15	ND	ND	Undefined	Undefined	ND	ND
Vanadium	12/27	2/16	0.01 - 0.0244	0.0076 - 0.0117	Undefined	Undefined	0.0234	0.0117
Zinc	10/23	2/14	0.0068 - 0.133	0.0087 - 0.021	Undefined	Undefined	0.0568	0.021
General Water Quality Parameters (mg/L)								
Alkalinity	NA	21/21	NA	210 - 430	NA	Normal	NA	422
Ammonia	NA	40/101	NA	0.045 - 12.6	NA	Undefined	NA	4.2
Chloride	NA	98/110	NA	0.02 - 120	NA	Undefined	NA	73
Fluoride	NA	110/113	NA	0.1 - 1.9	NA	Lognormal	NA	0.89
Nitrate	NA	52/64	NA	0.014 - 24.9	NA	Undefined	NA	11.4
Nitrate/Nitrite	NA	4/12	NA	0.02 - 4.1	NA	Undefined	NA	4.1
Phenols	NA	46/94	NA	0.00575 - 0.091	NA	Undefined	NA	0.03
Phosphorous	NA	75/102	NA	0.01 - 3.08	NA	Undefined	NA	0.954
Sulfate	NA	101/110	NA	2.79 - 321	NA	Undefined	NA	197
Sulfide	NA	0/6	NA	ND	NA	Undefined	NA	ND
TKN[a]	NA	38/53	NA	0.1 - 4.74	NA	Lognormal	NA	3.3

TABLE 4-8 (Continued)

Constituents	Frequency of Detection		Range of Detection		Distribution		95th Percentile	
	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered
TOC[b]	NA	17/25	NA	1 - 4.25	NA	Normal	NA	2.23
TOX[c]	NA	13/85	NA	0.012 - 0.12	NA	Undefined	NA	0.052
TON[d]	NA	61/86	NA	0.075 - 2.75	NA	Undefined	NA	0.9
Total solids	NA	18/18	NA	330 - 773	NA	Lognormal	NA	711
Total dissolved solids	20/20	NA	320 - 673	NA	Normal	NA	658	NA
Dissolved oxygen	NA	93/93	NA	0.1 - 10.4	NA	Lognormal	NA	7.84
pH (standard units)	NA	131/131	NA	6.3 - 7.9	NA	Normal	NA	7.7
Specific Conductivity (μmhos/cm)	NA	131/131	NA	370 - 1890	NA	Lognormal	NA	928

[a]Total Kjeldahl
[b]Total Organic Carbon
[c]Total Organic Halogens
[d]Total Organic Nitrogen

ND Not Detected
NA Not Analyzed

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Analyte	Operable Unit 1	Waste Pit Area (W1-W6, CW & BP)	Operable Unit 2	Flyash Piles (IFP & AFP)	South Field Area (SF)	Lime Sludge Ponds (LSP)	Solid Waste Landfill (SWL)	Operable Unit 3	Plant 1 Area	Plant 2/3 Area	Plant 4 Area	Plant 5 Area	Plant 6 Area	Plant 7 Area	Plant 8 Area	Plant 9 Area	Sewage Treatment Plant Area (STP)	Pilot Plant Area (13)	Laboratory Area (15)	General Sump	Administration Area (14)	Electrical Substation Area (16)	Maintenance/Stores Building (12)	Tank Farm Area (19)	Boiler House Area (10)	Drum Baling Area	Scrap Metal Pile, Decontamination Building ...	Graphite Furnace & Oil Burner (10D)	KC-2 Warehouse Area (63)	Garage	Health & Safety Building	Service Building (11)	K-65/Clearwell Line W. of Prod. Area	Clearwell Line E. of Prod. Area	Fire Training Area (73)	Outfall Pipeline	Operable Unit 4	Silos	Operable Unit 5	Area West of K-65 Silos	Trap Range (90)	Primary Sources/Uses
Radionuclides																																										
Uranium-238		●			●		●		●	●	●	●	●	●	●	●	●	●	●	●			●	●		●	●	●	●		●	●	●	●	●	●		●		●		Ores, ore concentrates, and recycled material.
Uranium-234		●			●		●		●	●	●	●	●		●	●	●	●	●	●			●	●		●	●	●			●	●	●	●	●	●		●		●		Ores, ore concentrates, and recycled material.
Thorium-230		●			●		●		●	●							●	●	●	●							●				●		●	●		●		●				Minor impurity (<1%) in ores and ore concentrates.
Radium-226		●			●		●		●	●							●	●	●	●						●	●				●		●	●		●		●				Impurity in uranium ores and ore concentrates.
Uranium-235/236		●			●		●		●	●	●	●	●	●	●	●	●	●	●	●			●	●		●	●	●			●	●	●	●	●	●		●		●		Ores, ore concentrates, and recycled material.
Thorium-232		●			●		●		●	●	●	●	●		●	●		●	●	●						●	●	●			●		●	●		●		●				Feed material (thorium nitrate tetrahydrate).
Radium-228		●			●		●		●	●	●	●	●		●	●		●	●	●						●	●				●		●	●		●		●				Impurity in thorium ores and ore concentrates.
Thorium-228		●			●		●		●	●	●	●	●		●	●		●	●	●						●	●	●			●		●	●		●		●				Feed material (thorium nitrate tetrahydrate).
Neptunium-237		●					●		●	●	●	●	●		●	●		●	●	●											●		●	●		●						Impurity in recycled uranium from other DOE facilities.
Plutonium-239/240		●					●		●	●	●	●	●		●	●		●	●	●											●		●	●		●						Impurity in recycled uranium from other DOE facilities.
Plutonium-238		●					●		●	●	●	●	●		●	●		●	●	●											●		●	●		●						Impurity in recycled uranium from other DOE facilities.
Strontium-90		●					●		●	●	●	●	●		●	●		●	●	●											●		●	●		●						Impurity in recycled uranium from other DOE facilities; fallout.
Technetium-99		●					●		●	●	●	●	●		●	●	●	●	●	●			●			●	●	●			●		●	●	●	●				●		Impurity in recycled uranium from other DOE facilities; fallout.
Cesium-137		●					●		●	●	●	●	●		●	●		●	●	●											●		●	●		●						Impurity in recycled uranium from other DOE facilities; fallout.
Metals																																										
Aluminum		●		●		●			●	●						●		●	●	●			●		●		●				●											Minor impurity (<1%) in ores & ore concentrates; major (>10%) component in flyash; hydrated alumina used in raffinate treatment for fluoride removal; cladding on fuel elements.
Antimony		●							●	●									●	●																						Minor impurity (<1%) in ores & ore concentrates.
Arsenic		●		●	●	●	●		●	●					●				●	●											●											Minor impurity (<1%) in ores & ore concentrates; minor component (<100 ppm) in flyash.
Barium		●		●					●	●			●					●	●	●											●											BaSO4 used in thorium raffinate treatment for radium removal; minor component (<0.5%) in flyash.
Beryllium				●	●	●	●													●											●											Minor component (<20 ppm) in flyash.
Boron		●							●	●									●	●											●											Minor impurity (<1%) in ores & ore concentrates.
Cadmium		●		●		●	●		●	●		●	●		●	●		●	●	●							●				●											Minor impurity (<1%) in ores & ore concentrates.
Calcium		●		●		●			●	●			●		●	●	●	●		●			●		●		●				●											Lime [Ca(OH)2] used for neutralization; major impurity (<3%) in ores & ore concentrates; major component (>13%) in flyash; CaCO3 used in heat treating.
Hexavalent Chrome		●																		●			●		●						●											Additive for process water treatment.
Chromium		●		●	●	●	●		●	●	●	●	●	●	●	●		●	●	●			●		●		●				●											Minor impurity (<1%) in ores & ore concentrates.
Cobalt		●		●	●		●		●	●									●	●											●											Minor impurity (<1%) in ores & ore concentrates.
Copper		●		●					●	●	●	●	●	●	●	●		●	●	●			●				●				●											Minor impurity (<1%) in ores & ore concentrates; cladding on fuel elements.
Cyanide				●															●	●											●											Laboratory reagent.
Iron		●		●					●	●	●	●	●	●	●	●		●	●	●			●		●	●	●				●											Major impurity (<5%) in ores & ore concentrates; major component (>5%) in flyash.
Lead		●		●	●	●	●		●	●		●	●		●	●		●	●	●			●		●						●	●									●	Minor impurity (<1%) in ores & ore concentrates.
Lithium		●							●			●	●		●	●		●	●	●											●											LiCO3 used in heat treating.
Magnesium		●		●		●			●	●	●	●	●		●	●	●	●	●	●			●		●		●				●	●			●							Reduction of UF4 to U; major impurity (<4%) in ores and ore concentrates; major component (>4%) in flyash.
Manganese		●		●	●		●		●	●					●				●	●											●											Minor impurity (<1%) in ores & ore concentrates.
Mercury		●			●					●	●	●			●	●		●	●	●			●		●						●											Al/U alloy dissolution in Plant 2/3; laboratory uses.
Molybdenum		●		●	●				●	●									●	●							●				●											Minor impurity (<1%) in ores & ore concentrates.
Nickel		●		●					●	●	●		●	●		●		●	●	●			●								●											Minor impurity (<1%) in ores & ore concentrates; cladding on fuel elements; corrosion product.
Potassium		●							●	●	●		●	●	●	●		●	●	●			●	●							●											KCl used in heat treating; HF neutralization and residue recovery.
Selenium				●																●																							Minor component (<100 ppm) in flyash.
Silicon		●					●		●	●					●			●	●	●			●								●											Major impurity (<5%) in ores & ore concentrates.
Silver									●		●								●	●			●				●				●											Algaecide in Plant 4 heat exchangers; photographic film coating/processing.
Sodium		●							●	●			●	●	●	●		●	●	●			●				●				●											Major impurity (<10%) in ores & ore concentrates; NaCl used in heat treating; neutralization (NaOH).
Thallium				●	●		●												●	●																							Laboratory reagent.
Vanadium		●		●					●	●									●	●																							Minor impurity (<3%) in ores & ore concentrates.
Zinc		●		●					●	●						●		●	●	●							●				●											Minor impurity (<1%) in ores & ore concentrates.
Zirconium		●							●	●		●				●		●	●	●											●											Cladding on fuel elements; coating on ingot molds.

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TABLE 4-9
SUMMARY OF POTENTIAL SOURCES AND EXPECTED CONTAMINANTS

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Analyte	Operable Unit 1	Waste Pit Area (W1-W6, CW & BP)	Operable Unit 2	Flyash Piles (IFP & AFP)	South Field Area (SF)	Lime Sludge Ponds (LSP)	Solid Waste Landfill (SWL)	Operable Unit 3	Plant 1 Area	Plant 2/3 Area	Plant 4 Area	Plant 5 Area	Plant 6 Area	Plant 7 Area	Plant 8 Area	Plant 9 Area	Sewage Treatment Plant Area (STP)	Pilot Plant Area (13)	Laboratory Area (15)	General Sump	Administration Area (14)	Electrical Substation Area (16)	Maintenance/Stores Building (12)	Tank Farm Area (19)	Boiler House Area (10)	Drum Baling Area	Scrap Metal Pile, Decontamination Building ...	Graphite Furnace & Oil Burner (10D)	KC-2 Warehouse Area (63)	Garage	Health & Safety Building	Service Building (11)	K-65/Clearwell Line W. of Prod. Area	Clearwell Line E. of Prod. Area	Fire Training Area (73)	Outfall Pipeline	Operable Unit 4	Silos	Operable Unit 5	Area West of K-65 Silos	Trap Range (90)	Primary Sources/Uses
Organic Compounds																																										
Acetone									●	●	●				●			●	●	●	●		●		●	●		●	●		●											Laboratory solvent.
Benzene				●								●	●					●	●	●			●								●											Laboratory solvent.
Carbon tetrachloride													●		●			●	●	●	●										●											Cleaning solvent.
Chlorobenzene													●						●	●																						Laboratory solvent.
Chloroform				●															●	●											●											Laboratory solvent.
Di-sec-butyl phenyl phosphonate																		●	●	●								●														Solvent for thorium extraction.
Ethylbenzene															●																											Laboratory solvent.
Ethylene glycol																			●	●										●	●											Antifreeze; laboratory reagent.
Methylethyl ketone (2-butanone)															●				●	●											●											Laboratory reagent.
Methylene chloride				●	●				●										●	●											●											Laboratory reagent.
Pentachlorophenol				●																																						Laboratory reagent.
Polychlorinated biphenyls									●	●		●				●		●	●	●		●						●	●		●				●							Coolant in transformers.
Solvesso-100																		●	●	●								●														Thorium extraction/purification.
Tetrachloroethene									●	●	●	●	●		●	●		●	●	●			●					●	●		●	●										Cleaning solvent; coolant in pilot plant remelt furnace.
1,1,1-Trichloroethane		●		●					●	●	●	●	●		●		●	●	●	●			●		●			●	●		●				●							Cleaning solvent.
Trichloroethene		●							●	●		●	●		●	●		●	●	●			●					●			●	●											Cleaning solvent.
Toluene				●									●		●				●	●											●				●								Laboratory reagent.
Vinyl chloride				●																												●											Degradation product of trichloroethene and tetrachloroethene.
Xylene									●						●				●	●											●												Laboratory reagent.
Kerosene		●							●	●								●	●	●	●		●	●				●	●		●	●	●	●				●					Solvent for uranium/thorium extraction.
Various oils		●							●	●	●	●	●		●	●		●	●	●	●		●	●	●	●	●	●	●	●	●	●			●							Cooling, lubricating, hydraulics.
Other Compounds																																										
Ammonia		●								●	●		●	●	●	●		●	●	●				●									●	●								Minor impurity (<1%) in ores & ore concentrates; neutralization; residue from uranium recovery and UF4 production.
Carbonate		●				●			●	●			●		●	●		●	●	●			●										●	●									Major component in soil and groundwater; CaCO3 used in heat treating.
Chloride		●				●			●	●			●		●	●	●	●	●	●			●	●	●		●	●					●	●									Minor impurity (<1%) in ores & ore concentrates; NaCl & KCl used in heat treating; HCl used to dissolve U metal.
Fluoride		●							●	●	●	●	●	●	●	●		●	●	●			●	●			●	●					●	●									Minor impurity (<1%) in ores & ore concentrates; anhydrous & aqueous HF.
Nitrate		●							●	●			●		●	●	●	●	●	●			●	●			●						●	●									Nitric acid used to dissolve uranium and thorium feed materials for extraction.
Phosphate		●								●					●			●	●	●			●										●	●									Minor impurity (<1%) in ores & ore concentrates; UAP process.
Sulfate		●								●	●				●			●	●	●			●		●								●	●									Major impurity (<5%) in ores & ore concentrates; H2SO4 used for OU3 production.
Diamyl-amyl phosphonate																		●	●	●								●															Solvent for thorium extraction.
Magnesium fluoride		●							●	●		●			●	●		●	●	●							●	●					●	●									By-product of reduction of UF4 to uranium metal.
Tributyl phosphate		●								●					●			●	●	●				●				●					●	●									Solvent for uranium extraction.

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TABLE 4-9 (Continued)
SUMMARY OF POTENTIAL SOURCES AND EXPECTED CONTAMINANTS

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TABLE 4-10

Surface Water 1993	Former Production Area	North of Railroad Tracks	Pilot Plant Drainage Ditch	East Drainage Ditch	Southfield	Storm Sewer Outfall Ditch	Paddy's Run	Northeast Drainage Ditch	Great Miami River
Radionuclides									
Uranium-238	■	■	■	■	■	■	■	■	◉
Total Uranium	■	■	■	■	■	■	■	■	■
Uranium-234	■	■	■	■	■	■	■	■	◉
Thorium-230	-	-	■	○	◉	◉	◉	◉	◉
Radium-226	■	-	-	-	-	-	X	■	■
Uranium-235/236	■	■	■	■	■	■	X	◉	-
Thorium-232	-	-	-	-	-	-	X	-	-
Total Thorium	X	-	X		-		X	X	X
Radium-228	-	-	-	-	-	-	X	-	X
Thorium-228	○	-	◉	-	-	-	-	○	-
Neptunium-237	-	-	◉		X				
Plutonium-239/240	-	-	■		-				
Plutonium-238	-	-	-		X				
Strontium-90	-	-	-		-				
Technetium-99	X	-	-		-	-	-		-
Ruthenium-106	-	-	-		-				
Cesium-137	-	-	-		-				
Metals									
Aluminum	■	○	■	◉	◉	○	○	-	■
Antimony	X	-	-	-	-	-	-	-	-
Arsenic	-	-	○	-	◉	○	○	○	◉
Barium	○	○	■	◉	◉	○	○	◉	■
Beryllium	-	-	-	-	-	-	-	-	X
Cadmium	-	-	-	○	-	-	○	-	X
Calcium	○	○	◉	○	◉	○	○	◉	◉
Chromium	-	-	X	-	-	-	-	-	X
Cobalt	-	-	-	-	-	-	-	-	-
Copper	-	-	◉	-	-	X	○	-	■
Cyanide	■	○	○	-	○	◉	-	■	■
Iron	■	-	■	■	X	◉	X	◉	■
Lead	X	-	○	X	-	■	■	◉	■
Magnesium	○	○	■	○	◉	◉	◉	◉	◉
Manganese	■	■	■	■	◉	◉	◉	■	■
Mercury	-	-	-	-	-	-	-	-	-
Molybdenum	-	-	-	-	-	-	-	-	-
Nickel	-	-	◉	-	-	-	○	-	◉
Potassium	■	○	■	◉	◉	◉	◉	◉	◉
Selenium	-	-	-		X	-	-	-	-
Silicon	■	○	■	■	■	◉	○	○	■
Silver	-	-	-		-	-	X	-	-
Sodium	■	○	■	■	○	◉	■	◉	○
Thallium	-	-	-	-	-	X	X	-	-
Vanadium	X	-	X	-	-	-	-	-	-
Zinc	■	-	X	-	○	○	X	■	■
Organic Compounds									
Volatiles	X		X	X	X		X		X
Semi-Volatiles	X	X	X	X	X	X	X	X	X
Pesticides/PCBs									

■ Detection greater than 2 X of 95 percentile background value
◉ Detection above 95 percentile background value, but less than 2 X.
○ Detection less than 95 percentile background value.
Blank, not analyzed
- Analyzed and not detected
X Detection were background level not recorded

TABLE 4-11

Surface Water 1993

	Former Production Area	North of Railroad Tracks	Pilot Plant Drainage Ditch	East Drainage Ditch	Southfield	Storm Sewer Outfall Ditch	Paddy's Run	Northeast Drainage Ditch	Great Miami River
Radionuclides									
Uranium-238	■	■	■	■	■	■	■	■	
Total Uranium	■	■	■	■	■	■	■		
Uranium-234	■	■	■						
Thorium-230			■						
Radium-226	X						X	■	X
Uranium-235/236	■	■	■	■	■	X	X		
Thorium-232							X		
Total Thorium	X		X				X	X	X
Radium-228							X		X
Thorium-228									
Neptunium-237					X				
Plutonium-239/240			■						
Plutonium-238					X				
Strontium-90									
Technetium-99	X								
Ruthenium-106									
Cesium-137									
Metals									
Aluminum			■						■
Antimony	X								
Arsenic									
Barium									
Beryllium									X
Cadmium									X
Calcium									
Chromium			X						X
Cobalt									
Copper						X			
Cyanide								■	
Iron			■		X				■
Lead	X			X		■	■		X
Magnesium									
Manganese		■	■	■				■	■
Mercury									
Molybdenum									
Nickel									
Potassium									
Selenium					X				
Silicon			■						■
Silver							X		
Sodium	■								
Thallium						X	X		
Vanadium	X		X						
Zinc			X				X	■	
Organic Compounds									
Volatiles	X		X	X	X		X		X
Semi-Volatiles	X	X	X	X	X	X	X	X	X
Pesticides/PCBs									

■ Detection greater than 5 X of 95 percentile background value

X Detection were background level not recorded

000720

5696

TABLE 4-12

Sediment 1993	Former Production Area	North of Railroad Tracks	Storm Sewer Outfall Ditch	East Drainage Ditch	Southfield	Paddy's Run	Northeast Drainage Ditch	Great Miami River
Radionuclides								
Uranium-238	■	■	O	■	■	■	◆	◆
Total Uranium	■	■	■	■	■	■	■	■
Uranium-234	■	■	O	■	■	■	◆	O
Thorium-230	■	■	◆	■	■	■	■	■
Radium-226	■	O	O	O	◆	O	O	◆
Uranium-235/236	■	■	-	O	■	◆	-	-
Thorium-232	■	◆	O	■	■	◆	■	◆
Total Thorium	■	◆	O	■	■	◆	■	◆
Radium-228	■	◆	O	O	■	O	-	-
Thorium-228	■	O	O	O	◆	O	O	O
Neptunium-237	-	X			X			
Plutonium-239/240		-			X			
Plutonium-238	X	-			X			
Strontium-90	■	■			■			
Technetium-99	X	-			-			
Ruthenium-106	-	-			-			
Cesium-137	O	-			O			
Metals								
Aluminum	■	■	◆	■	■	■	■	■
Antimony	-	-	-	-	-	-	-	-
Arsenic	◆	◆	O	◆	■	O	◆	O
Barium	■	■	◆	■	■	■	■	■
Beryllium	■	◆	■	-	■	■	■	■
Cadmium	-	-			O	-	-	-
Calcium	■	■	■	◆	■	■	■	■
Chromium	◆	O	O	◆	◆	O	O	O
Cobalt	■	■	O	■	■	◆	■	■
Copper	■	◆	O	■	■	◆	◆	■
Cyanide	-	-	-	-	■	◆	◆	-
Iron	■	■	◆	■	■	■	■	■
Lead	■	O	O	◆	■	O	■	◆
Magnesium	◆	◆	◆	O	◆	■	◆	◆
Manganese	◆	■	◆	■	■	■	■	◆
Mercury	-	-	-	-	O	O	-	-
Molybdenum	X	X	-	-	X	-	-	-
Nickel	◆	◆	O	■	■	O	◆	◆
Potassium	■	■	-	■	■	■	■	■
Selenium	-	-			■	■	■	◆
Silicon	◆	O	O	O	O	O	O	O
Silver	X	X	-	-	X	X		-
Sodium	◆	◆	O	◆	◆	O	-	O
Thallium	-	◆	-	-	■	-	-	-
Vanadium	■	■	◆	■	■	■	◆	◆
Zinc	■	■	■	■	■	■	■	■
Organic Compounds								
Volatiles	X	X	X	X	X	X	X	X
Semi-Volatiles	X	X	X	X	X	X	X	X
Pesticides/PCBs	X	-			X			

■ Detection greater than 2 X of 95 percentile background value
◆ Detection above 95 percentile background value, but less than 2 X.
O Detection less than 95 percentile background value
Blank, not analyzed
- Analyzed and not detected
X Detection where background level not recorded.

TABLE 4-13

Sediment 1993	Former Production Area	North of Railroad Tracks	Storm Sewer Outfall Ditch	East Drainage Ditch	Southfield	Paddy's Run	Northeast Drainage Ditch	Great Miami River
Radionuclides								
Uranium-238	■	■		■	■	■	■	
Total Uranium	■	■	■	■	■	■	■	
Uranium-234	■	■			■	■		
Thorium-230	■				■			
Radium-226								
Uranium-235/236	■							
Thorium-232	■				■			
Total Thorium	■				■			
Radium-228	■							
Thorium-228	■							
Neptunium-237		X			X			
Plutonium-239/240					X			
Plutonium-238	X				X			
Strontium-90	■							
Technetium-99	X							
Ruthenium-106								
Cesium-137								
Metals								
Aluminum	■	■		■	■			■
Antimony								
Arsenic					■			
Barium	■	■		■	■			■
Beryllium					■	■	■	
Cadmium								
Calcium	■	■				■		
Chromium								
Cobalt								
Copper	■				■			
Cyanide								
Iron								
Lead								
Magnesium								
Manganese								
Mercury								
Molybdenum	X	X			X			
Nickel								
Potassium	■			■	■	■		
Selenium					■			
Silicon								
Silver	X	X			X	X		
Sodium								
Thallium					■			
Vanadium								
Zinc	■	■	■	■	■	■	■	■
Organic Compounds								
Volatiles	X	X	X	X	X	X	X	X
Semi-Volatiles	X	X	X	X	X	X	X	X
Pesticides/PCBs	X				X			

■ Detection greater than 5 X of 95 percentile background value

X Detection where background level not recorded.

TABLE 4-14

FEMP SOIL DATA, 1988-1993 (SURFACE SOIL)
DEPTH: 0 - 1.5 FEET

Parameter	Units	Summary of Positive/Nonpositive Detections							95% Background Value
		Frequency of Detection	Total Validated Samples	Freq. of Detection Above Bkgd.	Range of Positive Detections	Average of Positive Detections	Minimum Nondetect	Maximum Nondetect	
RADIONUCLIDES									
Uranium-238	pCi/g	1404/1581	685	1273/1581	0.300-19100	91.4	0.600	120	1.24
Uranium, total	mg/kg	2216/2557	802	1937/2557	1.00-90300	241	2.00	46.0	3.73
Uranium-234	pCi/g	1086/1100	679	944/1100	0.200-18100	98.9	0.600	19.0	1.24
Thorium-230	pCi/g	926/970	705	499/970	0.200-7900	26.7	0.100	64.0	1.97
Radium-226	pCi/g	1099/1251	606	346/1251	0.300-2950	10.8	0.250	5.70	1.42
Lead-210	pCi/g	8/8	3	7/8	1.25-168	45.5			1.30
Polonium-210	pCi/g	10/10	10	10/10	1.45-84.5	29.5			NA
Uranium-235/236	pCi/g	769/1116	699	648/1116	0.0180-1020	7.99	0.100	0.100	0.156
Thorium-232	pCi/g	1218/1425	683	403/1425	0.180-283	3.29	0.100	11.4	1.36
Thorium, total	mg/kg	1417/1959	266	511/1959	1.01-2580	27.3	0.912	45.0	12.4
Radium-228	pCi/g	563/744	613	183/744	0.520-558	6.49	0.500	28.5	1.25
Thorium-228	pCi/g	882/935	671	305/935	0.200-315	3.54	0.100	0.910	1.43
Neptunium-237	pCi/g	12/568	512	12/568	0.214-2.63	0.840	0.200	6.00	NA
Plutonium-239/240	pCi/g	34/645	590	34/645	0.215-12.9	2.31	0.200	2.99	NA
Plutonium-238	pCi/g	39/647	590	39/647	0.207-151	14.5	0.200	5.71	NA
Strontium-90	pCi/g	234/639	564	234/639	0.510-26.3	1.72	0.500	5.00	0.424
Technetium-99	pCi/g	125/652	534	125/652	1.10-602	19.1	1.00	22.0	ND
Ruthenium-106	pCi/g	6/1026	504	6/1026	1.88-10.6	6.28	1.00	71.0	ND
Cesium-137	pCi/g	402/1086	545	108/1086	0.209-4.26	0.650	0.200	7.80	0.711
Gross alpha	pCi/g	330/358	22	330/358	4.34-1900	142	4.20	28.0	NA
Gross beta	pCi/g	325/354	22	325/354	4.53-2000	145	16.0	40.0	NA
Actinium-227	pCi/g	4/21	21	4/21	0.650-3.95	2.15	0.100	1.60	0.090

TABLE 4-14 (Continued)

Parameter	Units	Summary of Positive/Nonpositive Detections							95% Background Value
		Frequency of Detection	Total Validated Samples	Freq. of Detection Above Bkgd.	Range of Positive Detections	Average of Positive Detections	Minimum Nondetect	Maximum Nondetect	
Gross gamma	pCi/g	0/2	0	0/2			170	170	
Protactinium-231	pCi/g	1/21	21	1/21	5.04-5.04	5.04	0.700	9.00	ND
Radium-224	pCi/g	21/21	21	20/21	0.313-5.36	1.98			0.900
Uranium-236	pCi/g	91/121	0	80/121	0.404-5.00	0.390	0.028	2.50	0.0880
Thorium-234	pCi/g	20/21	21	20/21	2.05-2290	236	33.4	33.4	NA
INORGANICS									
Aluminum	mg/kg	428/428	425	106/428	483-25700	9300			11900
Antimony	mg/kg	40/233	230	40/233	2.80-59.8	21.5	0.280	19.3	ND
Arsenic	mg/kg	386/400	373	64/400	0.770-81.9	6.57	0.420	61.0	8.20
Barium	mg/kg	452/452	425	148/452	11.4-587	93.6			95.7
Beryllium	mg/kg	249/424	421	197/424	0.280-5.70	0.970	0.220	3.80	0.600
Boron	mg/kg	1/1	1	1/1	14.3-14.3	14.3			13.7
Cadmium	mg/kg	159/442	415	154/442	0.490-12.4	3.71	0.460	5.00	0.870
Calcium	mg/kg	418/428	425	365/428	778-347000	62300	1080	3270	4340
Chromium	mg/kg	441/446	419	212/446	1.60-80.1	16.4	2.10	12.4	15.5
Cobalt	mg/kg	403/428	425	41/428	1.80-32.9	10.0	1.50	10.9	14.2
Copper	mg/kg	386/428	425	278/428	3.80-695	22.5	1.90	34.1	14.1
Cyanide	mg/kg	107/384	384	66/384	0.110-22.8	0.840	0.090	3.40	0.270
Iron	mg/kg	428/428	425	127/428	24.5-45100	18500			21700
Lead	mg/kg	410/415	377	114/415	2.80-2180	55.4	0.470	10.7	26.4
Magnesium	mg/kg	428/428	425	361/428	227-65300	15800			2780
Manganese	mg/kg	411/413	410	20/413	9.90-4400	629	0.420	739	1350
Mercury	mg/kg	55/447	421	21/447	0.060-6.30	0.530	0.010	0.528	0.300
Molybdenum	mg/kg	142/403	400	142/403	0.600-13.3	5.28	0.910	19.0	NA
Nickel	mg/kg	369/454	419	171/422	3.80-72.2	21.3	3.80	44.3	20.9
Potassium	mg/kg	422/428	425	137/428	222-4230	1080	21.2	2490	1230

TABLE 4-14 (Continued)

Parameter	Units	Summary of Positive/Nonpositive Detections							95% Background Value
		Frequency of Detection	Total Validated Samples	Freq. of Detection Above Bkgd.	Range of Positive Detections	Average of Positive Detections	Minimum Nondetect	Maximum Nondetect	
Selenium	mg/kg	58/365	338	19/365	0.230-7.70	0.900	0.200	61.0	0.720
Silicon	mg/kg	262/278	277	36/278	31.8-6660	999	51.4	356	1800
Silver	mg/kg	167/434	407	167/434	0.470-36.4	5.73	0.200	9.90	ND
Sodium	mg/kg	341/428	425	303/428	25.2-2360	225	30.0	183	51.1
Thallium	mg/kg	59/425	422	4/425	0.110-0.750	0.340	0.110	1.60	0.580
Vanadium	mg/kg	425/428	425	69/428	4.30-49.0	23.9	8.00	28.4	30.4
Zinc	mg/kg	402/420	417	162/420	6.20-2150	84.8	10.0	67.3	59.6
VOLATILES									
1,1,1-Trichloroethane	µg/kg	38/385	350	38/385	1.00-9400	537	5.00	13000	NA
1,1,2,2-Tetrachloroethane	µg/kg	2/350	350	2/350	2.00-190	96.0	5.00	13000	NA
1,1,2-Trichloroethane	µg/kg	1/385	350	1/385	14.0-14.0	14.0	5.00	13000	NA
1,1,2-Trichlorotrifluoroethane	µg/kg	0/16	0	0/16			420	4200	NA
1,1-Dichloroethane	µg/kg	7/351	351	7/351	1.00-22.0	10.4	5.00	13000	NA
1,1-Dichloroethene	µg/kg	5/370	351	5/370	2.00-39.0	10.6	5.00	13000	NA
1,2-Dichloroethane	µg/kg	1/370	351	1/370	2.00-2.00	2.00	5.00	13000	NA
1,2-Dichloroethene (total)	µg/kg	9/351	351	9/351	1.00-340	55.8	5.00	13000	NA
1,2-Dichloropropane	µg/kg	0/350	350	0/350			5.00	13000	NA
2-Butanone	µg/kg	16/268	233	16/268	1.00-110	18.0	6.00	13000	NA
2-Hexanone	µg/kg	3/248	248	3/248	2.00-47.0	17.0	5.00	13000	NA
4-Methyl-2-pentanone	µg/kg	15/285	250	15/285	1.00-160	23.7	3.00	13000	NA
Acetone	µg/kg	40/383	348	40/383	3.00-450	44.7	6.00	13000	NA
Benzene	µg/kg	4/386	350	4/386	2.00-5.00	3.00	5.00	13000	NA
Bromodichloromethane	µg/kg	0/350	350	0/350			5.00	13000	NA
Bromoform	µg/kg	0/350	350	0/350			5.00	13000	NA
Bromomethane	µg/kg	1/351	351	1/351	720-720	720	10.0	13000	NA
Carbon disulfide	µg/kg	17/379	344	17/379	2.00-790	52.1	5.00	13000	NA

TABLE 4-14 (Continued)

Parameter	Units	Summary of Positive/Nonpositive Detections							95% Background Value
		Frequency of Detection	Total Validated Samples	Freq. of Detection Above Bkgd.	Range of Positive Detections	Average of Positive Detections	Minimum Nondetect	Maximum Nondetect	
Carbon tetrachloride	µg/kg	2/385	350	2/385	1100-1200	1150	5.00	13000	NA
Chlorobenzene	µg/kg	5/385	350	5/385	1.00-10.0	3.80	5.00	13000	NA
Chloroethane	µg/kg	0/370	351	0/370			10.0	13000	NA
Chloroform	µg/kg	8/351	351	8/351	1.00-280	39.9	5.00	13000	NA
Chloromethane	µg/kg	0/367	348	0/367			8.00	13000	NA
cis-1,3-Dichloropropene	µg/kg	0/350	350	0/350			5.00	13000	NA
Dibromochloromethane	µg/kg	0/350	350	0/350			5.00	13000	NA
Ethylbenzene	µg/kg	8/386	350	8/386	0.800-660	137	5.00	13000	NA
Methylene chloride	µg/kg	59/386	351	59/386	1.00-5500	200	5.00	15000	NA
Styrene	µg/kg	2/349	349	2/349	1.00-28.0	14.5	5.00	13000	NA
Tetrachloroethene	µg/kg	37/381	346	37/381	1.00-48000	1920	5.00	13000	NA
Toluene	µg/kg	73/386	350	73/386	0.700-200	17.5	5.00	13000	NA
trans-1,3-Dichloropropene	µg/kg	0/344	344	0/344			5.00	13000	NA
Trichloroethene	µg/kg	46/385	350	46/385	1.00-89000	3300	5.00	13000	NA
Trichlorofluoromethane	µg/kg	0/35	0	0/35			11.0	830	NA
Vinyl acetate	µg/kg	0/282	282	0/282			10.0	13000	NA
Vinyl chloride	µg/kg	0/370	351	0/370			10.0	13000	NA
Xylenes, total	µg/kg	11/370	350	11/370	2.00-2000	286	5.00	13000	NA
SEMIVOLATILES									
1,2,4-Trichlorobenzene	µg/kg	0/342	342	0/342			10.0	5600	NA
1,2-Dichlorobenzene	µg/kg	0/342	342	0/342			10.0	5600	NA
1,3-Dichlorobenzene	µg/kg	0/342	342	0/342			10.0	5600	NA
1,4-Dichlorobenzene	µg/kg	0/350	342	0/350			10.0	5600	NA
2,4,5-Trichlorophenol	µg/kg	0/358	334	0/358			25.0	27000	NA
2,4,6-Trichlorophenol	µg/kg	0/358	334	0/358			10.0	5600	NA
2,4-Dichlorophenol	µg/kg	1/334	334	1/334	100-100	100	10.0	5600	NA

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TABLE 4-14 (Continued)

Parameter	Units	Summary of Positive/Nonpositive Detections							95% Background Value
		Frequency of Detection	Total Validated Samples	Freq. of Detection Above Bkgd.	Range of Positive Detections	Average of Positive Detections	Minimum Nondetect	Maximum Nondetect	
2,4-Dimethylphenol	µg/kg	3/351	335	0/351	60.0-100	76.7	10.00	5600	NA
2,4-Dinitrophenol	µg/kg	0/318	318	0/318			25.00	27000	NA
2,4-Dinitrotoluene	µg/kg	1/366	342	1/366	53.0-53.0	53.0	10.00	5600	NA
2,6-Dinitrotoluene	µg/kg	1/342	342	1/342	11.0-11.0	11.0	340.0	5600	NA
2-Benzyl-4-chlorophenol	µg/kg	0/2	2	0/2			390.0	400	NA
2-Chloronaphthalene	µg/kg	0/342	342	0/342			10.0	5600	NA
2-Chlorophenol	µg/kg	1/334	334	1/334	48.0-48.0	48.0	10.0	5600	NA
2-Methylnaphthalene	µg/kg	28/342	342	28/342	25.0-1700	391	10.0	5600	NA
2-Methylphenol	µg/kg	1/342	334	1/342	45.0-45.0	45.0	10.0	5600	NA
2-Nitroaniline	µg/kg	0/342	341	0/342			25.0	27000	NA
2-Nitrophenol	µg/kg	0/334	334	0/334			10.0	5600	NA
3,3'-Dichlorobenzidine	µg/kg	1/341	341	1/341	190-190	190	10.0	11000	NA
3-Nitroaniline	None	0/321	321	0/321			25.0	27000	NA
4,6-Dinitro-2-methylphenol	µg/kg	0/329	329	0/329			25.0	27000	NA
4-Bromophenyl phenyl ether	µg/kg	0/342	342	0/342			10.0	5600	NA
4-Chloro-3-methylphenol	µg/kg	1/334	334	1/334	46.0-46.0	46.0	10.0	5600	NA
4-Chlorophenyl phenyl ether	µg/kg	0/342	342	0/342			10.0	5600	NA
4-Methylphenol	µg/kg	4/343	335	4/343	50.0-190	105	10.0	5600	NA
4-Nitroaniline	µg/kg	1/321	321	1/321	330-330	330	25.0	27000	NA
4-Nitrophenol	µg/kg	0/330	330	0/330			25.0	27000	NA
Acenaphthene	µg/kg	21/342	342	21/342	52.0-4800	726	10.0	5600	NA
Acenaphthylene	µg/kg	13/342	342	13/342	41.0-3100	629	10.0	5600	NA
Anthracene	µg/kg	38/346	346	38/346	1.00-11000	1180	340	4200	NA
Benzo(a)anthracene	µg/kg	82/346	346	82/346	1.00-61000	1700	340	4200	NA
Benzo(a)pyrene	µg/kg	66/345	345	66/345	1.00-69000	2390	270	4200	NA
Benzo(b)fluoranthene	µg/kg	78/346	346	78/346	34.0-39000	1540	10.0	4200	NA
Benzo(g,h,i)perylene	µg/kg	48/346	346	48/346	38.0-48000	2170	10.0	5600	NA

TABLE 4-14 (Continued)

Parameter	Units	Summary of Positive/Nonpositive Detections							95% Background Value
		Frequency of Detection	Total Validated Samples	Freq. of Detection Above Bkgd.	Range of Positive Detections	Average of Positive Detections	Minimum Nondetect	Maximum Nondetect	
Benzo(k)fluoranthene	µg/kg	74/346	346	74/346	19.0-69000	1750	10.00	5600	NA
Benzoic acid	µg/kg	9/287	287	9/287	55.0-250	105	25.0	27000	NA
Benzyl alcohol	µg/kg	2/295	295	2/295	69.0-290	179	10.0	5600	NA
Bis(2-chloroethoxy)methane	µg/kg	0/342	342	0/342			10.0	5600	NA
Bis(2-chloroethyl)ether	µg/kg	0/342	342	0/342			10.0	5600	NA
Bis(2-chloroisopropyl)ether	µg/kg	2/328	328	2/328	44.0-48.0	46.0	10.0	5600	NA
Bis(2-ethylhexyl)phthalate	µg/kg	99/341	341	99/341	36.0-11000	752	10.0	4200	NA
Butyl benzyl phthalate	µg/kg	5/344	344	5/344	42.0-750	200	10.0	5600	NA
Carbazole	µg/kg	11/161	161	11/161	7.00-570	130	10.0	560	NA
Chrysene	µg/kg	82/345	345	82/345	1.00-18000	1150	340	4200	NA
Di-n-butyl phthalate	µg/kg	41/346	346	41/346	1.00-6100	378	340	5600	NA
Di-n-octyl phthalate	µg/kg	5/344	344	5/344	7.00-630	271	10.0	5600	NA
Dibenzo(a,h)anthracene	µg/kg	27/346	346	27/346	39.0-23000	1740	10.0	5600	NA
Dibenzofuran	µg/kg	24/342	342	24/342	50.0-3400	530	10.0	5600	NA
Diethyl phthalate	µg/kg	3/342	342	3/342	1.00-52.0	22.3	340	5600	NA
Dimethyl phthalate	µg/kg	0/342	342	0/342			10.0	5600	NA
Fluoranthene	µg/kg	114/345	345	114/345	1.00-33000	1370	57.0	4200	NA
Fluorene	µg/kg	23/342	342	23/342	7.00-5700	692	10.0	5600	NA
Hexachlorobenzene	µg/kg	0/366	342	0/366			10.0	5600	NA
Hexachlorobutadiene	µg/kg	1/362	338	1/362	430-430	430	10.0	5600	NA
Hexachlorocyclopentadiene	µg/kg	0/340	340	0/340			10.0	5600	NA
Hexachloroethane	µg/kg	0/366	342	0/366			10.0	5600	NA
Indeno(1,2,3-cd)pyrene	µg/kg	50/346	346	50/346	35.0-49000	2150	10.0	5600	NA
Isophorone	µg/kg	1/342	342	1/342	830-830	830	10.0	5600	NA
N-Nitroso-di-n-propylamine	µg/kg	1/338	338	1/338	39.0-39.0	39.0	10.0	5600	NA
N-Nitrosodiphenylamine	µg/kg	4/342	342	4/342	43.0-1300	536	10.0	5600	NA
Naphthalene	µg/kg	28/342	342	28/342	1.00-1800	343	340	5600	NA

TABLE 4-14 (Continued)

Parameter	Units	Summary of Positive/Nonpositive Detections							95% Background Value
		Frequency of Detection	Total Validated Samples	Freq. of Detection Above Bkgd.	Range of Positive Detections	Average of Positive Detections	Minimum Nondetect	Maximum Nondetect	
Nitrobenzene	µg/kg	0/362	338	0/362			10.0	5600	NA
o,o,o-Triethylphosphorothioate	µg/kg	0/6	6	0/6			0.0300	0.040	NA
p-Chloroaniline	µg/kg	0/324	324	0/324			10.0	5600	NA
Pentachlorophenol	µg/kg	0/358	334	0/358			25.0	27000	NA
Phenanthrene	µg/kg	92/345	345	92/345	1.00-22000	1130	340	4200	NA
Phenol	µg/kg	9/335	335	9/335	1.00-730	174	340	5600	NA
Pyrene	µg/kg	115/345	345	115/345	1.00-22000	1150	74.0	4200	NA
Pyridine	µg/kg	0/24	0	0/24			200	10000	NA
Tributyl phosphate	µg/kg	8/39	39	8/39	46.0-1200	248	350	1500	NA
PESTICIDES									
4,4'-DDD	µg/kg	0/333	329	0/333			3.30	99000	NA
4,4'-DDE	µg/kg	3/333	329	3/333	11.0-38.0	23.0	3.30	99000	NA
4,4'-DDT	µg/kg	6/334	330	6/334	3.00-19.0	11.9	3.40	99000	NA
Aldrin	µg/kg	1/333	329	1/333	1.60-1.60	1.60	1.70	49000	NA
Alpha-BHC	µg/kg	0/333	329	0/333			1.70	49000	NA
Alpha-Chlordane	µg/kg	4/333	329	4/333	2.10-9.70	4.93	1.70	490000	NA
Aroclor-1016	µg/kg	0/336	332	0/336			33.0	490000	NA
Aroclor-1221	µg/kg	0/336	332	0/336			37.0	490000	NA
Aroclor-1232	µg/kg	0/336	332	0/336			33.0	490000	NA
Aroclor-1242	µg/kg	0/336	332	0/336			33.0	490000	NA
Aroclor-1248	µg/kg	0/336	332	0/336			33.0	490000	NA
Aroclor-1254	µg/kg	81/337	333	81/337	11.0-14000	1210	33.0	2600	NA
Aroclor-1260	µg/kg	17/338	334	17/338	120-2800	608	33.0	990000	NA
Beta-BHC	µg/kg	3/333	329	3/333	46.0-220	115	1.70	49000	NA
Delta-BHC	µg/kg	0/333	329	0/333			1.70	49000	NA
Dieldrin	µg/kg	5/333	329	5/333	0.550-20.0	6.89	3.30	99000	NA

TABLE 4-14 (Continued)

Parameter	Units	Summary of Positive/Nonpositive Detections							95% Background Value
		Frequency of Detection	Total Validated Samples	Freq. of Detection Above Bkgd.	Range of Positive Detections	Average of Positive Detections	Minimum Nondetect	Maximum Nondetect	
Endosulfan II	µg/kg	1/333	329	1/333	2.00-2.00	2.00	3.30	99000	NA
Endosulfan Sulfate	µg/kg	1/333	329	1/333	0.730-0.730	0.730	3.30	99000	NA
Endosulfan I	µg/kg	0/333	329	0/333			1.70	49000	NA
Endrin	µg/kg	5/351	329	5/351	0.940-19.0	6.61	2.10	99000	NA
Endrin Aldehyde	µg/kg	2/179	177	2/179	8.70-15.0	11.9	3.30	200	NA
Endrin Ketone	µg/kg	0/333	329	0/333			3.30	99000	NA
Gamma-BHC (Lindane)	µg/kg	0/351	329	0/351			1.40	49000	NA
Gamma-Chlordane	µg/kg	1/351	329	1/351	5.30-5.30	5.30	1.70	490000	NA
Heptachlor	µg/kg	0/351	329	0/351			1.00	49000	NA
Heptachlor Epoxide	µg/kg	2/351	329	2/351	1.00-2.80	1.90	1.70	49000	NA
Methoxychlor	µg/kg	3/351	329	3/351	0.850-3.50	1.88	10.0	490000	NA
Sulfotep	µg/kg	0/6	6	0/6			0.0300	0.0400	NA
Toxaphene	µg/kg	0/350	328	0/350			84.0	990000	NA
HERBICIDES									
2,4,5-TP (Silvex)	µg/kg	0/18	0	0/18			3.60	5.00	NA
2,4-D	µg/kg	0/18	0	0/18			5.00	30.0	NA
DIOXINS/FURANS									
1,2,3,4,6,7,8-Heptachloro-dibenzo-p-dioxin	ng/g	0/16	16	0/16			120	1000	NA
1,2,3,4,6,7,8-Heptachloro-dibenzofuran	ng/g	0/16	16	0/16			98.0	1000	NA
1,2,3,4,7,8,9-Heptachloro-dibenzofuran	ng/g	0/16	16	0/16			140	1000	NA
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	ng/g	0/16	16	0/16			100	1000	NA
1,2,3,4,7,8-Hexachloro-dibenzofuran	ng/g	0/17	17	0/17			66.0	1000	NA

TABLE 4-14 (Continued)

Parameter	Units	Summary of Positive/Nonpositive Detections							95% Background Value
		Frequency of Detection	Total Validated Samples	Freq. of Detection Above Bkgd.	Range of Positive Detections	Average of Positive Detections	Minimum Nondetect	Maximum Nondetect	
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	ng/g	0/16	16	0/16			94.0	1000	NA
1,2,3,6,7,8-Hexachlorodibenzo-furan	ng/g	0/17	17	0/17			61.0	1000	NA
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	ng/g	0/16	16	0/16			93.0	1000	NA
1,2,3,7,8,9-Hexachlorodibenzo-furan	ng/g	0/17	17	0/17			76.0	1000	NA
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	ng/g	0/16	16	0/16			120	1000	NA
1,2,3,7,8-Pentachlorodibenzo-furan	ng/g	0/16	16	0/16			60.0	1000	NA
2,3,4,6,7,8-Hexachlorodibenzo-furan	ng/g	0/17	17	0/17			70.0	1000	NA
2,3,4,7,8-Pentachlorodibenzo-furan	ng/g	0/16	16	0/16			60.0	1000	NA
2,3,7,8-Tetrachlorodibenzo-p-dioxin	ng/g	0/46	46	0/46			24.0	1000	NA
2,3,7,8-Tetrachlorodibenzofuran	ng/g	0/20	20	0/20			23.0	1000	NA
Heptachlorodibenzo-p-dioxins	ng/g	0/20	20	0/20			120	1000	NA
Heptachlorodibenzofurans	ng/g	1/20	20	1/20	320-320	320.00	180	1200	NA
Hexachlorodibenzo-p-dioxins	ng/g	0/26	26	0/26			83.0	1000	NA
Hexachlorodibenzofurans	ng/g	0/27	27	0/27			67.0	1000	NA
Octachlorodibenzo-p-dioxin	ng/g	6/20	20	6/20	240-1100	572	200	1300	NA
Octachlorodibenzofuran	ng/g	2/20	20	2/20	240-1300	770	90.0	1000	NA
Pentachlorodibenzo-p-dioxins	ng/g	0/26	26	0/26			100	1000	NA
Pentachlorodibenzofurans	ng/g	0/26	26	0/26			30.0	1000	NA
Tetrachlorodibenzo-p-dioxins	ng/g	0/26	26	0/26			36.0	1000	NA
Tetrachlorodibenzofurans	ng/g	0/26	26	0/26			31.0	1000	NA

TABLE 4-14 (Continued)

Parameter	Units	Summary of Positive/Nonpositive Detections							95% Background Value
		Frequency of Detection	Total Validated Samples	Freq. of Detection Above Bkgd.	Range of Positive Detections	Average of Positive Detections	Minimum Nondetect	Maximum Nondetect	
ORGANOPHOSPHORUS PESTICIDES									
Azinphosmethyl	µg/kg	0/7	7	0/7			82.0	107	NA
Demeton	µg/kg	0/7	7	0/7			66.0	85.0	NA
Diazinon	µg/kg	0/7	7	0/7			33.0	43.0	NA
Dimethoate	µg/kg	0/6	6	0/6			0.0300	0.0400	NA
Disulfoton	µg/kg	0/13	13	0/13			0.0300	43.0	NA
Ethion	µg/kg	0/7	7	0/7			33.0	43.0	NA
Famphur	µg/kg	0/6	6	0/6			0.0900	0.120	NA
Malathion	µg/kg	0/7	7	0/7			33.0	43.0	NA
Methyl Parathion	µg/kg	0/13	13	0/13			0.0600	43.0	NA
Parathion	µg/kg	0/13	13	0/13			0.0600	43.0	NA
Phorate	µg/kg	0/6	6	0/6			0.0600	0.0800	NA
Thionazin	µg/kg	0/6	6	0/6			0.0300	0.0400	NA
GENERAL CHEMISTRY									
Nitrate, as nitrogen	mg/kg	1/1	0	1/1	435-435	435			NA
Total organic carbon	mg/kg	1/1	1	1/1	38682-38682	38682			NA
Total petroleum hydrocarbons (TPH)	pCi/g	0/1	0	0/1			10.0	10.0	NA

TABLE 4-15

FEMP SOIL DATA 1988-1993 (SUBSURFACE SOIL)
DEPTH: >1.5 FEET

Parameter	Units	Summary of Positive/Nonpositive Detections							95% Background Value
		Frequency of Detection	Total Validated Samples	Freq. of Detection Above Bkgd.	Range of Positive Detections	Average of Positive Detections	Minimum Nondetect	Maximum Nondetect	
RADIONUCLIDES									
Uranium-238	pCi/g	436/508	483	226/508	0.200-317	9.27	0.600	9.30	1.12
Uranium, total	mg/kg	1164/1829	864	878/1829	0.500-69300	194	0.100	12.0	3.69
Uranium-234	pCi/g	418/492	472	223/492	0.200-319	9.40	0.600	1.20	1.04
Thorium-230	pCi/g	497/566	549	64/566	0.300-153	2.00	0.100	1.30	1.91
Radium-226	pCi/g	432/501	473	36/501	0.300-137	1.23	0.250	3.00	1.47
Lead-210	pCi/g	36/48	48	33/48	0.560-34.0	4.78	0.500	1.20	.850
Polonium-210	pCi/g	75/75	75	75/75	0.627-34.4	3.39			NA
Uranium-235/236	pCi/g	91/496	476	89/496	0.0480-36.2	3.43	0.100	1.20	0.150
Thorium-232	pCi/g	362/573	552	34/573	0.200-8.07	0.930	0.100	1.10	1.26
Thorium, total	mg/kg	777/1618	588	144/1618	0.912-290	9.75	0.800	45.0	11.1
Radium-228	pCi/g	214/506	485	27/506	0.510-23	1.17	0.500	4.00	1.31
Thorium-228	pCi/g	415/560	543	57/560	0.200-19.5	1.11	0.100	1.00	1.38
Neptunium-237	pCi/g	2/315	311	2/315	0.288-0.305	0.300	0.200	0.600	NA
Plutonium-239/240	pCi/g	17/362	359	17/362	0.300-5.50	1.30	0.200	0.700	NA
Plutonium-238	pCi/g	8/363	359	8/363	0.344-158	20.7	0.200	2.10	NA
Strontium-90	pCi/g	84/372	364	84/372	0.511-47.6	3.07	0.500	5.00	.436
Technetium-99	pCi/g	43/439	430	43/439	1.02-205	10.3	1.00	2.90	ND
Ruthenium-106	pCi/g	0/328	317	0/328			1.00	24.3	ND
Cesium-137	pCi/g	17/409	397	17/409	0.242-2.94	0.820	0.200	1.40	ND
Gross alpha	pCi/g	116/129	11	116/129	5.10-1054	37.1	3.60	11.0	NA
Gross beta	pCi/g	128/129	10	128/129	7.10-159	33.6	5.40	5.40	NA
Actinium-227	pCi/g	0/2	2	0/2			0.300	0.600	.105
Protactinium-231	pCi/g	0/4	4	0/4			1.10	7.20	ND
Radium-224	pCi/g	4/4	4	1/4	0.670-1.33	0.920			101

TABLE 4-15 (Continued)

Parameter	Units	Summary of Positive/Nonpositive Detections							95% Background Value
		Frequency of Detection	Total Validated Samples	Freq. of Detection Above Bkgd.	Range of Positive Detections	Average of Positive Detections	Minimum Nondetect	Maximum Nondetect	
INORGANICS									
Aluminum	mg/kg	338/338	334	25/338	1100-142000	10100			16100
Antimony	mg/kg	11/145	141	11/145	1.20-22.1	16.8	0.880	15.5	ND
Arsenic	mg/kg	308/312	304	36/312	0.0300-74.2	6.19	0.510	14.7	9.57
Barium	mg/kg	342/342	334	50/342	9.90-3610	91.4			119
Beryllium	mg/kg	231/333	329	185/333	0.290-5.20	1.03	0.350	4.00	0.620
Cadmium	mg/kg	172/328	320	172/328	0.920-8.00	3.76	0.670	9.60	0.910
Calcium	mg/kg	338/338	334	20/338	2180-314000	78000			150000
Chromium	mg/kg	327/329	321	51/329	4.70-115	16.4	5.80	6.90	20.7
Cobalt	mg/kg	309/338	334	34/338	2.60-105	10.8	3.30	11.7	15.7
Copper	mg/kg	304/336	332	103/336	5.00-171	19.7	1.90	37.3	20.0
Cyanide	mg/kg	35/313	309	26/313	0.110-9.80	0.950	0.000	5.10	.170
Iron	mg/kg	338/338	334	36/338	4000-193000	21000			30700
Lead	mg/kg	339/339	326	85/339	0.470-139	12.9			15.6
Magnesium	mg/kg	338/338	334	11/338	1390-93200	20600			42600
Manganese	mg/kg	338/338	334	23/338	107-12200	643			1300
Mercury	mg/kg	14/342	334	1/342	0.0400-2.30	0.260	0.0100	1.00	0.290
Molybdenum	mg/kg	113/317	313	103/317	1.60-11.1	4.58	1.30	23.1	2.70
Nickel	mg/kg	292/325	321	44/325	6.70-186	25.7	3.80	39.0	34.3
Potassium	mg/kg	337/338	334	28/338	204-10900	1220	21.2	21.2	1980
Selenium	mg/kg	27/300	292	27/300	0.320-3.30	0.970	0.220	3.90	ND
Silicon	mg/kg	139/152	152	4/152	17.6-5950	522	54.7	192	1590
Silver	mg/kg	164/320	312	164/320	0.410-31.1	5.75	0.210	9.60	ND
Sodium	mg/kg	287/338	334	25/338	42.2-1700	188	34.1	280	285
Thallium	mg/kg	30/337	333	4/337	0.210-0.720	0.350	0.0450	3.90	0.490
Vanadium	mg/kg	334/338	334	23/338	4.70-190	24.1	16.7	28.7	37.8
Zinc	mg/kg	332/336	332	44/336	16.7-780	63.5	37.7	82.9	82.0

TABLE 4-15 (Continued)

Parameter	Units	Summary of Positive/Nonpositive Detections							95% Background Value
		Frequency of Detection	Total Validated Samples	Freq. of Detection Above Bkgd.	Range of Positive Detections	Average of Positive Detections	Minimum Nondetect	Maximum Nondetect	
VOLATILES									
1,1,1-Trichloroethane	µg/kg	49/381	375	49/381	1.00-6600	234	5.00	5000	NA
1,1,2,2-Tetrachloroethane	µg/kg	9/378	376	9/378	2.00-190	38.6	5.00	1300000	NA
1,1,2-Trichloroethane	µg/kg	6/382	376	6/382	1.00-4.00	2.00	5.00	1300000	NA
1,1,2-Trichlorotrifluoroethane		0/4	0	0/4			420	4200	NA
1,1-Dichloroethane	µg/kg	39/378	376	39/378	1.00-460	45.9	5.00	1600	NA
1,1-Dichloroethene	µg/kg	25/378	376	25/378	1.00-460	31.8	5.00	1600	NA
1,2-Dichloroethane	µg/kg	6/377	375	6/377	2.00-10.0	4.00	5.00	1600	NA
1,2-Dichloroethene (total)	µg/kg	47/378	376	47/378	1.00-4300	165	5.00	1300	NA
1,2-Dichloropropane	µg/kg	0/378	376	0/378			5.00	1600	NA
2-Butanone	µg/kg	27/246	240	27/246	2.00-200	32.1	4.00	6300	NA
2-Hexanone	µg/kg	7/299	297	7/299	1.00-2600	373	1.00	3400	NA
4-Methyl-2-pentanone	µg/kg	53/304	298	53/304	1.00-2600	68.3	1.00	4200	NA
Acetone	µg/kg	67/380	374	67/380	4.00-230	47.1	4.00	10000	NA
Benzene	µg/kg	3/387	376	3/387	1.00-1300	456	5.00	2100	NA
Bromodichloromethane	µg/kg	2/378	376	2/378	7.00-13.0	10.0	5.00	1600	NA
Bromoform	µg/kg	0/378	376	0/378			5.00	1600	NA
Bromomethane	µg/kg	0/378	376	0/378			10.0	3400	NA
Carbon disulfide	µg/kg	95/382	376	94/382	1.00-390	16.8	5.00	2900	NA
Carbon tetrachloride	µg/kg	2/382	376	2/382	5.00-12.0	8.50	5.00	3800	NA
Chlorobenzene	µg/kg	2/382	376	2/382	1.00-2.00	1.50	5.00	4600	NA
Chloroethane	µg/kg	3/378	376	3/378	2.00-210	72.0	10.0	3400	NA
Chloroform	µg/kg	14/378	376	14/378	2.00-160	30.3	5.00	1600	NA
Chloromethane	µg/kg	1/373	371	1/373	12.0-12.0	12.0	10.0	13000	NA
cis-1,3-Dichloropropene	µg/kg	0/378	376	0/378			5.00	1600	NA
Dibromochloromethane	µg/kg	1/378	376	1/378	1300-1300	1300	5.00	1600	NA
Ethylbenzene	µg/kg	7/387	376	7/387	1.00-747	110	5.00	2100	NA
Methylene chloride	µg/kg	46/382	376	46/382	1.00-100	20.9	2.00	6700	NA
Styrene	µg/kg	2/378	376	2/378	1.00-2.00	1.50	5.00	1600	NA
Tetrachloroethene	µg/kg	46/381	375	46/381	1.00-21000	1350	5.00	305000	NA
Toluene	µg/kg	47/387	376	47/387	1.00-794	24.8	1.00	2800	NA

TABLE 4-15 (Continued)

Parameter	Units	Summary of Positive/Nonpositive Detections							95% Background Value
		Frequency of Detection	Total Validated Samples	Freq. of Detection Above Bkgd.	Range of Positive Detections	Average of Positive Detections	Minimum Nondetect	Maximum Nondetect	
trans-1,3-Dichloropropene	µg/kg	1/366	364	1/366	1300-1300	1300	5.00	1600	NA
Trichloroethene	µg/kg	51/381	375	51/381	1.00-150000	5790	5.00	5400	NA
Trichlorofluoromethane	µg/kg	0/4	0	0/4			420	4200	NA
Vinyl acetate	µg/kg	0/359	357	0/359			10.0	3400	NA
Vinyl chloride	µg/kg	6/378	376	6/378	2.00-110	22.2	10.0	3400	NA
Xylenes, total	µg/kg	14/383	376	14/383	3.00-31000	2750	3.00	1300	NA
SEMIVOLATILES									
1,2,4-Trichlorobenzene	µg/kg	1/309	308	1/309	220-220	220.00	330	3500	NA
1,2-Dichlorobenzene	µg/kg	0/309	308	0/309			330	3500	NA
1,3-Dichlorobenzene	µg/kg	0/309	308	0/309			330	3500	NA
1,4-Dichlorobenzene	µg/kg	1/309	308	1/309	210-210	210.00	330	3500	NA
2,4,5-Trichlorophenol	µg/kg	0/313	308	0/313			820	17000	NA
2,4,6-Trichlorophenol	µg/kg	0/313	308	0/313			330	3500	NA
2,4-Dichlorophenol	µg/kg	0/309	308	0/309			330	3500	NA
2,4-Dimethylphenol	µg/kg	1/313	308	1/313	100-100	100	330	3500	NA
2,4-Dinitrophenol	µg/kg	0/308	307	0/308			820	17000	NA
2,4-Dinitrotoluene	µg/kg	1/312	307	1/312	110-110	110	330	3500	NA
2,6-Dinitrotoluene	µg/kg	0/309	308	0/309			330	3500	NA
2-Benzyl-4-chlorophenol	µg/kg	0/2	2	0/2			400	420	NA
2-Chloronaphthalene	µg/kg	0/309	308	0/309			330	3500	NA
2-Chlorophenol	µg/kg	3/309	308	3/309	42.0-390	159	330	3500	NA
2-Methylnaphthalene	µg/kg	5/309	308	5/309	45.0-200	86.2	330	3500	NA
2-Methylphenol	µg/kg	0/309	308	0/309			330	3500	NA
2-Nitroaniline	µg/kg	1/309	308	1/309	2400-2400	2400.00	380	17000	NA
2-Nitrophenol	µg/kg	0/309	308	0/309			330	3500	NA
3,3'-Dichlorobenzidine	µg/kg	0/311	310	0/311			340	210000	NA
3-Nitroaniline	None	0/304	303	0/304			820	17000	NA
4,6-Dinitro-2-methylphenol	µg/kg	0/308	307	0/308			820	17000	NA
4-Bromophenyl phenyl ether	µg/kg	0/308	307	0/308			330	3500	NA
4-Chloro-3-methylphenol	µg/kg	4/309	308	4/309	43.0-88.0	57.0	330	3500	NA

TABLE 4-15 (Continued)

Parameter	Units	Summary of Positive/Nonpositive Detections							95% Background Value
		Frequency of Detection	Total Validated Samples	Freq. of Detection Above Bkgd.	Range of Positive Detections	Average of Positive Detections	Minimum Nondetect	Maximum Nondetect	
4-Chlorophenylphenyl ether	µg/kg	0/308	307	0/308			330	3500	NA
4-Methylphenol	µg/kg	1/309	308	1/309	110-110	110	330	3500	NA
4-Nitroaniline	µg/kg	0/300	300	0/300			820	17000	NA
4-Nitrophenol	µg/kg	4/307	306	4/307	58.0-330	148	820	17000	NA
Acenaphthene	µg/kg	2/308	307	2/308	77.0-250	163	330	3500	NA
Acenaphthylene	µg/kg	3/309	308	3/309	780-2100	1390	330	2100	NA
Anthracene	µg/kg	7/312	311	7/312	51.0-1400	531	330	100000	NA
Benzo(a)anthracene	µg/kg	20/312	311	20/312	38.0-17000	2450	330	2100	NA
Benzo(a)pyrene	µg/kg	13/311	310	13/311	63.0-8600	2010	330	100000	NA
Benzo(b)fluoranthene	µg/kg	17/312	311	17/312	39.0-23000	4610	45.0	2100	NA
Benzo(g,h,i)perylene	µg/kg	9/312	311	9/312	53.0-5900	1620	330	100000	NA
Benzo(k)fluoranthene	µg/kg	5/312	311	5/312	98.0-280	188	38.0	100000	NA
Benzoic acid	µg/kg	8/289	288	8/289	46.0-200	89.5	380	17000	NA
Benzyl alcohol	µg/kg	0/290	289	0/290			330	3500	NA
Bis(2-chloroethoxy)methane	µg/kg	0/309	308	0/309			330	3500	NA
Bis(2-chloroethyl)ether	µg/kg	0/309	308	0/309			330	3500	NA
Bis(2-chloroisopropyl)ether	µg/kg	0/275	274	0/275			330	3500	NA
Bis(2-ethylhexyl)phthalate	µg/kg	100/309	308	100/309	3.00-9100	871	330	100000	NA
Butyl benzyl phthalate	µg/kg	5/311	310	5/311	46.0-430	237	330	100000	NA
Carbazole	µg/kg	0/105	105	0/105			340	470	NA
Chrysene	µg/kg	19/312	311	19/312	47.0-17000	2440	330	2100	NA
Di-n-butyl phthalate	µg/kg	17/312	311	17/312	37.0-1400	229	51.0	100000	NA
Di-n-octyl phthalate	µg/kg	3/312	311	3/312	50.0-280	129	330	100000	NA
Dibenzo(a,h)anthracene	µg/kg	6/311	310	6/311	42.0-1100	537	330	100000	NA
Dibenzofuran	µg/kg	3/308	307	3/308	36.0-120	74.3	330	3500	NA
Diethyl phthalate	µg/kg	7/308	307	7/308	43.0-250	121	330	3500	NA
Dimethyl phthalate	µg/kg	0/309	308	0/309			330	3500	NA
Fluoranthene	µg/kg	32/312	311	32/312	40.0-34000	3010	330	2100	NA
Fluorene	µg/kg	2/307	306	2/307	77.0-370	223	330	3500	NA
Hexachlorobenzene	µg/kg	0/312	307	0/312			330	3500	NA
Hexachlorobutadiene	µg/kg	1/313	308	1/313	350-350	350	330	3500	NA

TABLE 4-15 (Continued)

Parameter	Units	Summary of Positive/Nonpositive Detections							95% Background Value
		Frequency of Detection	Total Validated Samples	Freq. of Detection Above Bkgd.	Range of Positive Detections	Average of Positive Detections	Minimum Nondetect	Maximum Nondetect	
Hexachlorocyclopentadiene	µg/kg	0/306	305	0/306			330	3500	NA
Hexachloroethane	µg/kg	0/313	308	0/313			330	3500	NA
Indeno(1,2,3-cd)pyrene	µg/kg	11/312	311	11/312	78.0-4900	1148	330	100000	NA
Isophorone	µg/kg	0/309	308	0/309			330	3500	NA
N-Nitroso-di-n-propylamine	µg/kg	1/301	300	1/301	190-190	190.00	330	3500	NA
N-Nitrosodimethylamine	µg/kg	1/2	2	1/2	5.00-5.00	5.00	420	420	NA
N-Nitrosodiphenylamine	µg/kg	1/308	307	1/308	72.0-72.0	72.0	330	3500	NA
Naphthalene	µg/kg	3/309	308	3/309	52.0-120	75.3	330	3500	NA
Nitrobenzene	µg/kg	0/303	298	0/303			330	3500	NA
P-Chloroaniline	µg/kg	0/304	303	0/304			330	3500	NA
Pentachlorophenol	µg/kg	4/312	307	4/312	49.0-260	122	820	17000	NA
Phenanthrene	µg/kg	29/312	311	29/312	39.0-18000	1550	88.0	2100	NA
Phenol	µg/kg	8/309	308	8/309	38.0-710	194	330	3500	NA
Pyrene	µg/kg	36/312	311	36/312	43.0-30000	2560	330	2100	NA
Pyridine	µg/kg	0/5	1	0/5			370	2000	NA
Total methylphenol	µg/kg	0/1	1	0/1			370	370	NA
Tributyl phosphate	µg/kg	0/19	19	0/19			350	480	NA
PESTICIDES									
4,4'-DDD	µg/kg	0/252	246	0/252			3.40	700	NA
4,4'-DDE	µg/kg	0/252	246	0/252			3.40	700	NA
4,4'-DDT	µg/kg	0/253	246	0/253			3.40	700	NA
Aldrin	µg/kg	0/252	246	0/252			1.70	350	NA
Alpha-BHC	µg/kg	1/253	246	1/253	17.0-17.0	17.0	1.70	350	NA
Alpha-Chlordane	µg/kg	0/253	246	0/253			1.70	3500	NA
Aroclor-1016	µg/kg	0/254	248	0/254			34.0	3500	NA
Aroclor-1221	µg/kg	0/253	247	0/253			68.0	3500	NA
Aroclor-1232	µg/kg	0/253	248	0/253			34.0	3500	NA
Aroclor-1242	µg/kg	0/253	248	0/253			34.0	3500	NA
Aroclor-1248	µg/kg	1/253	248	1/253	110-110	110	34.0	3500	NA
Aroclor-1254	µg/kg	23/254	247	23/254	9.90-1700	324	18.0	4300	NA

TABLE 4-15 (Continued)

Parameter	Units	Summary of Positive/Nonpositive Detections							95% Background Value
		Frequency of Detection	Total Validated Samples	Freq. of Detection Above Bkgd.	Range of Positive Detections	Average of Positive Detections	Minimum Nondetect	Maximum Nondetect	
Aroclor-1260	µg/kg	5/254	247	5/254	10.0-2700	972	34.0	7000	NA
Beta-BHC	µg/kg	0/253	246	0/253			1.70	350	NA
Delta-BHC	µg/kg	0/252	246	0/252			1.70	350	NA
Dieldrin	µg/kg	0/252	246	0/252			3.40	700	NA
Endosulfan II	µg/kg	0/253	246	0/253			3.40	700	NA
Endosulfan Sulfate	µg/kg	0/253	245	0/253			3.40	700	NA
Endosulfan I	µg/kg	1/252	246	1/252	1.90-1.90	1.90	1.70	350	NA
Endrin	µg/kg	0/252	246	0/252			3.40	700	NA
Endrin Aldehyde	µg/kg	1/104	100	1/104	5.00-5.00	5.00	3.40	97.0	NA
Endrin Ketone	µg/kg	0/252	246	0/252			3.40	700	NA
Gamma-BHC (Lindane)	µg/kg	0/252	246	0/252			1.70	350	NA
Gamma-Chlordane	µg/kg	0/253	246	0/253			1.70	3500	NA
Heptachlor	µg/kg	0/252	246	0/252			1.70	350	NA
Heptachlor Epoxide	µg/kg	0/253	246	0/253			1.70	350	NA
Methoxychlor	µg/kg	1/252	246	1/252	22.0-22.0	22.0	17.0	3500	NA
Sulfotep	µg/kg	0/1	1	0/1			50.0	50.0	NA
Toxaphene	µg/kg	0/252	247	0/252			160	7000	NA
DIOXINS/FURANS									
1,2,3,4,6,7,8-Heptachloro-dibenzo-p-dioxin	ng/g	0/6	6	0/6			960	1000	NA
1,2,3,4,6,7,8-Heptachloro-dibenzofuran	ng/g	0/6	6	0/6			960	1000	NA
1,2,3,4,7,8,9-Heptachloro-dibenzofuran	ng/g	0/6	6	0/6			960	1000	NA
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	ng/g	0/6	6	0/6			960	1000	NA
1,2,3,4,7,8-Hexachloro-dibenzofuran	ng/g	0/6	6	0/6			960	1000	NA
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	ng/g	0/6	6	0/6			960	1000	NA

TABLE 4-15 (Continued)

Parameter	Units	Summary of Positive/Nonpositive Detections							95% Background Value
		Frequency of Detection	Total Validated Samples	Freq. of Detection Above Bkgd.	Range of Positive Detections	Average of Positive Detections	Minimum Nondetect	Maximum Nondetect	
1,2,3,6,7,8-Hexachlorodibenzo-furan	ng/g	0/6	6	0/6			960	1000	NA
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	ng/g	0/6	6	0/6			960	1000	NA
1,2,3,7,8,9-Hexachlorodibenzo-furan	ng/g	0/6	6	0/6			960	1000	NA
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	ng/g	0/6	6	0/6			960	1000	NA
1,2,3,7,8-Pentachlorodibenzo-furan	ng/g	0/6	6	0/6			960	1000	NA
2,3,4,6,7,8-Hexachlorodibenzo-furan	ng/g	0/6	6	0/6			960	1000	NA
2,3,4,7,8-Pentachlorodibenzo-furan	ng/g	0/6	6	0/6			960	1000	NA
2,3,7,8-Tetrachlorodibenzo-p-dioxin	ng/g	0/10	10	0/10			71.0	1000	NA
2,3,7,8-Tetrachlorodibenzo-furan	ng/g	0/6	6	0/6			960	1000	NA
Heptachlorodibenzo-p-dioxins	ng/g	0/6	6	0/6			960	1000	NA
Heptachlorodibenzofurans	ng/g	0/6	6	0/6			960	1000	NA
Hexachlorodibenzo-p-dioxins	ng/g	0/6	6	0/6			960	1000	NA
Hexachlorodibenzofurans	ng/g	0/6	6	0/6			960	1000	NA
Octachlorodibenzo-p-dioxin	ng/g	0/6	6	0/6			960	1000	NA
Octachlorodibenzofuran	ng/g	1/6	6	1/6	1500-1500	1500	960	1000	NA
Pentachlorodibenzo-p-dioxins	ng/g	0/6	6	0/6			960	1000	NA
Pentachlorodibenzofurans	ng/g	0/6	6	0/6			960	1000	NA
Tetrachlorodibenzo-p-dioxins	ng/g	0/6	6	0/6			960	1000	NA
Tetrachlorodibenzofurans	ng/g	0/6	6	0/6			960	1000	NA
ORGANOPHOSPHORUS PESTICIDES									
Azinphosmethyl	µg/kg	0/6	6	0/6			81.0	82.0	NA
Demeton	µg/kg	0/6	6	0/6			65.0	66.0	NA
Diazinon	µg/kg	0/6	6	0/6			32.0	33.0	NA

TABLE 4-15 (Continued)

Parameter	Units	Summary of Positive/Nonpositive Detections							95% Background Value
		Frequency of Detection	Total Validated Samples	Freq. of Detection Above Bkgd.	Range of Positive Detections	Average of Positive Detections	Minimum Nondetect	Maximum Nondetect	
Dimethoate	µg/kg	0/1	1	0/1			50.0	50.0	NA
Disulfoton	µg/kg	0/7	7	0/7			32.0	50.0	NA
Ethion	µg/kg	0/6	6	0/6			32.0	33.0	NA
Famphur	µg/kg	0/1	1	0/1			100	100	NA
Malathion	µg/kg	0/6	6	0/6			32.0	33.0	NA
Methyl Parathion	µg/kg	0/7	7	0/7			32.0	50.0	NA
Parathion	µg/kg	0/7	7	0/7			32.0	50.0	NA
Phorate	µg/kg	0/1	1	0/1			50.0	50.0	NA
Thionazin	µg/kg	0/1	1	0/1			50.0	50.0	NA
GENERAL CHEMISTRY									
Total organic carbon	mg/kg	29/29	29	29/29	464-33200	8620			NA
Total petroleum hydrocarbons (TPH)	pCi/g	3/5	0	3/5	1270-23600	9010	10.0	10.0	NA

TABLE 4-16
SITEWIDE
PARAMETER OCCURRENCES BY DEPTH

RADIONUCLIDES (pCi/g)

Depth Interval, Feet	Number of Samples	Uranium-238	Total Uranium	Uranium-234	Thorium-230	Radium-226	Uranium-235/236	Thorium-232	Total Thorium	Radium-228	Thorium-228	Neptunium-237	Plutonium-239/240	Plutonium-238	Strontium-90	Technetium-99	Ruthenium-106	Cesium-137
Surface Soil:																		
95 % Background Value		1.24	3.73 ug/g	1.24	1.97	1.42	0.156	1.36	12.4	1.25	1.43	NA	NA	NA	0.424	ND	NA	0.711
0 - 1.5	895											X	X	X		X	X	
0.5 - 1	140											X	X	X		X	-	●
1 - 1.5	163											-	X	X		X	-	●
Subsurface Soil:																		
95 % Background Value		1.12	3.69 ug/g	1.04	1.91	1.47	0.150	1.26	11.1 ug/g	1.31	1.39	NA	NA	NA	0.436	ND	ND	ND
1.5 - 3	135					●		●			◐	-	X	X		X	-	X
3 - 5	99				●			●		●	◐	-	X	-		X	-	X
5 - 10	213											X	X	X		X	-	X
10 - 15	162					●		●	●	●	●	-	X	X		X	-	X
15 - 20	105					●		●	●	●	●	-	X	-	●	X	-	X

INORGANICS (mg/kg)

Depth Interval, Feet	Number of Samples	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Cyanide	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium	Silicon	Silver	Sodium	Thallium	Vanadium	Zinc
Surface Soil:																											
95 % Background Value		11,900	ND	8.2	96.7	0.60	0.87	4340	15.5	14.2	14.1	0.27	21,700	26.4	2780	1350	0.30	ND	20.9	1230	0.72	1800	ND	51.1	0.58	30.4	69.6
0 - 1.5	267	●	X	●						◐			◐			◐		X	●	◐		◐	X		●	●	
0.5 - 1	78	●	-			◐			◐	◐	◐		●			●	◐	X	●	◐		●	X		●	●	
1 - 1.5	66	◐	-	●	◐				●	●	◐	◐	●	◐		◐	◐	X	◐	◐	◐	●	X		○	●	
Subsurface Soil:																											
95 % Background Value		16,100	ND	9.57	119	0.62	0.91	150,000	20.7	15.7	20	0.17	30,700	16.6	42,600	1300	0.29	2.70	34.3	1980	ND	1590	ND	285	0.49	37.8	82
1.5 - 3	109	●	-	●	◐	◐		●	◐	●	◐		●	◐	●	◐		◐	●	●	X	●	X	◐	●	●	◐
3 - 5	79		X	◐	●	◐		●	●	●	●		◐	◐	●	●	○	◐	●	●	X	○	X	◐	●	●	
5 - 10	213		X					◐				◐			◐		○	◐			X	◐	X		○		
10 - 15	162	○	X	○		◐		●	●	●	●		○	●	●	○	○	●	●	●	X	○	X		○	○	◐
15 - 20	105	○	-	○	○			●	●	○	○	-	○	●	○	○	-	○	○	○	-	○	X	○	○	○	◐

ND - Not detected in background study.

NA - Not analyzed in background study.

"Blank" - Not analyzed.

- Analyzed and not detected.

○ Detection less than 95 percentile background concentration.

● Detection above but < 2X of 95 percentile background concentration.

◐ Detection 2X to 5X 95 percentile background concentration.

■ Detection greater than 5X 95 percentile background concentration.

X Detection where background level not recorded.

PDHOUS-DUD-010-94-7/June 21, 1994 2:12pm

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TABLE 4-16
(Continued)

Depth Interval, Feet	Number of Samples	VOLATILES (ug/kg)																												
		1,1,-Dichloroethane	1,1,1-Trichloroethane	1,1,2,2-Tetrachloroethane	1,1,2-Trichloroethane	1,1-Dichloroethene	1,2-Dichloroethane	1,2-Dichloroethene (Total)	2-Butanone	2-Hexanone	4-Methyl-2-pentanone	Acetone	Benzene	Bromodichloromethane	Bromomethane	Carbon disulfide	Carbon tetrachloride	Chlorobenzene	Chloroethane	Chloroform	Dibromochloromethane	Ethylbenzene	Methylene chloride	Styrene	Tetrachloroethene	Toluene	Total Xylenes	Trans-1,3-Dichloropropene	Trichloroethene	Vinyl chloride
Surface Soil:																														
0 - 0.5	204	X	X	-	-	X	-	X	X	X	X	X	X	-	X	X	X	X	-	X	-	X	X	X	X	X	X	-	X	-
0.5 - 1	65	X	X	X	X	X	X	X	X	X	X	X	X	-	-	X	-	X	-	X	-	X	X	-	X	X	X	-	X	-
1 - 1.5	60	-	X	-	-	-	-	X	X	-	X	X	-	-	-	X	-	-	-	X	-	-	X	-	X	X	X	-	X	-
Subsurface Soil:																														
1.5 - 3	200	X	X	X	X	X	-	X	X	X	X	X	X	X	-	X	X	X	-	X	-	X	X	X	X	X	X	-	X	X
3 - 5	57	X	X	X	X	X	X	X	X	X	X	X	X	-	-	X	-	-	X	X	X	X	X	-	X	X	X	X	X	X
5 - 10	90	X	X	X	X	X	X	X	X	X	X	X	-	X	-	X	-	-	-	X	-	X	X	-	X	X	X	-	X	X
10 - 15	31	X	X	X	-	X	X	X	-	X	X	X	-	-	-	X	-	-	-	-	-	-	X	-	X	X	X	-	X	X
15 - 20	20	-	X	-	-	-	-	-	X	-	X	X	-	-	-	X	-	-	-	X	-	X	X	-	X	X	X	-	X	-

[ ] "Blank" - Compound was not analyzed.

[X] Detected.

[-] Analyzed for and not detected.

TABLE 4-16
(Continued)

Depth Interval, Feet	Number of Samples	1,2,4-Trichlorobenzene	1,4-Dichlorobenzene	2,4-Dichlorophenol	2,4-Dimenthylphenol	2,4-Dinitrotoluene	2,6-Dinitrotoluene	2-Chlorophenol	2-Methylnaphthalene	2-Methylphenol	2-Nitroaniline	3,3-Dichlorobenzidine	4-Chloro-3-methylphenol	4-Methylphenol	4-Nitroaniline	4-Nitrophenol	Acenaphthene	Acenaphthylene	Anthracene	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Benzoic acid	Benzyl alcohol	bis(2-Chloroisopropyl)ether	Bis(2-ethylhexyl)phthalate	Butyl benzyl phthalate	Carbazole	Chrysene	Di-n-butyl phthalate	Di-n-octyl phthalate	Dibenzo(a,h)anthracene	Dibenzofuran	Diethyl phthalate	Fluoranthene	Fluorene	Hexachlorobutadiene	Idenol(1,2,3-cd)pyrene	Isophorone	N-Nitroso-di-n-propylamine	N-Nitrosodimethylamine	N-Nitrosodiphenylamine	Naphthalene	Pentachlorophenol	Phenanthrene	Phenol	Pyrene	Tributyl phosphate
SEMIVOLATILES (ug/kg)																																																			
Surface Soil:																																																			
0 - 0.5	186	-	-	X	X	X	-	X	X	X	-	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-	X	X	-	X	X	X		X	X	-	X	X	X	X
0.5 - 1	70	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	X	-	X	X	X	X	X	X	X	-	-	X	X	-	X	X	-	X	X	X	X	X	X	X	X	-	-		X	X	-	X	X	X	X
1 - 1.5	62	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	X	-	X	X	X	X	X	X	-	-	-	X	-	X	X	X	-	-	-	X	X	X	-	X	-	-		-	X	-	X	X	X	
Subsurface Soil:																																																			
1.5 - 3	141	X	X	-	X	X	-	X	X	-	X	-	X	X	-	X	X	X	X	X	X	X	X	X	X	-	-	X	X	-	X	X	X	X	X	X	X	X	X	X	-	X		X	X	X	X	X	X	-
3 - 5	62	-	-	-	-	-	-	-	X	-	-	-	X	-	-	X	-	-	-	X	-	-	-	-	X	-	-	X	X	-	-	X	X	-	-	X	X	-	-	-	-	-		-	-	X	X	X	X	
5 - 10	63	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	-	X	X	-	-	X	-	-	X	X	-	-	-	X	X	-	-	X	-	-	X	-	-	-	X	X	X	-
10 - 15	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	X	-	-	-	X	-	-	-	-	X	-	-	-	-	-		-	-	-	X	-	X	
15 - 20	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	

[ ] "Blank" - Compound was not analyzed.

[-] Analyzed for and not detected.

[X] Detected.

TABLE 4-16
(Continued)

Depth Interval, Feet	PESTICIDES/PCBs (ug/kg)																		DIOXINS/FURANS							
	Number of Samples	4,4'-DDE	4,4'-DDT	Aldrin	Alpha-BHC	Alpha-chlordane	Aroclor-1248	Aroclor-1254	Aroclor-1260	Beta-BHC	Dieldrin	Endosulfan I	Endosulfan II	Endosulfan sulfate	Endrin	Endrin aldehyde	Heptachlor epoxide	Methoxychlor	Number of Samples	Heptachlorodibenzofurans	Octachlorodibenzo-P-Dioxin	Octachlorodibenzofuran				
Surface Soil:																										
0 - 0.5	180	X	X	X	-	X	-	X	X	X	X	-	X	X	X	-	X	X	4	X	X	X				
0.5 - 1	59	-	-	-	-	-	-	X	X	X	-	-	-	-	-	-	-	-	2	-	-	X				
1 - 1.5	51	-	-	-	-	-	-	X	-	-	-	-	-	-	-	X	-	-								
Subsurface Soil:																										
1.5 - 3	92	-	-	-	X	-	-	X	X	-	-	X	-	-	-	X	-	-	6	-	-	X				
3 - 5	49	-	-	-	-	-	X	X	X	-	-	-	-	-	-	-	-	-								
5 - 10	59	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-								
10 - 15	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-								
15 - 20	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X								

"Blank" - Compound was not analyzed.

- Analyzed for and not detected.

X Detected

TABLE 4-17
TOTAL URANIUM

Depth Interval, Feet	Plant 1 Area	Plant 2/3 Area	Plant 4/5/7 Area	Plant 6 Area	Plant 8 Area	Plant 9 Area	Sewage Treatment Plant Area	Pilot Plant Area	Laboratory Area	Administration Area	Electrical Substation Area	Maintenance Building	Tank Farm and Boiler House	D&D Building and Drum Baling Area	Scrap Metal Pile & Decontamination Building	Graphite Furnace, Oil Burner, and Coal Pile Area	KC-2 Warehouse Area	Fire Training Area	Trap Range	Area West of K-65 Silos	K-65/Clearwell Line (West of Production Area)	Clearwell Line (East of Production Area)	Outfall Pipeline	Great Miami Riverbank Characterization	Southwest Field Area	Northeastern Area of FEMP	Southern Area of FEMP	Western Area of FEMP	Northwestern Area of FEMP	Area Outside of FEMP Adjacent to Boundary	Area 2-5 Miles Outside of FEMP Boundary
Surface Soil:	Background - 3.73 mg/kg																														
0 - 0.5	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	□	◉	■	■	■	■	■	●
0.5 - 1	■	■	-	■	□	■	■	■	■	■	□	■	□	■	■	■	-	■	□	■	■	□	■	□	●	■	■	■	●	□	●
1 - 1.5	■	■	■	■	■	■	■	■	■	■	□	●	◉	■	■	■	□	■	□	■	■	□	■	■	●	■	■	■	●	◉	□
Subsurface Soil:	Background - 3.69 mg/kg																														
1.5 - 3	■	■	■	■	■	■	■	■	■	■	□	■	◉	■	■	■	□	■	□	■	■	◉	□	■	●	■	◉	■	●	●	□
3 - 5	■	■	□	■	■	■	■	■	●	●	□	●	□	■	■	■	-	◉	□	■	■	□	●	■	□	●	●	■	●	■	□
5 - 10	■	■	■	■	■	■	■	■	■	■	□	●	●	■	●	■	-	●	O	■	■	●	●	●	●	●	●	■	●	●	□
10 - 15	■	■	■	■	■	■	■	■	■	●	□	●	●	■	■	■	-	●	-	●	●	●	■	●	●	●	●	●	●	●	□
15 - 20	■	■	□	■	■	■	■	■	■	◉	□	●	●	●	●	■	□	◉	□	●	■	●	□	□	●	◉	●	●	●	◉	□

- □ "Blank" - Not analyzed.
- - Analyzed and not detected.
- O Detection less than 95th percentile background value.
- ● Detection above but < 2 X 95th percentile background value.
- ◉ Detection 2 to 5 X 95th percentile background value.
- ■ Detection greater than 5 X 95th percentile background value.
- X Detection where background level not recorded.

TABLE 4-18
TOTAL URANIUM DETECTIONS BY AREA
MINIMUM - MAXIMUM (mg/kg)

LOCATION	DEPTH INTERVAL							
	SURFACE SOIL (Background - 3.73 mg/kg)			SUBSURFACE SOIL (Background - 3.69 mg/kg)				
	0.0 - 0.5 ft.	0.5 - 1.0 ft.	1.0 - 1.5 ft.	1.5 - 3.0 ft.	3.0 - 5.0 ft.	5.0 - 10.0 ft.	10.0 15.0 ft.	15.0 - 20.0 ft.
PLANT 1 AREA	1.74- 12336.91	2.20- 6140.00	7.14- 1050.00	1.11- 121.00	2.10- 91.00	2.30- 73.00	2.34- 22.00	2.90- 68.00
PLANT 2/3 AREA	6.90- 5685.00	6.14- 225.00	2.80- 1916.00	2.50- 558.00	7.20- 285.00	4.15- 711.00	2.50- 467.00	2.65- 735.00
PLANT 4/5/7 AREA	10.10- 652.00	ND	3.60- 407.00	7.26- 83.70	14.00- 191.00	3.00- 64.00	3.73- 29.00	67.00- 68.00
PLANT 6 AREA	3.70-90350.00	3.25- 1416.00	2.30- 8059.00	1.99- 54000.00	2.80-69300.00	1.74- 4763.00	4.22- 266.00	2.18- 479.00
PLANT 8 AREA	2.40- 541.00	-	2.00- 255.00	1.70- 349.00	3.17- 158.00	3.50- 386.00	1.98- 328.00	3.20- 136.00
PLANT 9 AREA	1.40- 217.00	17.63- 209.00	2.10- 3504.00	2.40- 354.00	1.55- 260.00	2.26- 292.00	2.00- 79.00	2.00- 115.40
SEWAGE TREATMENT PLANT	7.26- 7572.00	9.80- 2240.00	3.60- 976.00	2.70- 310.00	7.00- 58.00	9.00- 69.60	4.68- 214.00	3.28- 37.89
PILOT PLANT AREA	6.00- 242.00	34.30- 74.50	3.00- 47.00	2.80- 637.00	3.10- 170.00	2.05- 703.00	5.72- 629.00	2.49- 102.90
LABORATORY AREA	2.00- 43118.55	125.00- 1260.00	3.20- 3250.00	3.31- 72.00	2.00- 11.00	4.30- 21.10	3.00- 11.30	2.10- 30.00
ADMINISTRATION AREA	5 80- 297 00	21.00- 80.00	1.50- 43.00	1.40- 78.00	16.00- 16.00	0.70- 23.00	3.09- 15.00	11.00- 17.00
ELECTRICAL SUBSTATION AREA	14.00- 28.30	-	-	ND	-	ND	ND	ND
MAINTENANCE BUILDING AREA	4.30- 330.00	53.00- 70.10	3.10- 4.38	2.03- 136.60	10.30- 11.80	2.10- 7.31	2.40- 6.24	2.30- 5.36
TANK FARM AND BOILER HOUSE AREA	7.49- 53 30	-	13.10- 13.10	11.00- 11.00	-	4.00- 11.00	-	4.10- 4.10
D&D BUILDING AND DRUM BALING AREA	8 00- 3890.00	31.00- 1780 00	5.20- 668.31	1.60- 22.00	1.70- 190.00	27.00- 265.00	19.00- 174.00	6.00- 6.00
SCRAP METAL PILE	12.00- 21423.94	30.00- 2270.00	5.73- 962.00	13.00- 62.00	3.80- 51.00	4.22- 7.71	4.07- 36.00	4.40- 12.00
GRAPHITE FURNACE AREA	12 00- 467 00	24.00- 98.00	2.90- 428.00	2.10- 57.70	2.40- 52.00	2.30- 37.00	3.65- 39.00	1.64- 19.00
KC-2 WAREHOUSE	80 50- 175 00	11.00- 11.00	-	-	ND	ND	ND	-
FIRE TRAINING AREA	9.90- 1170.00	32.00- 32.00	59.00- 59.00	7.07- 59.20	14.30- 14.30	6.53- 13.60	3.40- 6.41	8.25- 13.80
TRAP RANGE	8.00- 23.70	-	-	-	-	2.30- 2.30	ND	-
AREA WEST OF K-65 SILOS	28 80- 64 00	12.30- 20.60	7.40- 99.60	4.30- 58.30	2.60- 26.60	0.50- 20.70	8.60- 11.40	4.15- 4.15
K-65/CLEARWELL LINE WEST	9.83- 628.82	7.45- 204.43	7.45- 233.04	5.01- 116.00	11.00- 40.60	4.09- 45.70	11.00- 11.00	11.00- 83.81
CLEARWELL LINE EAST	11.00- 30.00	-	-	12.00- 13.00	-	2.69- 14.00	5.46- 13.51	4.22- 4.22
OUTFALL PIPELINE	3.30- 28.89	3.60- 54.00	3.00- 28.00	-	9.70- 12.25	6.92- 15.60	5.92- 31.21	-
GREAT MIAMI RIVERBANK CHARACTERIZATION	-	-	2.20- 53.00	2.70- 53.80	2.10- 24.10	1.30- 11.00	1.10- 11.00	-
SOUTHWEST FIELD AREA	1.00- 9.00	7.00- 7.00	7.00- 7.00	1.00- 6.00	-	1.00- 6.00	1.00- 6.00	1.00- 5.00
NORTHEAST AREA OF FEMP	1.40- 5533.31	9.00- 893.00	3.70- 1100.00	3.70- 16.00	2.50- 14.00	2.40- 6.00	2.00- 6.00	2.66- 11.00
SOUTHERN AREA OF FEMP	1.50- 66.29	6.00- 443.58	1.53- 31.57	2.10- 11.00	1.80- 11.00	1.00- 11.00	1.44- 11.00	1.54- 16.00
WESTERN AREA OF FEMP	1.00- 2115.80	9.54- 806.00	2.60- 1790.00	2.00- 27.71	1.99- 22.00	2.00- 24.60	1.00- 17.00	2.00- 11.00
NORTHWESTERN AREA OF FEMP	3.00- 52.82	5.00- 7.00	5.00- 6.00	6.00- 7.00	4.00- 6.00	2.96- 4.00	2.24- 5.00	2.66- 6.00
AREA OUTSIDE OF FEMP ADJACENT TO BOUNDARY	1.21- 46 712	-	2.98- 12.00	2.55- 7.35	3.00- 11.50	1.27- 4.85	2.00- 3.94	1.00- 6.00
AREA 2-5 MILES OUTSIDE OF FEMP BOUNDARY	1.55- 5.13	-	4.72- 4.72	-	-	-	-	-

ND - NOT DETECTED

TABLE 4-19
RADIUM-226

Depth Interval, Feet	Plant 1 Area	Plant 2/3 Area	Plant 4/5/7 Area	Plant 6 Area	Plant 8 Area	Plant 9 Area	Sewage Treatment Plant Area	Pilot Plant Area	Laboratory Area	Administration Area	Electrical Substation Area	Maintenance Building	Tank Farm and Boiler House	D&D Building and Drum Baling Area	Scrap Metal Pile & Decontamination Building	Graphite Furnace, Oil Burner, and Coal Pile Area	KC-2 Warehouse Area	Fire Training Area	Trap Range	Area West of K-65 Silos	K-65/Clearwell Line (West of Production Area)	Clearwell Line (East of Production Area)	Outfall Pipeline	Great Miami Riverbank Characterization	Southwest Field Area	Northeastern Area of FEMP	Southern Area of FEMP	Western Area of FEMP	Northwestern Area of FEMP	Area Outside of FEMP Adjacent to Boundary	Area 2-5 Miles Outside of FEMP Boundary
Surface Soil: Background - 1.42 pCi/g																															
0 - 0.5	■	■	○	●	●	○	■	■	●	●	○	○	○	■	■	●		○	○	■	■		○			●	■	■	○	●	
0.5 - 1	■	●		○		○	■	■	●	●		○		●	●	●		○		■	■					○		■			
1 - 1.5	■	■	○	○	○	○	●	○	●	○		○	-	■	○	○		○		■	■			○		○	○	●		○	
Subsurface Soil: Background - 1.47 pCi/g																															
1.5 - 3	○	●	○	○	-	○	●	○	●	●		○			●	○				●	●			-		○	○	●		○	
3 - 6			○	○	-	○	○	●	-						○	○				■	○			○		○	○	○		○	
6 - 10	○	○	○	○	○	○	-	●	○	●		●			○	○			-	■	●	○	○	-		○	○	○		○	
10 - 15	○	●		○	○	○	○	○	○	○		○			○				○	-	○	○	○	○		○	○	○	○	●	
15 - 20	○	●		○		○	○					○								○	○					○	○	○	○	○	

- "Blank" - Not analyzed.
- - Analyzed and not detected.
- ○ Detection less than 95th percentile background value.
- ● Detection above but < 2 X 95th percentile background value.
- ● Detection 2 to 5 X 95th percentile background value.
- ■ Detection greater than 5 X 95th percentile background value.
- X Detection where background level not recorded.

TABLE 4-20
RADIUM-226 DETECTIONS BY AREA
MINIMUM - MAXIMUM (pCi/g)

LOCATION	DEPTH INTERVAL							
	SURFACE SOIL (Background - 1.42 pCi/g)			SUBSURFACE SOIL (Background - 1.47 pCi/g)				
	0.0 - 0.5 ft.	0.5 - 1.0 ft.	1.0 - 1.5 ft.	1.5 - 3.0 ft.	3.0 - 5.0 ft.	5.0 - 10.0 ft.	10.0 15.0 ft.	15.0 - 20.0 ft.
PLANT 1 AREA	0.42- 2720.00	0.69- 2630.00	0.60- 383.00	0.30- 1.45	-	0.70- 1.10	1.00- 1.00	0.60- 0.60
PLANT 2/3 AREA	0.30- 16.60	0.70- 4.90	0.30- 18.80	0.40- 3.91	-	0.30- 1.30	0.60- 2.44	3.17- 3.17
PLANT 4/5/7 AREA	0.68- 1.30	-	0.50- 1.40	1.10- 1.10	1.47- 1.47	0.80- 1.10	-	-
PLANT 6 AREA	0.40- 1.80	0.91- 0.91	0.50- 1.20	0.30- 1.35	0.50- 1.00	0.37- 1.37	0.72- 0.96	0.59- 0.99
PLANT 8 AREA	0 45- 1.94	-	0.80- 0.80	ND	ND	0.40- 0.90	0.63- 0.63	-
PLANT 9 AREA	0.30- 1.20	0.46- 0.94	0.68- 0.84	0.50- 0.95	0.48- 0.85	0.50- 0.73	0.52- 0.80	0.40- 0.93
SEWAGE TREATMENT PLANT	0.73- 188.00	0.99- 12.40	0.89- 3.10	0.92- 1.65	1.21- 1.21	ND	0.98- 1.31	0.81- 1.11
PILOT PLANT AREA	0 30- 8 00	0.91- 7 32	0.30- 0.90	0.30- 1.07	3.05- 3.14	0.30- 5.91	0.30- 0.52	-
LABORATORY AREA	0 70- 2 60	0.90- 2 00	0.40- 1.60	0.30- 1.60	ND	0.50- 1.00	0.79- 0.92	-
ADMINISTRATION AREA	0 30- 2 60	0 80- 1 70	0 50- 1.20	2.00- 2.00	-	0.30- 1.60	0.93- 1.04	-
ELECTRICAL SUBSTATION AREA	0 83- 1 24	-	-	-	-	-	-	-
MAINTENANCE BUILDING AREA	0.80- 1 20	0.62- 0.80	0.70- 1.30	1.20- 1.20	-	0.70- 1.50	1.10- 1.10	1.00- 1.00
TANK FARM AND BOILER HOUSE AREA	0 40- 0 40	-	ND	-	-	-	-	-
D&D BUILDING AND DRUM BALING AREA	0 90- 9 58	0.60- 2 60	0.70- 9 80	-	-	-	-	-
SCRAP METAL PILE	0 90- 2950 00	1 10- 1 70	0 40- 1.30	0.90- 1.70	0.52- 0.52	0.70- 0.70	0.66- 0.66	-
GRAPHITE FURNACE AREA	0 50- 1 80	0 80- 1 50	0.40- 1.30	0.40- 0.90	0.30- 0.50	0.30- 0.30	-	-
KC-2 WAREHOUSE	1 56- 3 39	-	-	-	-	-	-	-
FIRE TRAINING AREA	0 40- 1 30	0.40- 0.40	0.50- 0.50	-	-	-	-	-
TRAP RANGE	0 50- 1 40	-	-	-	-	ND	0.51- 0.51	-
AREA WEST OF K-65 SILOS	2 30- 34 70	0 40- 75 10	0.50- 12.60	0.40- 4.60	0.30- 137.00	0.30- 11.00	ND	1.00- 1.00
K-65/CLEARWELL LINE WEST	0 40- 220 00	0 70- 75.90	0.60- 11.90	2.04- 3.70	0.59- 0.59	0.88- 5.93	0.60- 0.60	1.10- 1.10
CLEARWELL LINE EAST	-	-	-	-	-	0.76- 1.10	0.77- 0.96	-
OUTFALL PIPELINE	0 90- 0 90	-	-	-	-	0.66- 0.66	0.30- 0.78	-
GREAT MIAMI RIVERBANK CHARACTERIZATION	-	-	0.60- 0.90	ND	0.30- 0.30	0.30- 0.30	0.30- 0.30	-
NORTHEAST AREA OF FEMP	0.30- 2.30	0.80- 1.10	0.30- 1.20	0.30- 1.07	0.80- 0.80	0.50- 0.50	0.60- 0.60	0.72- 0.81
SOUTHERN AREA OF FEMP	0.30- 10 80	-	0.67- 1.40	1.00- 1.00	1.22- 1.22	0.39- 1.20	0.41- 0.88	0.43- 0.87
WESTERN AREA OF FEMP	0.30- 51.20	0.50- 14.90	0.30- 1.60	0.30- 3.30	0.30- 1.10	0.70- 1.18	0.70- 0.90	0.69- 0.75
NORTHWESTERN AREA OF FEMP	0.60- 1.20	-	-	-	-	-	0.80- 0.81	0.70- 0.89
AREA OUTSIDE OF FEMP ADJACENT TO BOUNDARY	0.30- 1.90	-	0.70- 1.25	0.76- 1.22	0.76- 1.36	0.44- 1.40	0.39- 6.59	0.30- 0.80

ND - NOT DETECTED

TABLE 4-21
TOTAL THORIUM

Depth Interval, Feet	Plant 1 Area	Plant 2/3 Area	Plant 4/5/7 Area	Plant 6 Area	Plant 8 Area	Plant 9 Area	Sewage Treatment Plant Area	Pilot Plant Area	Laboratory Area	Administration Area	Electrical Substation Area	Maintenance Building	Tank Farm and Boiler House	D&D Building and Drum Baling Area	Scrap Metal Pile & Decontamination Building	Graphite Furnace, Oil Burner, and Coal Pile Area	KC-2 Warehouse Area	Fire Training Area	Trap Range	Area West of K-65 Silos	K-65/Clearwell Line (West of Production Area)	Clearwell Line (East of Production Area)	Outfall Pipeline	Great Miami Riverbank Characterization	Southwest Field Area	Northeastern Area of FEMP	Southern Area of FEMP	Western Area of FEMP	Northwestern Area of FEMP	Area Outside of FEMP Adjacent to Boundary	Area 2-5 Miles Outside of FEMP Boundary
Surface Soil: Background - 12.4 mg/kg																															
0 - 0.5	■	■	●	■	◉	■	■	■	■	●	○	●	●	■	■	◉	◉	■	○	●	■	●	◉			■	◉	■	●	●	
0.5 - 1	■	●	-	●		●	◉	●	■	○		●		●	■	●	-	○		○	■		◉			○	◉	●			
1 - 1.5	●	■	○	○	○	■	●	●	■	○		○	○	◉	○	●		○		○	◉		●	●		○	○	●		●	
Subsurface Soil: Background - 11.1 mg/kg																															
1.5 - 3	●	●	○	●	○	■	●	●	○	●		○	●	●	■	○		■		○	○	●	-	●		●	●	●		○	
3 - 5	●	●	●	○	○	●	●	■	○	●		○	○	-	■	◉	-	●		●	●		○	●		○	●	●		○	
5 - 10	●	●	●	●	●	●	●	■	○	●		○	●	●	●	○	●	■	○	●	●	○	○	●		●	●	●		○	
10 - 15	●	●		●	●	○	●	●	○	○		○	●	-	○	●	-	●	○	○	●	○	●	●		○	●	●	○	○	
15 - 20	●	●		●	○	●	○	●		○		○	○	-	○	○		○		○	●	○				○	○	●		●	

"Blank" - Not analyzed.

- Analyzed and not detected.

○ Detection less than 95th percentile background value.

● Detection above but < 2 X 95th percentile background value.

◉ Detection 2 to 5 X 95th percentile background value.

■ Detection greater than 5 X 95th percentile background value.

X Detection where background level not recorded.

TABLE 4-22
TOTAL THORIUM DETECTIONS BY AREA
MINIMUM - MAXIMUM (mg/kg)

LOCATION	DEPTH INTERVAL							
	SURFACE SOIL (Background - 12.4 mg/kg)			SUBSURFACE SOIL (Background - 11.1 mg/kg)				
	0.0 - 0.5 ft.	0.5 - 1.0 ft.	1.0 - 1.5 ft.	1.5 - 3.0 ft.	3.0 - 5.0 ft.	5.0 - 10.0 ft.	10.0 15.0 ft.	15.0 - 20.0 ft.
PLANT 1 AREA	1.01- 286.50	5.47- 171.60	3.65- 45.60	4.56- 50.20	5.47- 23.00	4.23- 23.00	3.90- 21.70	4.51- 25.00
PLANT 2/3 AREA	1.82- 88.00	2.74- 54.72	2.16- 62.20	4.56- 19.80	2.19- 13.50	3.79- 26.00	3.65- 36.00	4.58- 34.00
PLANT 4/5/7 AREA	5.47- 24.10	ND	2.74- 5.47	5.47- 5.47	12.30- 12.30	4.56- 23.00	ND	ND
PLANT 6 AREA	7.30- 92.10	2.44- 16.30	4.37- 10.94	1.18- 45.00	7.30- 9.12	1.72- 25.00	2.41- 23.00	4.28- 31.00
PLANT 8 AREA	1.82- 19.52	-	2.74- 9.79	4.93- 8.40	3.12- 9.79	4.56- 23.00	3.64- 24.00	6.79- 18.80
PLANT 9 AREA	3.65- 766.00	2.66- 43.00	4.44- 321.00	5.31- 66.00	3.23- 15.00	3.59- 28.00	2.47- 7.61	4.11- 28.50
SEWAGE TREATMENT PLANT	5.47- 564.57	5.02- 55.65	6.11- 12.77	5.47- 29.00	12.10- 12.10	7.52- 15.20	6.75- 24.00	8.21- 8.21
PILOT PLANT AREA	5.37- 184.00	9.94- 14.00	5.49- 48.00	1.23- 19.00	5.34- 83.00	2.74- 290.00	3.64- 28.60	6.21- 12.70
LABORATORY AREA	4.56- 2581.01	9.12- 523.50	2.98- 561.80	2.27- 9.12	3.65- 4.10	2.68- 5.47	1.82- 7.30	5.47- 5.47
ADMINISTRATION AREA	3.65- 19.00	7.30- 9.12	3.65- 10.94	0.91- 18.00	18.00- 18.00	4.51- 23.00	3.31- 8.93	5.30- 6.69
ELECTRICAL SUBSTATION AREA	4.75- 9.71	-	-	ND	-	ND	ND	ND
MAINTENANCE BUILDING AREA	4.56- 23.71	15.80- 15.80	3.65- 6.38	3.70- 5.47	4.52- 5.57	3.65- 5.47	3.36- 6.96	4.52- 8.27
TANK FARM AND BOILER HOUSE AREA	3.64- 18.00	-	6.38- 6.38	18.00- 18.00	3.86- 5.56	18.00- 18.00	-	4.62- 4.62
D&D BUILDING AND DRUM BALING AREA	9.12- 152.00	5.47- 17.33	5.47- 28.27	8.21- 18.00	ND	23.00- 23.00	ND	ND
SCRAP METAL PILE	8.46- 1769.29	-	6.38- 132.00	6.66- 69.00	1.65- 72.00	5.74- 12.80	1.85- 10.20	5.24- 9.05
GRAPHITE FURNACE AREA	3.65- 23.00	10.00- 13.68	3.65- 12.77	7.30- 10.94	1.82- 23.00	1.82- 9.12	18.00- 18.00	1.03- 8.37
KC-2 WAREHOUSE	ND	ND	-	-	ND	23.00- 23.00	ND	-
FIRE TRAINING AREA	3.00- 82.00	5.47- 5.47	5.47- 5.47	5.36- 136.00	10.00- 14.00	5.00- 78.00	3.00- 17.00	10.00- 10.00
TRAP RANGE	4.56- 9.42	-	-	-	-	1.95- 1.95	3.33- 3.33	-
AREA WEST OF K-65 SILOS	6.38- 12.77	2.74- 10.03	5.47- 10.03	2.74- 10.94	1.42- 11.86	0.91- 12.77	5.38- 7.30	6.38- 6.38
K-65/CLEARWELL LINE WEST	1.92- 364.80	2.74- 133.15	4.56- 46.51	8.81- 10.94	3.74- 18.00	6.40- 18.00	18.00- 18.00	7.30- 18.00
CLEARWELL LINE EAST	19.00- 19.00	-	-	18.00- 18.00	-	5.66- 8.89	4.36- 7.50	3.43- 3.43
OUTFALL PIPELINE	5.80- 25.00	3.20- 27.00	2.10- 24.00	ND	4.00- 7.00	2.00- 11.00	3.00- 12.00	-
GREAT MIAMI RIVERBANK CHARACTERIZATION	-	-	2.74- 18.00	4.56- 18.00	3.65- 18.00	2.74- 18.00	1.82- 18.00	-
NORTHEAST AREA OF FEMP	1.82- 954.35	7.30- 8.21	6.38- 10.94	5.00- 25.00	5.47- 5.47	6.38- 23.00	5.62- 6.38	4.56- 4.56
SOUTHERN AREA OF FEMP	1.64- 54.72	2.74- 12.47	1.69- 10.03	2.11- 18.00	1.80- 18.00	2.78- 18.00	1.26- 50.50	2.61- 5.67
WESTERN AREA OF FEMP	1.73- 346.56	2.74- 62.02	1.82- 34.66	4.56- 19.00	1.82- 11.86	5.07- 18.00	6.53- 18.00	4.64- 18.00
NORTHWESTERN AREA OF FEMP	5.47- 12.77	-	-	-	-	-	4.00- 6.56	-
AREA OUTSIDE OF FEMP ADJACENT TO BOUNDARY	3.65- 21.00	-	4.34- 12.77	3.34- 9.12	8.21- 9.97	1.63- 9.12	5.47- 7.30	1.01- 27.36

ND - NOT DETECTED

TABLE 4-23
ARSENIC

Depth Interval, Feet	Plant 1 Area	Plant 2/3 Area	Plant 4/5/7 Area	Plant 6 Area	Plant 8 Area	Plant 9 Area	Sewage Treatment Plant Area	Pilot Plant Area	Laboratory Area	Administration Area	Electrical Substation Area	Maintenance Building	Tank Farm and Boiler House	D&D Building and Drum Bailing Area	Scrap Metal Pile & Decontamination Building	Graphite Furnace, Oil Burner, and Coal Pile Area	KC-2 Warehouse Area	Fire Training Area	Trap Range	Area West of K-65 Silos	K-65/Clearwell Line (West of Production Area)	Clearwell Line (East of Production Area)	Outfall Pipeline	Great Miami Riverbank Characterization	Southwest Field Area	Northeastern Area of FEMP	Southern Area of FEMP	Western Area of FEMP	Northwestern Area of FEMP	Area Outside of FEMP Adjacent to Boundary	Area 2-5 Miles Outside of FEMP Boundary
Surface Soil; Background - 8.20 mg/kg																															
0 - 0.5	●	●	○	○	○	○	○	●	○	●		●	●	●	○	●	●	●	●	●	●					●	●	●	○	○	
0.5 - 1	●	●		●		○	○	○	○			●	●			■				●	●										
1 - 1.5	●	○	●	●	○	○	○	●	○	○		○	●		○	●				○						○		●			
Subsurface Soil; Background - 9.57 mg/kg																															
1.5 - 3	●	○	●	●	○	○	○	○	●	●		○	○	●	○	●		●		○						○		●			
3 - 5	○			○		○		●	○			○	○		○	●				●						○		○			
5 - 10	●	●	○	○	○	○		●	●	○		○				○				■	○					○					
10 - 15	○	○				○		○	○			○				○				○	○					○					
15 - 20	○					○		○	○			○														○		○			

- "Blank" - Not analyzed.
- - Analyzed and not detected.
- ○ Detection less than 95th percentile background value.
- ● Detection above but < 2 X 95th percentile background value.
- ● Detection 2 to 5 X 95th percentile background value.
- ■ Detection greater than 5 X 95th percentile background value.
- X Detection where background level not recorded.

TABLE 4-24
ARSENIC DETECTIONS BY AREA
MINIMUM - MAXIMUM (mg/kg)

LOCATION	DEPTH INTERVAL							
	SURFACE SOIL (Background - 8.20 mg/kg)			SUBSURFACE SOIL (Background - 9.57 mg/kg)				
	0.0 - 0.5 ft.	0.5 - 1.0 ft.	1.0 - 1.5 ft.	1.5 - 3.0 ft.	3.0 - 5.0 ft.	5.0 - 10.0 ft.	10.0 15.0 ft.	15.0 - 20.0 ft.
PLANT 1 AREA	2.30- 9.20	2.50- 13.70	3.60- 13.50	3.40- 14.40	4.00- 4.00	4.40- 18.70	3.10- 3.10	4.30- 4.30
PLANT 2/3 AREA	2.20- 12.00	5.90- 8.30	2.30- 7.50	3.10- 8.20	-	4.90- 17.30	2.30- 3.40	-
PLANT 4/5/7 AREA	5.70- 6.40	-	1.50- 9.60	11.30- 11.30	-	3.30- 5.50	-	-
PLANT 6 AREA	2.40- 7.40	1.80- 29.10	2.20- 12.20	3.90- 9.80	2.00- 4.60	2.60- 4.30	-	-
PLANT 8 AREA	0 77- 7.20	-	6.40- 6.40	1.40- 1.40	-	1.20- 3.80	-	-
PLANT 9 AREA	4.40- 4.40	6.20- 6.20	3.60- 5.40	4.20- 4.80	4.70- 4.70	3.60- 5.00	3.20- 3.20	2.90- 2.90
SEWAGE TREATMENT PLANT	4.20- 7.00	5.10- 5.10	6.40- 6.40	9.10- 9.10	-	-	-	-
PILOT PLANT AREA	1.50- 17.30	3.90- 6.70	2.60- 15.60	1.90- 7.10	4.00- 10.20	1.20- 14.90	2.40- 7.60	4.60- 4.60
LABORATORY AREA	5.60- 7.60	5.10- 5.10	4.70- 6.00	2.80- 17.20	4.10- 4.10	6.50- 9.80	5.70- 5.70	5.10- 5.10
ADMINISTRATION AREA	3 40- 11 60	-	4.80- 7.80	3.70- 16.30	-	4.40- 7.20	-	-
MAINTENANCE BUILDING AREA	2 30- 12 60	3.20- 9.10	3.60- 4.20	2.00- 8.20	2.50- 7.20	1.80- 6.60	2.50- 8.70	2.30- 2.30
TANK FARM AND BOILER HOUSE AREA	8.90- 8.90	22.30- 22.30	9.20- 9.20	7.20- 7.20	4.60- 4.60	-	-	-
D&D BUILDING AND DRUM BALING AREA	4.70- 9.50	-	-	13.50- 13.50	-	-	-	-
SCRAP METAL PILE	6 20- 8 00	-	3.30- 3.30	6.60- 6.60	4.10- 4.10	-	-	-
GRAPHITE FURNACE AREA	3 30- 23 10	3.70- 81.90	3.00- 14.00	0.03- 11.50	2.60- 15.00	2.80- 5.60	4.30- 4.30	-
KC-2 WAREHOUSE	3 10- 16 60	-	-	-	-	-	-	-
FIRE TRAINING AREA	2.10- 8.30	-	-	4.80- 10.00	-	-	-	-
TRAP RANGE	2.00- 25.30	-	-	-	-	-	-	-
AREA WEST OF K-65 SILOS	5 70- 9 00	6.60- 8.70	2.00- 6.80	3.70- 9.10	2.80- 34.30	3.10- 74.20	1.90- 3.90	-
K-65/CLEARWELL LINE WEST	6.00- 8.80	7.90- 8.80	-	-	-	8.50- 9.00	2.70- 2.70	-
NORTHEAST AREA OF FEMP	1.90- 13.50	-	4.60- 4.80	4.90- 8.60	4.30- 4.30	2.00- 3.60	2.80- 2.80	2.80- 2.80
SOUTHERN AREA OF FEMP	1.50- 8.70	-	-	-	-	-	-	-
WESTERN AREA OF FEMP	1.60- 32.50	-	3.30- 14.00	5.30- 10.60	5.40- 5.40	-	-	5.60- 5.60
NORTHWESTERN AREA OF FEMP	2.40- 6.00	-	-	-	-	-	-	-
AREA OUTSIDE OF FEMP ADJACENT TO BOUNDARY	1.90- 5.30	-	-	-	-	-	-	-

TABLE 4-25
BERYLLIUM

Depth Interval, Feet	Plant 1 Area	Plant 2/3 Area	Plant 4/5/7 Area	Plant 6 Area	Plant 8 Area	Plant 9 Area	Sewage Treatment Plant Area	Pilot Plant Area	Laboratory Area	Administration Area	Electrical Substation Area	Maintenance Building	Tank Farm and Boiler House	D&D Building and Drum Baling Area	Scrap Metal Pile & Decontamination Building	Graphite Furnace, Oil Burner, and Coal Pile Area	KC-2 Warehouse Area	Fire Training Area	Trap Range	Area West of K-65 Silos	K-65/Clearwell Line (West of Production Area)	Clearwell Line (East of Production Area)	Outfall Pipeline	Great Miami Riverbank Characterization	Southwest Field Area	Northeastern Area of FEMP	Southern Area of FEMP	Western Area of FEMP	Northwestern Area of FEMP	Area Outside of FEMP Adjacent to Boundary	Area 2-5 Miles Outside of FEMP Boundary
Surface Soil: Background - 0.6 mg/kg																															
0 - 0.5	●	●	-	●	●	○	●	●	●	●	●	●	-	●	●	●	●	●	●	●	●					■	●	●	●	●	
0.5 - 1	●	●		●		●	●	●	-			●	●			●				●	●										
1 - 1.5	●	■	●	●	■	●	●	●	●	●		●	-			-				●						●		●			
Subsurface Soil: Background - 0.62 mg/kg																															
1.5 - 3	●	●	-	●	●	●	●	●	●	●		●	●	○		●		○		●						●		-			
3 - 5	●			●		●		●	-			●	-			●				●						-		-			
5 - 10	●	●	■	-	●	○		●	-	●		●				●				■	●					●					
10 - 15	●	●				○		●	●			○				●				-	●					○					
15 - 20	■					○		●	●			○														○		●			

□ "Blank" - Not analyzed.

[-] Analyzed and not detected.

[○] Detection less than 95th percentile background value.

[●] Detection above but < 2 X 95th percentile background value.

[●] Detection 2 to 5 X 95th percentile background value.

■ Detection greater than 5 X 95th percentile background value.

[X] Detection where background level not recorded.

TABLE 4-26
BERYLLIUM DETECTIONS BY AREA
MINIMUM - MAXIMUM (mg/kg)

LOCATION	DEPTH INTERVAL							
	SURFACE SOIL (Background - 0.6 mg/kg)			SUBSURFACE SOIL (Background - 0.62 mg/kg)				
	0.0 - 0.5 ft.	0.5 - 1.0 ft.	1.0 - 1.5 ft.	1.5 - 3.0 ft.	3.0 - 5.0 ft.	5.0 - 10.0 ft.	10.0 15.0 ft.	15.0 - 20.0 ft.
PLANT 1 AREA	0.28- 2.20	0.42- 0 92	1.00- 2.00	0.41- 2.70	3.20- 3.20	1.60- 1.60	1.80- 1.80	3.50- 3.50
PLANT 2/3 AREA	0.68- 2.40	0.66- 1.70	2 50- 3.20	1.40- 1.40	-	1.00- 1.80	1.40- 2.20	-
PLANT 4/5/7 AREA	ND	-	0.78- 0.78	ND	-	3.90- 3.90	-	-
PLANT 6 AREA	0.73- 1 10	0.76- 0.82	0 95- 1.40	1.90- 1.90	0.29- 1.10	ND	-	-
PLANT 8 AREA	0 61- 2.70	-	3.50- 3.50	2.20- 2.20	-	2.20- 2.70	-	-
PLANT 9 AREA	0.46- 0.46	0.77- 0.77	0.49- 1.10	0.51- 0.79	0.80- 0.80	0.62- 0.62	0.45- 0:45	0.49- 0.49
SEWAGE TREATMENT PLANT	0.52- 1.10	0.63- 0.68	0.60- 1.30	1.00- 1.10	-	-	-	-
PILOT PLANT AREA	0 48- 1.70	0.82- 0 94	0.60- 1.30	0.70- 1.30	0.76- 0.76	0.36- 0.98	0.53- 0.99	0.66- 0.66
LABORATORY AREA	0 51- 1 30	ND	0.45- 1.50	0.48- 1.60	ND	ND	1.30- 1.30	2.80- 2.80
ADMINISTRATION AREA	1 10- 1 10	-	1.80- 1.80	1.20- 1.50	-	1.70- 1.70	-	-
ELECTRICAL SUBSTATION AREA	0 38- 0 80	-	-	-	-	-	-	-
MAINTENANCE BUILDING AREA	0 59- 1.70	0.57- 1.70	1.10- 1.10	0.62- 1.20	0.50- 1.20	0.47- 1.20	0.40- 0.52	0.33- 0.33
TANK FARM AND BOILER HOUSE AREA	ND	1.30- 1 30	ND	0.75- 0.75	ND	-	-	-
D&D BUILDING AND DRUM BALING AREA	0 59- 1 30	-	-	0.60- 0.60	-	-	-	-
SCRAP METAL PILE	0 63- 0 66	-	-	-	-	-	-	-
GRAPHITE FURNACE AREA	0 98- 1 80	0 70- 1 90	ND	0.63- 1.40	0.59- 2.20	0.77- 2.90	0.86- 0.86	-
KC-2 WAREHOUSE	0 57- 0 63	-	-	-	-	-	-	-
FIRE TRAINING AREA	0 53- 0 63	-	-	0.53- 0.53	-	-	-	-
TRAP RANGE	0 35- 0 73	-	-	-	-	-	-	-
AREA WEST OF K-65 SILOS	0 49- 0 96	0.52- 0 89	0.90- 0.90	0.47- 2.80	0.36- 2.90	0.49- 5.20	ND	-
K-65/CLEARWELL LINE WEST	0 89- 1 40	1.40- 1.80	-	-	-	0.61- 1.00	1.20- 1.20	-
NORTHEAST AREA OF FEMP	0 48- 5 70	-	0.64- 0.64	1.00- 1.00	ND	0.64- 0.68	0.44- 0.44	0.42- 0.42
SOUTHERN AREA OF FEMP	0 54- 1.70	-	-	-	-	-	-	-
WESTERN AREA OF FEMP	0.51- 1.80	-	0.92- 2.10	ND	ND	-	-	1.00- 1.00
NORTHWESTERN AREA OF FEMP	0.41- 1.70	-	-	-	-	-	-	-
AREA OUTSIDE OF FEMP ADJACENT TO BOUNDARY	1.30- 1.30	-	-	-	-	-	-	-

ND - NOT DETECTED

TABLE 4-27
CADMIUM

Depth Interval, Feet	Plant 1 Area	Plant 2/3 Area	Plant 4/5/7 Area	Plant 6 Area	Plant 8 Area	Plant 9 Area	Sewage Treatment Plant Area	Pilot Plant Area	Laboratory Area	Administration Area	Electrical Substation Area	Maintenance Building	Tank Farm and Boiler House	D&D Building and Drum Baling Area	Scrap Metal Pile & Decontamination Building	Graphite Furnace, Oil Burner, and Coal Pile Area	KC-2 Warehouse Area	Fire Training Area	Trap Range	Area West of K-65 Silos	K-65/Clearwell Line (West of Production Area)	Clearwell Line (East of Production Area)	Outfall Pipeline	Great Miami Riverbank Characterization	Southwest Field Area	Northeastern Area of FEMP	Southern Area of FEMP	Western Area of FEMP	Northwestern Area of FEMP	Area Outside of FEMP Adjacent to Boundary	Area 2-5 Miles Outside of FEMP Boundary
Surface Soil: Background - 0.87 mg/kg																															
0 - 0.5	■	■	-	■	◉	-	-	■	◉	-	-	■	●	●	●	■	-	■	○	■	◉					◉	◉	■	◉	-	
0.5 - 1		■		●		●	-	■	■			■	■			■				◉	●										
1 - 1.5	◉	◉	●	◉	-	■	-	-	●	●		■	◉		-	●				-						-		●			
Subsurface Soil: Background - 0.91 mg/kg																															
1.5 - 3	■	-	-	-	-	◉	-	◉	●	◉		■	■	●	-	■		◉		●						-		-			
3 - 5	●			■		◉		■	-			■	■		-	■				◉						-		●			
5 - 10	●	◉	◉		◉	-		◉	●	-		■				■				◉	-					-					
10 - 15	●	-				-		■	-			-				■				◉	◉					-					
15 - 20	-					-		■	-			-														-		■			

- "Blank" - Not analyzed.
- - Analyzed and not detected.
- ○ Detection less than 95th percentile background value.
- ● Detection above but < 2 X 95th percentile background value.
- ◉ Detection 2 to 5 X 95th percentile background value.
- ■ Detection greater than 5 X 95th percentile background value.
- X Detection where background level not recorded.

TABLE 4-28
CADMIUM DETECTIONS BY AREA
MINIMUM - MAXIMUM (mg/kg)

LOCATION	DEPTH INTERVAL							
	SURFACE SOIL (Background - 0.87 mg/kg)			SUBSURFACE SOIL (Background - 0.91 mg/kg)				
	0.0 - 0.5 ft.	0.5 - 1.0 ft.	1.0 - 1.5 ft.	1.5 - 3.0 ft.	3.0 - 5.0 ft.	5.0 - 10.0 ft.	10.0 15.0 ft.	15.0 - 20.0 ft.
PLANT 1 AREA	2.00- 6.70	ND	2.50- 4.50	1.90- 6.40	1.10- 1.10	1.40- 1.80	1.60- 1.60	ND
PLANT 2/3 AREA	1.30- 6.90	1.10- 6.20	1.10- 1.80	ND	-	1.20- 4.10	ND	-
PLANT 4/5/7 AREA	ND	-	1.60- 1.60	ND	-	2.00- 2.00	-	-
PLANT 6 AREA	0.87- 4.60	0.51- 4.30	2.30- 2.30	ND	0.92- 7.00	-	-	-
PLANT 8 AREA	1.40- 3.80	-	ND	ND	-	1.60- 1.90	-	-
PLANT 9 AREA	ND	2.90- 2.90	4.00- 6.30	3.70- 3.70	3.00- 3.00	ND	ND	ND
SEWAGE TREATMENT PLANT	ND	ND	ND	ND	-	-	-	-
PILOT PLANT AREA	3 40- 5 40	3.00- 4 50	ND	2.90- 2.90	2.60- 5.00	2.10- 4.50	4.20- 7.90	5.10- 5.10
LABORATORY AREA	2.20- 3.50	4.90- 4.90	1.20- 1.20	1.30- 1.30	ND	1.70- 1.80	ND	ND
ADMINISTRATION AREA	-	-	1.10- 1.10	2.30- 2.30	-	-	-	-
ELECTRICAL SUBSTATION AREA	ND	-	-	-	-	-	-	-
MAINTENANCE BUILDING AREA	5 10- 8.00	2.30- 7.10	5.10- 5.10	2.40- 7.00	2.00- 8.00	3.30- 6.90	ND	ND
TANK FARM AND BOILER HOUSE AREA	2 10- 2 10	5.40- 5.40	2.20- 2.20	5.60- 5.60	7.60- 7.60	-	-	-
D&D BUILDING AND DRUM BALING AREA	1 80- 1 80	-	-	1.00- 1.00	-	-	-	-
SCRAP METAL PILE	4 20- 4.20	-	ND	ND	ND	-	-	-
GRAPHITE FURNACE AREA	2 10- 6 20	1.90- 12.40	1.50- 2.70	1.40- 7.70	1.80- 6.00	1.50- 5.90	6.50- 6.50	-
KC-2 WAREHOUSE	ND	-	-	-	-	-	-	-
FIRE TRAINING AREA	4.10- 7.60	-	-	2.60- 4.20	-	-	-	-
TRAP RANGE	0 49- 0.49	-	-	-	-	-	-	-
AREA WEST OF K-65 SILOS	4 90- 4 90	1 90- 1.90	ND	1.20- 1.70	1.50- 2.20	1.20- 2.40	4.20- 4.20	-
K-65/CLEARWELL LINE WEST	1.10- 3.10	1.30- 1.50	-	-	-	ND	4.30- 4.30	-
NORTHEAST AREA OF FEMP	0 53- 1 90	-	ND	ND	ND	ND	ND	ND
SOUTHERN AREA OF FEMP	1 30- 2.80	-	-	-	-	-	-	-
WESTERN AREA OF FEMP	1.30- 6.70	-	1.60- 1.70	ND	1.10- 1.20	-	-	4.80- 4.80
NORTHWESTERN AREA OF FEMP	0 51- 1.90	-	-	-	-	-	-	-
AREA OUTSIDE OF FEMP ADJACENT TO BOUNDARY	-	-	-	-	-	-	-	-

ND - NOT DETECTED

TABLE 4-29
LEAD

Depth Interval, Feet	Plant 1 Area	Plant 2/3 Area	Plant 4/5/7 Area	Plant 6 Area	Plant 8 Area	Plant 9 Area	Sewage Treatment Plant Area	Pilot Plant Area	Laboratory Area	Administration Area	Electrical Substation Area	Maintenance Building	Tank Farm and Boiler House	D&D Building and Drum Baling Area	Scrap Metal Pile & Decontamination Building	Graphite Furnace, Oil Burner, and Coal Pile Area	KC-2 Warehouse Area	Fire Training Area	Trap Range	Area West of K-65 Silos	K-65/Clearwell Line (West of Production Area)	Clearwell Line (East of Production Area)	Outfall Pipeline	Great Miami Riverbank Characterization	Southwest Field Area	Northeastern Area of FEMP	Southern Area of FEMP	Western Area of FEMP	Northwestern Area of FEMP	Area Outside of FEMP Adjacent to Boundary	Area 2-5 Miles Outside of FEMP Boundary
Surface Soil: Background - 26.4 mg/kg																															
0 - 0.5	●	■	●	■	○	○	■	▒	○	●	■	■	○	■	■	▒	■	▒	■	○	■					●	▒	▒	●	●	
0.5 - 1	○	■		▒		○	○	●	●			■	●			●				○	○										
1 - 1.5	●	●	○	○	○	○	●	○	○	▒		○	○		○	○				○						○		●			
Subsurface Soil: Background - 16.6 mg/kg																															
1.5 - 3	●	●	○	●	○	○	●	●	●	●		●	○	○	○	●		▒		●						●		○			
3 - 5	○			▒		○		●	○			○	○		○	●				▒						○		○			
5 - 10	●	●	○	●	●	○		●	●	●		○				○				■	○					○					
10 - 15	○	○				○		●	○			●				○				○	○					○					
15 - 20	●					○		○	○			○														○		○			

□ "Blank" - Not analyzed.

[-] Analyzed and not detected.

[○] Detection less than 95th percentile background value.

[●] Detection above but < 2 X 95th percentile background value.

[▒] Detection 2 to 5 X 95th percentile background value.

■ Detection greater than 5 X 95th percentile background value.

[X] Detection where background level not recorded.

TABLE 4-30
LEAD DETECTIONS BY AREA
MINIMUM - MAXIMUM (mg/kg)

LOCATION	DEPTH INTERVAL							
	SURFACE SOIL (Background - 26.4 mg/kg)			SUBSURFACE SOIL (Background - 15.6 mg/kg)				
	0.0 - 0.5 ft.	0.5 - 1.0 ft.	1.0 - 1.5 ft.	1.5 - 3.0 ft.	3.0 - 5.0 ft.	5.0 - 10.0 ft.	10.0 15.0 ft.	15.0 - 20.0 ft.
PLANT 1 AREA	7.40- 60.50	2.90- 23.20	10.30- 37.70	4.40- 19.13	8.90- 8.90	9.30- 16.50	15.40- 15.40	28.20- 28.20
PLANT 2/3 AREA	4.50- 334 00	8.60- 440.00	3.40- 31.20	11.40- 18.40	-	8.30- 25.80	5.70- 12.10	-
PLANT 4/5/7 AREA	19.80- 29.40	-	10.50- 15.00	11.60- 11.60	-	8.30- 14.00	-	-
PLANT 6 AREA	5.30- 226.00	9.20- 88.00	11.30- 16.30	12.30- 30.00	2.90- 31.80	11.00- 17.60	-	-
PLANT 8 AREA	3.50- 17.00	-	3.70- 10.90	2.60- 2.60	-	15.00- 17.20	-	-
PLANT 9 AREA	9.10- 9.10	16.30- 16.30	6.10- 11.10	7.40- 8.10	12.80- 12.80	8.90- 10.20	7.70- 7.70	8.20- 8.20
SEWAGE TREATMENT PLANT	12.30- 570.00	17.40- 26 20	9.90- 31.40	11.60- 21.40	-	-	-	-
PILOT PLANT AREA	9 70- 117.00	15.50- 26.70	11.00- 21.30	12.50- 19.10	4.60- 15.90	7.70- 29.20	5.40- 16.90	8.40- 8.40
LABORATORY AREA	15.70- 22.30	42.30- 42.30	15.10- 18.50	11.00- 21.70	8.80- 8.80	7.90- 15.70	0.47- 0.47	4.30- 4.30
ADMINISTRATION AREA	11.40- 48 60	-	16.40- 54.80	2.40- 16.90	-	6.80- 19.10	-	-
ELECTRICAL SUBSTATION AREA	5 10- 543 00	-	-	-	-	-	-	-
MAINTENANCE BUILDING AREA	9.40- 334.00	6.40- 165.00	7.70- 8.85	2.90- 19.70	4.40- 11.00	1.40- 10.20	5.98- 22.00	6.10- 13.30
TANK FARM AND BOILER HOUSE AREA	22.70- 22.70	27.30- 27.30	12.80- 12.80	7.90- 7.90	6.10- 6.10	-	-	-
D&D BUILDING AND DRUM BALING AREA	79 40- 162.00	-	-	7.80- 7.80	-	-	-	-
SCRAP METAL PILE	51.30- 569.00	-	16.60- 16.60	13.10- 13.10	14.70- 14.70	-	-	-
GRAPHITE FURNACE AREA	9.20- 57.20	7.80- 38.20	10.20- 21.20	7.70- 18.00	7.00- 17.00	8.20- 14.30	8.90- 8.90	-
KC-2 WAREHOUSE	110.00- 220.00	-	-	-	-	-	-	-
FIRE TRAINING AREA	22.40- 114.00	-	-	14.80- 71.00	-	-	-	-
TRAP RANGE	17.50- 2180.00	-	-	-	-	-	-	-
AREA WEST OF K-65 SILOS	16.60- 26.10	16.70- 26 00	21.00- 21.00	9.30- 27.30	6.80- 40.00	8.90- 139.00	5.00- 10.20	-
K-65/CLEARWELL LINE WEST	14.80- 240.00	12.30- 18 00	-	-	-	10.40- 14.30	8.60- 8.60	-
NORTHEAST AREA OF FEMP	2.80- 32 30	-	14.10- 18.20	13.60- 17.90	9.20- 9.20	8.50- 8.80	7.70- 7.70	8.80- 8.80
SOUTHERN AREA OF FEMP	5.00- 61.50	-	-	-	-	-	-	-
WESTERN AREA OF FEMP	8.60- 111.00	-	10.30- 28.50	10.20- 13.30	7.50- 8.30	-	-	10.20- 10.20
NORTHWESTERN AREA OF FEMP	8.80- 33.30	-	-	-	-	-	-	-
AREA OUTSIDE OF FEMP ADJACENT TO BOUNDARY	16.90- 28.50	-	-	-	-	-	-	-

TABLE 4-31
MERCURY

Depth Interval, Feet	Plant 1 Area	Plant 2/3 Area	Plant 4/5/7 Area	Plant 6 Area	Plant 8 Area	Plant 9 Area	Sewage Treatment Plant Area	Pilot Plant Area	Laboratory Area	Administration Area	Electrical Substation Area	Maintenance Building	Tank Farm and Boiler House	D&D Building and Drum Baling Area	Scrap Metal Pile & Decontamination Building	Graphite Furnace, Oil Burner, and Coal Pile Area	KC-2 Warehouse Area	Fire Training Area	Trap Range	Area West of K-65 Silos	K-65/Clearwell Line (West of Production Area)	Clearwell Line (East of Production Area)	Outfall Pipeline	Great Miami Riverbank Characterization	Southwest Field Area	Northeastern Area of FEMP	Southern Area of FEMP	Western Area of FEMP	Northwestern Area of FEMP	Area Outside of FEMP Adjacent to Boundary	Area 2-5 Miles Outside of FEMP Boundary
Surface Soil: Background - 0.3 mg/kg																															
0 - 0.5	■	■	-	●	-	-	○	●	●	-	○	▒	▒	○	●	○	-	-	■	-	-					-	-	-	-	-	
0.5 - 1	-	▒		-		○	○	▒				●	○			●				-	-										
1 - 1.5	▒	●	-	-	-	-	○	-	○	-		-	●		-	-				-						-		-			
Subsurface Soil: Background - 0.29 mg/kg																															
1.5 - 3	-	■	-	-	-	-	○	-	○	-		-	-	○	-	-		○		-						-		-			
3 - 5	-			○		-		-	-			○	-		-	-				○						-		-			
5 - 10	-	-	-	-	-	-		○	-	-		-				-				○	-					-					
10 - 15	-	-				-		○	-			-				-				-	-					-					
15 - 20	-					-		-	-			-														-		-			

- ■ "Blank" - Not analyzed.
- - Analyzed and not detected.
- ○ Detection less than 95th percentile background value.
- ● Detection above but < 2 X 95th percentile background value.
- ▒ Detection 2 to 5 X 95th percentile background value.
- ■ Detection greater than 5 X 95th percentile background value.
- X Detection where background level not recorded.

TABLE 1-32
MERCURY DETECTIONS BY AREA
MINIMUM - MAXIMUM (mg/kg)

LOCATION	DEPTH INTERVAL							
	SURFACE SOIL (Background - 0.3 mg/kg)			SUBSURFACE SOIL (Background - 0.29 mg/kg)				
	0.0 - 0.5 ft.	0.5 - 1.0 ft.	1.0 - 1.5 ft.	1.5 - 3.0 ft.	3.0 - 5.0 ft.	5.0 - 10.0 ft.	10.0 15.0 ft.	15.0 - 20.0 ft.
PLANT 1 AREA	0.14- 4.60	ND	1.00- 1.00	ND	ND	ND	ND	ND
PLANT 2/3 AREA	0.08- 2.10	0.73- 0.73	0.48- 0.48	2.30- 2.30	-	ND	ND	-
PLANT 4/5/7 AREA	ND	-	ND	ND	-	ND	-	-
PLANT 6 AREA	0.39- 0.39	ND	ND	ND	0.05- 0.07	ND	-	-
PLANT 8 AREA	ND	-	ND	ND	-	ND	-	-
PLANT 9 AREA	ND	0.25- 0.25	ND	ND	ND	ND	ND	ND
SEWAGE TREATMENT PLANT	0 06- 0.12	0.08- 0 10	0.10- 0.10	0.06- 0.13	-	-	-	-
PILOT PLANT AREA	0 13- 0 34	1.10- 1 10	ND	ND	ND	0.24- 0.24	0.22- 0.22	ND
LABORATORY AREA	0 34- 0 34	-	0.06- 0.06	0.06- 0.06	ND	ND	ND	ND
ADMINISTRATION AREA	-	-	-	-	-	-	-	-
ELECTRICAL SUBSTATION AREA	0 17- 0 17	-	-	-	-	-	-	-
MAINTENANCE BUILDING AREA	0.37- 0.65	0.18- 0.46	ND	ND	0.09- 0.09	ND	ND	ND
TANK FARM AND BOILER HOUSE AREA	1 30- 1.30	0.15- 0.15	0.48- 0.48	ND	ND	-	-	-
D&D BUILDING AND DRUM BALING AREA	0 12- 0 23	-	-	0.04- 0.04	-	-	-	-
SCRAP METAL PILE	0 12- 0 48	-	ND	ND	ND	-	-	-
GRAPHITE FURNACE AREA	0 16- 0 28	0 13- 0 32	ND	ND	ND	ND	ND	-
KC-2 WAREHOUSE	ND	-	-	-	-	-	-	-
FIRE TRAINING AREA	ND	-	-	0.18- 0.18	-	-	-	-
TRAP RANGE	0 06- 6 30	-	-	-	-	-	-	-
AREA WEST OF K 65 SILOS	ND	ND	ND	ND	0.08- 0.08	0.05- 0.05	ND	-
K-65/CLEARWELL LINE WEST	ND	ND	-	-	-	ND	ND	-
NORTHEAST AREA OF FEMP	ND	-	ND	ND	ND	ND	ND	ND
SOUTHERN AREA OF FEMP	ND	-	-	-	-	-	-	-
WESTERN AREA OF FEMP	ND	-	ND	ND	ND	-	-	ND
NORTHWESTERN AREA OF FEMP	ND	-	-	-	-	-	-	-
AREA OUTSIDE OF FEMP ADJACENT TO BOUNDARY	-	-	-	-	-	-	-	-

ND - NOT DETECTED

TABLE 4-33
PRODUCTION AREA
PARAMETER OCCURRENCES BY DEPTH

RADIONUCLIDES (pCi/g)

Depth Interval, Feet	Number of Samples	Uranium-238	Total Uranium	Uranium-234	Thorium-230	Radium-226	Lead-210	Polonium-210	Uranium-235/236	Thorium-232	Total Thorium	Radium-228	Thorium-228	Neptunium-237	Plutonium-239/240	Plutonium-238	Strontium-90	Technetium-99	Ruthenium-106	Cesium-137
Surface Soil:																				
95 % Background Value		1.24	3.73 ug/g	1.24	1.97	1.42	1.30	NA	0.156	1.36	12.4	1.25	1.43	NA	NA	NA	0.424	ND	NA	0.711
0 - 0.5	348							X						X	X	X		X	X	
0.5 - 1	96							X						X	X	X		X	-	●
1 - 1.5	104						○	X						-	X	X		X	-	○
Subsurface Soil:																				
95 % Background Value		1.12	3.69 ug/g	1.04	1.91	1.47	0.850	NA	0.150	1.26	11.1 ug/g	1.31	1.39	NA	NA	NA	0.436	ND	ND	ND
1.5 - 3	89					●		X		●			●	-	X	X		X	-	X
3 - 5	40				●			X		●		●	●	-	X	-		X	-	X
5 - 10	121							X						X	X	X		X	-	X
10 - 15	70					●		X		●	●	●	●	-	X	-		X	-	X
15 - 20	38					●				●	●	●	●	-	-	-		X	-	X

INORGANICS (mg/kg)

Depth Interval, Feet	Number of Samples	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Cyanide	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium	Silicon	Silver	Sodium	Thallium	Vanadium	Zinc
Surface Soil:																											
95 % Background Value		11,900	ND	8.2	95.7	0.60	0.87	4340	15.5	14.2	14.1	0.27	21,700	26.4	2780	1350	0.30	ND	20.9	1230	0.72	1800	ND	51.1	0.68	30.4	69.6
0 - 0.5	147	●	X	○		○				●			●			●		X	●	●	●	●	X		○	●	
0.5 - 1	72	●	-			○			○	○	○		●			●	○	X	●	○		●	X		●	●	
1 - 1.5	49	○	-	●	○				●	●	○	○	●	○		○	○	X	●	○	○	●	X		○	●	
Subsurface Soil:																											
95 % Background Value		16,100	ND	9.57	119	0.62	0.91	150,000	20.7	15.7	20	0.17	30,700	15.6	42,600	1300	0.29	2.70	34.3	1980	ND	1690	ND	285	0.49	37.8	82
1.5 - 3	100	●	X	●	○	○		●	○	●	○		●	○	●	○		○	●	●	X	●	X		●	●	○
3 - 5	72		X	○	●			●	●	●	●		○	○	●	●	○	○	●	●	X	○	X	○	●	●	
5 - 10	103		X					○				○			○		○	○			X	○	X		○		
10 - 15	18	○	X	○		○		●	●	●	●		○	●	●	○	○	●	●	●	X	○	X		○	○	○
15 - 20	5	○	-	○	○			●	○	○	○	-	○	●	○	○	-	○	○	○	-	○	X	○	○	○	

ND - Not detected in background study.

NA - Not analyzed in background study.

"Blank" - Not analyzed.

- Analyzed and not detected.

○ Detection less than 95 percentile background concentration.

● Detection above but < 2X of 95 percentile background concentration.

Detection 2X to 5X 95 percentile background concentration.

Detection greater than 5X 95 percentile background concentration.

X Detection where background level not recorded.

5696

TABLE 4-33
(Continued)

Depth Interval, Feet	Number of Samples	1,1,-Dichloroethane	1,1,1-Trichloroethane	1,1,2,2-Tetrachloroethane	1,1,2-Trichloroethane	1,1-Dichloroethene	1,2-Dichloroethane	1,2-Dichloroethene (Total)	2-Butanone	2-Hexanone	4-Methyl-2-pentanone	Acetone	Benzene	Bromodichloromethane	Bromomethane	Carbon disulfide	Carbon tetrachloride	Chlorobenzene	Chloroethane	Chloroform	Dibromochloromethane	Ethylbenzene	Methylene chloride	Styrene	Tetrachloroethene	Toluene	Total Xylenes	Trans-1,3-Dichloropropene	Trichloroethene	Vinyl chloride	
	VOLATILES (ug/kg)																														
Surface Soil:																															
0 - 0.5	112	X	X	-	-	X	-	X	X	X	X	X	X	-	X	X	X	X	-	X	-	X	X	X	X	X	X	-	X	-	
0.5 - 1	64	X	X	X	X	X	X	X	X	X	X	X	X	-	-	X	-	X	-	X	-	X	X	-	X	X	X	-	X	-	
1 - 1.5	46	-	X	-	-	-	-	X	X	-	X	X	-	-	-	X	-	-	-	X	-	-	X	-	X	X	X	-	X	-	
Subsurface Soil:																															
1.5 - 3	132	X	X	X	X	X	-	X	X	X	X	X	X	X	-	X	X	X	-	X	-	X	X	X	X	X	X	-	X	X	
3 - 5	73	X	X	X	X	X	X	X	X	X	X	X	X	-	-	X	-	-	X	X	X	X	X	-	X	X	X	X	X	X	
5 - 10	82	X	X	X	X	X	X	X	X	X	X	X	-	X	-	X	-	-	-	X	-	X	X	-	X	X	X	-	X	X	
10 - 15	28	X	X	X	-	X	X	X	-	X	X	X	-	-	-	X	-	-	-	-	-	-	X	-	X	X	X	-	X	X	
15 - 20	13	-	X	-	-	-	-	-	X	-	X	X	-	-	-	X	-	-	-	X	-	X	X	-	X	X	X	-	X	-	

[ ] "Blank" - Compound was not analyzed.

[X] Detected.

[-] Analyzed for and not detected.

TABLE 4-33
(Continued)

Depth Interval, Feet	Number of Samples	1,2,4-Trichlorobenzene	1,4-Dichlorobenzene	2,4-Dichlorophenol	2,4-Dimenthylphenol	2,4-Dinitrotoluene	2,6-Dinitrotoluene	2-Chlorophenol	2-Methylnaphthalene	2-Methylphenol	2-Nitroaniline	3,3-Dichlorobenzidine	4-Chloro-3-methylphenol	4-Methylphenol	4-Nitroaniline	4-Nitrophenol	Acenaphthene	Acenaphthylene	Anthracene	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Benzoic acid	Benzyl alcohol	bis(2-Chloroisopropyl)ether	Bis(2-ethylhexyl)phthalate	Butyl benzyl phthalate	Carbazole	Chrysene	Di-n-butyl phthalate	Di-n-octyl phthalate	Dibenzo(a,h)anthracene	Dibenzofuran	Diethyl phthalate	Fluoranthene	Fluorene	Hexachlorobutadiene	Ideno(1,2,3-cd)pyrene	Isophorone	N-Nitroso-di-n-propylamine	N-Nitrosodimethylamine	N-Nitrosodiphenylamine	Naphthalene	Pentachlorophenol	Phenanthrene	Phenol	Pyrene	Tributyl phosphate
SEMIVOLATILES (ug/kg)																																																			
Surface Soil:																																																			
0 - 0.5	110	-	-	X	X	X	-	X	X	X	-	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-	X	X	-	X	X	X		X	X	-	X	X	X	X
0.5 - 1	64	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	X	-	X	X	X	X	X	X	X	-	-	X	X	-	X	X	-	X	X	X	X	X	X	X	-	-		X	X	-	X	X	X	X
1 - 1.5	47	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	X	-	X	X	X	X	X	X	-	-	-	X	-	X	X	X	-	-	-	X	X	X	-	X	-	-		-	X	-	X	X	X	
Subsurface Soil:																																																			
1.5 - 3	118	X	X	-	X	X	-	X	X	-	X	-	X	X	-	X	X	X	X	X	X	X	X	X	X	-	-	X	X	-	X	X	X	X	X	X	X	X	X	X	-	X		X	X	X	X	X	X	-
3 - 5	57	-	-	-	-	-	-	-	X	-	-	-	X	-	-	X	-	-	-	X	-	-	-	-	X	-	-	X	X	-	-	X	X	-	-	X	X	-	-	-	-	-		-	-	X	X	X	X	
5 - 10	67	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	-	X	X	-	-	X	-	-	X	X	-	-	-	X	X	-	-	X	-	-	X	-	-	-	X	X	X	-
10 - 15	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	X	-	-	-	X	-	-	-	-	X	-	-	-	-	-		-	-	-	X	-	X	
15 - 20	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	

[ ] "Blank" - Compound was not analyzed.

[X] Detected.

[-] Analyzed for and not detected.

5696

TABLE 4-33
(Continued)

Depth Interval, Feet	PESTICIDES/PCBs (ug/kg)																		DIOXINS/FURANS					
	Number of Samples	4,4'-DDE	4,4'-DDT	Aldrin	Alpha-BHC	Alpha-chlordane	Aroclor-1248	Aroclor-1254	Aroclor-1260	Beta-BHC	Dieldrin	Endosulfan I	Endosulfan II	Endosulfan sulfate	Endrin	Endrin aldehyde	Heptachlor epoxide	Methoxychlor	Number of Samples	Heptachlorodibenzofurans	Octachlorodibenzo-P-Dioxin	Octachlorodibenzofuran		
Surface Soil:																								
0 - 0.5	113	X	X	X	-	X	-	X	X	X	X	-	X	X	X	-	X	X	4	X	X	X		
0.5 - 1	59	-	-	-	-	-	-	X	X	X	-	-	-	-	-	-	-	-	2	-	-	X		
1 - 1.5	45	-	-	-	-	-	-	X	-	-	-	-	-	-	-	X	-	-						
Subsurface Soil:																								
1.5 - 3	92	-	-	-	X	-	-	X	X	-	-	X	-	-	-	X	-	-	6	-	-	X		
3 - 5	48	-	-	-	-	-	X	X	X	-	-	-	-	-	-	-	-	-						
5 - 10	72	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-						
10 - 15	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
15 - 20	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X						

"Blank" - Compound was not analyzed.

- Analyzed for and not detected.

X Detected.

000765

TABLE 4-34
NORTHEASTERN AREA OF FEMP
PARAMETER OCCURRENCES BY DEPTH

RADIONUCLIDES (pCi/g)

Depth Interval, Feet	Number of Samples	Uranium-238	Total Uranium	Thorium-234	Uranium-234	Thorium-230	Radium-226	Uranium-235/236	Thorium-232	Total Thorium	Radium-228	Thorium-228	Radium-224	Neptunium-237	Plutonium-239/240	Plutonium-238	Strontium-90	Technetium-99	Ruthenium-106	Cesium-137
Surface Soil:																				
95% Background Value		1.24	3.77 ug/g	NA	1.24	1.97	1.42	0.156	1.36	12.4	1.25	1.47	0.900	NA	NA	NA	0.424	ND	NA	0.711
0 - 0.5	79	■	■	X	■	■	●	■	■	■	■	■	●	-	-	-	■	X	-	●
0.5 - 1	3	■	■		■	●	○	■	○	○	○	○		-	-	-	-	-	-	-
1 - 1.5	4	■	■		■	●	○	■	○	○	●	○		-	-	-	●	-	-	-
Subsurface Soil:																				
95% Background Value		1.23	3.73 ug/g	NA	1.11	1.91	1.47	0.138	1.26	11.4 ug/g	1.31	1.39	1.01	ND	ND	ND	0.436	ND	ND	ND
1.5 - 3	3	■	■		■	○	○	-	○	⊗	○	○		-	-	-	■	-	-	-
3 - 5	2	○	●		○	○	○	-	○	○	-	○								
5 - 10	3	○	●		●	○	○	-	○	⊗	-	○								
10 - 15	2	○	●		○	○	○	-	○	○	○	●			-	-	⊗	-	-	-
15 - 20	4	●	●		●	○	○	-	○	○	○	○							-	-

INORGANICS (mg/kg)

Depth Interval, Feet	Number of Samples	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Cyanide	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium	Silicon	Silver	Sodium	Thallium	Vanadium	Zinc
Surface Soil:																											
95% Background Value		11,900	ND	8.2	95.7	0.60	0.87	4340	15.5	14.2	14.1	0.27	21,700	26.4	2780	1360	0.30	ND	20.9	1230	0.72	1800	ND	51.1	0.58	30.4	59.6
0 - 0.5	23	●	X	●	⊗	■	⊗	■	●	●	⊗	●	⊗	●	■	⊗	-	X	⊗	●	○	○	X	⊗	●	●	●
0.5 - 1	0																										
1 - 1.5	2	●	-	○	●	●	-	●	○	○	●	○	○	○	○	○	-	X	○	○	-	○	X	●	-	●	○
Subsurface Soil:																											
95% Background Value		16,100	ND	9.57	119	0.62	0.91	160,000	20.7	16.7	20	0.17	30,700	16.6	42,600	1300	0.29	2.70	34.3	1980	ND	1690	ND	285	0.49	37.5	82
1.5 - 3	2	●	-	○	○	●	-	○	●	○	●	-	○	●	○	○	-	⊗	○	○	-	○	X	○	-	●	○
3 - 5	1	○	-	○	○	-	-	○	○	○	●	-	●	○	○	○	-	-	-	○	-	○	-	-	-	○	○
5 - 10	2	○		○	○	●	-	○	○	○	○	-	○	○	○	○	-	⊗	○	●	-		X	○	-	○	○
10 - 15	1	○		○	○	○	-	●	○	○	○	-	○	○	○	○	-	-	○	○	-		-	○	-	○	○
15 - 20	1	○		○	○	○	-	○	○	○	○	-	○	○	○	○	-	-	○	○	-		-	○	-	○	○

ND - Not detected in background study.

NA - Not analyzed in background study.

"Blank" - Not analyzed.

- Analyzed and not detected.

○ Detection less than 95 percentile background value.

● Detection above but < 2X of 95 percentile background value.

⊗ Detection 2X to 5X 95 percentile background value.

■ Detection greater than 5X 95 percentile background value.

X Detection where background level not recorded.

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TABLE 4-34
(Continued)

Depth Interval, Feet	VOLATILES (ug/kg)											SEMIVOLATILES (ug/kg)												PESTICIDES /PCBs(ug/kg)											
	Number of Samples	1,1,1-Trichloroethane	Acetone	Carbon disulfide	Methylene chloride							Number of Samples	Benzoic acid	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Bis(2-ethylhexyl)phthalate	Chrysene	Fluoranthene	Phenanthrene	Pyrene		Number of Samples	Endrin Aldehyde										
Surface Soil:																																			
0 - 0.5	23	-	X	-	X							22	X	X	X	X	X	X	X	X	X	X		22	X										
0.5 - 1	0											0												0											
1 - 1.5	2	-	-	-	-							2	-	-	-	-	-	-	-		-	-		2	-										
Subsurface Soil:																																			
1.5 - 3	2	-	-	-	-							2	-	-	-	-	-	-	-		-	-		2	-										
3 - 5	1	-	-	-	-							1	-	-	-	-	-	-	-		-	-		1	-										
5 - 10	2	-	-	-	-							2	-	-	-	-	-	X	-		-	-		2	-										
10 - 15	1	X	X	X	-							1	-	-	-	-	-	X	-		-	-		1	-										
15 - 20	1	-	-	-	-							1	-	-	-	-	-	-	-		-	-		1	-										

[ ] "Blank" - Compound was not analyzed.

[-] Analyzed and not detected.

[X] Detection where background level not recorded.

TABLE 4-35
SOUTHERN AREA OF FEMP
PARAMETER OCCURRENCES BY DEPTH

RADIONUCLIDES (pCi/g)

Depth Interval, Feet	Number of Samples	Uranium-238	Total Uranium	Uranium-234	Thorium-230	Radium-226	Uranium-235/236	Thorium-232	Total Thorium	Radium-228	Thorium-228	Neptunium-237	Plutonium-239/240	Plutonium-238	Strontium-90	Technetium-99	Ruthenium-106	Cesium-137
Surface Soil:																		
95 % Background Value		1.24	3.73 ug/g	1.24	1.97	1.42	0.156	1.36	12.4 ug/g	1.25	1.43	NA	NA	NA	0.424	ND	ND	0.711
0 - 0.5	53	■	■	■	■	■	■	●	●	●	●	-	X	-	■	X	X	●
0.5 - 1	2	■	■	■	■	□	■	●	●		●		-	-	-	-		
1 - 1.5	4	■	■	■	●	○	-	○	○	○	●	-	-	-	●	-	-	●
Subsurface Soil:																		
95 % Background Value		1.12	3.69 ug/g	1.04	1.91	1.47	0.160	1.26	11.1 ug/g	1.31	1.38	NA	NA	NA	0.436	ND	ND	ND
1.5 - 3	3	●	●	●	●	○	-	○	●	○	○	-	-	-	-	-	-	-
3 - 5	7	●	●	●	●	○	-	○	●	○	●	-	-	-	-	-	-	-
5-10	16	●	●	●	●	○	-	○	●	○	●	-	-	-	-	-	-	-
10 - 15	13	●	●	●	●	○	-	●	●	○	●	-	-	X	●	-	-	-
15 - 20	9	●	●	○	○	○	-	○	○	○	●	-	-	-	●	-	-	-

INORGANICS (mg/kg)

Depth Interval, Feet	Number of Samples	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Cyanide	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium	Silicon	Silver	Sodium	Thallium	Vanadium	Zinc
Surface Soil:																											
95 % Background Value		11,900	ND	8.2	95.7	0.60	0.87	4340	15.5	14.2	14.1	0.27	21,700	26.4	2780	1350	0.30	ND	20.9	1230	0.72	1800	ND	51.1	0.68	30.4	69.6
0 - 0.5	20	●	X	●	●	●	●	■	●	○	●	●	●	●	■	○	-	X	●	●	●	○	X	●	-	○	●
0.5 - 1	0																										
1 - 1.5	0																										
Subsurface Soil:																											
95 % Background Value		16,100	ND	9.57	119	0.62	0.91	150,000	20.7	16.7	20	0.17	30,700	16.6	42,600	1300	0.29	2.70	34.3	1980	ND	1590	ND	285	0.49	37.8	82
1.5 - 3	0																										
3 - 5	0																										
5-10	0																										
10 - 15	0																										
15 - 20	0																										

ND - Not detected in background study.

NA - Not analyzed in background study.

"Blank" - Not analyzed.

- Analyzed and not detected.

○ Detection less than 95 percentile background value.

● Detection above but < 2X of 95 percentile background value.

Detection 2X to 5X 95 percentile background value.

■ Detection greater than 5X 95 percentile background value.

X Detection where background level not recorded.

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TABLE 4-35
(Continued)

Depth Interval, Feet	VOLATILES (ug/kg)							SEMIVOLATILES (ug/kg)																			
	Number of Samples	2-Butanone	Acetone	Chlorobenzene	Tetrachloroethene	Toluene	Trichloroethene	Number of Samples	2-Methylphenol	Anthracene	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Bis(2-ethylhexyl)phthalate	Carbazole	Chrysene	Diethylphthalate	Di-n-octyl phthalate	Fluoranthene	Fluorene	Ideno(1,2,3-cd)pyrene	Phenanthrene	Phenol	Pyrene
Surface Soil:																											
0 - 0.5	20	X	X	X	X	X	X	20	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
0.5 - 1	0							0																			
1 - 1.5	0							0																			
Subsurface Soil:																											
1.5 - 3	0							0																			
3 - 5	0							0																			
5-10	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-
10 - 15	0							0																			
15 - 20	0							0																			

"Blank" - Compound was not analyzed.

- Analyzed and not detected.

X Detection where background level not recorded.

TABLE 4-36
WESTERN AREA OF FEMP
PARAMETER OCCURRENCES BY DEPTH

RADIONUCLIDES (pCi/g)

Depth Interval, Feet	Number of Samples	Uranium-238	Total Uranium	Uranium-234	Thorium-230	Radium-226	Uranium-235/236	Thorium-232	Total Thorium	Radium-228	Thorium-228	Neptunium-237	Plutonium-239/240	Plutonium-238	Strontium-90	Technetium-99	Ruthenium-106	Cesium-137
Surface Soil:																		
95 % Background Value		1.24	3.73 ug/g	1.24	1.97	1.42	0.156	1.36	12.4 ug/g	1.26	1.43	NA	NA	NA	0.424	ND	ND	0.711
0 - 0.5	208											X	X	X	●	X	X	●
0.5 - 1	15				●			●	●			-	-	-	●	-	-	○
1 - 1.5	16				●	●		●	●			-	-	-		X	-	○
Subsurface Soil:																		
95 % Background Value		1.12	3.69 ug/g	1.04	1.91	1.47	0.160	1.26	11.1 ug/g	1.31	1.38	NA	NA	NA	0.436	ND	ND	ND
1.5 - 3	4	●		●	○	●	-	●	●	●	○	-	-	-	-		-	-
3 - 5	4	●		○	●	○	-	●	●	○	●	-	-	-		-	-	-
5-10	7				●	○		●	●	○	●	-	-	-	●	-	-	X
10 - 15	8	●	●	●	○	○	-	○	●	○	○	-	X	X		X	-	-
15 - 20	3	●	●	○	○	○	-	-	●	○	○	-	X	-	-	-	-	-

INORGANICS (mg/kg)

Depth Interval, Feet	Number of Samples	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Cyanide	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium	Silicon	Silver	Sodium	Thallium	Vanadium	Zinc
Surface Soil:																											
95 % Background Value		11,900	ND	8.2	96.7	0.60	0.87	4340	16.5	14.2	14.1	0.27	21,700	26.4	2780	1360	0.30	ND	20.9	1230	0.72	1800	ND	51.1	0.58	30.4	59.6
0 - 0.5	47	●	X	●	●	●			●	○	●	●	●	●		●	-	X	●	●		●	X		○	●	●
0.5 - 1	0																										
1 - 1.5	12	●	-	●	●	●	●		●	●	●	○	●	●		○	-	X	●	●	●	○	X	●	○	●	●
Subsurface Soil:																											
95 % Background Value		16,100	ND	9.57	119	0.62	0.91	150,000	20.7	16.7	20	0.17	30,700	15.6	42,600	1300	0.29	2.70	34.3	1980	ND	1890	ND	285	0.49	37.8	92
1.5 - 3	2	○	-	●	○	-	-	○	○	○	○	-	○	○	○	○	-	-	○	○	X	○		○	○	○	○
3 - 5	2	○	-	○	○	-	●	○	○	○	○	-	○	○	○	○	-	-	○	○	-	○		○	○	○	○
5-10	0																										
10 - 15	0																										
15 - 20	1	○	-	○	○	●		○	●	○	○	-	○	○	○	○	-	-	○	○	-		X	○	-	○	○

ND - Not detected in background study.

NA - Not analyzed in background study.

"Blank" - Not analyzed.

- Analyzed and not detected.

○ Detection less than 95 percentile background value.

● Detection above but < 2X of 95 percentile background value.

Detection 2X to 5X 95 percentile background value.

Detection greater than 5X 95 percentile background value.

X Detection where background level not recorded.

5696

TABLE 4-36
(Continued)

Depth Interval, Feet	VOLATILES (ug/kg)																SEMIVOLATILES (ug/kg)																										
	Number of Samples	1,1,1-Trichloroethane	2-Butanone	2-Hexanone	4-Methyl-2-Pentanone	Acetone	Benzene	Carbon disulfide	Chlorobenzene	Chloroform	Chloromethane	Methylene chloride	Tetrachloroethene	Toluene	Total xylenes	Trichloroethene	Number of Samples	2-Chlorophenol	2-Methylnaphthalene	Acenaphthylene	Anthracene	Benzoic acid	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Bis(2-chloroisopropyl)ether	Bis(2-ethylhexyl)phthalate	Carbazole	Chrysene	Dibenzofuran	Dibenzo(a,h)anthracene	Diethylphthalate	Di-n-butyl phthalate	Fluoranthene	Ideno(1,2,3-cd)pyrene	Naphthalene	Phenanthrene	Phenol	Pyrene
Surface Soil:																																											
0 - 0.5	31	-	X	X	-	X	X	-	X	-	-	X	X	X	X	X	29	-	-	X	X	-	X	X	X	X	X	X	X	X	X	-	X	-	X	X	X	-	X	-	X
0.5 - 1	0																1	-	X	X	-	-	X	X	X	-	-	-	-	-	X	X	-	-	-	X	-	X	X	-	X
1 - 1.5	12	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	12	-	-	-	-	-	X	-	X	-	X	-	X	-	X	-	-	-	X	X	-	-	X	-	X
Subsurface Soil:																																											
1.5 - 3	20	X	-	-	X	X	-	X	-	-	X	X	-	X	-	-	22	X	-	X	X	X	X	X	X	X	-	-	X	-	X	-	X	X	-	X	X	-	X	X	X
3 - 5	3	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	2	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-
5-10	1	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	0																									
10 - 15	0																0																									
15 - 20	1	-	X	-	-	-	-	-	-	X	-	-	-	X	-	X	1	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-

"Blank" - Compound was not analyzed.

- Analyzed and not detected.

X Detection where background level not recorded.

TABLE 4-36
(Continued)

Depth Interval, Feet	PESTICIDES/PCBs (ug/kg)											DIOXINS/FURANS (ng/g)										
	Number of Samples	4,4'-DDE	Aroclor-1254	Aroclor-1260	Dieldrin							Number of Samples	Octachlorodibenzo-p-dioxin									
Surface Soil:																						
0 - 0.5	40	X	X	X	X							11	X									
0.5 - 1	1	-	-	-	-							0										
1 - 1.5	12	-	-	-	-							4	-									
Subsurface Soil:																						
1.5 - 3	3	-	-	-	-							0										
3 - 5	1	-	-	-	-							0										
5-10	0											0										
10 - 15	0											0										
15 - 20	1	-	-	-	-							0										

[ ] "Blank" - Compound was not analyzed.

[-] Analyzed and not detected.

[X] Detection where background level not recorded.

TABLE 4-37
NORTHWESTERN AREA OF FEMP
PARAMETER OCCURRENCES BY DEPTH

RADIONUCLIDES (pCi/g)

Depth Interval, Feet	Number of Samples	Uranium-238	Total Uranium	Uranium-234	Thorium-230	Radium-226	Uranium-235/236	Thorium-232	Total Thorium	Radium-228	Thorium-228	Neptunium-237	Plutonium-239/240	Plutonium-238	Strontium-90	Technetium-99	Ruthenium-106	Cesium-137
Surface Soil:																		
95 % Background Value		1.24	3.73 ug/g	1.24	1.97	1.42	0.156	1.36	12.4	1.26	1.43	NA	NA	NA	0.424	ND	NA	0.711
0 - 0.5	40				●	○		●	●	●	●	X	-	-	■	X	-	▒
0.5 - 1	2		●															
1 - 1.5	2		●															
Subsurface Soil:																		
95 % Background Value		1.12	3.69 ug/g	1.04	1.91	1.47	0.150	1.26	11.1 ug/g	1.31	1.39	NA	NA	NA	0.436	ND	ND	ND
1.5 - 3	2		●															
3 - 5	2		●															
5 - 10	2	○	●	○			-											
10 - 15	3	○	●	○	○	○	-	○	○	○	●	-	-	-	■	X	-	-
15 - 20	1	●	●			○	-			●							-	-

INORGANICS (mg/kg)

Depth Interval, Feet	Number of Samples	Aluminum	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Calcium	Chromium	Cobalt	Copper	Cyanide	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium	Silicon	Silver	Sodium	Thallium	Vanadium	Zinc
Surface Soil:																												
95 % Background Value		11,900	ND	8.2	96.7	0.60	13.7	0.87	4340	16.5	14.2	14.1	0.27	21,700	26.4	2780	1350	0.30	ND	20.9	1230	0.72	1800	ND	61.1	0.88	30.4	69.6
0 - 0.5	20	●	X	○	●	▒	●	▒	■	●	●	●	■	●	●	■	●	-	X	●	●	●	○	X	▒	●	○	▒
0.5 - 1	0																											
1 - 1.5	0																											
Subsurface Soil:																												
95 % Background Value		16,100	ND	9.57	119	0.62		0.91	160,000	20.7	16.7	20	0.17	30,700	16.6	42,600	1300	0.29	2.70	34.3	1980	ND	1590	ND	285	0.49	37.8	82
1.5 - 3	0																											
3 - 5	0																											
5 - 10	0																											
10 - 15	0																											
15 - 20	0																											

ND - Not detected in background study.

NA - Not analyzed in background study.

"Blank" - Not analyzed.

- Analyzed and not detected.

○ Detection less than 95 percentile background value.

● Detection above but < 2X of 95 percentile background value.

▒ Detection 2X to 5X 95 percentile background value.

■ Detection greater than 5X 95 percentile background value.

X Detection where background level not recorded.

TABLE 4-37
(Continued)

Depth Interval, Feet	VOLATILES (ug/kg)							SEMIVOLATILES (ug/kg)											PESTICIDES /PCBs(ug/kg)										
	Number of Samples	1,1,1-Trichloroethene	4-Methyl-2-pentanone	Methylene chloride	Toluene	Trichloroethene		Number of Samples	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Bis(2-ethylhexyl)phthalate	Chrysene	Di-n-butyl phthalate	Fluoranthene	Phenanthrene	Pyrene		Number of Samples	4,4'-DDT									
Surface Soil:																													
0 - 0.5	18	-	X	-	X	X		18	X	X	X	X	X	X	X	X	X		13	X									
0.5 - 1	0							0											0										
1 - 1.5	0							0											0										
Subsurface Soil:																													
1.5 - 3	0							0											0										
3 - 5	0							0											0										
5 - 10	2	X	-	X	-	-		0											0										
10 - 15	0							0											0										
15 - 20	0							0											0										

"Blank" - Compound was not analyzed.

- Analyzed and not detected.

X Detection where background level not recorded.

TABLE 4-38
AREA OUTSIDE OF FEMP ADJACENT BOUNDARY
PARAMETER OCCURRENCES BY DEPTH

RADIONUCLIDES (pCi/g)

Depth Interval, Feet	Number of Samples	Uranium-238	Total Uranium	Uranium-234	Thorium-230	Radium-226	Uranium-235/236	Thorium-232	Total Thorium	Radium-228	Thorium-228	Neptunium-237	Plutonium-239/240	Plutonium-238	Strontium-90	Technetium-99	Ruthenium-106	Cesium-137
Surface Soil:																		
95 % Background Value		1.24	3.73 ug/g	1.24	1.97	1.42	0.156	1.36	12.4 ug/g	1.25	1.43	NA	NA	NA	0.424	ND	ND	0.711
0 - 0.5	40	■	■	■	●	●	■	●	●	●	●	-	X	-	●	X	-	●
0.5 - 1	0																	
1 - 1.5	9	●	■	■	●	○	-	●	●	○	●	-	-	-	●	-	-	○
Subsurface Soil:																		
95 % Background Value		1.12	3.69 ug/g	1.04	1.91	1.47	0.160	1.26	11.1 ug/g	1.31	1.38	NA	NA	NA	0.436	ND	ND	ND
1.5 - 3	8	●	●	●	●	○	○	○	○	○	●	-	-	-	■	-	-	X
3 - 5	4	■	■	■	●	○	◆	○	○	●	●	-	-	-	●	-	-	-
5-10	7	○	●	●	○	○	-	○	○	○	○	-	-	-	■	X	-	-
10 - 15	6	●	●	●	○	●	-	○	○	○	○	-	-	-	-	-	-	-
15 - 20	5	●	●	●	●	○	-	●	●	●	●	-	-	-	-	-	-	-

INORGANICS (mg/kg)

Depth Interval, Feet	Number of Samples	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Cyanide	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium	Silicon	Silver	Sodium	Thallium	Vanadium	Zinc
Surface Soil:																											
95 % Background Value		11,900	ND	8.2	95.7	0.60	0.87	4340	15.5	14.2	14.1	0.27	21,700	26.4	2780	1350	0.30	ND	20.9	1230	0.72	1800	ND	61.1	0.58	30.4	59.6
0 - 0.5	5	○	-	○	◆	◆	-	◆	○	◆	●	●	●	●	●	●	-	-	○	●	○	○	-	○	○	●	●
0.5 - 1	0																										
1 - 1.5	0																										
Subsurface Soil:																											
95 % Background Value		16,100	ND	9.57	119	0.62	0.91	150,000	20.7	15.7	20	0.17	30,700	15.6	42,600	1300	0.29	2.70	34.3	1980	ND	1590	ND	286	0.49	37.8	82
1.5 - 3	0																										
3 - 5	0																										
5-10	0																										
10 - 15	0																										
15 - 20	0																										

ND - Not detected in background study.

NA - Not analyzed in background study.

"Blank" - Not analyzed.

- Analyzed and not detected.

○ Detection less than 95 percentile background value.

● Detection above but < 2X of 95 percentile background value.

◆ Detection 2X to 5X 95 percentile background value.

■ Detection greater than 5X 95 percentile background value.

X Detection where background level not recorded.

TABLE 4-38
(Continued)

Depth Interval, Feet	VOLATILES (ug/kg)								SEMIVOLATILES (ug/kg)												PESTICIDES/PCBs (ug/kg)									
	Number of Samples	Ethylbenzene	Acetone	Tetrachloroethene	Toluene	Total Xylenes			Number of Samples	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Bis(2-ethylhexyl)phthalate	Chrysene	Fluoranthene	Ideno(1,2,3-cd)pyrene	Phenanthrene	Pyrene	Number of Samples	4,4'-DDT	Alpha-chlordane	Gamma-chlordane						
Surface Soil:																														
0 - 0.5	5	-	X	X	X	-			5	X	X	X	X	X	X	X	X	X	X	X	8	X	X	X						
0.5 - 1	0								0												0									
1 - 1.5	0								0												0									
Subsurface Soil:																														
1.5 - 3	0								0												0									
3 - 5	0								0												0									
5-10	0								0												0									
10 - 15	0								0												0									
15 - 20	1	X	-	-	X	X			0												0									

"Blank" - Compound was not analyzed.

- Analyzed and not detected.

X Detection where background level not recorded.

TABLE 4-39
AREA 2-5 MILES OUTSIDE OF FEMP BOUNDARY
PARAMETER OCCURRENCES BY DEPTH

RADIONUCLIDES (pCi/g)

Depth Interval, Feet	Number of Samples	Uranium-238	Total Uranium	Uranium-234	Thorium-230	Radium-226	Uranium-235/236	Thorium-232	Total Thorium	Radium-228	Thorium-228	Neptunium-237	Plutonium-239/240	Plutonium-238	Strontium-90	Technetium-99	Ruthenium-106	Cesium-137
Surface Soil:																		
95 % Background Value		1.24	3.73 ug/g	1.24	1.97	1.42	0.156	1.36	12.4 ug/g	1.25	1.43	NA	NA	NA	0.424	ND	ND	0.711
0 - 0.5	84	●	●	●			○											
0.5 - 1	1	●	●	●			○											
1 - 1.5	0																	
Subsurface Soil:																		
95 % Background Value		1.12	3.69 ug/g	1.04	1.91	1.47	0.150	1.26	11.1 ug/g	1.31	1.38	NA	NA	NA	0.436	ND	ND	ND
1.5 - 3	0																	
3 - 5	0																	
5 - 10	0																	
10 - 15	0																	
15 - 20	0																	

INORGANICS (mg/kg)

Depth Interval, Feet	Number of Samples	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Cyanide	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium	Silicon	Silver	Sodium	Thallium	Vanadium	Zinc
Surface Soil:																											
95 % Background Value		11,900	ND	8.2	95.7	0.60	0.87	4340	16.5	14.2	14.1	0.27	21,700	26.4	2780	1350	0.30	ND	20.9	1230	0.72	1800	ND	51.1	0.58	30.4	69.6
0 - 0.5	0																										
0.5 - 1	0																										
1 - 1.5	0																										
Subsurface Soil:																											
95 % Background Value		16,100	ND	9.57	119	0.62	0.91	150,000	20.7	16.7	20	0.17	30,700	15.6	42,600	1300	0.29	2.70	34.3	1980	ND	1590	ND	286	0.49	37.8	82
1.5 - 3	0																										
3 - 5	0																										
5 - 10	0																										
10 - 15	0																										
15 - 20	0																										

ND - Not detected in background study.

NA - Not analyzed in background study.

"Blank" - Not analyzed.

- Analyzed and not detected.

○ Detection less than 95 percentile background value.

● Detection above but < 2X of 95 percentile background value.

Detection 2X to 5X 95 percentile background value.

Detection greater than 5X 95 percentile background value.

X Detection where background level not recorded.

TABLE 4-39
(Continued)

Depth Interval, Feet	VOLATILES (ug/kg)							SEMIVOLATILES(ug/kg)													PESTICIDES/PCBs (ug/kg)									
	Number of Samples	Acetone						Number of Samples	Benzo(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Bis(2-ethylhexyl)Phthalate	Chrysene	Fluoranthene	Ideno(1,2,3-cd)pyrene	Phenanthrene	Pyrene		Number of Samles	4,4'-DDT	Alpha-Chlordane	Gamma-Chlordane						
Surface Soil:																														
0 - 0.5	4							3													5									
0.5 - 1	0							0													0									
1 - 1.5	0							0													0									
Subsurface Soil:																														
1.5 - 3	0							0													0									
3 - 5	0							0													0									
5 - 10	0							0													0									
10 - 15	0							0													0									
15 - 20	0							0													0									

[ ] "Blank" - Compound was not analyzed.

[-] Analyzed for and not detected.

[X] Detected.

000178

5696

TABLE 4-40
FEMP SURFACE SOIL
CONSTITUENTS DETECTED AT 5 X BACKGROUND

	Plant 1 Area	Plant 2/3 Area	Plant 4/5/7 Area	Plant 6 Area	Plant 8 Area	Plant 9 Area	Sewage Treatment Plant Area	Pilot Plant Area	Laboratory Area	Administration Area	Electrical Substation Area	Maintenance Building	Tank Farm and Boiler House	D&D Building and Drum Baling Area	Scrap Metal Pile	Graphite Furnace	KC-2 Warehouse Area	Fire Training Area	Trap Range	Area West of K-65 Silo	K-65/Clearwell Line West	Clearwell Line East	Outfall Pipeline	Great Miami Riverbank Characterization	Southwest Field Area	Northeastern Area of FEMP	Southern Area of FEMP	Western Area of FEMP	Northwestern Area of FEMP	Area Outside of FEMP Adjacent Boundary	Area 2-5 Miles Outside of FEMP Boundary
Radionuclides																															
Uranium-238	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●		●			●	●	●	●	●	
Total Uranium	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	
Uranium-234	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●		●			●	●	●	●	●	
Thorium-230	●	●	●			●	●	●	●	●				●	●	●		●			●					●	●	●			
Radium-226	●	●					●	●						●	●					●	●						●	●			
Uranium-235/236	●	●	●	●	●	●	●	●	●	●		●		●	●	●	●	●	●	●	●					●	●	●	●	●	
Thorium-232	●					●	●	●	●					●	●						●					●		●			
Total Thorium	●	●		●		●	●	●	●					●	●			●			●					●		●			
Radium-228	●	●				●	●	●	●					●	●											●		●			
Thorium-228	●	●		●		●	●	●	●					●	●						●					●		●			
Neptunium-237		X				X															X							X	X		
Plutonium-239/240		X					X	X	X			X				X		X	X	X	X						X	X			
Plutonium-238		X	X	X			X	X	X	X								X			X							X			
Strontium-90	●	●				●	●		●					●	●	●		●								●	●	●	●		
Technetium-99	X	X		X	X	X	X	X	X	X		X		X	X	X		X		X	X		X			X	X	X	X	X	
Ruthenium-106		X																			X						X	X			
Cesium-137	●																														
Metals																															
Aluminum																															
Antimony	X				X		X											X	X	X	X					X	X	X	X		
Arsenic																●															
Barium									●							●															
Beryllium		●			●																					●					
Cadmium	●	●		●		●		●	●			●	●			●		●		●								●			
Calcium	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●					●	●	●	●		
Chromium																															
Cobalt																															
Copper											●			●	●																
Cyanide												●				●			●							●			●		
Iron																															
Lead		●		●			●				●	●		●	●		●		●		●										
Magnesium	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●					●	●	●	●		
Manganese																															
Mercury	●	●																	●												
Molybdenum	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X					X	X	X	X		
Nickel																															
Potassium																															
Selenium																●												●			
Silicon																															
Silver	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X		X	X					X	X	X	X		
Sodium	●			●	●	●		●	●	●		●			●	●	●											●			
Thallium																															
Vanadium																															
Zinc	●						●					●			●		●	●													
Organic Compounds																															
Volatiles	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X			X					X	X	X	X	X	
Semi-Volatiles	X	X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X		X					X	X	X	X	X	
Pesticides	X			X						X		X				X		X			X					X		X	X	X	
PCBs	X	X		X		X	X		X	X	X	X	X	X	X	X	X	X			X							X			
Dioxins/Furans																X		X										X			

● Detection greater than 5 times background

X Constituent detected but no background level obtained

Expected contamination

000779

TABLE 4-41
FEMP SUBSURFACE SOIL
CONSTITUENTS DETECTED AT 5 X BACKGROUND

	Plant 1 Area	Plant 2/3 Area	Plant 4/5/7 Area	Plant 6 Area	Plant 8 Area	Plant 9 Area	Sewage Treatment Plant Area	Pilot Plant Area	Laboratory Area	Administration Area	Electrical Substation Area	Maintenance Building	Tank Farm and Boiler House	D&D Building and Drum Bailing Area	Scrap Metal Pile	Graphite Furnace	KC-2 Warehouse Area	Fire Training Area	Trap Range	Area West of K-65 Silo	K-65/Clearwell Line West	Clearwell Line East	Outfall Pipeline	Great Miami Riverbank Characterization	Southwest Field Area	Northeastern Area of FEMP	Southern Area of FEMP	Western Area of FEMP	Northwestern Area of FEMP	Area Outside of FEMP Adjacent Boundary	Area 2-5 Miles Outside of FEMP Boundary
Radionuclides																															
Uranium-238	●	●	●	●	●	●	●	●	●	●					●	●				●	●			●		●		●		●	
Total Uranium	●	●	●	●	●	●	●	●	●	●		●		●	●	●		●		●	●		●	●		●		●		●	
Uranium-234	●	●	●	●	●	●	●	●	●						●	●				●	●			●		●		●		●	
Thorium-230		●		●	●		●														●										
Radium-226																				●											
Uranium-235/236		●	●	●	●	●	●	●	●						●	●					●							●			
Thorium-232								●																							
Total Thorium						●		●							●																
Radium-228	●							●							●																
Thorium-228								●										●													
Neptunium-237																					X	X									
Plutonium-239/240		X		X																X								X			
Plutonium-238				X					X											X	X						X	X			
Strontium-90	●	●		●	●	●	●								●					●						●		●	●	●	
Technetium-99	X	X		X	X	X	X	X								X				X	X							X	X	X	
Ruthenium-106																															
Cesium-137		X			X	X	X													X			X	X				X		X	
Metals																															
Aluminum																●				●											
Antimony		X		X																											
Arsenic																				●											
Barium								●				●								●											
Beryllium	●		●																	●											
Cadmium	●			●				●				●	●			●												●			
Calcium																				●											
Chromium																				●											
Cobalt																				●											
Copper																				●											
Cyanide				●								●				●				●											
Iron																				●											
Lead																				●											
Magnesium																															
Manganese																				●											
Mercury		●																													
Molybdenum																															
Nickel																				●											
Potassium																				●											
Selenium	X	X		X	X			X	X				X			X				X								X			
Silicon																															
Silver	X	X		X		X		X	X			X	X	X	X	X		X		X						X		X			
Sodium								●																							
Thallium																															
Vanadium																				●											
Zinc	●																			●											
Organic Compounds																															
Volatiles	X	X	X	X		X		X	X	X		X	X	X	X	X		X		X	X	X				X		X	X	X	
Semi-Volatiles	X	X	X	X		X	X		X	X		X	X		X	X		X		X	X					X		X			
Pesticides	X									X		X				X															
PCBs	X	X		X					X			X				X		X			X					X		X	X	X	
Dioxins/Furans																		X													

● Detection greater than 5 times background

X Constituent detected but no background level obtained

Expected contamination

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TABLE 4-42
ISOLATED DETECTIONS OF PARAMETERS OUTSIDE THE 20 MG/KG URANIUM ENVELOPE

	Detections Within 20 mg/kg Uranium Envelope	Trap Range	Near Sewage Treatment Plant	Near K-48 Silos	Southern Area	Northwestern Area	Northeastern Area
Radionuclides							
Uranium-238	Yes						
Total Uranium	Yes						
Uranium-234	Yes						
Thorium-230							
Radium-226							
Uranium-235/236	Yes						
Thorium-232	Yes						
Total Thorium	No						
Radium-228	Yes						
Thorium-228	Yes						
Neptunium-237	Yes						
Plutonium-239/240	Yes						
Plutonium-238	Yes						
Strontium-90	No			◐	■	■	■
Technetium-99	Yes						
Ruthenium-106	Yes						
Cesium-137	Yes				●		●
Inorganics							
Aluminum	Yes						
Antimony	No			X			
Arsenic	No	◐		◐	●		
Barium	No	●				●	
Beryllium	No				◐	◐	
Cadmium	No			■			
Calcium	No	■		■	■	■	
Chromium	No	◐		●			
Cobalt	No		◐				
Copper	No	◐		●	●	●	
Cyanide	No	■			◐	■	
Iron	No	●					
Lead	No	■				●	
Magnesium	No	■		■	■	■	
Manganese	No		◐				
Mercury	No	■					
Molybdenum	No	X			X	X	X
Nickel	No			●		●	●
Potassium	No					●	●
Selenium	No					●	
Silicon	Yes						
Silver	No			X			
Sodium	No				◐	◐	
Thallium	Yes						
Vanadium	No						
Zinc	No					◐	
Organic Compounds							
Volatiles	No			X	X	X	
Semi-Volatiles	Yes						
Pesticides	Yes						
PCBs	Yes						
Dioxins	Yes						

- ● Detection above but < 2 X 95th percentile background value.
- ◐ Detection 2 to 5 X 95th percentile background value
- ■ Detection greater than 5 X 95th percentile background value.
- X Detection where background level not recorded.
- ○ Detection less than 95th percentile background value.

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TABLE 4-43

AQUEOUS SPECIES IN PERCHED GROUNDWATER[1]

Constituent	Species in Groundwater	Abundance (percent)[2]
Ag^{+} - Silver	$AgCl^{0}$	63.63
	Ag^{+}	26.51
	$AgCl_2^{-}$	9.71
Al^{+3} - Aluminum	$Al(OH)_4^{-}$	96.36
	$Al(OH)_3^{0}$	2.84
Ba^{+2} - Barium	Ba^{+2}	99.81
Be^{+2} - Beryllium	Be^{+2}	99.93
Ca^{+2} - Calcium	Ca^{+2}	89.94
	$CaHCO_3^{+}$	4.79
	$CaSO_4^{0}$	4.43
Cd^{+2} - Cadmium	Cd^{+2}	100.00
Cl^{-} - Chloride	Cl^{-}	99.83
Co^{+2} - Cobalt	$Co_2(OH)_3^{+}$	85.33
	$HCoO_2^{-}$	13.54
	Co^{+2}	1.12
CrO_4^{-2} - Chromium	$Cr(OH)_2^{+}$	85.94
	$Cr(OH)_3^{0}$	11.88
	$CrOH^{+2}$	2.02
Cs^{+} - Cesium	Cs^{+}	99.94

TABLE 4-43 (Continued)

Constituent	Species in Groundwater	Abundance (percent)[2]
Cu^{+2} - Copper	$CuCO_3^0$	93.55
	$Cu(CO_3)_2^{-2}$	2.67
	$CuOH^+$	1.91
	Cu^{+2}	1.69
F^- - Fluoride	F^-	94.43
	AsO_3F^{-2}	2.35
	MgF^+	2.31
Fe^{+2} Iron	$Fe(OH)_3^0$	55.15
	Fe^{+2}	19.55
	$FeHCO_3^+$	10.39
	$FeCO_3^0$	6.44
	$Fe(OH)_2^+$	6.37
	$FeSO_4^0$	1.25
$H_2AsO_4^-$ - Arsenic	AsO_3F^{-2}	98.44
	$HAsO_3F^-$	1.56
HCO_3^- - Bicarbonate	HCO_3^-	89.64
	CO_2^0	6.52
	$CaHCO_3^+$	1.82
	$MgHCO_3^+$	1.06

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TABLE 4-43 (Continued)

Constituent	Species in Groundwater	Abundance (percent)[2]
HPO_4^{-2} - Phosphorous	HPO_4^{-2}	37.55
	$CaHPO_4^0$	22.01
	$MgHPO_4^0$	19.68
	$H2PO_4^-$	13.96
	$CaPO_4^-$	1.97
	$MgPO_4^-$	1.60
	$MgH_2PO_4^+$	0.70
	$FeHPO_4^0$	0.68
	$CaH_2PO_4^+$	0.63
	$NaHPO_4^-$	0.45
Hg^{+2} - Mercury	Hg_2^{+2}	100.00
K^+ - Potassium	K^+	99.51
Mg^{+2} - Magnesium	Mg^{+2}	87.51
	$MgSO_4^0$	7.25
	$MgHCO_3^+$	4.66
Mn^{+2} - Manganese	Mn^{+2}	75.37
	$MnCO_3^0$	15.30
	$MnSO_4^0$	6.16
	$MnHCO_3^+$	2.72
MoO_4^{-2} - Molybdenum	MoO_4^{-2}	100.00
NO_3^- - Nitrogen	N_2^0	100.00
Na^+ - Sodium	Na^+	98.53
	$NaHCO_3^0$	1.01

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TABLE 4-43 (Continued)

Constituent	Species in Groundwater	Abundance (percent)[2]
Ni^{+2} - Nickel	Ni^{+2}	95.12
	$NiSO_4^0$	4.88
Np^{+4} - Neptunium	$Np(HPO_4)_5^{-6}$	99.82
Pb^{+2} - Lead	Pb^{+2}	97.92
	$PbCl^+$	1.95
Pu^{+4} - Plutonium	$Pu(OH)_5^-$	80.85
	$Pu(HPO_4)_4^{-4}$	18.26
Ra^{+2} - Radium	Ra^{+2}	100.00
SO_4^{-2} - Sulfate	SO_4^{-2}	78.61
	$CaSO_4^0$	10.24
	$MgSO_4^0$	10.08
	$NaSO_4^-$	0.74
SeO_3^{-2} - Selenium	SeO_3^{-2}	68.64
	$HSeO_3^-$	31.36
SiO_2^0 - Silicon	SiO_2^0	95.79
	$H_6(H_2SiO_4)_4^{-2}$	3.87
Sr^{+2} - Strontium	Sr^{+2}	92.38
	$SrSO_4^0$	7.31
TcO_4^- - Technetium	TcO_4^-	100.00

TABLE 4-43 (Continued)

Constituent	Species in Groundwater	Abundance (percent)[2]
Th^{+4} - Thorium	$Th(OH)_4^0$	68.15
	$Th(HPO_4)_3^{-2}$	31.80
Tl^+ - Thallium	Tl^+	100.00
UO_2^{+2} - Uranium	$UO_2(CO_3)_3^{-4}$	79.48
	$UO_2(CO_3)_2^{-2}$	20.25
VO^{+2} - Vanadium	VO_3OH^{-2}	40.75
	$VO_2(OH)_2^-$	28.63
	$H_2VO_4^-$	23.16
	HVO_4^{-2}	7.45
Zn^{+2} - Zinc	Zn^{+2}	88.87
	$ZnHCO_3^+$	9.89
	$ZnOH^+$	1.00

[1]Based on EQ3/6 Geochemical Code (Version 7; Wolery, 1992)

[2]The sum of individual species accounts for more than 99% of constituent in groundwater.

TABLE 4-44

SUMMARY OF THE NATURE, EXTENT AND SOURCES OF PERCHED GROUNDWATER CONTAMINANTS

Parameter	Extent (C or I)[1]	Nature (Solubility/Absorption)[2]	Potential Process or Material Sources
Uranium-238	C	MS to HS/MA	Uranium ores, ore concentrates, and recycled material
Uranium-234	C	MS to HS/MA	Uranium ores, ore concentrates, and recycled material
Uranium-235/236	C	MS to HS/MA	Uranium ores, ore concentrates, and recycled material
Thorium-230	I	LS/MA	Minor impurity in uranium ores and ore concentrates
Radium-226	I	LS to MS/HA	Impurity in uranium ores and ore concentrates
Thorium-232	I	LS/MA	Thorium feed material
Radium-228	I	LS to MS/HA	Impurity in thorium ores and ore concentrates
Thorium-228	I	LS/MA	Impurity in thorium ores and ore concentrates
Strontium-90	I	MS to HS/MA	Impurity in recycled uranium from other DOE facilities, fallout
Technetium-99	C	HS/LA	Impurity in recycled uranium from other DOE facilities, fallout
Ruthenium-106	ND	MS/MA	Impurity in recycled uranium from other DOE facilities, fallout
Cesium-137	I	HS/HA	Impurity in recycled uranium from other DOE facilities, fallout
Plutonium-239/240	I	LS/MA	Impurity in recycled uranium from other DOE facilities
Plutonium-238	I	LS/MA	Impurity in recycled uranium from other DOE facilities

TABLE 4-44 (Continued)

Parameter	Extent (C or I)[1]	Nature (Solubility/Absorption)[2]	Potential Process or Material Sources
Neptunium-237	I	MS/MA	Impurity in recycled uranium from other DOE facilities
Aluminum	I	LS/MA	Minor impurity in uranium ores, hydrated aluminum used in raffinate treatment for fluoride removal, cladding
Antimony	I	MS/MA	Minor impurity in uranium ores
Arsenic	I	MS/LA	Minor impurity in uranium ores
Barium	I	LS to MS/HA	Minor constituent in native soils, $BaSO_4$ used in thorium raffinate treatment, BaCl and $BaSO_4$ disposal in waste pits
Beryllium	I	LS/MA	
Cadmium	I	MS/HA	Minor impurity in uranium ores
Calcium	C	MS/MA	Major constituent in native soils, lime used for neutralization, major impurity in uranium ore concentrates
Chromium	I	MS/MA	Minor impurity in uranium ores
Cobalt	I	MS/MA to HA	Minor impurity in uranium ores
Copper	I	MS/MA	Minor impurity in uranium ores, cladding
Cyanide	I	HS/LA	Natural vegetation by-product, laboratory reagent
Iron	C	LS/MA	Minor constituent in native soils, major impurity in uranium ores
Lead	I	LS/HA	Minor impurity in uranium ores
Magnesium	C	MS/MA	Major constituent in native soils, reduction of UF_4 to U, major impurity in uranium ores

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TABLE 4-44 (Continued)

Parameter	Extent (C or I)[1]	Nature (Solubility/Absorption)[2]	Potential Process or Material Sources
Manganese	C	MS/MA	Minor constituent in soils, minor impurity in uranium ores
Mercury	I	LS/HA	Al/U alloy dissolution in Plant 2/3, laboratory uses
Molybdenum	I	MS/LA	Minor impurity in uranium ores
Nickel	I	MS/HA	Minor impurity in uranium ores, cladding
Potassium	I	MS to HS/MA	KCl used in heat treating, HF neutralization and residue recovery
Selenium	I	MS/LA to MA	
Silicon	I	MS/LA to MA	Major constituents in native soils, major impurity in uranium ores
Silver	I	LS/MA to HA	Algaecide in Plant 4 heat exchangers, photo lab
Sodium	C	MS to HS/MA	Major constituent in native soils, major impurity in uranium ores, NaCl heat treating, NaOH neutralization
Thallium	I	LS to MS/MA	Laboratory reagent
Vanadium	C	MS/MA	Minor impurity in uranium ores
Zinc	C	MS/MA to HA	Minor impurity in uranium ores, cladding
Volatile Organic Compounds	C	Variable	Solvents/degreasers, various
Semivolatile Organic Compounds	I	Variable	Various, tributylphosphate and kerosene used in refining
Ammonia	I	HS/LA	Minor impurity in uranium ores, neutralization, residue from U recovery and UF_4 production

TABLE 4-44 (Continued)

Parameter	Extent (C or I)[1]	Nature (Solubility/Absorption)[2]	Potential Process or Material Sources
Chloride	C	HS/LA	Minor impurity in uranium ores, NaCl and KCl used in heat treating, HCl used to dissolved U metal
Fluoride	I	MS to HS/LA	Minor impurity in uranium ores, anhydrous and aqueous HF
Nitrate	C	HS/LA	HNO_3 used to dissolve uranium and thorium feed materials
Phosphorous	C	MS/LA	Minor impurity in uranium ores
Sulfate	C	MS to HS/LA	Major impurity in uranium ores, H_2SO_4

[1] C Contamination is of extent that it is discernable on contour maps of groundwater analytical results.
I Isolated occurrences at above background concentrations. Quantity released to groundwater not sufficient to be discerned as plumes in monitor well network. Many detections at above background concentrations possibly due to natural conditions.
ND Not detected

[2] Solubility in groundwater
LS - Low solubility
MS - Medium solubility
HS - High solubility

Tendency to absorb to soil matrix
LA - Low absorption
MA - Medium absorption
HA - High absorption

TABLE 4-45

SUMMARY STATISTICS FOR MAJOR CONTAMINANTS IN FEMP TYPE 1 WELLS[1]

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Uranium-238	P101	FIL	pCi/L	126/148		2.55	.400 - 44100	.200 - 1.00	A
Uranium-238	P101	UNF	pCi/L	191/211	185/211	219	.300 - 39000	.200 - 1.00	0.800
Uranium, total	P102	FIL	µg/L	174/181	169/181	3.70	.290 - 129000	.100 - 1.00	1.40
Uranium, total	P102	UNF	µg/L	273/275	268/275	3.25	.400 - 436000	.100 - .100	1.30
Uranium-234	P103	FIL	pCi/L	129/147	124/147	214	.300 - 42800	.200 - .700	0.600
Uranium-234	P103	UNF	pCi/L	186/206	175/206	262	.00100 - 25000	.200- 1.00	0.900
Thorium-230	P104	FIL	pCi/L	45/148	45/148	.150	.251 - 24.3	.200 - 1.00	ND
Thorium-230	P104	UNF	pCi/L	104/192	38/192	.500	.227 - 28.0	.200 - 4.70	1.30
Radium-226	P105	FIL	pCi/L	21/152	21/152	.500	1.07 - 16.6	.0900 - 1.20	0.900
Radium-226	P105	UNF	pCi/L	86/195	86/195	.500	1.01 - 35.8	.14400 - 25.0	0.900
Lead-210	P106	FIL	pCi/L	0/1	0/1			3.00 - 3.00	NA
Lead-210	P106	UNF	pCi/L	0/3	0/3			3.00 - 3.00	NA
Polonium-210	P107	UNF	pCi/L	0/2	0/2			1.20 - 1.70	NA
Uranium-235/236	P108	FIL	pCi/L	78/148	78/148	.550	.236 - 2170	.100 - 1.20	ND
Uranium-235/236	P108	UNF	pCi/L	100/189	100/189	.600	.208 - 2490	.100 - 208	ND
Thorium-232	P109	FIL	pCi/L	14/147	14/147	.100	.216 - 10.0	.100 - 8.5	ND

TABLE 4-45 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Thorium-232	P109	UNF	pCi/L	61/192	53/192	.150	.300 - 11.5	.100 - 4.70	0.340
Thorium, total	P110	FIL	µg/L	40/71	40/71	1.82	.912 - 10.6	.500 - 9.48	ND
Thorium, total	P110	UNF	µg/L	119/173	64/173	2.74	.700 - 23000	.500 - 43.0	3.10
Radium-228	P111	FIL	pCi/L	26/153	26/153	1.50	3.10 - 16.0	.0330 - 5.00	2.20
Radium-228	P111	UNF	pCi/L	32/190	32/190	1.50	3.10 - 219	1.49 - 44.0	3.00
Thorium-228	P112	FIL	pCi/L	22/146	22/146	.100	.300 - 10.0	-.0140 - 1.03	0.100
Thorium-228	P112	UNF	pCi/L	92/192	19/192	.400	.293 - 14.0	.200 - 13.8	1.50
Neptunium-237	P113	FIL	pCi/L	7/36	7/36	.525	0 - 1.97	.251 - 1.00	NA
Neptunium-237	P113	UNF	pCi/L	1/106	1/106	.500	.626 - .626	.200 - 8.60	0.250
Plutonium-239/240	P114	FIL	pCi/L	4/44	4/44	.553	.506 - 1.00	.156 - 1.00	NA
Plutonium-239/240	P114	UNF	pCi/L	2/116	2/116	.500	1.00 - 1.00	.0940 - 1.00	ND
Plutonium-238	P115	FIL	pCi/L	4/44	4/44	.800	.913 - 1.00	0 - 1.00	NA
Plutonium-238	P115	UNF	pCi/L	3/116	3/116	.500	.744 - 1.00	.116 - 1.00	0.0750
Strontium-90	P116	FIL	pCi/L	9/49	9/49	1.20	1.20 - 5.00	-.115 - 5.00	NA
Strontium-90	P116	UNF	pCi/L	10/112	7/112	2.50	1.01 - 7.68	.600 - 5.00	2.00
Technetium-99	P117	FIL	pCi/L	56/138	45/138	7.95	15.1 - 2670	-1.82 - 30.0	30.0
Technetium-99	P117	UNF	pCi/L	64/170	55/170	7.53	15.8 - 6130	12.0 - 35.1	30.0
Ruthenium-106	P118	FIL	pCi/L	0/41	0/41			110 - 153	NA
Ruthenium-106	P118	UNF	pCi/L	0/109	0/109			119 - 165	ND

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TABLE 4-45 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Aluminum	P201	FIL	mg/L	73/196	42/196	.0462	.0144 - 10.4	.0114 - 20.0	0.123
Antimony	P202	FIL	mg/L	24/192	19/192	.00785	.00550 - .0987	.000500 - 45.0	0.0272
Arsenic	P203	FIL	mg/L	50/202	1/202	.00100	.00120 - .191	.00100 - .00500	0.122
Barium	P204	FIL	mg/L	197/202	2/202	.0532	.00750 - .589	.0138 - .400	0.454
Beryllium	P205	FIL	mg/L	14/192	13/192	.000500	.00120 - .0343	.000300 - .0100	0.00180
Cadmium	P207	FIL	mg/L	35/202	17/202	.00150	.00270 - .0500	.00100 - .0146	0.00600
Calcium	P208	FIL	mg/L	203/204	95/204	149	4.65 - 1800	91.6 - 91.6	131
Chromium	P210	FIL	mg/L	45/201	27/201	.00230	.00480 - .818	.00200 - .0200	0.0340
Cobalt	P211	FIL	mg/L	23/192	23/192	.00300	.00630 - .0886	.00300 - .0257	ND
Copper	P212	FIL	mg/L	40/202	22/202	.00200	.00340 - .298	.00200 - .0251	0.0190
Cyanide	P213	UNF	mg/L	15/208	15/208	.00250	.00200 - .552	.0000200 -.0200	ND
Iron	P214	FIL	mg/L	98/203	11/203	.0154	.0104 - 21.3	.00500 - .340	3.58
Lead	P215	FIL	mg/L	36/203	5/203	.000500	.00100 - .0114	.00100 - .00690	0.00870
Magnesium	P216	FIL	mg/L	203/204	97/204	44.1	1.55 - 690	26.9 - 26.9	47.8
Manganese	P217	FIL	mg/L	175/202	95/202	.0646	.00250 - 35.0	.00100 - .0200	0.180
Mercury	P218	FIL	mg/L	4/202	4/202	.0000500	.000200-.00180	.000100 -.00100	0.0004
Molybdenum	P219	FIL	mg/L	36/146	25/146	.00500	.00450 - 1.42	.00300 - .0490	0.0170
Nickel	P220	FIL	mg/L	41/202	33/202	.00900	.00370 - .981	.00300 - .0936	0.0220
Potassium	P223	FIL	mg/L	177/203	5/203	1.81	.380 - 12400	.340 - 1.52	29.3

TABLE 4-45 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Selenium	P225	FIL	mg/L	19/202	19/202	.000950	.00110 - .0494	.00100 - .0200	ND
Silicon	P226	FIL	mg/L	90/91	31/91	6.75	3.37 - 15.0	6.96 - 6.96	7.43
Silver	P227	FIL	mg/L	31/202	12/202	.00150	.00290 - .264	.000500 - .050	0.0400
Sodium	P228	FIL	mg/L	203/203	35/203	28.1	2.35 - 1300		56.3
Thallium	P230	FIL	mg/L	4/192	4/192	.000500	.00100 - .00280	.00100 - .0410	ND
Vanadium	P233	FIL	mg/L	36/195	23/195	.00200	.00290 - .299	.00290 - .0500	0.0195
Zinc	P236	FIL	mg/L	72/195	13/195	.00300	.00200 - 1.78	.00210 - .0360	0.0443
Ammonia	P705	UNF	mg/L	100/181	4/181	.0500	.0300 - 220	.0200 - .400	4.34
Chloride	P715	UNF	mg/L	169/173	54/173	3.78	.0320 - 6300	2.20 - 13.0	45.0
Fluoride	P721	UNF	mg/L	170/170	10/170	.400	.125 - 6.80		1.30
Nitrate	P729	UNF	mg/L	153/253	105/253	.0400	.0120 - 2670	.0200 - .200	0.290
Sulfate	P744	UNF	mg/L	168/171	56/171	41.0	.170 - 6200	.500 - 2.00	136

[1]Based on Table E.1-1 in Appendix E
[2]Frequency of detection is defined as (number of detectable results)/(number of wells tested)

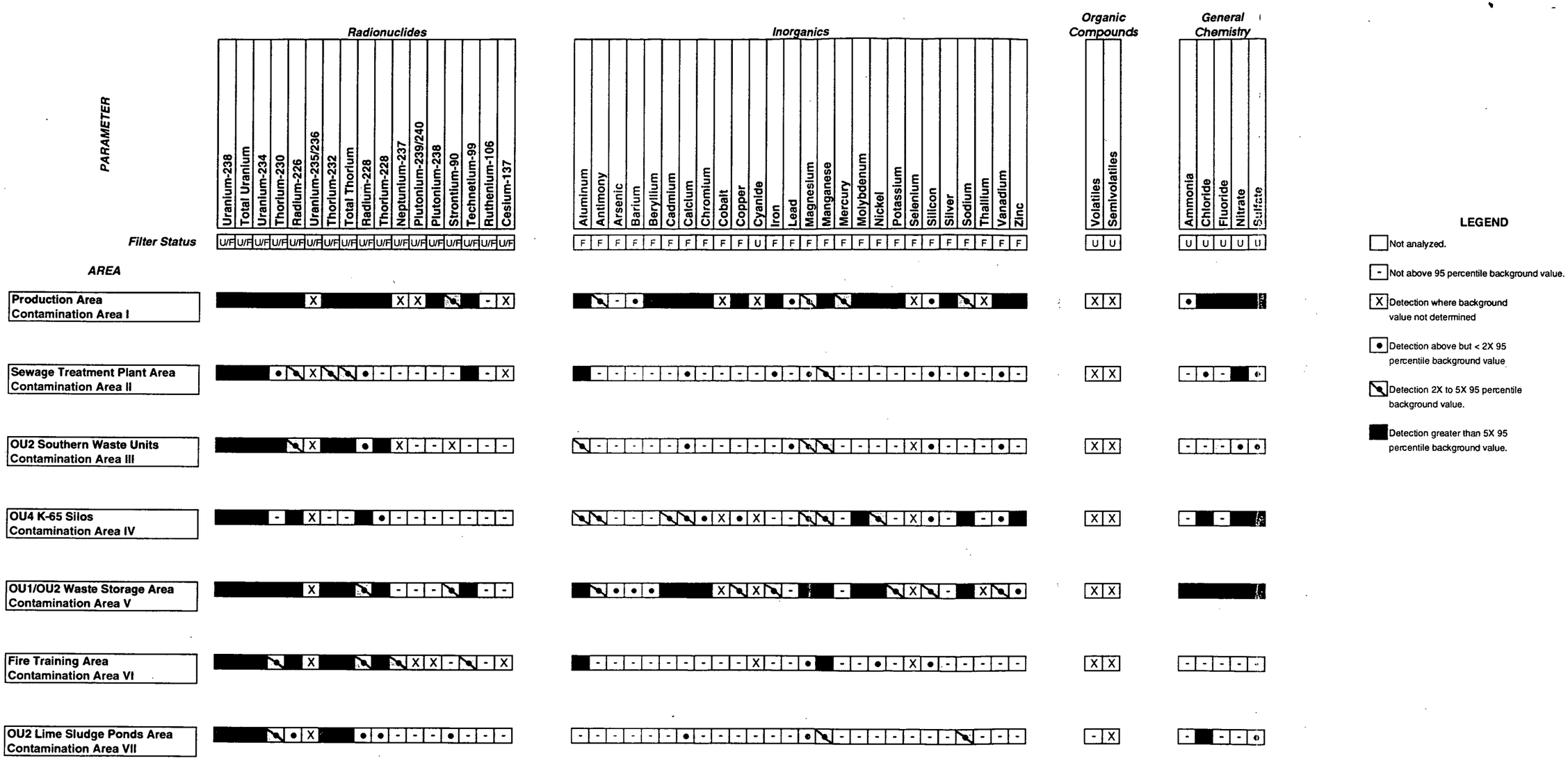

TABLE 4-46
SUMMARY OF PARAMETER OCCURRENCE IN SEVEN PERCHED GROUNDWATER CONTAMINATION AREAS

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TABLE 4-47

SUMMARY STATISTICS FOR MAJOR CONTAMINANTS
DETECTED IN THE PRODUCTION AREA
CONTAMINATION AREA I[1]

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Uranium-238	FIL	pCi/L	77/89		10.4	.500 - 44100	.200 - 1.00	A
Uranium-238	UNF	pCi/L	111/121	108/121	34.2	.300 - 39000	.200 - .200	0.800
Uranium, total	FIL	µg/L	114/117	111/117	1100	.290 - 12900	.100 - 1.00	1.40
Uranium, total	UNF	µg/L	175/175	173/175	7000	.400 - 436000		1.30
Uranium-234	FIL	pCi/L	79/88	76/88	178	.300 - 42800		0.600
Uranium-234	UNF	pCi/L	109/121	102/121	33.1	.001 - 25000	.200 - .200	0.900
Thorium-230	FIL	pCi/L	31/89	31/89	0.50	.300 - 24.3	.200 - .100	ND
Thorium-230	UNF	pCi/L	67/106	24/106	0.80	.251 - 12.0	.200 - 4.70	1.30
Radium-226	FIL	pCi/L	13/91	13/91	0.50	1.10 - 16.6	.900 - 1.20	0.900
Radium-226	UNF	pCi/L	55/105	55/105	5.80	1.01 - 8.30	.144 - 1.00	0.900
Uranium-235/236	FIL	pCi/L	56/89	56/89	0.50	.300 - 2170	.100 - 1.20	ND
Uranium-235/236	UNF	pCi/L	68/104	68/104	14.9	.300 - 2490	.100 - 208	ND
Thorium-232	FIL	pCi/L	9/88	9/88	0.30	.243 - 10.0	.100 - 8.50	ND
Thorium-232	UNF	pCi/L	39/106	33/106	0.65	.300 - 11.3	.100 - 4.70	0.34
Thorium, total	FIL	µg/L	25/42	25/42	4.56	.912 - 8.77	.500 - 7.50	ND
Thorium, total	UNF	µg/L	73/93	38/93	2.75	.912 - 23000	.700 - 43.0	3.10
Radium-228	FIL	pCi/L	17/92	17/92	1.50	3.10 - 16.0	1.50 - 5.00	2.20
Radium-228	UNF	pCi/L	22/105	22/105	1.50	3.10 - 219	1.49 - 3.30	3.00
Thorium-228	FIL	pCi/L	18/87	18/87	0.50	.300 - 10.0	.200 - 1.00	0.100

TABLE 4-47 (Continued)

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Thorium-228	UNF	pCi/L	63/106	10/106	0.50	.300 - 5.99	.200 - 13.0	1.50
Neptunium-237	FIL	pCi/L	3/17	3/17	0.25	1.00 - 1.97	.500 - 1.00	NA
Neptunium-237	UNF	pCi/L	0/45	0/45			.200 - 8.60	0.25
Plutonium-239/240	FIL	pCi/L	3/22	3/22	0.375	.506 - 1.00	.500 - 1.00	A
Plutonium-239/240	UNF	pCi/L	0/46	0/46			.094 - 1.00	ND
Plutonium-238	FIL	pCi/L	3/22	3/22	0.375	.913 - 1.00	.500 - 1.00	NA
Plutonium-238	UNF	pCi/L	1/46	1/46	0.375	.744 - .744	.116 - 1.00	0.08
Strontium-90	FIL	pCi/L	5/24	5/24	1.23	2.09 - 5.00	1.00 - 5.00	NA
Strontium-90	UNF	pCi/L	2/42	1/42	1.50	1.01 - 7.68	.600 - 5.00	2.00
Technetium-99	FIL	pCi/L	37/81	30/81	1680	15.1 - 2670	13.5 - 30.0	30.0
Technetium-99	UNF	pCi/L	46/92	41/92	1600	17.2 - 6130	12.0 - 30.0	30.0
Ruthenium-106	FIL	pCi/L	0/22	0/22			150 - 150	NA
Ruthenium-106	UNF	pCi/L	0/44	0/44			119 - 165	ND
Aluminum	FIL	mg/L	46/119	26/119	0.891	.037 - 10.4	.014 - 20.0	0.122
Antimony	FIL	mg/L	12/116	10/116	0.019	.006 - .087	.001 - 45.0	0.027
Arsenic	FIL	mg/L	25/119	0/119	0.001	.001 - .032	.001 - .005	0.122
Barium	FIL	mg/L	116/119	1/119	0.129	.008 - .589	.014 - .200	0.451
Beryllium	FIL	mg/L	10/116	9/116	0.008	.001 - .034	.0003 - .010	0.002
Cadmium	FIL	mg/L	19/119	6/119	0.015	.003 - 0.04	.001 - .015	0.006
Calcium	FIL	mg/L	120/121	58/121	225	4.65 - 841	91.6 - 91.6	131
Chromium	FIL	mg/L	22/118	16/118	0.208	.009 - .818	.002 - .020	0.034
Cobalt	FIL	mg/L	9/116	9/116	0.004	.007 - .087	.003 - .026	ND
Copper	FIL	mg/L	25/119	13/119	0.050	.003 - .298	.002 - .025	0.019
Cyanide	UNF	mg/L	8/119	8/119	0.001	.003 - .552	.001 - .020	ND

TABLE 4-47 (Continued)

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Iron	FIL	mg/L	57/120	0/120	0.112	.010 - 20.4	.005 - .340	3060
Lead	FIL	mg/L	22/120	3/120	0.001	.001 - .011	.001 - .007	0.009
Magnesium	FIL	mg/L	120/121	51/121	74.1	1.55 - 217	26.9 - 26.9	47.8
Manganese	FIL	mg/L	107/119	61/119	0.265	.004 - 9.03	.002 - .015	0.18
Mercury	FIL	mg/L	4/119	2/119	0.001	.0002 - .002	.0001 - .0003	0.0004
Molybdenum	FIL	mg/L	12/69	10/69	0.025	0.010 - 1.42	.010 - .045	0.017
Nickel	FIL	mg/L	19/119	16/119	0.058	.008 - .227	.005 - .038	0.022
Potassium	FIL	mg/L	101/120	3/120	2.92	.437 - 12400	.340 - 1.52	29.3
Selenium	FIL	mg/L	10/119	10/119	0.001	.001 - .006	.001 - .005	ND
Silicon	FIL	mg/L	47/48	14/48	5.56	3.85 - 12.1	6.96 - 6.96	7.43
Silver	FIL	mg/L	19/119	9/119	0.102	.003 - .264	.001 - .010	0.04
Sodium	FIL	mg/L	120/120	32/120	32.8	2.35 - 255		38.3
Thallium	FIL	mg/L	2/116	2/116	0.009	.003 - .003	.001 - .010	ND
Vanadium	FIL	mg/L	20/118	12/118	0.044	.003 - .299	.003 - .050	0.020
Zinc	FIL	mg/L	42/118	6/118	0.004	.002 - .758	.003 - .034	0.044
Ammonia	UNF	mg/L	57/97	1/97	0.025	0.030 - 5.33	.020 - .400	4.34
Chloride	UNF	mg/L	85/86	25/86	12.9	1.70 - 698	6.30 - 6.30	45.0
Fluoride	UNF	mg/L	85/85	4/85	0.18	.125 - 6.80		1.30
Nitrate	UNF	mg/L	103/174	80/174	5.05	0.030 - 677	.020 - .200	0.290
Sulfate	UNF	mg/L	84/84	20/84	69.1	2.30 - 751		136

[1]Based on Table E.1-2 in Appendix E
[2]Frequency of detection is defined as (number of detectable results)/(number of wells tested)

TABLE 4-48

SUMMARY STATISTICS FOR MAJOR CONTAMINANTS DETECTED IN THE SEWAGE TREATMENT PLANT AREA CONTAMINATION AREA II[1]

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Uranium-238	FIL	pCi/L	8/9		101	1.30 - 101		A
Uranium-238	UNF	pCi/L	8/9	8/9	49.6	1.20 - 97.2		0.800
Uranium, total	FIL	µg/L	9/9	9/9	273	3.49 - 273		1.40
Uranium, total	UNF	µg/L	9/9	9/9	289	2.30 - 289		1.30
Uranium-234	FIL	pCi/L	9/9	8/9	88.3	1.80 - 88.3		0.600
Uranium-234	UNF	pCi/L	8/9	8/8	47.0	1.30 - 91.0		0.900
Thorium-230	FIL	pCi/L	0/7	0/7			.200 - .300	ND
Thorium-230	UNF	pCi/L	6/8	1/8	1.35	.300 - 1.50	.200 - .200	1.30
Radium-226	FIL	pCi/L	2/9	2/9	1.20	1.20 - 1.20	1.00 - 1.20	0.900
Radium-226	UNF	pCi/L	4/8	8/8	2.25	1.50 - 2.70	1.00 - 1.00	0.900
Uranium-235/236	FIL	pCi/L	5/9	5/9	3.10	.240 - 3.10	.200 - .200	ND
Uranium-235/236	UNF	pCi/L	4/8	4/8	2.15	.300 - 4.20	.200 - .410	ND
Thorium-232	FIL	pCi/L	0/7	0/7			.200 - .300	ND
Thorium-232	UNF	pCi/L	4/8	3/8	0.65	.300 - .900	.200 - .400	0.340
Thorium, total	FIL	µg/L	1/1	1/1	0	1.82 - 1.82		ND
Thorium, total	UNF	µg/L	4/6	2/6	4.614	.912 - 8.21	2.04 - 2.90	3.10
Radium-228	FIL	pCi/L	0/9	0/9			3.00 - 3.40	2.20
Radium-228	UNF	pCi/L	1/8	1/8	2.50	3.50 - 3.50	3.00 - 3.00	3.00
Thorium-228	FIL	pCi/L	0/7	0/7			.200 - .300	0.100

TABLE 4-48 (Continued)

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Thorium-228	UNF	pCi/L	4/8	0/8	0.75	.500 - 1.04	.200 - .300	1.50
Neptunium-237	FIL	pCi/L	0/2	0/2			.500 - .500	NA
Plutonium-239/240	FIL	pCi/L	0/2	0/2			.500 - .500	A
Plutonium-239/240	UNF	pCi/L	0/2	0/2			.500 - .500	ND
Plutonium-238	FIL	pCi/L	0/2	0/2			.500 - .500	NA
Plutonium-238	UNF	pCi/L	0/2	0/2			.500 - .500	0.075
Strontium-90	FIL	pCi/L	0/3	0/3			1.00 - 1.70	NA
Strontium-90	UNF	pCi/L	0/2	0/2			1.00 - 1.00	2.00
Technetium-99	FIL	pCi/L	4/8	4/8	173	223 - 1610	15.0 - 21.4	30.0
Technetium-99	UNF	pCi/L	4/7	4/7	7.50	106 - 2880	15.0 - 16.0	30.0
Ruthenium-106	FIL	pCi/L	0/2	0/2			150 - 150	NA
Ruthenium-106	UNF	pCi/L	0/2	0/2			150 - 150	ND
Aluminum	FIL	mg/L	1/9	1/9	0.007	3.48 - 3.48	.014 - .185	0.123
Antimony	FIL	mg/L	0/9	0/9			.005 - .045	0.027
Arsenic	FIL	mg/L	2/9	0/9	0.001	.002 - .006	.001 - .002	0.122
Barium	FIL	mg/L	9/9	0/9	0.079	.048 - .159		0.451
Beryllium	FIL	mg/L	0/9	0/9			.001 - .005	0.002
Cadmium	FIL	mg/L	0/9	0/9			.003 - .005	0.006
Calcium	FIL	mg/L	9/9	2/9	129	81.7 - 195		131
Chromium	FIL	mg/L	2/9	0/9	0.002	.005 - .008	.004 - .010	0.034
Cobalt	FIL	mg/L	0/9	0/9			.006 - .017	ND
Copper	FIL	mg/L	1/9	0/9	0.002	.007 - .007	.004 - .010	0.019
Cyanide	UNF	mg/L	0/9	0/9			.002 - .010	ND
Iron	FIL	mg/L	3/9	0/9	0.012	.051 - 6.92	.019 - .083	3060

TABLE 4-48 (Continued)

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Lead	FIL	mg/L	2/9	0/9	0.001	.001 - .002	.001 - .003	0.009
Magnesium	FIL	mg/L	9/9	5/9	42.0	27.1 - 75.4		47.8
Manganese	FIL	mg/L	7/9	4/9	0.001	.092 - .800	.001 - .001	0.18
Mercury	FIL	mg/L	0/9	0/9			.0001 - .0002	0.0004
Molybdenum	FIL	mg/L	2/8	0/8	0.007	.011 - .012	.010 - .020	0.017
Nickel	FIL	mg/L	0/9	0/9			.018 - .020	0.022
Potassium	FIL	mg/L	9/9	0/9	0.843	.380 - 3.01		29.3
Selenium	FIL	mg/L	0/9	0/9			.002 - .005	ND
Silicon	FIL	mg/L	5/5	3/5	8.28	5.45 - 9.66		7.43
Silver	FIL	mg/L	0/9	0/9			.001 - .010	0.040
Sodium	FIL	mg/L	9/9	4/9	87.5	9.16 - 87.5		38.3
Thallium	FIL	mg/L	0/9	0/9			.001 - .002	ND
Vanadium	FIL	mg/L	3/9	2/9	0.002	.007 - .027	.004 - .024	0.020
Zinc	FIL	mg/L	5/9	0/9	0.003	.007 - .030	.006 - .010	0.044
Ammonia	UNF	mg/L	4/9	0/9	0.025	.048 - .366	.030 - .050	4.34
Chloride	UNF	mg/L	8/8	1/8	13.1	.032 - 61.0		45.0
Fluoride	UNF	mg/L	8/8	0/8	0.355	.290 - .510		1.30
Nitrate	UNF	mg/L	5/8	5/8	6.31	.620 - 18.1	.020 - .100	0.29
Sulfate	UNF	mg/L	8/8	2/8	57.1	.170 - 150		136

[1]Based on Table E.1-3 in Appendix E
[2]Frequency of detection is defined as (number of detectable results)/(number of wells tested)

TABLE 4-49

SUMMARY STATISTICS FOR FEMP TYPE 1 WELLS IN PERCHED GROUNDWATER CONTAMINATION AREA III[1]

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Uranium-238	P101	FIL	pCi/L	3/3		1.43	.930 - 2.43		A
Uranium-238	P101	UNF	pCi/L	5/5	5/5	8.87	1.19 - 12.5		0.800
Uranium, total	P102	FIL	μg/L	3/3	3/3	4.33	2.70 - 6.14		1.40
Uranium, total	P102	UNF	μg/L	5/5	5/5	22.6	3.00 - 31.1		1.30
Uranium-234	P103	FIL	pCi/L	3/3	3/3	1.72	.700 - 2.62		0.600
Uranium-234	P103	UNF	pCi/L	5/5	5/5	8.72	1.16 - 11.4		0.900
Thorium-230	P104	FIL	pCi/L	1/3	1/3	2.36	2.36 - 2.36	.200 - .200	ND
Thorium-230	P104	UNF	pCi/L	3/5	1/5	11.8	.227 - 11.2	.200 - .200	1.30
Radium-226	P105	FIL	pCi/L	0/3	0/3				0.900
Radium-226	P105	UNF	pCi/L	2/5	2/5	3.18	1.36 - 3.18	1.00 - 1.00	0.900
Uranium-235/236	P108	FIL	pCi/L	0/3	0/3			.200 - .200	ND
Uranium-235/236	P108	UNF	pCi/L	3/5	3/5	0.340	.303 - .560	.200 - .200	ND
Thorium-232	P109	FIL	pCi/L	1/3	1/3	0.216	.216 - .216	.200 - .200	ND
Thorium-232	P109	UNF	pCi/L	1/5	1/5	7.50	8.56 - 8.56	.200 - .200	0.340
Thorium, total	P110	FIL	μg/L	1/3	1/3	1.97	1.97 - 1.97	.640 - .660	ND

TABLE 4-49 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Thorium, total	P110	UNF	µg/L	1/5	1/5	69.0	78.0 - 78.0	.500 - 1.12	3.10
Radium-228	P111	FIL	pCi/L	0/3	0/3			03-Mar	2.20
Radium-228	P111	UNF	pCi/L	1/5	1/5	10.1	5.93 - 5.93	3.00 - 5.45	3.00
Thorium-228	P112	FIL	pCi/L	0/3	0/3			.200 - .344	0.100
Thorium-228	P112	UNF	pCi/L	1/5	1/5	8.15	9.87 - 9.87	.200 - .200	1.50
Neptunium-237	P113	FIL	pCi/L	1/3	1/3	0.344	0 - 0	.500 - .500	Not Tested
Neptunium-237	P113	UNF	pCi/L	0/5	0/5			.500 - .500	0.250
Plutonium-239/240	P114	FIL	pCi/L	0/3	0/3			.500 - .500	NA
Plutonium-239/240	P114	UNF	pCi/L	0/5	0/5			.500 - .500	ND
Plutonium-238	P115	FIL	pCi/L	0/3	0/3			.500 - .500	Not Tested
Plutonium-238	P115	UNF	pCi/L	0/5	0/5			.500 - .500	0.0750
Strontium-90	P116	FIL	pCi/L	1/3	1/3	0.500	1.33 - 1.33	01-Jan	Not Tested
Strontium-90	P116	UNF	pCi/L	1/5	0/5	0.500	1.19 - 1.19	1.00 - 1.02	2.00
Technetium-99	P117	FIL	pCi/L	0/3	0/3			15.0 - 15.0	30.0
Technetium-99	P117	UNF	pCi/L	0/5	0/5			15.0 - 15.0	30.0
Ruthenium-106	P118	FIL	pCi/L	0/3	0/3			150 - 150	Not Tested
Ruthenium-106	P118	UNF	pCi/L	0/5	0/5			150 - 154	ND
Aluminum	P201	FIL	mg/L	3/5	2/5	0.435	.0556 - .435	.0827 - .196	0.123

TABLE 4-49 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Antimony	P202	FIL	mg/L	2/5	0/5	0.00610	.00610 - .00740	.00100 - .0140	0.0272
Arsenic	P203	FIL	mg/L	1/5	0/5	0.00100	.00410 - .00410	.00100 - .00200	0.122
Barium	P204	FIL	mg/L	5/5	0/5	0.0870	.0459 - .201		0.451
Beryllium	P205	FIL	mg/L	0/5	0/5			.00120 - .00360	0.00180
Cadmium	P207	FIL	mg/L	0/5	0/5			.00200 - .00500	0.00600
Calcium	P208	FIL	mg/L	5/5	1/5	87.3	61.8 - 153		131
Chromium	P210	FIL	mg/L	0/5	0/5			.00400 - .0100	0.0340
Cobalt	P211	FIL	mg/L	0/5	0/5			.00300 - .0170	ND
Copper	P212	FIL	mg/L	0/5	0/5			.00480 - .0127	0.0190
Cyanide	P213	UNF	mg/L	0/5	0/5			.00100 - .00500	ND
Iron	P214	FIL	mg/L	2/5	0/5	0.334	.0246 - .334	.0220 - .0514	306
Lead	P215	FIL	mg/L	1/5	1/5	0.00100	.00970 - .00970	.00100 - .00200	0.00870
Magnesium	P216	FIL	mg/L	5/5	3/5	57.4	18.7 - 139		47.8
Manganese	P217	FIL	mg/L	4/5	2/5	0.274	.00410 - .378	.00200 - .00200	0.180
Mercury	P218	FIL	mg/L	0/5	0/5			.000200 -.000200	0.0004
Molybdenum	P219	FIL	mg/L	2/5	0/5	0.0100	.00450 - .00550	.0100 - .0200	0.0170
Nickel	P220	FIL	mg/L	1/5	0/5	0.0100	.00540 - .00540	.00300 - .0200	0.0220
Potassium	P223	FIL	mg/L	5/5	0/5	1.33	1.18 - 5.98		29.3

TABLE 4-49 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Selenium	P225	FIL	mg/L	1/5	1/5	0.00100	.0182 - .0182	.00100 - .00200	ND
Silicon	P226	FIL	mg/L	5/5	4/5	8.20	6.22 - 10.8		7.43
Silver	P227	FIL	mg/L	0/5	0/5			.00200 - .0100	0.0400
Sodium	P228	FIL	mg/L	5/5	1/5	12.5	12.5 - 40.9		38.3
Thallium	P230	FIL	mg/L	0/5	0/5			.00100 - .00200	ND
Vanadium	P233	FIL	mg/L	1/5	1/5	0.0100	.0318 - .0318	.00990 - .0165	0.0195
Zinc	P236	FIL	mg/L	3/5	0/5		.00450 - .0170	.00500 - .00500	0.0443
Ammonia	P705	UNF	mg/L	2/5	0/5		.110 - .260	.0300 - .100	4.34
Chloride	P715	UNF	mg/L	6/6	0/6		1.19 - 330		45.0
Fluoride	P721	UNF	mg/L	5/5	0/5		.190 - .640		1.30
Nitrate	P729	UNF	mg/L	2/4	1/4	0.390	.260 - .520		0.290
Sulfate	P744	UNF	mg/L	6/6	1/6	75.60	47.5 - 167.0		136

[1]Based on Table E.1-4 in Appendix E
[2]Frequency of detection is defined as (number of detectable results)/(number of wells tested)

TABLE 4-50

SUMMARY STATISTICS FOR MAJOR CONTAMINANTS DETECTED IN THE OU4 K-65 SILOS AREA CONTAMINATION AREA IV[1]

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Uranium-238	FIL	pCi/L	2/3		1.00	1.00 - 87.9		A
Uranium-238	UNF	pCi/L	10/12	10/12	273	1.08 - 434	1.00 - 1.00	0.800
Uranium, total	FIL	µg/L	4/4	4/4	407	2.90 - 810		1.40
Uranium, total	UNF	µg/L	12/12	12/12	784	1.51 - 1250		1.30
Uranium-234	FIL	pCi/L	2/3	2/3	1.30	1.30 - 73.4		0.60
Uranium-234	UNF	pCi/L	5/7	5/7	3.04	1.17 - 427		0.90
Thorium-230	FIL	pCi/L	1/3	1/3	0.100	.600 - .600	.200 - 1.00	ND
Thorium-230	UNF	pCi/L	2/8	0/8	0.750	.370 - .400	.200 - 1.00	1.30
Radium-226	FIL	pCi/L	0/3	0/3			1.00 - 1.00	0.900
Radium-226	UNF	pCi/L	1/13	1/13	0.500	35.8 - 35.8	1.00 - 25.0	0.900
Uranium-235/236	FIL	pCi/L	1/3	1/3	0.100	3.40 - 3.40	.200 - .200	ND
Uranium-235/236	UNF	pCi/L	2/7	2/7	0.500	3.50 - 21.0	.200 - 1.00	ND
Thorium-232	FIL	pCi/L	0/3	0/3			.200 - 1.00	ND
Thorium-232	UNF	pCi/L	0/8	0/8			.200 - 1.00	0.340
Thorium, total	FIL	µg/L	0/1	0/1			4.00 - 4.00	ND
Thorium, total	UNF	µg/L	0/8	0/8			.500 - 9.10	3.10
Radium-228	FIL	pCi/L	0/3	0/3			3.00 - 3.00	2.20
Radium-228	UNF	pCi/L	1/8	1/8	225	23.7 - 23.7	3.00 - 44.0	3.00
Thorium-228	FIL	pCi/L	0/3	0/3			.200 - 100	0.10

TABLE 4-50 (Continued)

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Thorium-228	UNF	pCi/L	2/8	2/8	1.27	1.54 - 1.96	.200 - .200	1.50
Neptunium-237	FIL	pCi/L	0/1	0/1			1.00 - 1.00	NA
Neptunium-237	UNF	pCi/L	0/6	0/6			.500 - 1.00	0.250
Plutonium-239/240	FIL	pCi/L	0/1	0/1			1.00 - 1.00	NA
Plutonium-239/240	UNF	pCi/L	0/6	0/6			.500 - 1.00	ND
Plutonium-238	FIL	pCi/L	0/1	0/1			1.00 - 1.00	NA
Plutonium-238	UNF	pCi/L	0/6	0/6			.500 - 1.00	0.075
Strontium-90	FIL	pCi/L	0/1	0/1			5.00 - 5.00	NA
Strontium-90	UNF	pCi/L	0/6	0/6			1.00 - 5.00	2.00
Technetium-99	FIL	pCi/L	0/3	0/3			15.0 - 30.0	30.0
Technetium-99	UNF	pCi/L	1/6	0/6	15.0	20.1 - 20.1	15.0 - 30.0	30.0
Ruthenium-106	FIL	pCi/L	0/1	0/1				NA
Ruthenium-106	UNF	pCi/L	0/6	0/6			150 - 150	ND
Aluminum	FIL	mg/L	4/6	2/6	0.220	.075 - .263	.059 - .098	0.123
Antimony	FIL	mg/L	2/6	2/6	0.053	.067 - .099	.014 - .078	0.027
Arsenic	FIL	mg/L	1/7	0/7	0.001	.003 - .003	.002 - .002	0.122
Barium	FIL	mg/L	7/7	0/7	0.063	.018 - .284		0.451
Beryllium	FIL	mg/L	0/6	0/6			.002 - .005	0.002
Cadmium	FIL	mg/L	5/7	4/7	0.010	.005 - .023	.005 - .005	0.006
Calcium	FIL	mg/L	7/7	5/7	208	127 - 500		131
Chromium	FIL	mg/L	5/7	3/7	0.040	.012 - .046	.006 - .006	0.034
Cobalt	FIL	mg/L	3/6	3/6	0.162	.013 - .020	.010 - .017	ND
Copper	FIL	mg/L	4/7	3/7	0.013	.013 - .030	.009 - .010	0.019
Cyanide	UNF	mg/L	3/10	3/10	0.003	.007 - .054	.00002 - .005	ND

TABLE 4-50 (Continued)

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Iron	FIL	mg/L	5/7	0/7	1.70	.085 - 20.1	.022 - .022	3060
Lead	FIL	mg/L	1/7	0/7	0.001	.002 - .002	.001 - .002	0.009
Magnesium	FIL	mg/L	7/7	6/7	83.3	44.2 - 154		47.8
Manganese	FIL	mg/L	6/7	4/7	0.230	.012 - .620	.004 - .004	0.180
Mercury	FIL	mg/L	0/7	0/7			.0001 - .0002	0.0004
Molybdenum	FIL	mg/L	4/7	4/7	0.026	.018 - .266	.017 - .020	0.017
Nickel	FIL	mg/L	4/7	4/7	0.030	.024 - .063	.018 - .097	0.022
Potassium	FIL	mg/L	7/7	0/7	3.49	.990 - 3.49		29.3
Selenium	FIL	mg/L	3/7	3/7	0.001	.004 - .049	.002 - .002	ND
Silicon	FIL	mg/L	6/6	2/6	5.93	4.60 - 8.73		7.43
Silver	FIL	mg/L	4/7	0/7	0.037	.018 - .038	.0005 - .002	0.040
Sodium	FIL	mg/L	7/7	5/7	114	18.0 - 1070		38.3
Thallium	FIL	mg/L	0/6	0/6			.001 - .010	ND
Vanadium	FIL	mg/L	4/6	3/6	0.025	.011 - .027	.024 - .024	0.020
Zinc	FIL	mg/L	4/6	3/6	0.275	.014 - 1.78	.006 - .012	0.044
Ammonia	UNF	mg/L	2/8	0/8	0.050	.230 - .600	.030 - .100	4.34
Chloride	UNF	mg/L	8/8	4/8	119.9	4.14 - 3230		45.0
Fluoride	UNF	mg/L	8/8	0/8	0.650	.200 - .680		1.30
Nitrate	UNF	mg/L	7/8	5/8	496	.072 - 554	.100 - .100	0.290
Sulfate	UNF	mg/L	8/8	7/8	869	102 - 1290		136

[1]Based on Table E.1-5 in Appendix E
[2]Frequency of detection is defined as (number of detectable results)/(number of wells tested)

TABLE 4-51

SUMMARY STATISTICS FOR MAJOR CONTAMINANTS DETECTED IN THE OU1/OU2 WASTE STORAGE AREA CONTAMINATION AREA V[1]

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Uranium-238	FIL	pCi/L	21/24		137	.800 - 3810		A
Uranium-238	UNF	pCi/L	31/31	31/31	1.70	.900 - 856		0.800
Uranium, total	FIL	µg/L	24/26	24/26	107	1.70 - 2360	.100 - .100	1.40
Uranium, total	UNF	µg/L	34/34	34/34	388	1.80 - 2550		1.30
Uranium-234	FIL	pCi/L	20/24	20/24	25.7	.800 - 712	.700 - .700	0.600
Uranium-234	UNF	pCi/L	31/31	31/31	2.50	.900 - 682		0.900
Thorium-230	FIL	pCi/L	6/24	6/24	0.200	.290 - .500	.200 - 1.00	ND
Thorium-230	UNF	pCi/L	11/31	5/31	0.100	.260 - 24.6	.200 - 1.00	1.30
Radium-226	FIL	pCi/L	3/24	3/24	0.500	1.90 - 10.1	1.00 - 1.00	0.90
Radium-226	UNF	pCi/L	13/30	13/30	0.500	1.10 - 16.1	1.00 - 1.00	0.90
Uranium-235/236	FIL	pCi/L	11/24	11/24	2.30	.300 - 76.7	.200 - 1.00	ND
Uranium-235/236	UNF	pCi/L	15/31	15/31	0.100	.208 - 25.1	.200 - 1.00	ND
Thorium-232	FIL	pCi/L	2/24	2/24	0.100	.400 - 2.40	.200 - 1.00	ND
Thorium-232	UNF	pCi/L	8/31	7/31	0.200	.300 - 11.5	.200 - 1.00	0.340
Thorium, total	FIL	µg/L	8/16	9/16	1.66	.912 - 3.65	1.84 - 3.00	ND
Thorium, total	UNF	µg/L	22/29	9/29	0.250	.700 - 104	.500 - 7.00	3.10
Radium-228	FIL	pCi/L	7/24	7/24	5.95	5.10 - 10.4	3.00 - 3.00	2.20
Radium-228	UNF	pCi/L	4/30	4/30	1.50	3.30 - 4.00	3.00 - 3.00	3.00
Thorium-228	FIL	pCi/L	2/24	2/24	0.100	1.18 - 1.30	.200 - 1.00	0.100

TABLE 4-51 (Continued)

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Thorium-228	UNF	pCi/L	10/31	2/31	0.150	.293 - 14.0	.200 - 1.00	1.50
Neptunium-237	FIL	pCi/L	0/7	0/7			.500 - 1.00	NA
Neptunium-237	UNF	pCi/L	0/26	0/26			.500 - 1.00	0.250
Plutonium-239/240	FIL	pCi/L	0/9	0/9			.500 - 1.00	NA
Plutonium-239/240	UNF	pCi/L	0/29	0/29			.500 - 1.00	ND
Plutonium-238	FIL	pCi/L	0/9	0/9			.500 - 1.00	NA
Plutonium-238	UNF	pCi/L	0/29	0/29			.500 - 1.00	0.075
Strontium-90	FIL	pCi/L	1/09	1/09	0.500	1.32 - 1.32	1.00 - 5.00	NA
Strontium-90	UNF	pCi/L	4/29	3/29	2.50	1.35 - 5.30	1.00 - 5.00	2.00
Technetium-99	FIL	pCi/L	10/24	8/24	66.3	15.8 - 488	15.0 - 30.0	30.0
Technetium-99	UNF	pCi/L	6/30	5/30	7.50	24.4 - 426	15.0 - 30.0	30.0
Ruthenium-106	FIL	pCi/L	0/7	0/7			150 - 150	NA
Ruthenium-106	UNF	pCi/L	0/26	0/26			150 - 150	ND
Aluminum	FIL	mg/L	8/29	4/29	0.010	.015 - 1.59	.011 - .500	0.123
Antimony	FIL	mg/L	3/28	3/28	0.050	.054 - .077	.005 - .047	0.027
Arsenic	FIL	mg/L	12/30	1/30	0.001	.001- .191	.001 - .003	0.122
Barium	FIL	mg/L	28/30	1/30	0.041	.017 - .486	.200 - .400	0.451
Beryllium	FIL	mg/L	1/28	1/28	0.001	.002 - .002	.0003 - .010	0.002
Cadmium	FIL	mg/L	4/30	3/30	0.002	.005 - .050	.001 - .005	0.006
Calcium	FIL	mg/L	30/30	21/30	145	42.8 - 1800		131
Chromium	FIL	mg/L	8/30	5/30	0.003	.007- .300	.005 - .020	0.034
Cobalt	FIL	mg/L	8/28	8/28	0.007	.006 - .017	.005 - .025	ND
Copper	FIL	mg/L	6/30	3/30	0.004	.005 - .060	.002 - .025	0.019
Cyanide	UNF	mg/L	2/30	2/30	0.005	.010 - .030	.002 - .020	ND

TABLE 4-51 (Continued)

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Iron	FIL	mg/L	12/30	0/30	0.068	.050 - 14.2	.020 - .233	3060
Lead	FIL	mg/L	3/30	0/30	0.001	.001 - .002	.001 - .005	0.009
Magnesium	FIL	mg/L	30/30	24/30	70.9	14.0 - 690		47.8
Manganese	FIL	mg/L	23/30	13/30	0.017	.009 - 35.0	.001 - .020	0.180
Mercury	FIL	mg/L	2/30	2/30	0.0001	.0002 - .0004	.0001 - .001	0.0004
Molybdenum	FIL	mg/L	10/29	8/29	0.014	.013 - 1.01	.005 - .049	0.017
Nickel	FIL	mg/L	7/30	7/30	0.010	.023 - .981	.005 - .030	0.022
Potassium	FIL	mg/L	27/30	2/30	1.50	1.25 - 100	.891 - 1.27	29.3
Selenium	FIL	mg/L	3/30	3/30	0.001	.002 - .006	.001 - .020	ND
Silicon	FIL	mg/L	11/11	6/11	5.22	3.37 - 15.0		7.43
Silver	FIL	mg/L	3/30	0/30	0.003	.010 - .020	.001 - .050	0.040
Sodium	FIL	mg/L	30/30	10/30	24.7	3.86 - 1300		38.3
Thallium	FIL	mg/L	1/28	1/28	0.001	.001 - .001	.001 - .041	ND
Vanadium	FIL	mg/L	3/29	2/29	0.002	.004 - .061	.003 - .050	0.020
Zinc	FIL	mg/L	8/28	3/28	0.004	.009 - .058	.004 - .032	0.044
Ammonia	UNF	mg/L	19/33	3/33	0.130	.060 - 220	.020 - .400	4.34
Chloride	UNF	mg/L	32/34	15/34	41.5	.500 - 6300	8.20 - 13.0	45
Fluoride	UNF	mg/L	34/34	5/34	0.420	.190 - 6.76		1.30
Nitrate	UNF	mg/L	23/30	11/30	0.110	.040 - 197	.002 - .100	0.290
Sulfate	UNF	mg/L	34/34	21/34	331	13.0 - 1200		136

[1]Based on Table E.1-6 in Appendix E
[2]Frequency of detection is defined as (number of detectable results)/(number of wells tested)

TABLE 4-52

SUMMARY STATISTICS FOR MAJOR CONTAMINANTS
DETECTED IN THE FIRE TRAINING AREA
CONTAMINATION AREA VI[1]

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Uranium-238	FIL	pCi/L	5/5		2.91	1.10 - 46.4		A
Uranium-238	UNF	pCi/L	3/6	3/6	9.01	3.28 - 15.2		0.800
Uranium, total	FIL	μg/L	6/6	6/6	9.32	4.10 - 138		1.40
Uranium, total	UNF	μg/L	9/9	9/9	7.70	7.70 - 168		1.30
Uranium-234	FIL	pCi/L	5/5	5/5	3.47	1.60 - 47.8		0.600
Uranium-234	UNF	pCi/L	3/6	3/6	8.70	3.63 - 15.7		0.900
Thorium-230	FIL	pCi/L	2/6	2/6	0.439	.727 - 1.41	.200 - .300	ND
Thorium-230	UNF	pCi/L	5/6	2/6	0.850	.600 - 3.44		1.30
Radium-226	FIL	pCi/L	0/6	0/6			.090 - 1.00	0.900
Radium-226	UNF	pCi/L	4/6	4/6	3.55	2.60 - 4.50	1.00 - 1.00	0.900
Uranium-235/236	FIL	pCi/L	3/5	3/5	0.236	.236 - 2.60	.200 - .200	ND
Uranium-235/236	UNF	pCi/L	2/6	2/6	2.40	.800 - 1.20	.200 - .200	ND
Thorium-232	FIL	pCi/L	1/6	1/6	0.100	1.17 - 1.17	.200 - .200	ND
Thorium-232	UNF	pCi/L	2/6	2/6	0.400	.473 - 2.84	.200 - .200	0.340
Thorium, total	FIL	μg/L	2/3	2/3	10.6	.912 - 10.6	1.28 - 1.28	ND

TABLE 4-52 (Continued)

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Thorium, total	UNF	µg/L	6/6	5/6	6.62	1.82 - 25.6		3.10
Radium-228	FIL	pCi/L	1/6	1/6	0.758	4.70 - 4.70	.033 - 300	2.20
Radium-228	UNF	pCi/L	1/6	1/6	3.30	5.10 - 5.10	3.00 - 3.00	3.00
Thorium-228	FIL	pCi/L	1/6	1/6	0.047	1.00 - 1.00	-0.214	0.100
Thorium-228	UNF	pCi/L	4/6	1/6	0.450	.488 - 3.40	.200 - .200	1.50
Neptunium-237	FIL	pCi/L	1/2	1/2	0.477	.954 - .954	.251 - .251	NA
Neptunium-237	UNF	pCi/L	1/4	1/4	0.563	.626 - .626	1.00 - 1.00	0.250
Plutonium-239/240	FIL	pCi/L	1/2	1/2	0.500	1.00 - 1.00	.156 - .156	NA
Plutonium-239/240	UNF	pCi/L	0/5	0/5			.500 - 1.00	ND
Plutonium-238	FIL	pCi/L	1/2	1/2	0.500	1.00 - 1.00	0 - 0	NA
Plutonium-238	UNF	pCi/L	0/5	0/5			.500 - 1.00	0.075
Strontium-90	FIL	pCi/L	0/3	0/3			-1.115	NA
Strontium-90	UNF	pCi/L	0/5	0/5			1.00 - 5.00	2.00
Technetium-99	FIL	pCi/L	2/5	1/5	-0.91	27.7 - 63.1	-16.82	30.0
Technetium-99	UNF	pCi/L	2/5	2/5	56.5	56.5 - 60.8	15.0 - 30.0	30.0
Ruthenium-106	FIL	pCi/L	0/2	0/2			110 - 130	NA
Ruthenium-106	UNF	pCi/L	0/4	0/4			150 - 150	ND
Aluminum	FIL	mg/L	4/7	3/7	0.030	.092 - 1.49	.060 - .060	0.123
Antimony	FIL	mg/L	0/7	0/7			.005 - .030	0.027

TABLE 4-52 (Continued)

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Arsenic	FIL	mg/L	3/7	0/7	0.001	.002 - .004	.002 - .002	0.122
Barium	FIL	mg/L	7/7	0/7	0.122	.053 - .127		0.451
Beryllium	FIL	mg/L	0/7	0/7			.0003 - .002	0.002
Cadmium	FIL	mg/L	1/7	0/7	0.001	.003 - .003	.001 - .005	0.006
Calcium	FIL	mg/L	7/7	0/7	112	103 - 130		131
Chromium	FIL	mg/L	1/7	0/7	0.002	.025 - .025	.003 - .010	0.034
Cobalt	FIL	mg/L	0/7	0/7			.003 - .010	ND
Copper	FIL	mg/L	0/7	0/7			.002 - .010	0.019
Cyanide	UNF	mg/L	1/9	1/9	0.005	.002 - .002	.002 - .010	ND
Iron	FIL	mg/L	3/7	0/7	0.024	.059 - 1.61	.020 - .047	3060
Lead	FIL	mg/L	3/7	0/7	0.001	.001 - .005	.001 - .002	0.009
Magnesium	FIL	mg/L	7/7	1/7	40.4	23.4 - 49.3		47.8
Manganese	FIL	mg/L	6/7	3/7	0.076	.076 - 1.47	.004 - .004	0.180
Mercury	FIL	mg/L	0/7	0/7			.0002 - .0002	0.0004
Molybdenum	FIL	mg/L	0/5	0/5			.010 - .020	0.017
Nickel	FIL	mg/L	2/7	1/7	0.009	.009 - .026	.007 - .020	0.022
Potassium	FIL	mg/L	7/7	0/7	1.32	.737 - 4.23		29.3
Selenium	FIL	mg/L	1/7	1/7	0.001	.002 - .002	.001 - .002	ND
Silicon	FIL	mg/L	2/2	1/2	3.70	7.40 - 7.88		7.43

TABLE 4-52 (Continued)

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Silver	FIL	mg/L	1/7	0/7	0.001	.018 - .018	.003 - .010	0.040
Sodium	FIL	mg/L	7/7	1/7	29.8	6.67 - 42.3		38.3
Thallium	FIL	mg/L	0/7	0/7			.001 - .002	ND
Vanadium	FIL	mg/L	2/7	0/7	0.001	.003 - .014	.003 - .010	0.020
Zinc	FIL	mg/L	2/7	0/7	0.010	.006 - .010	.004 - .036	0.044
Ammonia	UNF	mg/L	1/5	0/5	0.025	.160 - .160	.050 - .100	4.34
Chloride	UNF	mg/L	5/5	0/5	8.90	3.50 - 35.0		45.0
Fluoride	UNF	mg/L	5/5	0/5	0.400	.300 - .600		1.30
Nitrate	UNF	mg/L	1/7	0/7	0.050	.130 - .130	.100 - .100	0.29
Sulfate	UNF	mg/L	5/5	0/5	69.0	18.0 - 77.0		136

[1]Based on Table E.1-7 in Appendix E
[2]Frequency of detection is defined as (number of detectable results)/(number of wells tested)

TABLE 4-53

SUMMARY STATISTICS FOR MAJOR CONTAMINANTS DETECTED IN THE OU2 LIME SLUDGE PONDS AREA CONTAMINATION AREA VII[1]

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Uranium-238	FIL	pCi/L	3/3		11.8	.416 - 11.8		A
Uranium-238	UNF	pCi/L	6/6	6/6	4.47	1.80 - 11.8		0.800
Uranium, total	FIL	µg/L	2/3	2/3	39.6	8.30 - 39.6	1.00 - 1.00	1.40
Uranium, total	UNF	µg/L	6/6	5/6	11.99	1.00 - 30.4		1.30
Uranium-234	FIL	pCi/L	3/3	2/3	12.0	.391 - 12.0		0.600
Uranium-234	UNF	pCi/L	6/6	6/6	4.93	1.40 - 11.02		0.900
Thorium-230	FIL	pCi/L	2/3	2/3	0.400	.251 - .400	.410 - .410	ND
Thorium-230	UNF	pCi/L	4/6	3/6	1.60	1.29 - 3.04	.200 - .308	1.30
Radium-226	FIL	pCi/L	0/3	0/3			1.00 - 1.00	0.900
Radium-226	UNF	pCi/L	1/6	1/6	0.500	1.21 - 1.21	1.00 - 1.00	0.900
Uranium-235/236	FIL	pCi/L	1/3	1/3	0.600	.600 - .600	.200 - .200	ND
Uranium-235/236	UNF	pCi/L	2/6	2/6	0.100	.212 - .700	.200 - 1.00	ND
Thorium-232	FIL	pCi/L	0/3	0/3			.200 - 1.03	ND
Thorium-232	UNF	pCi/L	3/6	3/6	2.26	.7423 - 2.60	.200 - 1.00	0.340
Thorium, total	FIL	µg/L	0/2	0/2			.500 - 9.48	ND

TABLE 4-53 (Continued)

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Thorium, total	UNF	µg/L	4/6	4/6	20.7	6.83 - 23.9	1.55 - 4.00	3.10
Radium-228	FIL	pCi/L	0/3	0/3			3.00 - 3.00	2.20
Radium-228	UNF	pCi/L	1/6	1/6	1.50	3.68 - 3.68	3.00 - 3.00	3.00
Thorium-228	FIL	pCi/L	0/3	0/3			.200 - 1.03	0.100
Thorium-228	UNF	pCi/L	3/6	1/6	1.27	.780 - 2.37	.240 - 1.00	1.50
Neptunium-237	FIL	pCi/L	0/2	0/2			.500 - .500	NA
Neptunium-237	UNF	pCi/L	0/6	0/6			.500 - 1.00	0.250
Plutonium-239/240	FIL	pCi/L	0/2	0/2			.500 - .500	NA
Plutonium-239/240	UNF	pCi/L	0/6	0/6			.500 - 1.00	ND
Plutonium-238	FIL	pCi/L	0/2	0/2			.500 - .500	NA
Plutonium-238	UNF	pCi/L	0/6	0/6			.500 - 1.00	0.075
Strontium-90	FIL	pCi/L	0/2	0/2			1.00 - 1.00	NA
Strontium-90	UNF	pCi/L	1/6	1/6	0.500	3.45 - 3.45	1.00 - 5.00	2.00
Technetium-99	FIL	pCi/L	0/3	0/3			15.0 - 15.1	30.0
Technetium-99	UNF	pCi/L	0/6	0/6			15.0 - 30.0	30.0
Ruthenium-106	FIL	pCi/L	0/2	0/2			150 - 153	NA
Ruthenium-106	UNF	pCi/L	0/6	0/6			150 - 150	ND
Aluminum	FIL	mg/L	0/3	0/3			.071 - .252	0.123
Antimony	FIL	mg/L	0/3	0/3			.004 - .045	0.027

TABLE 4-53 (Continued)

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Arsenic	FIL	mg/L	0/3	0/3			.001 - .002	0.122
Barium	FIL	mg/L	3/3	0/3	0.078	.078 - .126		0.451
Beryllium	FIL	mg/L	0/3	0/3			.001 - .003	0.002
Cadmium	FIL	mg/L	0/3	0/3			.002 - .005	0.006
Calcium	FIL	mg/L	3/3	1/3	138	118 - 138		131
Chromium	FIL	mg/L	0/3	0/3			.004 - .010	0.034
Cobalt	FIL	mg/L	0/3	0/3			.003 - .010	ND
Copper	FIL	mg/L	0/3	0/3			.002 - .010	0.019
Cyanide	UNF	mg/L	0/6	0/6			.001 - .010	ND
Iron	FIL	mg/L	1/3	0/3	0.010	.509 - .509	.020 - .0316	3060
Lead	FIL	mg/L	0/3	0/3			.001 - .002	0.009
Magnesium	FIL	mg/L	3/3	2/3	56.6	44.9 - 56.6		47.8
Manganese	FIL	mg/L	3/3	1/3	0.032	.032 - .418		0.180
Mercury	FIL	mg/L	0/3	0/3			.0002 - .0002	0.0004
Molybdenum	FIL	mg/L	1/3	0/3	0.010	.005 - .005	.007 - .020	0.017
Nickel	FIL	mg/L	2/3	0/3	0.010	.004 - .012	.020 - .020	0.022
Potassium	FIL	mg/L	1/3	0/3	0.753	.753 - .753	.434 - .654	29.3
Selenium	FIL	mg/L	0/3	0/3	0.001		.001 - .002	ND
Silicon	FIL	mg/L	3/3	0/3	5.28	5.28 - 5.68		7.43

TABLE 4-53 (Continued)

Parameter	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Silver	FIL	mg/L	0/3	0/3			.002 - .010	0.040
Sodium	FIL	mg/L	3/3	1/3	20.8	20.8 - 157		38.3
Thallium	FIL	mg/L	0/3	0/3	0.001		.001 - .002	ND
Vanadium	FIL	mg/L	0/3	0/3			.008 - .012	0.020
Zinc	FIL	mg/L	1/3	0/3	0.003	.004 - .004	.002 - .005	0.044
Ammonia	UNF	mg/L	2/6	0/6	0.145	.140 - .150	.100 - .100	4.34
Chloride	UNF	mg/L	6/6	5/6	310.0	44.1 - 574		45.0
Fluoride	UNF	mg/L	6/6	0/6	0.365	.200 - .500		1.30
Nitrate	UNF	mg/L	0/6	0/6			.020 - .020	0.290
Sulfate	UNF	mg/L	6/6	2/6	67.6	57.4 - 148		136

[1]Based on Table E.1-8 in Appendix E
[2]Frequency of detection is defined as (number of detectable results)/(number of wells tested)

TABLE 4-54

SUMMARY STATISTICS FOR MAJOR CONTAMINANTS IN FEMP TYPE 2 WELLS[1]

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Result	95th Percentile of Background
Uranium-238	P101	FIL	pCi/L	106/129	77/129	1.40	.240 - 381	.200 - 1.00	0.900
Uranium-238	P101	UNF	pCi/L	114/156	96/156	1.30	.300 - 707	.200 - 3.40	0.640
Uranium, total	P102	FIL	ug/L	127/135	108/135	197	.200 - 1130	.100 - 1.00	0.800
Uranium, total	P102	UNF	ug/L	159/171	129/171	2.50	.200 - 207	.100 - 1.00	1.20
Uranium-234	P103	FIL	pCi/L	105/128	79/128	1.55	.270 - 358.0	.200 - 1.00	0.900
Uranium-234	P103	UNF	pCi/L	121/156	93/156	1.40	.268 - 662	.200 - 3.40	0.800
Thorium-230	P104	FIL	pCi/L	19/127	18/127	.100	.253 - 3.08	.200 - 1.00	0.290
Thorium-230	P104	UNF	pCi/L	66/158	10/158	.200	.211 - 2.85	.200 - 1.72	0.890
Radium-226	P105	FIL	pCi/L	20/127	4/127	.500	1.10 - 4.10	.600 - 1.20	1.90
Radium-226	P105	UNF	pCi/L	22/158	12/158	.500	1.10 - 14.9	.500 - 2.00	1.5
Lead-210	P106	FIL	pCi/L	0/1	0/1			3.00 - 3.00	NA
Uranium-235/236	P108	FIL	pCi/L	25/128	25/128	.100	.240 - 15.7	.100 - 1.00	ND
Uranium-235/236	P108	UNF	pCi/L	31/156	31/156	.100	.220 - 31.7	.100 - 3.40	0.094
Thorium-232	P109	FIL	pCi/L	11/127	11/127	.100	.300 - 2.70	.200 - 1.00	0.300
Thorium-232	P109	UNF	pCi/L	13/158	13/158	.100	.300 - 2.70	.200 - 1.10	NA
Thorium, total	P110	FIL	ug/L	38/80		3.410	0 - 9.12	.500 - 13.0	2.80
Thorium, total	P110	UNF	ug/L	57/140	33/140	1.820000	0 - 24.60000	.500 - 10.0	0.970
Radium-228	P111	FIL	pCi/L	0/129	0/129			1.30 - 5.65	ND
Radium-228	P111	UNF	pCi/L	11/158	8/158	1.50	3.10 - 5.30	1.20 - 3.40	3.60
Thorium-228	P112	FIL	pCi/L	17/127	9/127	.100	.210 - 2.55	.100 - 1.00	0.400

TABLE 4-54 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Result	95th Percentile of Background
Thorium-228	P112	UNF	pCi/L	18/158	10/158	.100	.300 - 1.97	.100 - 1.00	0.770
Neptunium-237	P113	FIL	pCi/L	3/51	2/51	.500	0 - 2.50	.500 - 1.10	0.120
Neptunium-237	P113	UNF	pCi/L	4/123	1/123	.500	0 - .796	.500 - 1.00	0.25
Plutonium-239/240	P114	FIL	pCi/L	0/63	0/63			.500 - 1.00	0.0420
Plutonium-239/240	P114	UNF	pCi/L	3/138	3/138	.500	.900 - 1.40	.0431 - 1.00	0.0500
Plutonium-238	P115	FIL	pCi/L	1/64	1/64	.500	.890 - .890	.500 - 1.00	ND
Plutonium-238	P115	UNF	pCi/L	1/138	1/138	.500	.637 - .637	.500 - 1.00	0.0480
Strontium-90	P116	FIL	pCi/L	4/61	4/61	2.50	1.17 - 5.69	.500 - 6.98	ND
Strontium-90	P116	UNF	pCi/L	11/137	11/137	2.50	1.37 - 32.3	.500 - 5.00	0.65
Technetium-99	P117	FIL	pCi/L	7/70	7/70	19.90	19.2 - 204	12.0 - 30.0	ND
Technetium-99	P117	UNF	pCi/L	12/140	9/140	15.0	17.8 - 211	13.5 - 34.3	22
Ruthenium-106	P118	FIL	pCi/L	0/52	0/52			150 - 150	ND
Ruthenium-106	P118	UNF	pCi/L	0/124	0/124			150 - 168	ND
Aluminum	P201	UNF	mg/L	68/133	33/133	.03150	.0191 - 92.0	.0140 - .500	0.225
Antimony	P202	UNF	mg/L	2/133	2/133	.0225	.00290 - .00510	.00110 - .0587	ND
Arsenic	P203	UNF	mg/L	37/134	9/134	.00100	.00100 - .350	.00100 - .00600	0.0294
Barium	P204	UNF	mg/L	126/134	2/134	.0592	.00340 - 8.69	.00300 - .200	0.768
Beryllium	P205	UNF	mg/L	1/133	1/133	.000500	.00150 - .00150	.000300 - .0100	ND
Cadmium	P207	UNF	mg/L	18/134	5/134	.00150	.00220 - .0459	.00100 - .0104	0.0135
Calcium	P208	UNF	mg/L	134/134	25/134	146	1.63 - 411		159
Chromium	P210	UNF	mg/L	32/135	9/135	.00250	.00360 - 1.11	.00300 - .0292	0.0211
Cobalt	P211	UNF	mg/L	13/133	6/133	.00400	.00500 - .168	.00300 - .0250	0.00860
Copper	P212	UNF	mg/L	23/134	6/134	.00375	.00360 - .694	.00200 - .124	0.0354
Cyanide	P213	UNF	mg/L	2/137	2/137	.00500	.0400 - .0440	0 - .0500	ND

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TABLE 4-54 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Result	95th Percentile of Background
Iron	P214	UNF	mg/L	115/134	22/134	1.88	.0329 - 913	.0120 - .587	5.72
Lead	P215	UNF	mg/L	43/134	29/134	.00100	.00100 - .244	.00100 - .044	0.00200
Magnesium	P216	UNF	mg/L	134/134	29/134	30.00	.285 - 507		38.5
Manganese	P217	UNF	mg/L	122/134	11/134	.188	.00130 - 139	.00100 - .0200	0.904
Mercury	P218	UNF	mg/L	2/137	2/137	.000100	.000400 - .000600	.000100 - .000200	ND
Molybdenum	P219	UNF	mg/L	6/72	6/72	.00500	.00740 - .435	.00100 - .0250	ND
Nickel	P220	UNF	mg/L	20/134	5/134	.0100	.00720 - .621	.00300 - .0310	0.0514
Osmium	P222	UNF	mg/L	0/1	0/1			.0500 - .0500	NA
Potassium	P223	UNF	mg/L	115/134	99/134	2.720	.724 - 182	.350 - 4.02	1.96
Selenium	P225	UNF	mg/L	26/134	26/134	.00105	.00100 - .0112	.00100 - .0100	0.000750
Silicon	P226	UNF	mg/L	25/25	7/25	5.04	2.07 - 12.8		5.81
Silver	P227	UNF	mg/L	3/134	0/134	.00200	.00300 - .00420	.00100 - .0300	0.0117
Sodium	P228	UNF	mg/L	133/134	11/134	16.3	3.76 - 130	.182 - .182	47.1
Thallium	P230	UNF	mg/L	1/133	1/133	.00100	.00110 - .00110	.00100 - .0100	ND
Vanadium	P233	UNF	mg/L	15/133	6/133	.00200	.00310 - .251	.00210 - .0500	0.0117
Zinc	P236	UNF	mg/L	46/134	23/134	.00633	.00500 - 1.12	.00340 - .232	0.0210
Ammonia	P705	UNF	mg/L	61/154	4/154	.0550	.0200 - 17.0	.0200 - .400	4.20
Chloride	P715	UNF	mg/L	149/156	12/156	25.0	3.00 - 340	3.50 - 28.0	73.0
Fluoride	P721	UNF	mg/L	141/155	3/155	.180	.090 - 1.36	.100 - .280	0.890
Nitrate	P729	UNF	mg/L	100/139	7/139	.750	.0160 - 79.4	.0200 - 2.50	11.4
Sulfate	P744	UNF	mg/L	149/155	22/155	44.0	.0620 - 740	2.00 - 218	197

[1]Based on Table E.2-1 in Appendix E
[2]Frequency of detection is defined as (number of detectable results)/(number of wells tested)

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TABLE 4-55

SUMMARY OF THE NATURE, EXTENT AND SOURCES OF CONTAMINATION IN THE GMA[1,2]

Parameter	Nature[(3)] Solubility/Absorption	Extent					
		Waste Storage Area A Plume	Waste Storage Area B Plume	Plant 6 Plume	South Plume A	South Plume B	South Plume C
Uranium-238	MS to HS/MA	C	C	C	C	C, PRRS ?	C
Uranium-234	MS to HS/MA	C	C	C	C	C	C
Uranium-235/236	MS to HS/MA	I	-	-	C	I	-
Thorium-230	LS/MA	I	I	I	I	I	I
Radium-226	LS to MS/HA	-	I	-	-	I	I
Thorium-232	LS/MA	I	I	-	I	I	I
Radium-228	LS to MS/HA	I	-	-	-	I	I
Thorium-228	LS/MA	I	I	-	-	I	I
Strontium-90	MS to HS/MA	I	-	-	I	I	-
Technetium-99	HS/LA	C	I	-	-	I	-
Ruthenium-106	MS/MA	-	-	-	-	-	-
Cesium-137	HS/MA	-	-	I	-	-	-
Plutonium-239/240	LS/MA	I	-	I	-	I	-
Plutonium-238	LS/MA	I	-	-	I	-	-
Neptunium-237	MS/MA	-	I	-	-	I	-
Aluminum	LS/MA	I	I	-	I	I	I
Antimony	MS/MA	I	-	-	I	I	-
Arsenic	MS/LA	-	-	-	-	PRRS	-
Barium	LS to MS/HA	-	-	-	-	PRRS	-
Beryllium	LS/MA	-	-	-	-	PRRS	-
Cadmium	MS/HA	-	-	C	-	PRRS	-

TABLE 4-55 (Continued)

Parameter	Nature[3] Solubility/Absorption	Extent: Waste Storage Area A Plume	Waste Storage Area B Plume	Plant 6 Plume	South Plume A	South Plume B	South Plume C
Calcium	MS/MA	C	-	C	C	C, PRRS	-
Chromium	MS/MA	I	I	-	C	PRRS	I
Cobalt	MS/MA to HA	I	-	C	-	PRRS	-
Copper	MS/MA	I	-	-	-	PRRS	-
Cyanide	HS/LA	I	-	-	I	I	-
Iron	LS/MA	C	I	I	I	PRRS, I	PRRS
Lead	LS/HA	I	I	I	I	PRRS, I	-
Magnesium	MS/MA	C	I	I	C	C, PRRS	-
Manganese	MS/MA	I	I	I	I	PRRS	I, PRRS
Mercury	LS/HA	-	-	-	-	PRRS	-
Molybdenum	MS/LA	I	I	I	-	I	-
Nickel	MS/HA	I	I	-	-	PRRS	I, PRRS
Potassium	MS to HS/MA	C	I	I	C	PRRS	PRRS
Selenium	MS/LA to MA	I	I	I	I	I, PRRS	I, PRRS
Silicon	MS/LA to MA	I	I	I	I	PRRS	PRRS
Silver	LS/MA to HA	I	-	-	-	PRRS	PRRS
Sodium	MS to HS/MA	C	-	-	-	PRRS	I, PRRS
Thallium	LS to MS/MA	I	I	-	-	I	-
Vanadium	MS/MA	-	-	-	I	PRRS	-
Zinc	MS/MA to HA	I	I	I	I	PRRS, I	-
Volatile Organic Compounds	Variable	C	I	I	I	PRRS, I	PRRS
Semivolatile Organic Compounds	Variable	I	I	I	I	I	-
Ammonia	HS/LA	C	-	-	-	-	-
Chloride	HS/LA	C	-	I	-	-	-

TABLE 4-55 (Continued)

Parameter	Nature[3] Solubility/Absorption	Extent: Waste Storage Area A Plume	Waste Storage Area B Plume	Plant 6 Plume	South Plume A	South Plume B	South Plume C
Fluoride	MS to HS/LA	I	-	-	-	-	-
Nitrate	HS/LA	C	-	-	-	-	-
Phosphorous	MS/LA	-	I	-	-	PRRS	PRRS
Sulfate	MS to HS/LA	C	-	C	-	I	-

[1]C = Contamination is of extent that it is discernable on contour maps of groundwater analytical results, and is attributable to the FEMP.

I = At least one isolated occurrence above background - Quantity released to groundwater not sufficient to be discerned as plumes in monitor well network - many detections at above background concentrations possibly due to natural conditions and/or attributable to the FEMP.

PRRS = Contamination may be attributable in part or whole to Paddys Run Road Site (PRRS, RI, 1992).

\- = Not detected above background.

[2]Based on isoconcentration maps in Plate volume, and Tables E.1-2 to E.1-8.

[3]Solubility in Groundwater
- LS - Low Solubility
- MS - Medium Solubility
- HS - High Solubility

Tendency to absorb to soil matrix
- LA - Low Absorption
- MA - Medium Absorption
- HA - High Absorption

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PARAMETER

Radionuclides

AREA	Uranium-238	Total Uranium	Uranium-234	Thorium-230	Radium-226	Uranium-235/236	Thorium-232	Total Thorium	Radium-228	Thorium-228	Neptunium-237	Plutonium-239/240	Plutonium-238	Strontium-90	Technetium-99	Ruthenium-106	Cesium-137
Filter Status	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F
Waste Storage Area A Plume - Type 2	■	■	■	2-5X	2-5X	■	■	■	●	●	-	-	X	■	■	-	-
Waste Storage Area A Plume - Type 3	■	■	■	2-5X	●	2-5X	2-5X	■	●	-	-	-	■	-	-	-	-
Waste Storage Area A Plume - Type 4	●	■	-	2-5X	2-5X	-	●	●	-	-	-	-	-	2-5X	-	-	-
Waste Storage Area B Plume - Type 2	■	■	■	2-5X	■	■	2-5X	■	●	2-5X	■	-	-	-	●	-	-
Waste Storage Area B Plume - Type 3	■	■	■	●	2-5X	■	-	■	-	-	-	-	-	-	-	-	-
Waste Storage Area B Plume - Type 4	-	-	●	-	-	-	2-5X	2-5X	-	-	-	-	-	-	-	-	-
Plant 6 Plume - Type 2 Wells	■	■	■	2-5X	-	■	●	2-5X	-	-	-	■	-	-	-	-	X
Plant 6 Plume - Type 3 Wells	2-5X	■	●	●	●	-	2-5X	■	-	-	-	-	-	-	-	-	-
Plant 6 Plume - Type 4 Wells	●	2-5X	●	●	-	-	2-5X	2-5X	-	-	-	-	-	-	-	-	-
South Plume A - Type 2 Wells	■	■	■	2-5X	-	■	2-5X	2-5X	-	●	2-5X	-	■	X	-	-	-
South Plume A - Type 3 Wells	2-5X	■	2-5X	-	-	-	2-5X	■	-	-	-	-	-	-	-	-	-
South Plume A - Type 4 Wells	-	-	-	-	-	-	-	●	-	-	-	-	-	-	-	-	-
South Plume B - Type 2 Wells	■	■	■	■	■	■	■	■	●	■	■	■	-	■	●	-	-
South Plume B - Type 3 Wells	■	■	■	2-5X	2-5X	■	2-5X	■	-	■	■	■	■	2-5X	●	-	-
South Plume B - Type 4 Wells	●	■	2-5X	●	-	-	●	●	-	-	-	-	-	-	-	-	-
South Plume C - Type 2 Wells	■	■	2-5X	■	●	X	■	■	-	■	-	-	-	-	-	-	-
South Plume C - Type 3 Wells	-	-	●	■	2-5X	-	-	-	●	2-5X	-	-	-	-	-	-	-

Inorganics

AREA	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Cyanide	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium	Silicon	Silver	Sodium	Thallium	Vanadium	Zinc
Filter Status	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Waste Storage Area A Plume - Type 2	■	X	-	-	-	-	2-5X	-	-	2-5X	X	2-5X	■	2-5X	●	-	X	-	■	2-5X	●	-	2-5X	X	-	2-5X
Waste Storage Area A Plume - Type 3	2-5X	-	-	-	-	●	●	-	●	-	-	■	-	●	2-5X	-	X	-	■	2-5X	●	■	●	-	-	●
Waste Storage Area A Plume - Type 4	■	X	-	-	-	-	●	■	●	-	-	2-5X	■	2-5X	-	-	-	2-5X	●	-		-	●	-	-	-
Waste Storage Area B Plume - Type 2	■	-	-	-	-	-	-	-	-	-	-	2-5X	■	●	●	-	X	-	2-5X	2-5X	-	-	-	-	-	2-5X
Waste Storage Area B Plume - Type 3	-	-	-	-	-	-	-	-	-	-	-	2-5X	2-5X	●	●	-	-	-	●	●	-	-	-	-	-	●
Waste Storage Area B Plume - Type 4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plant 6 Plume - Type 2 Wells	-	-	-	-	-	2-5X	2-5X	-	●	-	-	●	●	●	2-5X	-	X	-	2-5X	■		-	-	-	-	■
Plant 6 Plume - Type 3 Wells	●	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	●	-		-	-	-	-	-
Plant 6 Plume - Type 4 Wells	-	-	-	-	-	-	●	-	-	-	-	●	●	●	-	-	-	-	-	2-5X		-	-	-	-	-
South Plume A - Type 2 Wells	■	X	-	-	-	-	●	2-5X	-	-	-	2-5X	■	●	●	-	-	-	2-5X	■	2-5X	-	-	-	●	2-5X
South Plume A - Type 3 Wells	2-5X	-	-	-	-	-	-	-	-	-	-	-	2-5X	-	●	-	-	-	●	2-5X	●	-	-	-	-	-
South Plume A - Type 4 Wells	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-		-	-	-	-	-
South Plume B - Type 2 Wells	■	-	■	■	X	-	2-5X	■	■	■	-	■	■	■	■	X	X	■	■	2-5X	●	-	2-5X	-	■	■
South Plume B - Type 3 Wells	■	X	■	-	X	■	-	■	■	■	-	■	■	-	-	X	-	■	●	■	-	■	-	X	■	■
South Plume B - Type 4 Wells	-	-	-	-	-	-	-	●	-	-	-	-	●	-	-	X	X	-	●	2-5X	-	●	-	-	-	2-5X
South Plume C - Type 2 Wells	■	-	■	-	-	-	-	-	-	-	-	●	-	-	●	-		-	■	2-5X		-	2-5X	-	-	-
South Plume C - Type 3 Wells	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	●	-	■	-	●	-	-	-	-	-

Organic Compounds

AREA	Volatiles	Semi-Volatiles
Filter Status	U	U
Waste Storage Area A Plume - Type 2	X	X
Waste Storage Area A Plume - Type 3	X	X
Waste Storage Area A Plume - Type 4	X	X
Waste Storage Area B Plume - Type 2	X	X
Waste Storage Area B Plume - Type 3	X	X
Waste Storage Area B Plume - Type 4		
Plant 6 Plume - Type 2 Wells	X	X
Plant 6 Plume - Type 3 Wells	X	
Plant 6 Plume - Type 4 Wells	X	
South Plume A - Type 2 Wells	X	X
South Plume A - Type 3 Wells		
South Plume A - Type 4 Wells		
South Plume B - Type 2 Wells	X	X
South Plume B - Type 3 Wells	X	X
South Plume B - Type 4 Wells	X	
South Plume C - Type 2 Wells	X	
South Plume C - Type 3 Wells		X

General Chemistry

AREA	Ammonia	Chloride	Fluoride	Nitrate	Sulfate
Filter Status	U	U	U	U	U
Waste Storage Area A Plume - Type 2	2-5X	2-5X	●	■	2-5X
Waste Storage Area A Plume - Type 3	●	2-5X	-	-	2-5X
Waste Storage Area A Plume - Type 4	-	2-5X	-	-	2-5X
Waste Storage Area B Plume - Type 2	-	-	-	-	-
Waste Storage Area B Plume - Type 3	-	-	-	-	-
Waste Storage Area B Plume - Type 4	-	-	-	-	-
Plant 6 Plume - Type 2 Wells	-	●	-	-	2-5X
Plant 6 Plume - Type 3 Wells	-	-	-	-	-
Plant 6 Plume - Type 4 Wells	-	2-5X	-	-	-
South Plume A - Type 2 Wells	-	-	-	-	-
South Plume A - Type 3 Wells	-	-	-	-	-
South Plume A - Type 4 Wells	-	-	-	-	-
South Plume B - Type 2 Wells	-	-	-	-	●
South Plume B - Type 3 Wells	-	-	-	-	-
South Plume B - Type 4 Wells	-	-	-	-	-
South Plume C - Type 2 Wells	-	-	-	-	-
South Plume C - Type 3 Wells	-	-	-	-	-

LEGEND

- (blank) Not analyzed.
- (-) Not above 95th percentile background value.
- (X) Detection where background not determined.
- (●) Detection above but < 2X 95 percentile background value
- (2-5X) Detection 2X to 5X 95 percentile background value.
- (■) Detection greater than 5X 95 percentile background value.

TABLE 4-56
SUMMARY OF PARAMETER OCCURRENCE IN SIX GREAT MIAMI AQUIFER PLUMES

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TABLE 4-57

SUMMARY STATISTICS FOR MAJOR CONTAMINANTS DETECTED IN THE WASTE STORAGE AREA A PLUME TYPE 2 WELLS[1]

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Uranium-238	P101	FIL	pCi/L	15/20	12/20	.325	.240 - 108	.200 - .500	0.900
Uranium-238	P101	UNF	pCi/L	21/25	16/25	.800	.301 - 20.6	.200 - .200	0.640
Uranium, total	P102	FIL	ug/L	17/20	15/20	.450	.300 - 65.9	.100 - 1.00	0.800
Uranium, total	P102	UNF	ug/L	23/25	18/25	.400	.200 - 64.7	.100 - 1.00	1.20
Uranium-234	P103	FIL	pCi/L	14/20	12/20	.275	.270 - 84.4	.200 - .600	0.900
Uranium-234	P103	UNF	pCi/L	21/25	17/25	.900	.268 - 28.7	.200 - .400	0.800
Thorium-230	P104	FIL	pCi/L	3/20	3/20	.100	.300 - .600	.200 - .301	0.290
Thorium-230	P104	UNF	pCi/L	9/25	0/25	.200	.300 - .712	.200 - 1.72	0.890
Radium-226	P105	FIL	pCi/L	7/20	2/20	.950	1.20 - 4.10	1.00 - 1.00	1.90
Radium-226	P105	UNF	pCi/L	1/25	0/25	.500	1.34 - 1.34	.500 - 1.00	1.5
Uranium-235/236	P108	FIL	pCi/L	2/20	2/20	.100	.700 - 6.30	.200 - .200	ND
Uranium-235/236	P108	UNF	pCi/L	5/25	5/25	.100	.277 - 1.10	.200 - 1.00	0.0940
Thorium-232	P109	FIL	pCi/L	2/20	2/20	.100	.700 - 1.20	.200 - .400	0.300
Thorium-232	P109	UNF	pCi/L	2/25	2/25	.150	.700 - 1.20	.200 - 1.00	0.230
Thorium, total	P110	FIL	ug/L	8/11		.912	.912 - 1.82	.500 - 1.07	NA
Thorium, total	P110	UNF	ug/L	13/25	7/25	.800	0 - 10.900	.500 - 5.00	0.970
Radium-228	P111	FIL	pCi/L	0/20	0/20			3.00 - 3.00	ND
Radium-228	P111	UNF	pCi/L	1/25	1/25	1.50	4.31 - 4.31	1.50 - 3.00	3.60
Thorium-228	P112	FIL	pCi/L	2/20	0/20	.100	.300 - .300	.200 - .300	0.400
Thorium-228	P112	UNF	pCi/L	1/25	1/25	.150	1.22 - 1.22	.200 - 1.00	0.770
Neptunium-237	P113	FIL	pCi/L	0/7	0/7			.500 - 1.00	0.120

TABLE 4-57 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Neptunium-237	P113	UNF	pCi/L	0/23	0/23			.500 - 1.00	0.25
Plutonium-239/240	P114	FIL	pCi/L	0/8	0/8			.500 - 1.00	0.0420
Plutonium-239/240	P114	UNF	pCi/L	0/25	0/25			.0431 - 1.00	0.0500
Plutonium-238	P115	FIL	pCi/L	1/8	1/8	.250	.890 - .890	.500 - 1.00	ND
Plutonium-238	P115	UNF	pCi/L	0/25	0/25			.500 - 1.00	0.0480
Strontium-90	P116	FIL	pCi/L	1/7	1/7	1.40	1.40 - 1.40	1.00 - 5.00	ND
Strontium-90	P116	UNF	pCi/L	7/24	7/24	2.50	1.37 - 32.3	1.00 - 5.00	0.65
Technetium-99	P117	FIL	pCi/L	3/9	3/9	156	35.7 - 204	15.0 - 30.0	ND
Technetium-99	P117	UNF	pCi/L	6/22	6/22	7.50	193 - 211	15.0 - 30.0	22
Ruthenium-106	P118	FIL	pCi/L	0/5	0/5			150 - 150	ND
Ruthenium-106	P118	UNF	pCi/L	0/23	0/23			150 - 155	ND
Aluminum	P201	UNF	mg/L	6/24	4/24	.0778	.0634 - 1.23	.0140 - .327	0.225
Antimony	P202	UNF	mg/L	1/24	1/24	.0190	.00290 - .00290	.00500 - .0450	ND
Arsenic	P203	UNF	mg/L	6/24	0/24	.00135	.00190 - .00830	.00100 - .00500	0.0294
Barium	P204	UNF	mg/L	22/24	0/24	.0895	.042 - .1320	.200 - .200	0.768
Beryllium	P205	UNF	mg/L	0/24	0/24			.00100 - .00500	ND
Cadmium	P207	UNF	mg/L	1/24	0/24	.00125	.00320 - .0032	.00100 - .00510	0.0135
Calcium	P208	UNF	mg/L	24/24	9/24	168.5	86.7 - 326		159
Chromium	P210	UNF	mg/L	5/24	0/24	.00405	.00360 - .0198	.00300 - .0192	0.0211
Cobalt	P211	UNF	mg/L	1/24	0/24	.00605	.00810 - .00810	.00500 - .0100	0.0086
Copper	P212	UNF	mg/L	3/24	1/24	.003430	.00520 - .176	.00300 - .0200	0.0354
Cyanide	P213	UNF	mg/L	1/25	1/25	.0100	.0440 - .0440	0 - .0200	ND
Iron	P214	UNF	mg/L	21/24	5/24	4.675	.0672 - 26.7	[illegible]	5.72
Lead	P215	UNF	mg/L	6/24	4/24	4.680	.00120 - .0415	.00100 - [illegible]	[illegible]0200
Magnesium	P216	UNF	mg/L	24/24	6/24	38.7	22.1 - 154		38.5

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TABLE 4-57 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Manganese	P217	UNF	mg/L	24/24	1/24	.3090	.00140 - .932		0.904
Mercury	P218	UNF	mg/L	0/24	0/24			.000200 - .000200	ND
Molybdenum	P219	UNF	mg/L	1/21	1/21	.00750	.435 - .435	.00100 - .0250	ND
Nickel	P220	UNF	mg/L	3/24	0/24	.01280	.0230 - .0509	.0100 - .031	0.0514
Osmium	P222	UNF	mg/L	0/1	0/1			.0500 - .0500	NA
Potassium	P223	UNF	mg/L	22/24	19/24	2.020	1.01 - 31.4	.820 - 1.20	1.96
Selenium	P225	UNF	mg/L	4/24	4/24	.000775	.00100 - .00220	.00100 - .00500	0.00075
Silicon	P226	UNF	mg/L	4/4	4/4	7.35	6.22 - 8.10		5.81
Silver	P227	UNF	mg/L	2/24	0/24	.00250	.00300 - .00420	.00100 - .0100	0.0117
Sodium	P228	UNF	mg/L	24/24	4/24	14.90	11.3 - 115		47.1
Thallium	P230	UNF	mg/L	1/24	1/24	.00100	.00110 - .00110	.00100 - .0100	ND
Vanadium	P233	UNF	mg/L	0/24	0/24			.00300 - .0500	0.0117
Zinc	P236	UNF	mg/L	6/24	3/24	.00685	.0117 - .0630	.00500 - .0200	0.0210
Ammonia	P705	UNF	mg/L	18/25	2/25	.0520	.0520 - 17.0	.0200 - .100	4.20
Chloride	P715	UNF	mg/L	25/25	7/25	26.0	19.0 - 340		73.0
Fluoride	P721	UNF	mg/L	23/25	1/25	.0750	.150 - 1.36	.150 - .15	0.890
Nitrate	P729	UNF	mg/L	15/24	7/24	5.61	.0200 - 79.4	.0200 - .100	11.4
Sulfate	P744	UNF	mg/L	25/25	6/25	110	55.0 - 550		197

[1]Based on Table E.2-4 in Appendix E
[2]Frequency of detection is defined as (number of detectable results)/(number of wells tested)

TABLE 4-58

SUMMARY STATISTICS FOR MAJOR CONTAMINANTS DETECTED IN THE WASTE STORAGE AREA B PLUME TYPE 2 WELLS[1]

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Uranium-238	P101	FIL	pCi/L	13/14	11/14	1.74	.500 - 9.10	.200 - .200	0.900
Uranium-238	P101	UNF	pCi/L	15/17	14/17	4.66	.579 - 12.3	.200 - .200	0.640
Uranium, total	P102	FIL	ug/L	14/14	12/14	5.01	.500 - 26.8		0.800
Uranium, total	P102	UNF	ug/L	17/17	16/17	13.8	.700 - 27.2		1.20
Uranium-234	P103	FIL	pCi/L	12/13	11/13	3.74	.547 - 8.90	.500 - .500	0.900
Uranium-234	P103	UNF	pCi/L	15/17	14/17	4.72	.300 - 11.9	.200 - .200	0.800
Thorium-230	P104	FIL	pCi/L	3/13	3/13	.408	.400 - .740	.200 - .300	0.290
Thorium-230	P104	UNF	pCi/L	4/17	1/17	.500	.250 - 1.65	.200 - 1.00	0.890
Radium-226	P105	FIL	pCi/L	0/13	0/13			1.00 - 1.00	1.90
Radium-226	P105	UNF	pCi/L	1/17	1/17	.500	12.3 - 12.3	1.00 - 1.00	1.5
Lead-210	P106	FIL	pCi/L	0/1	0/1			3.00 - 3.00	NA
Uranium-235/236	P108	FIL	pCi/L	3/13	3/13	.100	.240 - .400	.200 - .200	ND
Uranium-235/236	P108	UNF	pCi/L	2/17	2/17	.500	.300 - .600	.200 - 1.00	0.0940
Thorium-232	P109	FIL	pCi/L	0/13	0/13			.200 - .300	0.300
Thorium-232	P109	UNF	pCi/L	2/17	2/17	.500	.600 - 1.02	.200 - 1.00	0.230
Thorium, total	P110	FIL	ug/L	1/7		.875	2.74 - 2.740	.764 - 1.75	NA
Thorium, total	P110	UNF	ug/L	5/17	4/17	2.00	.912 - 9.18	.500 - 4.00	0.970
Radium-228	P111	FIL	pCi/L	0/14	0/14			3.00 - 5.65	ND
Radium-228	P111	UNF	pCi/L	2/17	2/17	1.50	3.70 - 5.10	3.00 - 3.00	3.60
Thorium-228	P112	FIL	pCi/L	2/13	0/13	.100	.210 - .300	.200 - .490	0.400
Thorium-228	P112	UNF	pCi/L	1/17	1/17	.500	1.69 - 1.69	.200 - 1.00	0.770

TABLE 4-58 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Neptunium-237	P113	FIL	pCi/L	1/6	1/6	.250	.738 - .738	.500 - .500	0.120
Neptunium-237	P113	UNF	pCi/L	0/16	0/16			.500 - 1.00	0.25
Plutonium-239/240	P114	FIL	pCi/L	0/6	0/6			.500 - .500	0.0420
Plutonium-239/240	P114	UNF	pCi/L	0/17	0/17			.500 - 1.00	0.0500
Plutonium-238	P115	FIL	pCi/L	0/7	0/7			.500 - .500	ND
Plutonium-238	P115	UNF	pCi/L	0/17	0/17			.500 - 1.00	0.0480
Strontium-90	P116	FIL	pCi/L	0/7	0/7			1.00 - 2.68	ND
Strontium-90	P116	UNF	pCi/L	0/17	0/17			1.00 - 5.00	0.65
Technetium-99	P117	FIL	pCi/L	0/7	0/7			15.0 - 15.0	ND
Technetium-99	P117	UNF	pCi/L	1/17	1/17	15.0	36.6 - 36.6	15.0 - 30.0	22
Ruthenium-106	P118	FIL	pCi/L	0/6	0/6			150 - 150	ND
Ruthenium-106	P118	UNF	pCi/L	0/16	0/16			150 - 168	ND
Aluminum	P201	UNF	mg/L	8/16	4/16	1.22	.0321 - 2.41	.020 - .0962	0.225
Antimony	P202	UNF	mg/L	0/16	0/16			.00320 - .0587	ND
Arsenic	P203	UNF	mg/L	3/16	0/16	.00675	.00110 - .0130	.00100 - .00340	0.0294
Barium	P204	UNF	mg/L	15/16	0/16	.0730	.0331 - .0693	.200 - .200	0.768
Beryllium	P205	UNF	mg/L	0/16	0/16			.000800 - .0100	ND
Cadmium	p207	UNF	mg/L	1/16	0/16	.00100	.00220 - .00220	.00100 - .00500	0.0135
Calcium	P208	UNF	mg/L	16/16	0/16	115	80.2 - 122		159
Chromium	P210	UNF	mg/L	3/16	0/16	.0133	.00550 - .0210	.00300 - .0113	0.0211
Cobalt	P211	UNF	mg/L	1/16	0/16	.00950	.00650 - .00650	.00300 - .0250	0.00860
Copper	P212	UNF	mg/L	2/16	0/16	.00985	.00360 - .00720	.00200 - .0250	0.0354
Cyanide	P213	UNF	mg/L	0/16	0/16			0 - .0100	ND
Iron	P214	UNF	mg/L	11/16	1/16	6.94	.101 - 13.8	.0150 - .176	5.72
Lead	P215	UNF	mg/L	4/16	4/16	.0118	.00260 - .0230	.00100 - .0032	0.00200

TABLE 4-58 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Magnesium	P216	UNF	mg/L	16/16	1/16	43.6	20.4 - 60.0		38.5
Manganese	P217	UNF	mg/L	11/16	1/16	.344	.0135 - 1.29	.00100 - .010	0.904
Mercury	P218	UNF	mg/L	0/16	0/16			.000100 - .000200	ND
Molybdenum	P219	UNF	mg/L	1/8	1/8	.00485	.00740 - .00740	.00320 - .0250	ND
Nickel	P220	UNF	mg/L	2/16	0/16	.0193	.00750 - .0290	.00300 - .0310	0.0514
Potassium	P223	UNF	mg/L	12/16	10/16	3.25	1.27 - 4.10	2.77 - 2.98	1.96
Selenium	P225	UNF	mg/L	3/16	3/16	.000900	.00120 - .00240	.00100 - .00250	0.000750
Silicon	P226	UNF	mg/L	6/6	0/6	5.46	2.26 - 5.71		5.81
Silver	P227	UNF	mg/L	0/16	0/16			.00100 - .0100	0.0117
Sodium	P228	UNF	mg/L	16/16	0/16	10.1	6.82 - 17.3		47.1
Thallium	P230	UNF	mg/L	0/16	0/16			.00100 - .0100	ND
Vanadium	P233	UNF	mg/L	0/16	0/16			.00210 - .0500	0.0117
Zinc	P236	UNF	mg/L	2/16	2/16	.0417	.0411 - .0710	.00470 - .0522	0.0210
Ammonia	P705	UNF	mg/L	6/16	0/16	.0300	.0200 - .300	.0200 - .100	4.20
Chloride	P715	UNF	mg/L	17/17	0/17	24. 5	6.45 - 31.0		73.0
Fluoride	P721	UNF	mg/L	14/16	0/16	.220	.130 - .280	.100 - .260	0.890
Nitrate	P729	UNF	mg/L	14/15	0/15	2.80	.180 - 2.86		11.4
Sulfate	P744	UNF	mg/L	17/17	0/17	80.8	45.0 - 136		197

[1]Based on Table E.2-7 in Appendix E
[2]Frequency of detection is defined as (number of detectable results)/(number of wells tested)

TABLE 4-59

SUMMARY STATISTICS FOR MAJOR CONTAMINANTS DETECTED IN PLANT 6 PLUME TYPE 2 WELLS[1]

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Uranium-238	P101	FIL	pCi/L	12/13	10/13	2.90	.600 - 10.3		0.900
Uranium-238	P101	UNF	pCi/L	13/14	12/14	3.25	.500 - 15.5	.200 - .200	0.640
Uranium, total	P102	FIL	ug/L	13/13	11/13	9.90	.400 - 51.8		0.800
Uranium, total	P102	UNF	ug/L	14/14	11/14	10.55	.500 - 37.0		1.200
Uranium-234	P103	FIL	pCi/L	12/13	8/13	3.30	.52 - 8.7		0.900
Uranium-234	P103	UNF	pCi/L	14/14	9/14	3.50	.300 - 16.2		0.800
Thorium-230	P104	FIL	pCi/L	3/13	3/13	.300	.300 - .300	.200 - .300	0.290
Thorium-230	P104	UNF	pCi/L	8/14	1/14	.300	.300 - 2.80	.200 - .400	0.890
Radium-226	P105	FIL	pCi/L	1/12	0/12	.500	1.60 - 1.60	1.00 - 1.00	1.900
Radium-226	P105	UNF	pCi/L	2/14	1/14	.500	1.30 - 1.50	1.00 - 1.00	1.5
Uranium-235/236	P108	FIL	pCi/L	1/13	1/13	.100	.300 - .300	.200 - .200	ND
Uranium-235/236	P108	UNF	pCi/L	1/14	1/14	.100	.500 - .500	.200 - .200	0.094
Thorium-232	P109	FIL	pCi/L	2/13	2/13	.100	.300 - .500	.200 - .300	0.300
Thorium-232	P109	UNF	pCi/L	0/14	0/14			.200 - .500	0.230
Thorium, total	P110	FIL	ug/L	7/9		.912	0.000 - 4.56	.500 - 4.10	NA
Thorium, total	P110	UNF	ug/L	7/11	3/11	.900	.912 - 2.7400	.500 - 6.00	0.970
Radium-228	P111	FIL	pCi/L	0/13	0/13			3.00 - 3.00	ND
Radium-228	P111	UNF	pCi/L	0/14	0/14			3.00 - 3.00	3.60
Thorium-228	P112	FIL	pCi/L	1/13	0/13	.100	.300 - .300	.200 - .300	0.40
Thorium-228	P112	UNF	pCi/L	1/14	0/14	.100	.300 - .300	.200 - .300	0.770
Neptunium-237	P113	FIL	pCi/L	0/2	0/2			.500 - 1.00	0.5

TABLE 4-59 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Neptunium-237	P113	UNF	pCi/L	0/8	0/8			1.00 - 1.00	0.25
Plutonium-239/240	P114	FIL	pCi/L	0/4	0/4			.500 - 1.00	0.0420
Plutonium-239/240	P114	UNF	pCi/L	1/10	1/10	.500	.900 - .900	.500 - 1.00	0.0500
Plutonium-238	P115	FIL	pCi/L	0/4	0/4			.500 - 1.00	ND
Plutonium-238	P115	UNF	pCi/L	0/10	0/10			.500 - 1.00	0.0480
Strontium-90	P116	FIL	pCi/L	0/3	0/3			1.61 - 5.00	ND
Strontium-90	P116	UNF	pCi/L	0/10	0/10			1.00 - 5.00	0.65
Technetium-99	P117	FIL	pCi/L	0/7	0/7			15.0 - 30.0	ND
Technetium-99	P117	UNF	pCi/L	0/12	0/12			15.0 - 30.0	22
Ruthenium-106	P118	FIL	pCi/L	0/3	0/3			150 - 150	ND
Ruthenium-106	P118	UNF	pCi/L	0/8	0/8			150 - 150	ND
Aluminum	P201	UNF	mg/L	7/14	0/14	.0323	.0424 - .1490	.020 - .0629	0.225
Antimony	P202	UNF	mg/L	0/14	0/14			.0157 - .0450	ND
Arsenic	P203	UNF	mg/L	2/14	0/14	.00150	.00100 - .00490	.00200 - .00340	0.0294
Barium	P204	UNF	mg/L	14/14	0/14	.06405	.0312 - .105		0.768
Beryllium	P205	UNF	mg/L	0/14	0/14			.000300 - .00100	ND
Cadmium	P207	UNF	mg/L	7/14	3/14	.00240	.0029 - .0459	.00200 - .00300	0.0135
Calcium	P208	UNF	mg/L	14/14	7/14	250	97.7 - 333		159
Chromium	P210	UNF	mg/L	2/14	0/14	.00250	.0081 - .0118	.00300 - .00600	0.0211
Cobalt	P211	UNF	mg/L	2/14	2/14	.0077	.0093 - .0114	.00340 - .0130	0.00860
Copper	P212	UNF	mg/L	0/14	0/14			.00300 - .0134	0.0354
Cyanide	P213	UNF	mg/L	0/14	0/14			.010 - .020	ND
Iron	P214	UNF	mg/L	14/14	1/14	3.78	.0828 - 5.85		5.72
Lead	P215	UNF	mg/L	3/14	2/14	.00100	.0011 - .0028	.00100 - .00310	0.00200
Magnesium	P216	UNF	mg/L	14/14	5/14	40.4	27.5 - 56.8		38.5

TABLE 4-59 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Manganese	P217	UNF	mg/L	14/14	2/14	.709	.133 - 2.66		0.904
Mercury	P218	UNF	mg/L	0/14	0/14			.000200 - .000200	ND
Molybdenum	P219	UNF	mg/L	1/6	1/6	.0100	.0142 - .0142	.010 - .0250	ND
Nickel	P220	UNF	mg/L	1/14	0/14	.0100	.0116 - .0116	.00700 - .0310	0.0514
Potassium	P223	UNF	mg/L	11/14	11/14	4.190	2.08 - 5.75	1.77 - 2.77	1.96
Selenium	P225	UNF	mg/L	2/14	2/14	.000500	.0016 - .0112	.00100 - .010	0.000750
Silver	P227	UNF	mg/L	0/14	0/14			.00290 - .00700	0.0117
Sodium	P228	UNF	mg/L	14/14	0/14	10.900	7.48 - 39.8		47.1
Thallium	P230	UNF	mg/L	0/14	0/14			.00100 - .010	ND
Vanadium	P233	UNF	mg/L	2/14	0/14	.00150	.00310 - .00510	.00290 - .00700	0.0117
Zinc	P236	UNF	mg/L	3/14	2/14	.009480	.00880 - .0470	.00930 - .0358	0.0210
Ammonia	P705	UNF	mg/L	6/14	0/14	.0100	.0300 - .130	.020 - .0650	4.20
Chloride	P715	UNF	mg/L	14/14	1/14	22.0	15.0 - 77.0		73.0
Fluoride	P721	UNF	mg/L	13/14	0/14	.150	.140 - .230	.150 - .150	0.890
Nitrate	P729	UNF	mg/L	2/12	0/12	.0500	.110 - .110	.020 - .100	11.4
Sulfate	P744	UNF	mg/L	14/14	8/14	512.0	87.0 - 740		197

[1]Based on Table E.2-10 in Appendix E
[2]Frequency of detection is defined as (number of detectable results)/(number of wells tested)

TABLE 4-60

SUMMARY STATISTICS FOR MAJOR CONTAMINANTS DETECTED IN SOUTH PLUME A TYPE 2 WELLS[1]

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Uranium-238	P101	FIL	pCi/L	7/7	6/7	.440	.440 - 381		0.900
Uranium-238	P101	UNF	pCi/L	11/12	11/12	1.375	.760 - 707	1.00 - 1.00	0.640
Uranium, total	P102	FIL	ug/L	12/12	12/12	82.0	1.30 - 1130		0.800
Uranium, total	P102	UNF	ug/L	15/15	14/15	126	.900 - 2070		1.20
Uranium-234	P103	FIL	pCi/L	7/7	6/7	.670	.670 - 357.5		0.900
Uranium-234	P103	UNF	pCi/L	11/12	10/12	1.41	.682 - 662	1.00 - 1.00	0.800
Thorium-230	P104	FIL	pCi/L	1/7	0/7	.160	.253 - .253	.200 - .320	0.290
Thorium-230	P104	UNF	pCi/L	9/13	2/13	.298	.211 - 2.06	.200 - 1.00	0.890
Radium-226	P105	FIL	pCi/L	2/7	0/7	.500	1.10 - 1.20	1.00 - 1.00	1.90
Radium-226	P105	UNF	pCi/L	1/13	0/13	.500	1.19 - 1.19	1.00 - 1.40	1.5
Uranium-235/236	P108	FIL	pCi/L	3/7	3/7	.100	5.00 - 15.7	.200 - .200	ND
Uranium-235/236	P108	UNF	pCi/L	8/12	8/12	.4285	.460 - 31.7	.200 - 1.00	0.094
Thorium-232	P109	FIL	pCi/L	0/7	0/7			.200 - .300	0.300
Thorium-232	P109	UNF	pCi/L	1/13	1/13	.100	1.05 - 1.05	.200 - 1.00	0.230
Thorium, total	P110	FIL	ug/L	2/7		1.08	.912 - 1.82	.500 - 2.16	NA
Thorium, total	P110	UNF	ug/L	2/13	2/13	.530	1.27 - 3.72	.750 - 4.30	0.970
Radium-228	P111	FIL	pCi/L	0/7	0/7			3.00 - 3.00	ND
Radium-228	P111	UNF	pCi/L	1/13	0/13	1.50	3.5 - 3.5	3.00 - 3.40	3.60
Thorium-228	P112	FIL	pCi/L	1/7	1/7	.190	.500 - .500	.200 - .380	0.400
Thorium-228	P112	UNF	pCi/L	1/13	0/13	.101	.300 - .300	.200 - 1.00	0.770
Neptunium-237	P113	FIL	pCi/L	1/4	0/4	.375	0 - 0	.500 - .500	0.120

TABLE 4-60 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Neptunium-237	P113	UNF	pCi/L	4/13	1/13	.200	0.00 - .7960	.500 - 1.00	0.25
Plutonium-239/240	P114	FIL	pCi/L	0/5	0/5			.500 - .500	0.0420
Plutonium-239/240	P114	UNF	pCi/L	0/13	0/13			.500 - 1.00	0.0500
Plutonium-238	P115	FIL	pCi/L	0/5	0/5			.500 - .500	ND
Plutonium-238	P115	UNF	pCi/L	1/13	1/13	.250	.637 - .637	.500 - 1.00	0.0480
Strontium-90	P116	FIL	pCi/L	1/4	1/4	.835	1.17 - 1.17	1.00 - 1.00	ND
Strontium-90	P116	UNF	pCi/L	0/13	0/13			1.00 - 5.00	0.65
Technetium-99	P117	FIL	pCi/L	0/4	0/4			15.0 - 15.0	ND
Technetium-99	P117	UNF	pCi/L	0/13	0/13			15.0 - 30.0	22
Ruthenium-106	P118	FIL	pCi/L	0/4	0/4			150 - 150	ND
Ruthenium-106	P118	UNF	pCi/L	0/13	0/13			150 - 150	ND
Aluminum	P201	UNF	mg/L	7/11	7/11	.906	.234 - 5.11	.020 - .223	0.225
Antimony	P202	UNF	mg/L	1/11	1/11	.00250	.005100 - .005100	.00140 - .0450	ND
Arsenic	P203	UNF	mg/L	5/11	0/11	.00310	.00120 - .00420	.00100 - .00200	0.0294
Barium	P204	UNF	mg/L	11/11	0/11	.0425	.0398 - .0961		0.768
Beryllium	P205	UNF	mg/L	0/11	0/11			.00100 - .00220	ND
Cadmium	P207	UNF	mg/L	0/11	0/11			.00200 - .00500	0.0135
Calcium	P208	UNF	mg/L	11/11	2/11	105	90.4 - 198		159
Chromium	P210	UNF	mg/L	4/11	3/11	.00500	.00520 - .0436	.00400 - .0100	0.0211
Cobalt	P211	UNF	mg/L	0/11	0/11			.00300 - .0100	0.00860
Copper	P212	UNF	mg/L	1/11	0/11	.00100	.0296 - .0296	.00200 - .0171	0.0354
Cyanide	P213	UNF	mg/L	0/11	0/11			.00100 - .00200	ND
Iron	P214	UNF	mg/L	9/11	1/11	2.17	.0329 - 15.1	.0329 - .0621	5.72
Lead	P215	UNF	mg/L	6/11	4/11	.00340	.00130 - .0160	.00100 - .00200	0.00200
Magnesium	P216	UNF	mg/L	11/11	2/11	29.8	23.6 - 60.2		38.5

TABLE 4-60 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Manganese	P217	UNF	mg/L	10/11	1/11	.0796	.00200 - 1.22	.0100 - .010	0.904
Mercury	P218	UNF	mg/L	0/11	0/11			.000200 - .000200	ND
Molybdenum	P219	UNF	mg/L	0/9	0/9			.00300 - .0250	ND
Nickel	P220	UNF	mg/L	3/11	0/11	.0100	.00720 - .0489	.00300 - .0200	0.0514
Potassium	P223	UNF	mg/L	11/11	9/11	2.43	1.68 - 4.40		1.96
Selenium	P225	UNF	mg/L	5/11	5/11	.00100	.00100 - .00650	.00100 - .00200	0.000750
Silicon	P226	UNF	mg/L	8/8	2/8	10.0	3.45 - 12.8		5.81
Silver	P227	UNF	mg/L	0/11	0/11			.00200 - .0100	0.0117
Sodium	P228	UNF	mg/L	11/11	0/11	6.94	5.71 - 12.7		47.1
Thallium	P230	UNF	mg/L	0/11	0/11			.00100 - .0100	ND
Vanadium	P233	UNF	mg/L	2/11	1/11	.00500	.00400 - .0185	.00300 - .0136	0.0117
Zinc	P236	UNF	mg/L	8/11	1/11	.0114	.00740 - .0801	.00500 - .0139	0.0210
Ammonia	P705	UNF	mg/L	1/11	0/11	.0500	.120 - .120	.100 - .300	4.20
Chloride	P715	UNF	mg/L	11/12	0/12	17.145	4.62 - 29.1	5.70 - 5.70	73.0
Fluoride	P721	UNF	mg/L	12/12	0/12	.170	.0900 - .510		0.890
Nitrate	P729	UNF	mg/L	14/15	0/15	1.57	.260 - 2.29		11.4
Sulfate	P744	UNF	mg/L	12/12	0/12	48.6	26.0 - 95.4		197

[1]Based on Table E.2-13 in Appendix E
[2]Frequency of detection is defined as (number of detectable results)/(number of wells tested)

TABLE 4-61

SUMMARY STATISTICS FOR MAJOR CONTAMINANTS DETECTED IN SOUTH PLUME B TYPE 2 WELLS[1]

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Uranium-238	P101	FIL	pCi/L	32/40	21/40	4.70	.300 - 84.8	.200 - 1.00	0.900
Uranium-238	P101	UNF	pCi/L	30/42	25/42	.450	.400 - 111	.200 - .500	0.640
Uranium, total	P102	FIL	ug/L	40/41	34/41	.700	.200 - 350	1.00 - 1.00	0.800
Uranium, total	P102	UNF	ug/L	50/51	43/51	1.80	.200 - 332	.100 - .100	1.20
Uranium-234	P103	FIL	pCi/L	31/40	22/40	4.20	.400 - 84.4	.200 - 1.00	0.900
Uranium-234	P103	UNF	pCi/L	32/42	24/42	.550	.300 - 110	.400 - .400	0.800
Thorium-230	P104	FIL	pCi/L	5/39	5/39	.300	.300 - 1.62	.200 - 1.00	0.290
Thorium-230	P104	UNF	pCi/L	20/43	4/43	.150	.281 - 1.80	.200 - 1.00	0.890
Radium-226	P105	FIL	pCi/L	4/40	0/40	.500	1.10 - 1.50	.600 - 1.00	1.90
Radium-226	P105	UNF	pCi/L	10/43	7/43	.500	1.10 - 14.9	.600 - 2.00	1.5
Uranium-235/236	P108	FIL	pCi/L	13/40	13/40	.300	.500 - 8.00	.100 - 1.00	ND
Uranium-235/236	P108	UNF	pCi/L	15/42	15/42	.100	.220 - 5.54	.100 - 1.00	0.0904
Thorium-232	P109	FIL	pCi/L	5/39	5/39	.100	.300 - 2.70	.200 - 1.00	0.300
Thorium-232	P109	UNF	pCi/L	4/43	4/43	.100	.300 - 2.70	.200 - 1.00	0.230
Thorium, total	P110	FIL	ug/L	9/22		1.66	.912 - 7.30	.920 - 13.0	NA
Thorium, total	P110	UNF	ug/L	9/31	6/31	2.95	.912 - 24.6000	.500 - 9.10	0.970
Radium-228	P111	FIL	pCi/L	0/40	0/40			1.30 - 3.00	ND
Radium-228	P111	UNF	pCi/L	4/43	2/43	1.60	3.10 - 4.40	1.20 - 3.30	3.60
Thorium-228	P112	FIL	pCi/L	4/39	2/39	.100	.300 - 2.55	.100 - 1.00	0.400
Thorium-228	P112	UNF	pCi/L	6/43	2/43	.100	.300 - 1.70	.100 - 1.00	0.770
Neptunium-237	P113	FIL	pCi/L	1/16	1/16	.500	2.50 - 2.50	.500 - 1.10	0.120

TABLE 4-61 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Neptunium-237	P113	UNF	pCi/L	0/28	0/28			.500 - 1.00	0.25
Plutonium-239/240	P114	FIL	pCi/L	0/23	0/23			.500 - 1.00	0.0420
Plutonium-239/240	P114	UNF	pCi/L	1/36	1/36	.500	1.40 - 1.40	.500 - 1.00	0.0500
Plutonium-238	P115	FIL	pCi/L	0/23	0/23			.500 - 1.00	ND
Plutonium-238	P115	UNF	pCi/L	0/36	0/36			.500 - 1.00	0.0480
Strontium-90	P116	FIL	pCi/L	2/23	2/23	2.50	1.40 - 5.69	.500 - 6.98	ND
Strontium-90	P116	UNF	pCi/L	2/36	2/36	2.50	1.40 - 17.4	.500 - 5.00	0.65
Technetium-99	P117	FIL	pCi/L	4/25	4/25	24.6	19.2 - 24.6	12.0 - 30.0	ND
Technetium-99	P117	UNF	pCi/L	4/36	1/36	15.0	17.8 - 24.1	13.5 - 30.0	22
Ruthenium-106	P118	FIL	pCi/L	0/17	0/17			150 - 150	ND
Ruthenium-106	P118	UNF	pCi/L	0/29	0/29			150 - 150	ND
Aluminum	P201	UNF	mg/L	29/38	16/38	.058	.0250 - 92.0	.014 - .500	0.225
Antimony	P202	UNF	mg/L	0/38	0/38			.00110 - .045	ND
Arsenic	P203	UNF	mg/L	13/39	6/39	.00100	.00100 - .350	.00100 - .00600	0.0294
Barium	P204	UNF	mg/L	36/39	1/39	.054	.0246 - 8.69	.200 - .200	0.768
Beryllium	P205	UNF	mg/L	1/38	1/38	.000500	.00150 - .00150	.00100 - .0100	ND
Cadmium	P207	UNF	mg/L	2/39	0/39	.00150	.00380 - .00530	.00100 - .0104	0.0135
Calcium	P208	UNF	mg/L	39/39	5/39	102	73.6 - 411		159
Chromium	P210	UNF	mg/L	11/40	5/40	.00320	.00480 - 1.11	.00400 - .0292	0.0211
Cobalt	P211	UNF	mg/L	7/38	3/38	.00325	.00500 - .168	.00300 - .0250	0.00860
Copper	P212	UNF	mg/L	11/39	4/39	.00200	.00440 - .694	.00200 - .124	0.0354
Cyanide	P213	UNF	mg/L	0/39	0/39			.00100 - .0467	ND
Iron	P214	UNF	mg/L	33/39	12/39	.221	.0550 - 913	.0226 - .587	5.72
Lead	P215	UNF	mg/L	16/39	10/39	.00140	.00120 - .244	.00100 - .0444	0.00200
Magnesium	P216	UNF	mg/L	39/39	10/39	29.1	17.9 - 507		38.5

TABLE 4-61 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Manganese	p217	UNF	mg/L	34/39	5/39	.187	.00130 - 139	.00100 - .020	0.904
Mercury	P218	UNF	mg/L	2/39	2/39	.000100	.000400 - .000600	.000200 - .000200	ND
Molybdenum	P219	UNF	mg/L	3/18	3/18	.00895	.010 - .0124	.00300 - .0250	ND
Nickel	P220	UNF	mg/L	8/39	3/39	.010	.0115 - .621	.00300 - .0310	0.0514
Potassium	P223	UNF	mg/L	36/39	33/39	4.23	.724 - 140	1.89 - 2.02	1.96
Selenium	P225	UNF	mg/L	6/39	6/39	.000500	.00100 - .00220	.00100 - .0100	0.000750
Silicon	P226	UNF	mg/L	6/6	1/6	4.75	3.07 - 5.99		5.81
Silver	P227	UNF	mg/L	1/39	0/39	.00350	.00310 - .00310	.00100 - .0300	0.0117
Sodium	P228	UNF	mg/L	39/39	3/39	14.4	9.67 - 130		47.1
Thallium	P230	UNF	mg/L	0/38	0/38			.00100 - .0100	ND
Vanadium	P233	UNF	mg/L	9/38	5/38	.00175	.00500 - .251	.00300 - .0500	0.0117
Zinc	P236	UNF	mg/L	14/39	10/39	.00390	.00690 - 1.12	.00500 - .232	0.0210
Ammonia	P705	UNF	mg/L	11/40	0/40	.110	.020 - .340	.0200 - .150	4.20
Chloride	P715	UNF	mg/L	39/40	0/40	22.0	3.00 - 64.0	17.8 - 17.8	73.0
Fluoride	P721	UNF	mg/L	35/40	0/40	.173	.100 - .700	.100 - .280	0.890
Nitrate	P729	UNF	mg/L	28/32	0/32	2.27	.080 - 7.91	.049 - .257	11.4
Sulfate	P744	UNF	mg/L	38/39	1/39	69.0	18.6 - 238	218 - 218	197

[1]Based on Table E.2-16 in Appendix E
[2]Frequency of detection is defined as (number of detectable results)/(number of wells tested)

TABLE 4-62

SUMMARY STATISTICS FOR MAJOR CONTAMINANTS DETECTED IN SOUTH PLUME C TYPE 2 WELLS[1]

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Uranium-238	P101	FIL	pCi/L	5/8	5/8	.650	1.01 - 5.97	.200 - 1.00	0.900
Uranium-238	P101	UNF	pCi/L	5/7	5/7	1.10	.700 - 2.79	.200 - 3.40	0.640
Uranium, total	P102	FIL	ug/L	6/8	6/8	4.60	1.70 - 11.4	1.00 - 1.00	0.800
Uranium, total	P102	UNF	ug/L	7/7	6/7	4.70	.770 - 8.39		1.20
Uranium-234	P103	FIL	pCi/L	6/8	6/8	.950	.900 - 4.40	1.00 - 1.00	0.900
Uranium-234	P103	UNF	pCi/L	5/7	5/7	1.20	.800 - 2.42	.200 - 3.40	0.800
Thorium-230	P104	FIL	pCi/L	1/8	1/8	.125	3.08 - 3.08	.200 - 1.00	0.290
Thorium-230	P104	UNF	pCi/L	2/7	1/7	.250	.400 - 1.10	.400 - 1.00	0.890
Radium-226	P105	FIL	pCi/L	3/8	1/8	.900	1.30 - 3.30	1.00 - 1.00	1.90
Radium-226	P105	UNF	pCi/L	2/7	2/7	2.10	2.10 - 2.60	1.00 - 1.00	1.5
Uranium-235/236	P108	FIL	pCi/L	1/8	1/8	.450	.800 - .800	.200 - 1.00	ND
Uranium-235/236	P108	UNF	pCi/L	0/7	0/7			.200 - 3.40	0.0940
Thorium-232	P109	FIL	pCi/L	1/8	1/8	.750	1.30 - 1.30	.200 - 1.00	0.300
Thorium-232	P109	UNF	pCi/L	1/7	1/7	.300	1.30 - 1.30	.200 - 1.10	0.230
Thorium, total	P110	FIL	ug/L	2/8		2.78	4.56 - 9.12	1.60 - 9.30	NA
Thorium, total	P110	UNF	ug/L	3/6	2/6	6.40	.912 - 11.9	1.90 - 9.50	0.970
Radium-228	P111	FIL	pCi/L	0/8	0/8			3.00 - 3.00	ND
Radium-228	P111	UNF	pCi/L	0/7	0/7			3.00 - 3.00	3.60
Thorium-228	P112	FIL	pCi/L	2/8	2/8	.150	1.66 - 2.09	.200 - 1.00	0.400
Thorium-228	P112	UNF	pCi/L	2/7	2/7	.400	1.89 - 1.97	.200 - 1.00	0.770
Neptunium-237	P113	FIL	pCi/L	0/8	0/8			1.00 - 1.00	0.120

TABLE 4-62 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Neptunium-237	P113	UNF	pCi/L	0/6	0/6			1.00 - 1.00	0.25
Plutonium-239/240	P114	FIL	pCi/L	0/8	0/8			1.00 - 1.00	0.0420
Plutonium-239/240	P114	UNF	pCi/L	0/6	0/6			1.00 - 1.00	0.0500
Plutonium-238	P115	FIL	pCi/L	0/8	0/8			1.00 - 1.00	ND
Plutonium-238	P115	UNF	pCi/L	0/6	0/6			1.00 - 1.00	0.0480
Strontium-90	P116	FIL	pCi/L	0/8	0/8			5.00 - 5.00	ND
Strontium-90	P116	UNF	pCi/L	0/6	0/6			5.00 - 5.00	0.65
Technetium-99	P117	FIL	pCi/L	0/8	0/8			30.0 - 30.0	ND
Technetium-99	P117	UNF	pCi/L	0/6	0/6			30.0 - 30.0	22
Ruthenium-106	P118	FIL	pCi/L	0/8	0/8			150 - 150	ND
Ruthenium-106	P118	UNF	pCi/L	0/6	0/6			150 - 150	ND
Aluminum	P201	UNF	mg/L	1/4	1/4	.0100	2.59 - 2.59	.0200 - .0380	0.225
Antimony	P202	UNF	mg/L	0/4	0/4			.0450 - .0450	ND
Arsenic	P203	UNF	mg/L	2/4	1/4	.00100	.00240 - .168	.00200 - .00200	0.0294
Barium	P204	UNF	mg/L	4/4	0/4	.104	.00340 - .584		0.768
Beryllium	P205	UNF	mg/L	0/4	0/4			.00100 - .00100	ND
Cadmium	P207	UNF	mg/L	0/4	0/4			.00300 - .00300	0.0135
Calcium	P208	UNF	mg/L	4/4	0/4	41.400000	1.63 - 133		159
Chromium	P210	UNF	mg/L	1/4	0/4	.00250	.0206 - .0206	.00500 - .0240	0.0211
Cobalt	P211	UNF	mg/L	0/4	0/4			.00600 - .00800	0.00860
Copper	P212	UNF	mg/L	3/4	0/4	.00575	.00500 - .0115	.00400 - .00400	0.0354
Cyanide	P213	UNF	mg/L	0/4	0/4			.0100 - .0100	ND
Iron	P214	UNF	mg/L	3/4	1/4	.195	.342 - 10.6	.0944 - .0944	5.72
Lead	P215	UNF	mg/L	1/4	0/4	.00105	.00110 - .00110	.00100 - .00320	0.00200
Magnesium	P216	UNF	mg/L	4/4	0/4	10.8	.285 - 29.9		38.5

TABLE 4-62 (Continued)

Parameter	PCode	Filter Flag	Units	Frequency of Detection[2]	Frequency of Detection > Background	Median	Range of Detection Results	Range of Non-Detect Results	95th Percentile of Background
Manganese	P217	UNF	mg/L	4/4	1/4	.479	.00590 - .953		0.904
Mercury	P218	UNF	mg/L	0/5	0/5			.000200 - .000200	ND
Nickel	P220	UNF	mg/L	0/4	0/4			.0190 - .0200	0.0514
Potassium	P223	UNF	mg/L	3/4	3/4	6.94	3.51 - 182	.350 - .350	1.96
Selenium	P225	UNF	mg/L	2/4	2/4	.00105	.00160 - .00160	.00100 - .00002	0.000750
Silver	P227	UNF	mg/L	0/4	0/4			.00300 - .00700	0.0117
Sodium	P228	UNF	mg/L	3/4	1/4	7.00	13.9 - 101	.182 - .182	47.1
Thallium	P230	UNF	mg/L	0/4	0/4			.00120 - .00200	ND
Vanadium	P233	UNF	mg/L	1/4	0/4	.00150	.00710 - .00710	.00300 - .00400	0.0117
Zinc	P236	UNF	mg/L	3/4	0/4	.00595	.00530 - .0148	.00600 - .00600	0.0210
Ammonia	P705	UNF	mg/L	3/8	0/8	.235	.209 - 3.10	.070 - .100	4.20
Chloride	P715	UNF	mg/L	8/8	0/8	23.0	13.3 - 54.0		73.0
Fluoride	P721	UNF	mg/L	7/8	0/8	.155	.110 - .200	.100 - .100	0.890
Nitrate	P729	UNF	mg/L	5/8	0/8	.400	.139 - 1.44	.0290 - .100	11.4
Sulfate	P744	UNF	mg/L	6/8	0/8	110	25.0 - 111	2.00 - 2.00	197

[1]Based on Table E.2-19 in Appendix E
[2]Frequency of detection is defined as (number of detectable results)/(number of wells tested)

TABLE 4-63

POTENTIALLY AFFECTED AREA RADIONUCLIDE CONCENTRATIONS IN SOIL, AGRICULTURAL CROP, AND GARDEN PRODUCE SAMPLES FROM REFERENCE LOCATIONS AND ON-SITE/OFF-PROPERTY LOCATIONS

			Contaminant Type and Concentration (pCi/g)				
Sample Location	Sample Type	No. of Samples	Cesium-137	Strontium-90	Uranium-234	Uranium-235/236	Uranium-238
Indiana Control	Soil	4	0.3	1.2	2.4	< 0.6	3.2
	Alfalfa	1	< 0.5	0.5	2.4	0.6	1.1
	Field Corn	2	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Green Peppers	2	< 0.3	< 0.5	< 0.6	< 0.6	< 0.6
	Okra	1	< 0.4	< 0.5	< 0.6	< 0.6	< 0.6
	Potato Flesh	2	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Potato Peels	2	< 0.3	< 0.5	2.7	< 1.4	< 1.4
	Soybean Shells	1	< 0.2	0.6	0.7	< 0.6	< 0.6
	Soybean	2	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Tomato	3	< 0.4	< 0.5	2.5	< 0.6	0.8
Sampling Site (G6) Southeast of the FEMP	Soil	2	0.3	1.3	3.7	< 0.6	2.9
	Cantaloupe	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Corn	2	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Pumpkin	2	< 0.4	< 0.5	1.5	< 0.6	0.8
	Soybean	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Tomato	1	< 0.5	< 0.5	1.9	< 0.6	0.7

TABLE 4-63 (Continued)

Sample Location	Sample Type	No. of Samples	Contaminant Type and Concentration (pCi/g)				
			Cesium-137	Strontium-90	Uranium-234	Uranium-235/236	Uranium-238
Sampling Site (G1) Northwest of the FEMP	Soil	1	0.2	< 0.5	1.7	< 0.6	1.6
	Cucumber	1	1.1	< 0.6	3	< 0.6	1.8
	Green Pepper	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Okra	1	< 0.3	< 0.5	< 0.6	< 0.6	< 0.6
	Squash	2	< 0.4	< 0.5	< 0.6	< 0.6	< 0.6
	Tomato	1	< 0.3	< 0.5	< 0.6	< 0.6	< 0.6
Sampling Sites (G2, G3, G4, G5) Northeast of the FEMP	Garden Soil	3	0.3	0.8	1.3	< 0.6	1.5
	Soil	1	0.2	< 0.5	< 0.5	< 0.6	2.1
	Field Corn Soil	1	< 0.2	2.7	1.3	< 0.6	1.7
	Alfalfa	1	< 0.4	< 0.5	1.2	< 0.6	< 0.6
	Cabbage	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Corn	2	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Green Peppers	2	< 0.2	< 0.5	1	< 0.6	< 0.6
	Okra	2	< 0.5	< 0.5	1.4	< 0.6	0.8
	Potato Flesh	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Potato Peels	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Sweet Potato	1	< 0.2	< 0.5			
	Tomato	3	< 0.3	< 0.5	0.8	< 0.6	< 0.6

TABLE 4-64

POTENTIALLY AFFECTED AREA RADIONUCLIDE CONCENTRATIONS IN VEGETATION AND SOIL SAMPLES COLLECTED ON PROPERTY

			Contaminant Type and Concentration (pCi/g)				
Sample Location	Sample Type	No. of Samples	Cesium-137	Strontium-90	Uranium-234	Uranium-235/236	Uranium-238
Study Area A	Forb Leaves	2	0.4	< 0.5	2.50	< 0.6	2.40
	Forb Roots	2	< 0.3	< 0.70	1.90	< 0.6	1.00
	Grass Leaves	2	< 0.3	< 0.70	3.20	< 0.6	0.90
	Grass Roots	2	< 0.5	< 0.5	2.20	< 0.6	2.00
	Cattail Leaves	1	< 0.4	< 1	1.4	< 0.6	1.9
	Cattail Roots	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
Study Area B	Cattail Leaves	1	< 0.6	< 0.9	< 0.6	< 0.6	0.80
	Cattail Roots	1	< 0.2		< 0.6	< 0.6	< 0.6
	Forb Leaves	3	< 0.2	0.70	2.50	< 0.6	1.40
	Forb Roots	3	0.30	0.70	3.40	0.90	5.00
	Grass Leaves	3	0.40	< 1.5	4.00	< 0.6	1.70
	Grass Roots	3	0.80	< 0.8	10.70	< 0.6	6.60
	Sedge Leaves	1	< 0.2	< 0.7	< 0.6	< 0.6	< 0.6
	Sedge Roots	1	< 0.2		< 0.6	< 0.6	< 0.6
Study Area C	Forb Leaves	2	< 0.2	0.9	3	< 0.6	1.7
	Forb Roots	2	0.8	< 0.5	13.7	0.9	14.3
	Grass Leaves	2	< 0.3	< 0.6	12.1	< 0.6	10.8
	Grass Roots	2	1.4	< 0.5	12.9	1.2	13.7

TABLE 4-64 (Continued)

Sample Location	Sample Type	No. of Samples	Contaminant Type and Concentration (pCi/g)				
			Cesium-137	Strontium-90	Uranium-234	Uranium-235/236	Uranium-238
Study Area D	Cattail Roots	1	< 0.2	< 0.5	1.6	< 0.6	2.2
	Cattail Stems	1	< 0.2	< 1.0	< 0.6	< 0.6	< 0.6
	Forbs	1	< 0.3	< 0.6	< 0.6	< 0.6	< 0.6
	Forb Roots	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Grass Leaves	3	< 0.3	< 0.8	< 0.6	< 0.6	< 0.6
	Grass Roots	4	0.5	< 0.5	2.2	< 0.6	2.1
	Grass Stems	1	< 0.4	< 0.6	1.3	< 0.6	1.6
Study Area E	Grass Leaves	1	< 0.2	< 0.8	< 0.6	< 0.6	< 0.6
	Grass Roots	1	0.6	< 0.4	< 0.6	< 0.6	< 0.6
Study Area F	Soil	1	< 0.2	0.6	3.9	< 0.6	12.40
	Onion Bulbs	1	0.30	< 0.5	< 0.6	< 0.6	< 0.6
	Onion Leaves	1	< 0.7	< 1.9	1.00	< 0.6	0.7
	Cattail leaves	2	< 0.3	< 0.5	0.7	< 0.6	0.7
	Cattail Roots	1	< 0.3	< 0.5	2.6	< 0.6	3.8
	Forb Leaves	3	< 0.4	< 0.5	0.9	< 0.6	0.7
	Forb Roots	3	< 0.3	< 0.6	2.3	< 0.6	1.7
	Grass Leaves	6	< 0.4	< 1.5	2.3	< 0.6	3.2
	Grass Roots	6	0.60	< 0.5	7.70	1.30	22.30
	Moss	1	< 0.2	< 0.5	4.8	0.8	6.3

TABLE 4-64 (Continued)

Sample Location	Sample Type	No. of Samples	Contaminant Type and Concentration (pCi/g)				
			Cesium-137	Strontium-90	Uranium-234	Uranium-235/236	Uranium-238
Study Area G	Roots	1		< 0.5	< 0.6	< 0.6	< 0.6
	Stems/Leaves	1		< 0.5	< 0.6	< 0.6	< 0.6
	Forb leaves	1	< 0.3	< 0.6	3.1	< 0.6	3.3
	Forb Roots	3	< 0.8	< 0.5	10.4	1.2	12
	Grass Roots	1	1	< 0.5	8.4	0.3	9.5
	Grass Shoots and Stems	1	< 0.8	0.6	0.8	< 0.6	< 0.6
	Moss	1	0.6		< 0.6	< 0.6	< 0.6

TABLE 4-65

POTENTIALLY AFFECTED AREA RADIONUCLIDE CONCENTRATIONS IN FISH, BENTHIC, AND MAMMAL SAMPLES COLLECTED ON PROPERTY

			Contaminant Type and Concentration (pCi/g)				
Sample Location	Sample Type	No. of Samples	Cesium-137	Strontium-90	Uranium-234	Uranium-235/236	Uranium-238
Study Area A	Bluegill	1	< 0.2	< 0.5	0.7	< 0.6	1.00
	Creek Chub	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Sucker	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Small Mammal* Carcass	1	< 0.2	< 0.1	< 0.6	< 0.6	< 0.6
	Small Mammal* Organs	1	< 1.1	< 2.5	8.3	1.1	9.6
Study Area B	Opossum Muscle	1	< 0.2	< 0.5	< 0.2	< 0.2	< 0.2
	Opossum Organs	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
Study Area E	Rabbit Carcass	1		< 0.5	< 0.6	< 0.6	< 0.6
	Small Mammal*	1			< 0.6	< 0.6	< 0.6
Study Area F	Benthic Macroinvertebrate	2	< 4.00	< 3.7	3.60	< 1.5	2.80
	Crayfish	1	< 1.94	< 1.2	3.50	< 0.6	0.90
	Fish	1	< 0.42	< 0.5	< 0.6	< 0.6	< 0.6
	Bluegill	1	< 0.19	< 0.5	< 0.6	< 0.6	< 0.6
	Creek Chub	2	< 1.9	< 0.5	1.00	< 0.6	0.70
	Sucker	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Opossum Muscle	1		< 0.5	< 0.6	< 0.6	< 0.6

* Composite Samples

TABLE 4-66

POTENTIALLY AFFECTED AREA RADIONUCLIDE CONCENTRATIONS IN ONSITE FISH, BENTHIC, AND MAMMAL SAMPLES COLLECTED OFF PROPERTY

Sample Location	Sample Type	No. of Samples	Contaminant Type and Concentration (pCi/g)				
			Cesium-137	Strontium-90	Uranium-234	Uranium-235/236	Uranium-238
Sampling Sites Northeast of the FEMP (Great Miami River)	Channel Catfish	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Shad	2	< 0.3	< 0.5	< 0.6	< 0.6	< 0.6
	Channel Catfish	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Fish Composite	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Channel Catfish Fillet	2	0.35	< 0.5	< 0.6	< 0.6	< 0.6
Sampling Sites Southeast of the FEMP (Great Miami River)	Benthic Macroinvertebrates	1	< 0.64	< 1.7	1.80	0.40	< 1.80
	Bass	1	< 0.28				
	Drum	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Shad	3	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Fish Composite	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
Sampling Sites Southwest of the FEMP (Great Miami River)	Benthic Macroinvertebrate	1	< 2.1	< 4.7			
	Crayfish	1	< 2.36	< 1.8	1.5	< 0.6	< 0.6
	Bluegill	1	< 1.24		2.4	0.55	1.3
	Creek Chub	1	< 0.24	< 0.5	< 0.6	< 0.6	< 0.6
	Green Sunfish	1	< 0.3	< 0.5	< 0.6	< 0.6	< 0.6

TABLE 4-66 (Continued)

Sample Location	Sample Type	No. of Samples	Contaminant Type and Concentration (pCi/g)				
			Cesium-137	Strontium-90	Uranium-234	Uranium-235/236	Uranium-238
	L. Sunfish	1	< 0.3	< 0.5	< 0.6	< 0.6	< 0.6
	Shad	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Sucker	1	< 0.42	< 0.5	0.6	< 0.6	< 0.6
	Chopped Meat	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6
	Liver	1	< 0.2	< 0.5	< 0.6	< 0.6	< 0.6

TABLE 4-67

POTENTIALLY AFFECTED AREA CONTAMINANT CONCENTRATIONS IN VEGETATION, FISH, AND MAMMAL SAMPLES COLLECTED ON PROPERTY

Sample Location	Sample Type	No. of Samples	Inorganic Contaminants (mg/kg)									
			Aluminum	Arsenic	Barium	Cadmium	Fluoride	Lead	Silver	Sulfate	Vanadium	Zinc
Study Area A	Grass Leaves	1	4950	12	9	<0.5	330	< 3	< 0.5	2400	1	13
	Grass Roots	1	4940	8	36.1	0.7	620	3	< 0.5	1300	10	35.7
Study Area C	Grass Leaves	2	52	9	2.8	< 0.5	340	< 3	<0.5	1600	< 1	9.5
	Grass Roots	2	10600	10	59.8	0.9	58	12	< 0.5	240	20	115
Study Area E	Grass Leaves	1	2840	7	12.5	< 0.5	720	< 3	< 0.5	1100	< 1	12.3
	Rabbit Carcass	1	4	8	0.2	0.5	540	3	0.5	160	1	10.9
	Small Mammal	1	42	13	1	0.5	710	3	0.5	1700	1	38.3
Study Area F	Grass Leaves	1	25	13	3.2	< 0.5	210	< 3	< 0.5	320	< 1	4.4
	Grass Roots	1		< 3	17.5	< 0.5	< 50	< 3	< 0.5	830	3	8
	Minnow Composite	1	28	6	1	4.2	1400	< 3	<0.5	830	< 1	33.2
Study Area G	Grass Leaves	1	2840	7	12.5	< 0.5	720	3	< 0.5	1100	< 1	12.3
	Grass Roots	1	1680	11	24.9	< 0.5	15	4	< 0.5	67	4	20.6

TABLE 4-67 (Continued)

Sample Location	Sample Type	No. of Samples	Organic Contaminants (μg/kg)											
			Butyl benzyl-phthalate	N-Nitroso-di-n-propylamine	Penta-chloro-phenol	Phenol	1,2,4-Trichloro-benzene	1,4-Di-chloro-benzene	2-Chloro-phenol	2,4-Di-nitro-toluene	4-Chloro-3-methyl-phenol	4-Nitro-phenol	Acenaph-thene	Pyrene
Study Area A	Grass Leaves	1												
	Grass Roots	1												
Study Area C	Grass Leaves	2	1800											
	Grass Roots	2	1300	96	112	92	82	86	101	52	105	106	94	104
Study Area E	Grass Leaves	1												
	Rabbit Carcass	1												
	Small Mammal	1												
Study Area F	Grass Leaves	1	2000											
	Grass Roots	1	1000											
	Minnow Composite	1												

5696

TABLE 4-68

HAZARDOUS WASTE MANAGEMENT UNIT - SURFACE AND SUBSURFACE SOIL CONTAMINATION RELATIONSHIPS

		Contaminants Present in Soils					
		RCRA Metals		VOCs		SVOCs	
HWMU/Number	Basis for Listing	Surface	Subsurface	Surface	Subsurface	Surface	Subsurface
Fire Training Area	Spent solvents (F001-F003, F005)	Yes	Yes	Yes	Yes	Yes	Yes
NAR System Components (3B/3D)	Corrosive residues (D002, D005, D007)	Yes	Yes	Yes	Yes	No	Yes
Tank Farm Sump (19E)	Corrosive residues (D002, D005, D007)	No	Yes	Yes	Yes	Yes	Yes
Wheelabrator (158)	Storage of RCRA Wastes (D006)	Yes	Yes	Yes	Yes	Yes	Yes
Box Furnace (8A)	Spent solvents (D005, D007, D008, D011, F001/F002)	Yes	No	No	No	Yes	No
Oxidation Furnace (8A)	Spent solvents, TCLP inorganics (D005, D008, F001/F002)	Yes	No	No	No	Yes	No
Primary Calciner (8A)	Spent solvents (F001/F002)	Yes	No	No	No	Yes	No
Plant 8 East Drum Storage Pad (74C)	Storage of RCRA wastes	Yes	No	No	*	No	*
Plant 8 West Drum Storage Pad (74D)	Storage of RCRA wastes	Yes	No	*	*	Yes	*
Abandoned Sump West of Pilot Plant (13E)	TCLP inorganics (D008, F003, F001/F002)	Yes	Yes	Yes	Yes	Yes	Yes
Plant 1 Storage Building (67)	Storage of RCRA wastes	Yes	*	Yes	*	No	*
Trane Incinerator (39A)	Spent solvents, TCLP inorganics (D008, F001/F002)	No	Yes	No	Yes	Yes	Yes
BioSurge Lagoon (BSL)	Spent solvents	*	*	*	*	*	*
Sludge Drying Beds (25F)	Spent solvents (F001/F002)	Yes	Yes	No	No	Yes	No

TABLE 4-68 (Continued)

		Contaminants Present in Soils					
		RCRA Metals		VOCs		SVOCs	
HWMU/Number	Basis for Listing	Surface	Subsurface	Surface	Subsurface	Surface	Subsurface
UNH Tanks NFS Storage Area (2E)	Corrosive residues (D002, D005, D007)	Yes	No	No	*		*
UNH Tanks North of Plant 2 (2A)	Corrosive residues (D002, D005, D007)	Yes	No	*	*	*	*
UNH Tanks Southeast of Plant 2 (39)	Corrosive residues (D002, D005, D007)	Yes	Yes	Yes	Yes	Yes	Yes
UNH Tanks Digestion Area (43)	Corrosive residues (D002, D005, D007)	Yes	No	Yes	Yes	Yes	Yes
UNH Tanks Raffinate Building (3E)	Corrosive residues (D002, D005, D007)	No	Yes	Yes	Yes	*	*

* Not sampled in the immediate vicinity of the unit.

5696

TABLE 4-69

HAZARDOUS WASTE MANAGEMENT UNIT - PERCHED GROUNDWATER PLUME RELATIONSHIPS

HWMU	Basis for Listing	Plume Area	Contaminants Present In Plume: RCRA Metals	Total VOCs	Total SVOCs	Comments
Fire Training Area	Spent solvents (F001-F003, F005)	Area VI	Yes	Yes	Yes	Sole contributor to Area VI Plume
NAR System Components	Corrosive residues (D002, D005, D007)	Area I	Yes	Yes	Yes	Multiple (HWMU and non-HWMU) sources also present
Tank Farm Sump	Corrosive residues (D002, D005, D007)	Area I	Yes	Yes	Yes	Multiple (HWMU and non-HWMU) sources also present
Wheelabrator	Storage of RCRA Wastes (D006)	Area I	Yes	Yes	Yes	Multiple (HWMU and non-HWMU) sources also present
Box Furnace	Spent solvents (D005, D007, D008, D011, F001/F002)	Area I	Yes	Yes	Yes	Multiple (HWMU and non-HWMU) sources also present
Oxidation Furnace	Spent solvents, TCLP inorganics (D005, D008, F001/F002)	Area I	Yes	Yes	Yes	Multiple (HWMU and non-HWMU) sources also present
Primary Calciner	Spent solvents (F001/F002)	Area I	Yes	Yes	Yes	Multiple (HWMU and non-HWMU) sources also present
Plant 8 East Drum Storage Pad	Storage of RCRA wastes	Area I	Yes	Yes	Yes	Multiple (HWMU and non-HWMU) sources also present
Plant 8 West Drum Storage Pad	Storage of RCRA wastes	Area I	Yes	Yes	Yes	Multiple (HWMU and non-HWMU) sources also present
Abandoned Sump West of Pilot Plant	TCLP inorganics (D008, F003, F001/F002)	Area I	Yes	Yes	Yes	Multiple (HWMU and non-HWMU) sources also present
Plant 1 Storage Building	Storage of RCRA wastes	Area I	Yes	Yes	Yes	Multiple (HWMU and non-HWMU) sources also present
Waste Pit 4	TCLP inorganics (D005)	Area V	Yes	Yes	Yes	Multiple (HWMU and non-HWMU) sources also present
Trane Incinerator	Spent solvents, TCLP inorganics (D008, F001/F002)	Area I	Yes	Yes	Yes	Multiple (HWMU and non-HWMU) sources also present
BioSurge Lagoon	Spent solvents (F001/F002)	-	-	-	-	Unit located on fringe of Area V plume; appears to be a noncontributing source
Sludge Drying Beds	Spent solvents (F001/F002)	Area II	No	Yes	Yes	Multiple non-HWMU sources also present at sewage treatment/incinerator complex

TABLE 4-69 (Continued)

HWMU	Basis for Listing	Plume Area	Contaminants Present In Plume: RCRA Metals	Total VOCs	Total SVOCs	Comm[illegible]
Waste Pit 5	Spent solvents (F001/F002)	Area V	Yes	Yes	Yes	Multiple (HWMU [illegible]d non-HWMU) source[illegible] [illegible]so present
UNH Tanks NFS Storage Area	Corrosive residues (D002, D005, D007)	Area I	Yes	Yes	Yes	Multiple (HWM[illegible] and non-HWMU) sourc[illegible] also present
UNH Tanks North of Plant 2	Corrosive residues (D002, D005, D007)	Area I	Yes	Yes	Yes	Multiple (HWMU and non-HWMU) sources also present
UNH Tanks Southeast of Plant 2	Corrosive residues (D002, D005, D007)	Area I	Yes	Yes	Yes	Multiple (HWMU and non-HWMU) sources also present
UNH Tanks Digestion Area	Corrosive residues (D002, D005, D007)	Area I	Yes	Yes	Yes	Multiple (HWMU and non-HWMU) sources also present
UNH Tanks Raffinate Building	Corrosive residues (D002, D005, D007)	Area I	Yes	Yes	Yes	Multiple (HWMU and non-HWMU) sources also present
Experimental Treatment Facility	Spent solvents (F001/F002)	Area V	Yes	Yes	Yes	Multiple (HWMU and non-HWMU) sources also present

X = Data available for June submittal.

RADIONUCLIDE	ELEMENT NAME	HALF-LIFE	PRINCIPAL RADIATION EMITTED
U-238	URANIUM	4.47×10^9 YEARS	α
↓			
Th-234	THORIUM	24.1 DAYS	$\beta\ \gamma$
↓			
Pa-234m	PROTACTINIUM	1.17 MIN.	$\beta\ \gamma$
99.87% | 0.13%			
Pa-234	PROTACTINIUM	6.7 HOURS	$\beta\ \gamma$
↓			
U-234	URANIUM	2.45×10^5 YEARS	$\alpha\ \gamma$
↓			
Th-230	THORIUM	7.7×10^4 YEARS	$\alpha\ \gamma$
↓			
Ra-226	RADIUM	1600 YEARS	$\alpha\ \gamma$
↓			
Rn-222	RADON	3.82 DAYS	$\alpha\ \gamma$
↓			
Po-218	POLONIUM	3.05 MIN.	$\alpha\ \beta$
↓			
Pb-214	LEAD	26.8 MIN.	$\beta\ \gamma$
↓			
Bi-214	BISMUTH	19.9 MIN.	$\alpha\ \beta\ \gamma$
↓			
Po-214	POLONIUM	63.7 MICROSEC.	$\alpha\ \gamma$
↓			
Pb-210	LEAD	22.3 YEARS	$\alpha\ \beta\ \gamma$
↓			
Bi-210	BISMUTH	5.01 DAYS	$\alpha\ \beta$
↓			
Po-210	POLONIUM	138 DAYS	$\alpha\ \gamma$
↓			
Pb-206	LEAD	STABLE	—

LEGEND:

α = ALPHA
β = BETA
γ = GAMMA

NOTE:

SOME MINOR DECAY BRANCHES HAVE BEEN ELIMINATED FOR SIMPLICITY.

DRAFT

ACAD: W:/DATA/CADD/4P94/CHAIN.DWG 6/15/94 FIG41PLOT,FIG41DWG MB

FIGURE 4-1. NATURALLY OCCURRING RADIOACTIVE DECAY CHAIN URANIUM SERIES

RADIONUCLIDE	ELEMENT NAME	HALF-LIFE	PRINCIPAL RADIATION EMITTED
Th-232	THORIUM	1.41×10^{10} YEARS	$\alpha\ \gamma$
↓			
Ra-228	RADIUM	5.75 YEARS	β
↓			
Ac-228	ACTINIUM	6.13 HOURS	$\beta\ \gamma$
↓			
Th-228	THORIUM	1.91 YEARS	$\alpha\ \gamma$
↓			
Ra-224	RADIUM	3.62 DAYS	$\alpha\ \gamma$
↓			
Rn-220	RADON	55.61 SEC.	α
↓			
Po-216	POLONIUM	0.15 SEC.	α
↓			
Pb-212	LEAD	10.6 HOURS	$\beta\ \gamma$
↓			
Bi-212	BISMUTH	60.55 MIN.	$\alpha\ \beta\ \gamma$
35.9% / 64.1%			
Po-212	POLONIUM	0.30 MICROSEC.	α
Tl-208	THALLIUM	3.05 MIN.	$\beta\ \gamma$
↓			
Pb-208	LEAD	STABLE	—

LEGEND:

α = ALPHA
β = BETA
γ = GAMMA

NOTE:

SOME MINOR DECAY BRANCHES HAVE BEEN ELIMINATED FOR SIMPLICITY.

DRAFT

ACAD: W:/DATA/CADD/4P94/CHAIN.DWG 6/15/94 MB FIG42PLOT, FIG42DWG

FIGURE 4-2. NATURALLY OCCURRING RADIOACTIVE DECAY CHAIN THORIUM SERIES

RADIONUCLIDE	ELEMENT NAME	HALF-LIFE	PRINCIPAL RADIATION EMITTED
U-235	URANIUM	7.04×10^8 YEARS	$\alpha\ \gamma$
↓			
Th-231	THORIUM	25.5 HOURS	$\beta\ \gamma$
↓			
Pa-231	PROTACTINIUM	3.28×10^4 YEARS	$\alpha\ \gamma$
↓			
Ac-227	ACTINIUM	21.8 YEARS	$\alpha\ \beta\ \gamma$
1.2% / 98.8%			
Th-227	THORIUM	18.9 DAYS	$\alpha\ \gamma$
Fr-223	FRANCIUM	21.8 MIN.	$\alpha\ \gamma$
↓			
Ra-223	RADIUM	11.4 DAYS	α
↓			
Rn-219	RADON	3.96 SEC.	$\alpha\ \gamma$
↓			
Po-215	POLONIUM	7.8×10^{-4} SEC.	α
↓			
Pb-211	LEAD	36.1 MIN.	$\beta\ \gamma$
↓			
Bi-211	BISMUTH	2.13 MIN.	$\alpha\ \beta\ \gamma$
99.73% / 0.27%			
Po-211	POLONIUM	0.52 SEC.	$\alpha\ \gamma$
Tl-207	THALLIUM	4.77 MIN.	$\beta\ \gamma$
↓			
Pb-207	LEAD	STABLE	—

LEGEND:

α = ALPHA
β = BETA
γ = GAMMA

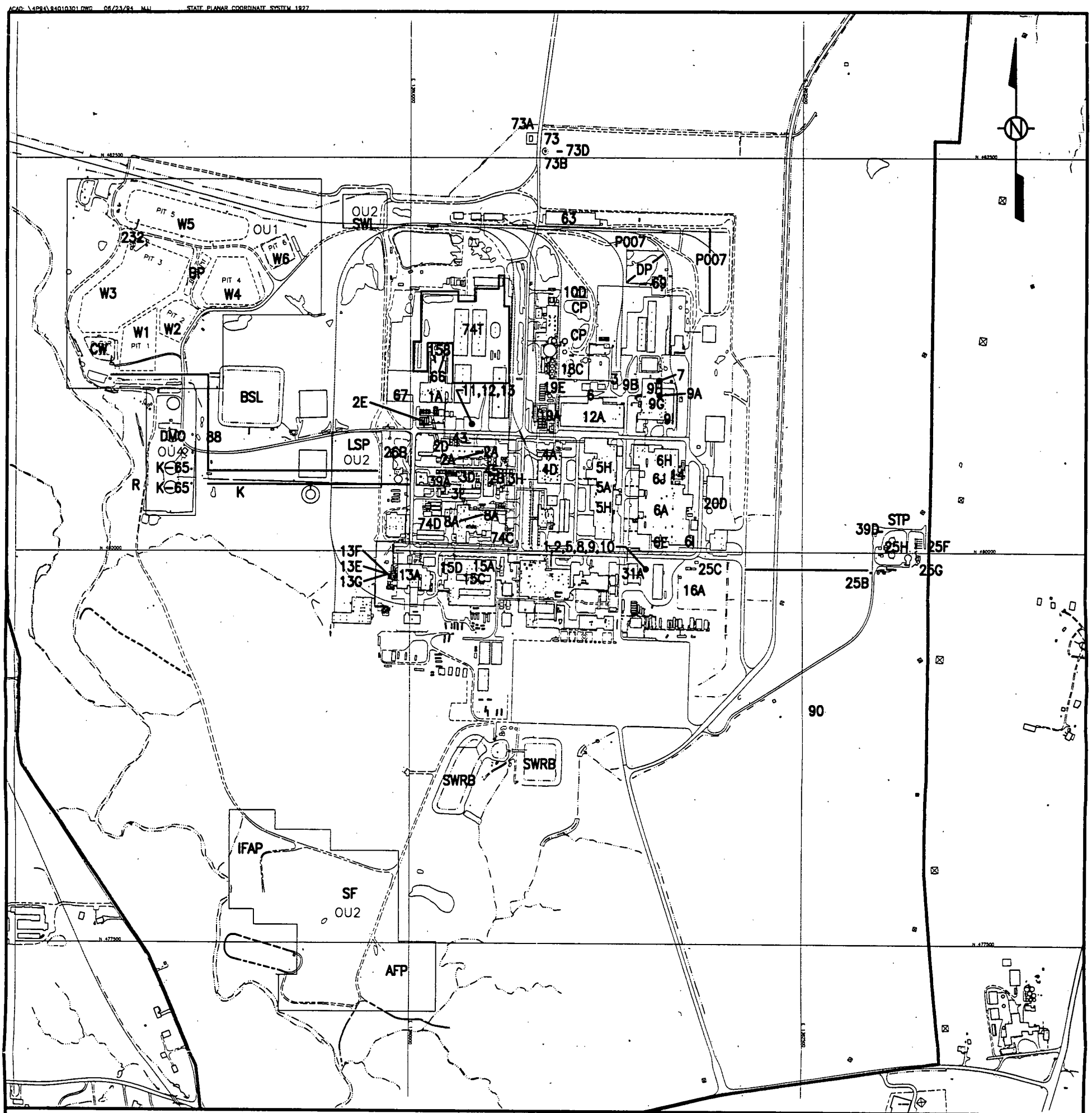
NOTE:

SOME MINOR DECAY BRANCHES HAVE BEEN ELIMINATED FOR SIMPLICITY.

DRAFT

ACAD: W:/DATA/CADD/4P94/CHAIN.DWG 6/15/94 MB FIG43PLOT, FIG43DWG

FIGURE 4-3. NATURALLY OCCURRING RADIOACTIVE DECAY CHAIN ACTINIUM SERIES



LEGEND:

UNDERGROUND STORAGE TANKS

1 TANK 1, GASOLINE, REMOVED
2 TANK 2, GASOLINE, REMOVED
3 TANK 3
4 TANK 4
5 TANK 5
6 TANK 6
7 TANK 7
8 TANK 8, GASOLINE REMOVED
9 TANK 9, DIESEL, REMOVED
10 TANK 10, GASOLINE & KEROSENE, REMOVED
11 TANK 11, GASOLINE & KEROSENE, REMOVED
12 TANK 12, GASOLINE, REMOVED
13 TANK 13, GASOLINE & KEROSENE, REMOVED
14 TANK 14, VIRGIN WATER-SOLUBLE MACHINE COOLING OIL

OPERABLE UNIT 1

W1 WASTE PIT 1
W2 WASTE PIT 2
W3 WASTE PIT 4 (HWMU 233)
W4 WASTE PIT 5 (HWMU 234)
W5 WASTE PIT 6
CW CLEARWELL
BP BURN PIT
232 EXPERIMENTAL TREATMENT FACILITY ("GREENHOUSE" HWMU 232)

OPERABLE UNIT 2

AFP ACTIVE FLYASH PILE
IFAP INACTIVE FLYASH PILE
LSP LIME SLUDGE PONDS
SF SOUTH FIELD
SWL SOLID WASTE LANDFILL

OPERABLE UNIT 3

1A PREPARATION PLANT
2A ORE REFINERY PLANT (INCLUDES HWMU 41 UNH TANKS)
2B GENERAL SUMP REFINERY SUMP CONTROL BUILDING
2D METAL DISSOLVER BUILDING
2E NFS UNH TANKS (HWMU 42)
3D NAR TOWERS
3E HOT RAFFINATE BUILDING (INCLUDES HWMU 44 UNH TANKS)
3H REFINERY SUMP
4A GREEN SALT PLANT
4D KEY SUMPS
5A METALS PRODUCTION PLANT
5H KEY SUMPS
6A METALS FABRICATION PLANT
6E SALT-OIL HEAT TRACING
6H WATER TREATMENT
6I SCRAP METAL PICKLING
6J SLUG PICKLING AREA
7A uF_6 TO uF_4 REDUCTION PLANT

OPERABLE UNIT 3, CONT.

8A SCRAP RECOVERY PLANT
INCLUDES: HWMU 85 BOX FURNANCE
HWMU 86 OXIDATION FURNANCE
HWMU 90 PRIMARY CALCINER
9A SPECIAL PRODUCTS PLANT
9B SUMP TREATMENT
9G SUMP AND ZIRNLO PROCESS AREA
9H SUMP
9I 4700 GALLON SUMP
10D OIL BURNER/GRAPHITE BURNER PAD
12A MAINTENANCE BUILDING
13A PILOT PLANT WET SIDE
13E MAIN SUMP
13F SOLVENT STORAGE
13G TANK FARM
15A LABORATORY
15C SUMP
15D FORMER DRUM STORAGE
16A MAIN ELECTRICAL SUBSTATION
18C COAL PILE RUNOFF BASIN
19A MAIN TANK FARM
19E SUMP (HWMU 203)
20D WATER TOWER SANDBLASTING RESIDUE
25B EFFLUENT LINE
25C SEWAGE LIFT STATION
25F SLUDGE DRYING BEDS (HWMU 224)
25G CLARIFIER BASINS
25H TRICKLING FILTERS

OPERABLE UNIT 3, CONT.

28B WATER TOWER SANDBLASTING RESIDUE
31A ENGINE HOUSE/GARAGE
39A TRANE INCINERATOR (HWMU 40)
39D INCINERATOR
43 UNH TANKS (HWMU 45)
63 KC-2 WAREHOUSE
66 DRUM RECONDITION BUILDING
67 PLANT 1 THORIUM WAREHOUSE (HWMU 11)
69 FORMER DECONTAMINATION BUILDING
73 FIRE TRAINING AREA (HWMU 185)
73A TRAINING BUILDING
73B BURN POND AND DRAIN PIT
73D BURN TROUGH
74C PLANT 8 EAST DRUM STORAGE PAD (HWMU 87)
74D PLANT 8 WEST DRUM STORAGE PAD (HWMU 88)
74T PLANT 1 STORAGE PAD
88 CLEARWELL LINE
158 WHEELABORATOR (HWMU 158)
BSL BIO-SURGE LAGOON (HWMU 223)
CP COAL PILE
DP DECONTAMINATION PAD
K K-65 SLURRY LINE
P007 OUTSIDE EQUIPMENT STORAGE AREAS
STP SEWAGE TREATMENT PLANT

OPERABLE UNIT 4

K-65 (INCLUDES SUBGRADE DECANT TANK)
DMO DRY METAL OXIDE SILO

OPERABLE UNIT 5

R RUBBLE PILE
90 TRAP RANGE

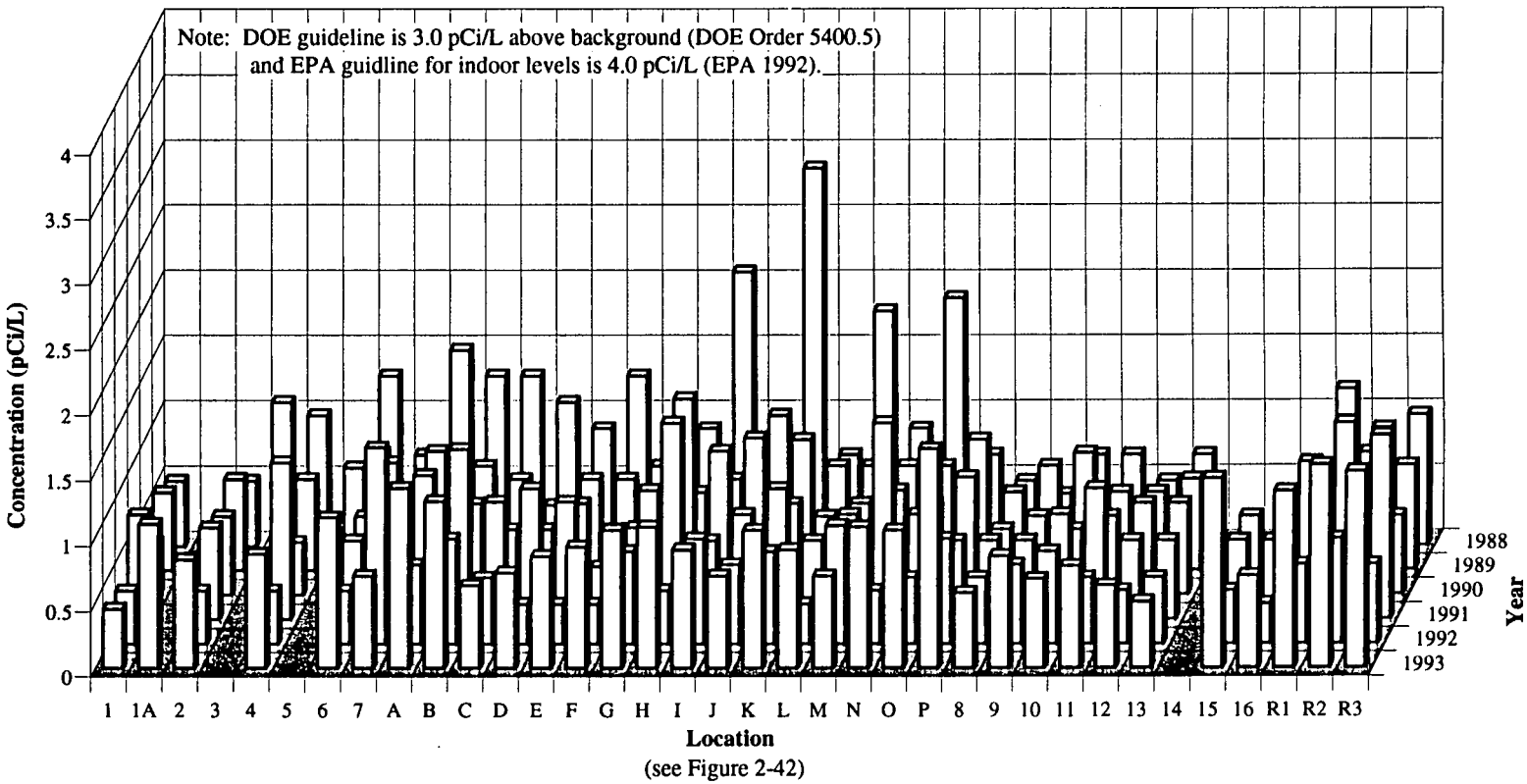
SCALE IN FEET
0 400 800

FIGURE 4-4
LOCATION OF POTENTIAL SOURCES OF CONTAMINATION
OPERABLE UNIT 5

DRAFT

000862

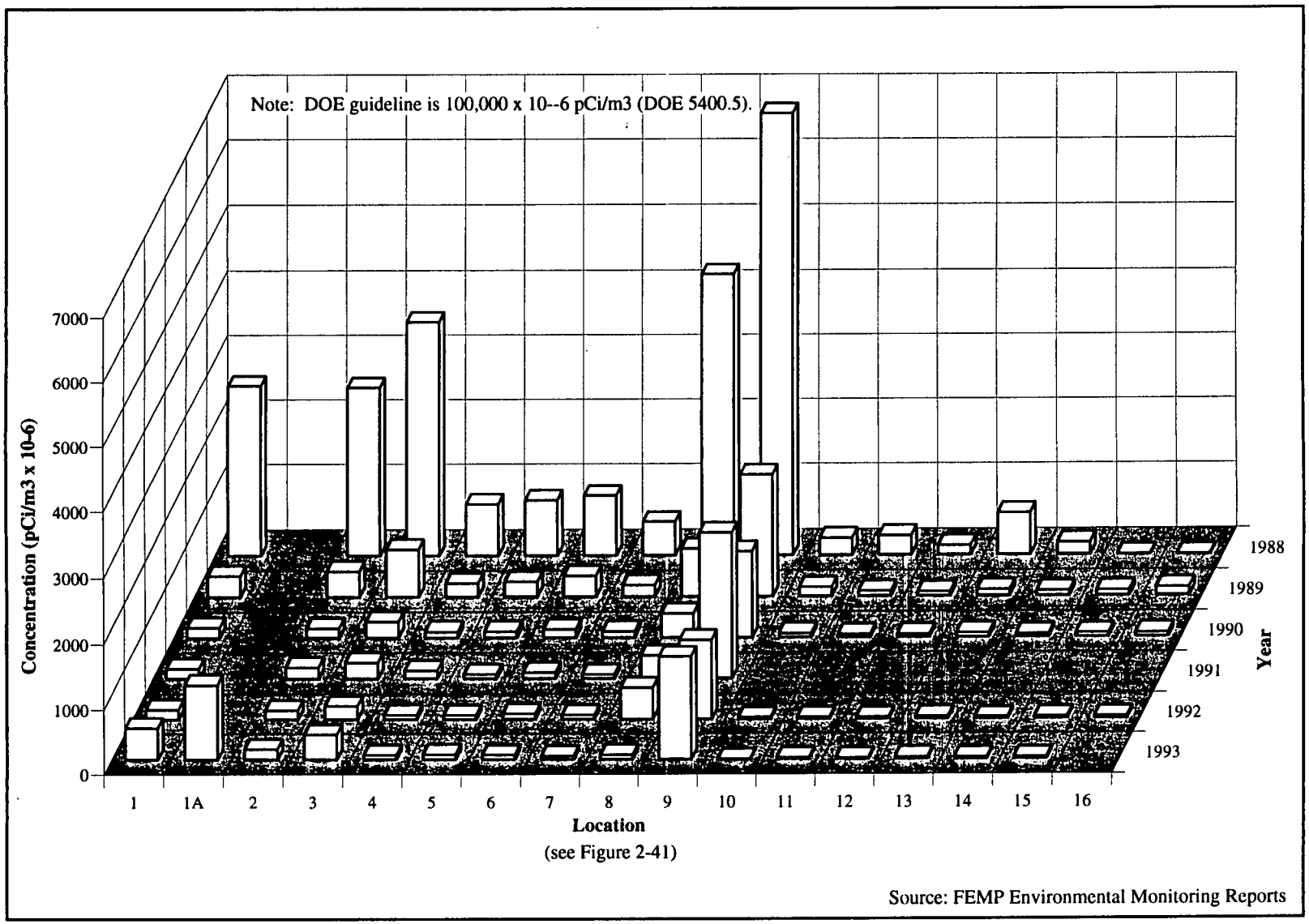
5696



Source: FEMP Environmental Monitoring Reports

FIGURE 4-5. AVERAGE AIRBORNE RADON LEVELS

000863



Source: FEMP Environmental Monitoring Reports

FIGURE 4-6. AVERAGE AIRBORNE URANIUM LEVELS

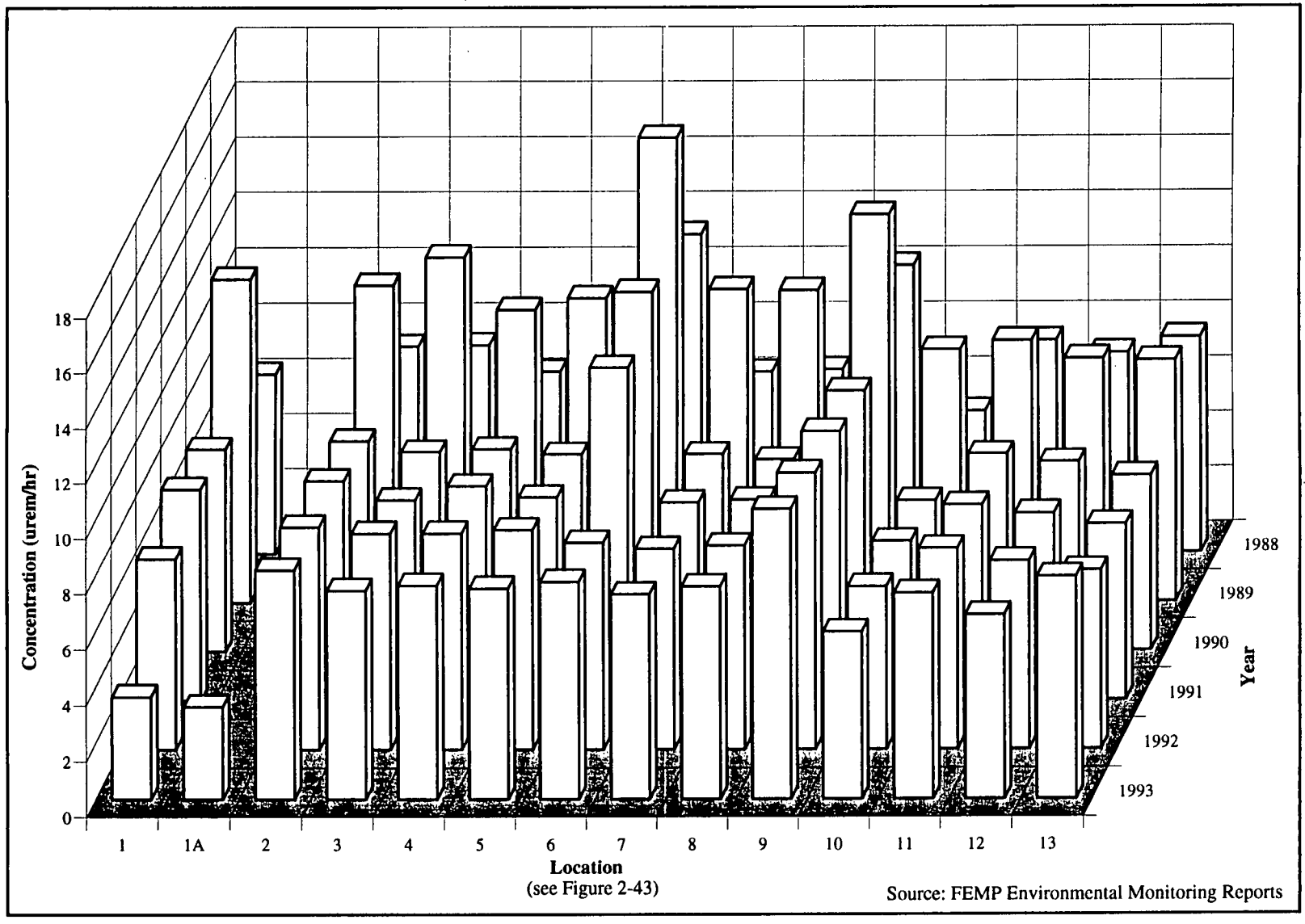


FIGURE 4-7. AVERAGE DIRECT RADIATION DOSE

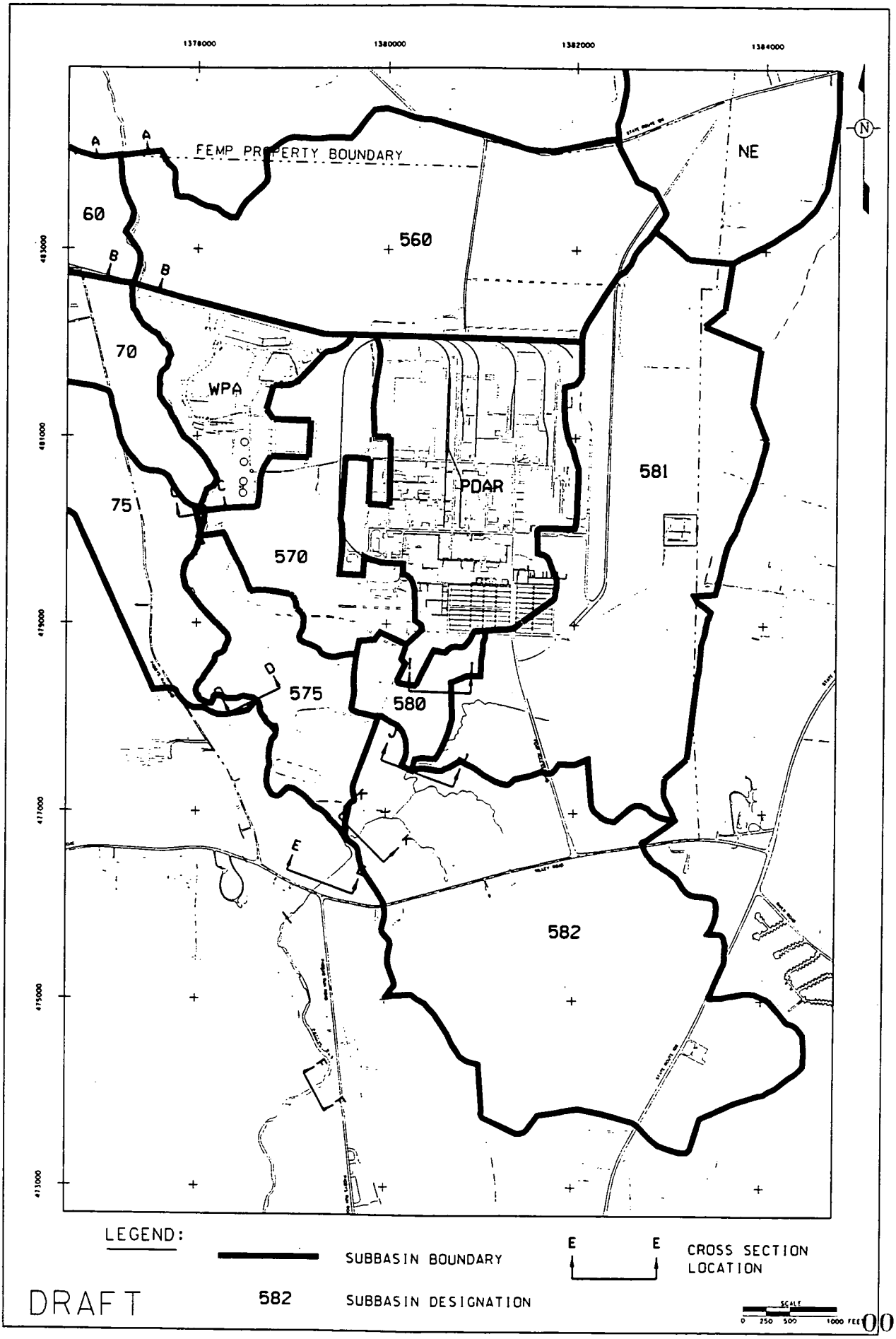
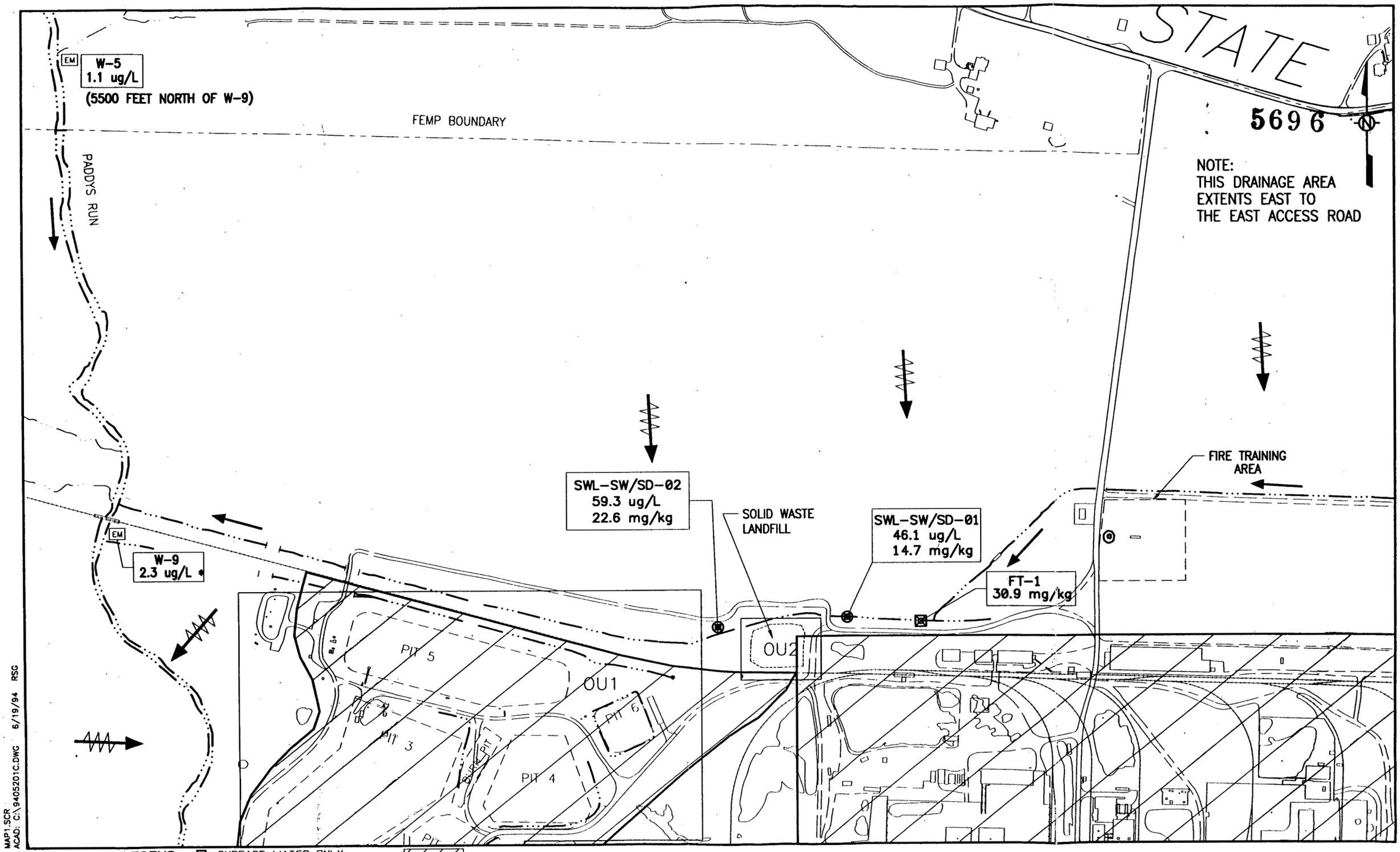


Figure 4-8: Drainage Subbasins for Surface Water Model Contamination Calculations



MAP1.SCR
ACAD: C:\9405201C.DWG 6/19/94 RSG

LEGEND

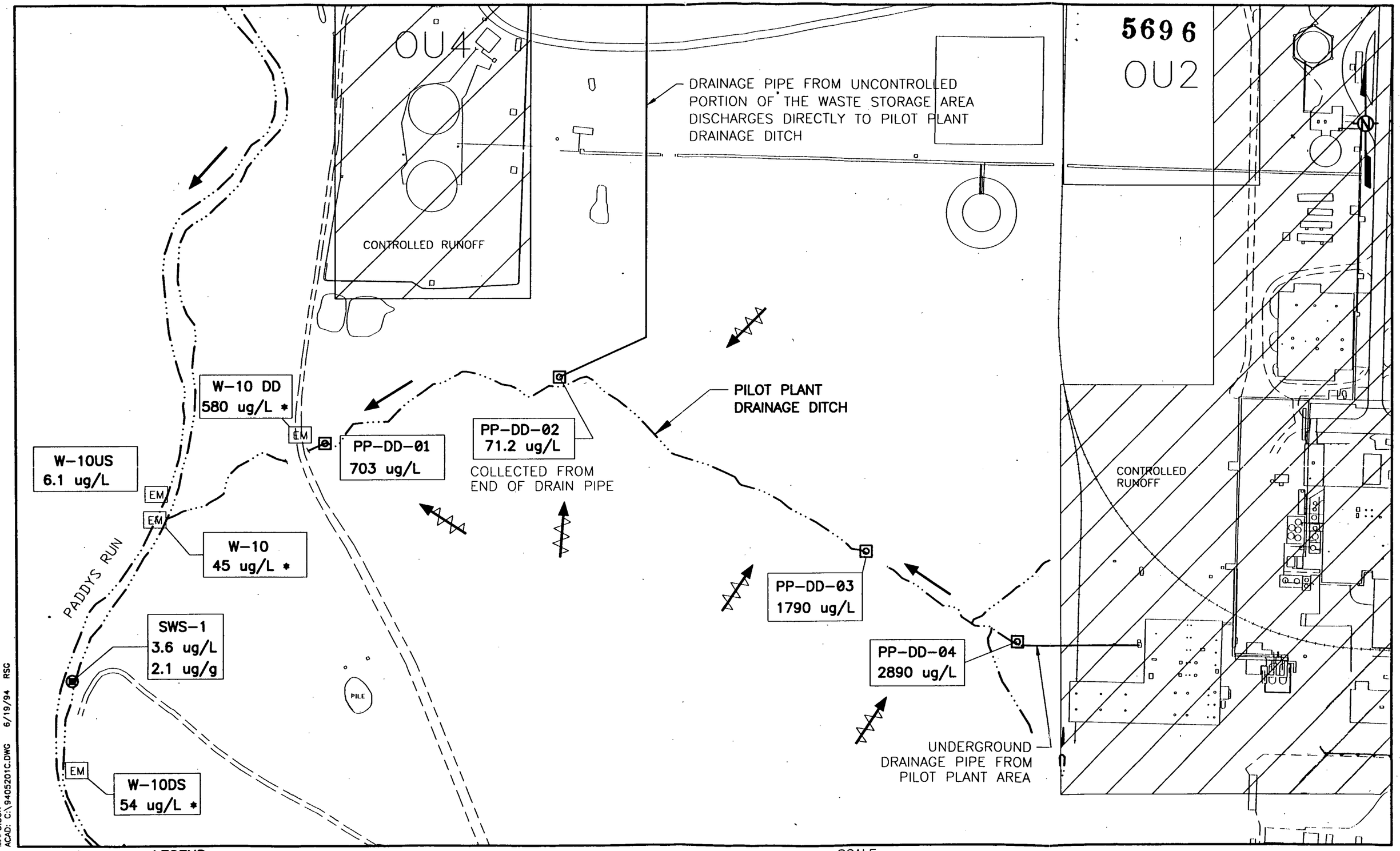
- SURFACE WATER ONLY
- SEDIMENT ONLY
- SURFACE WATER AND SEDIMENT
- DIRECTION OF SURFACE WATER
- * DATA PRESENTED IS THE UCL ON THE MEDIAN, 1993
- CONTROLLED RUNOFF AREA
- GENERAL DIRECTION OF SURFACE WATER RUNOFF
- EM ENVIRONMENTAL MONITORING LOCATION

SCALE
0 300 600 FEET

DRAFT

000867

FIGURE 4-9
NORTH DRAINAGE AREA
1993 RI/FS SURFACE WATER AND SEDIMENT TOTAL URANIUM DATA



MAP5.SCR
ACAD: C:\9405201C.DWG 6/19/94 RSC

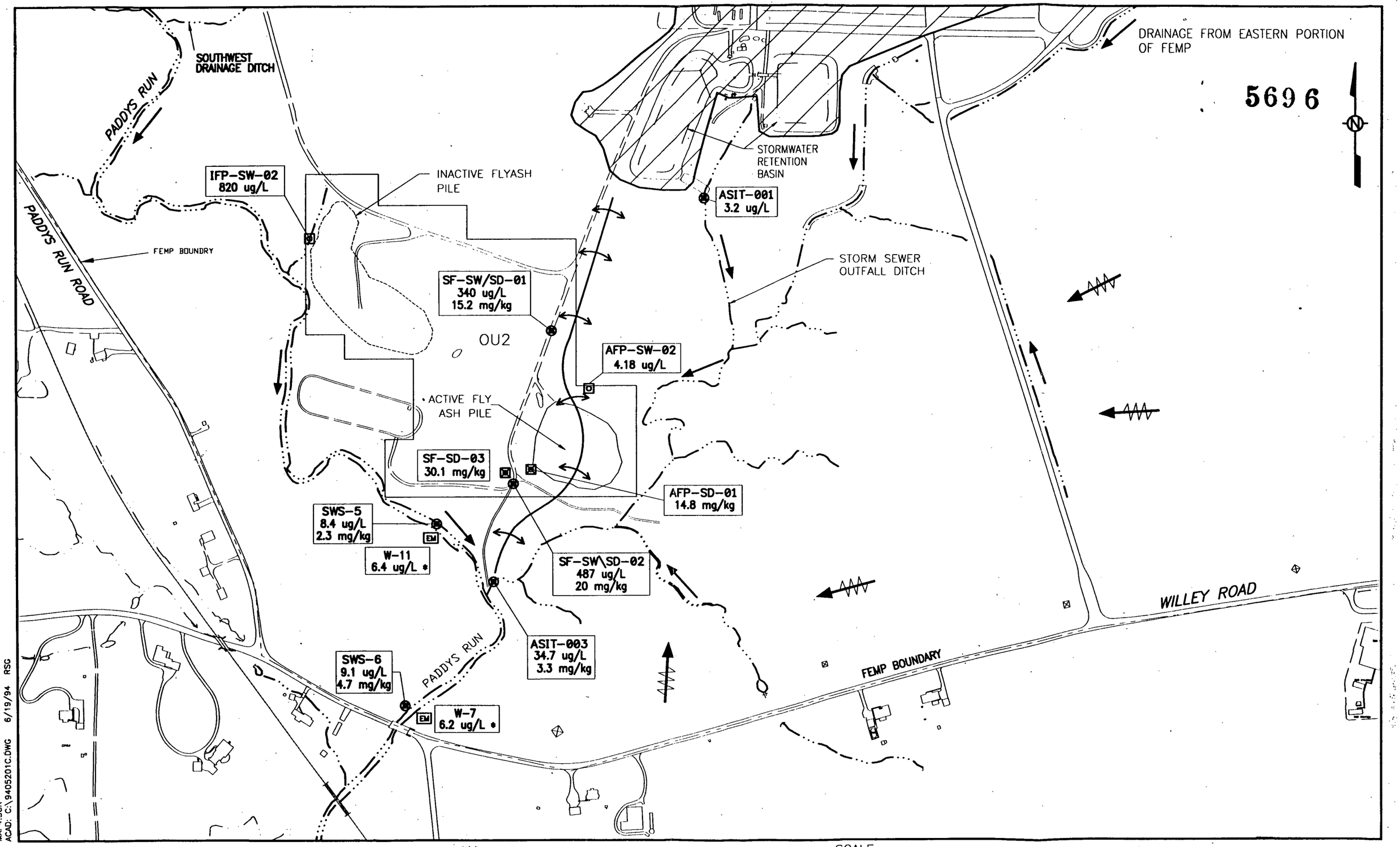
LEGEND

- SURFACE WATER ONLY
- SURFACE WATER AND SEDIMENT
- EM ENVIRONMENTAL MONITORING LOCATION
- DIRECTION OF SURFACE WATER
- GENERAL DIRECTION OF SURFACE WATER RUNOFF
- DATA PRESENTED IS THE UCL ON THE MEDIAN, 1993

SCALE 0 150 300 FEET

DRAFT

FIGURE 4-10 000868
PILOT PLANT DRAINAGE DITCH
1993 RI/FS SURFACE WATER AND SEDIMENT TOTAL URANIUM DATA



MAP4.SCR
ACAD: C:\9405201C.DWG 6/19/94 RSG

LEGEND

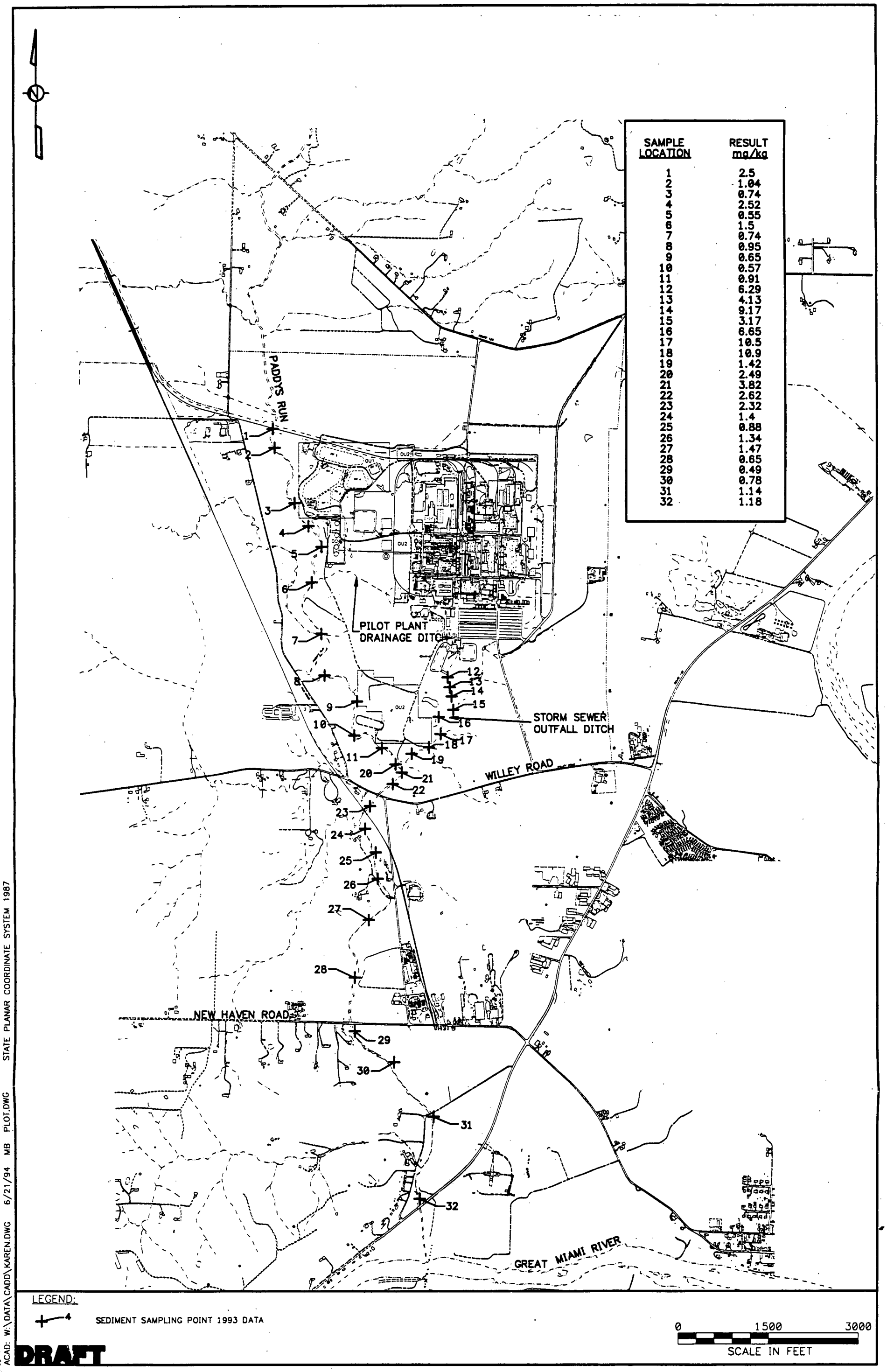
- SURFACE WATER ONLY
- SURFACE WATER AND SEDIMENT
- SEDIMENT ONLY
- EM ENVIRONMENTAL MONITORING LOCATION
- GENERAL DIRECTION OF SURFACE WATER
- DIRECTION OF SURFACE WATER
- * DATA PRESENTED IS THE UCL ON THE MEDIAN, 1993

SCALE
0 300 600 FEET

DRAFT

FIGURE 4-11
SOUTH DRAINAGE AREA
1993 RI/FS SURFACE WATER AND SEDIMENT TOTAL URANIUM DATA

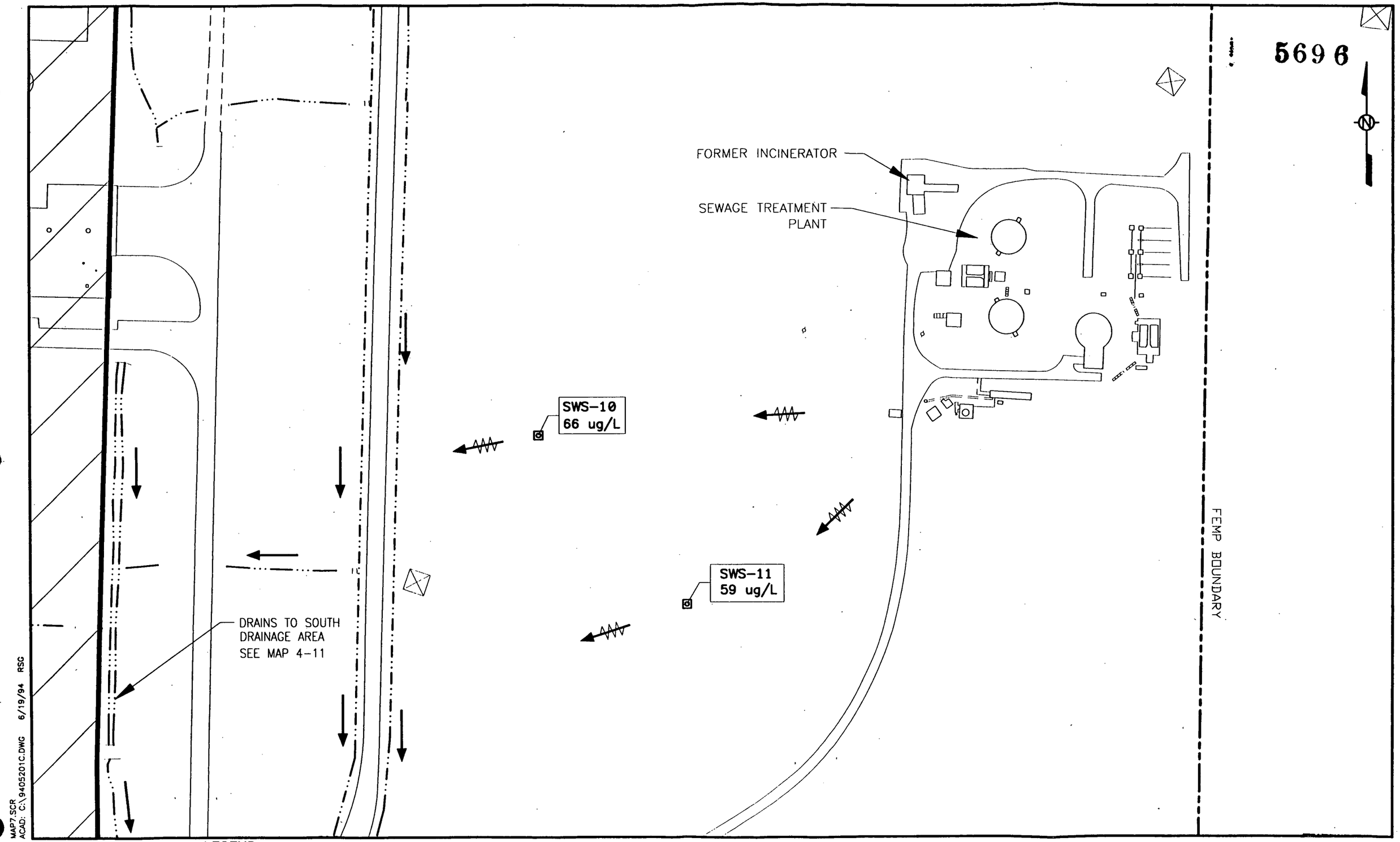
000869



SAMPLE LOCATION	RESULT mg/kg
1	2.5
2	1.04
3	0.74
4	2.52
5	0.55
6	1.5
7	0.74
8	0.95
9	0.65
10	0.57
11	0.91
12	6.29
13	4.13
14	9.17
15	3.17
16	6.65
17	10.5
18	10.9
19	1.42
20	2.49
21	3.82
22	2.62
23	2.32
24	1.4
25	0.88
26	1.34
27	1.47
28	0.65
29	0.49
30	0.78
31	1.14
32	1.18

ACAD: W:\DATA\CADD\KAREN.DWG 6/21/94 MB PLOT.DWG STATE PLANAR COORDINATE SYSTEM 1987

FIGURE 4-12 ENVIRONMENTAL MONITORING PROGRAM, PADDYS RUN AND SSOD, SEDIMENT TOTAL URANIUM (mg/kg) DATA



LEGEND

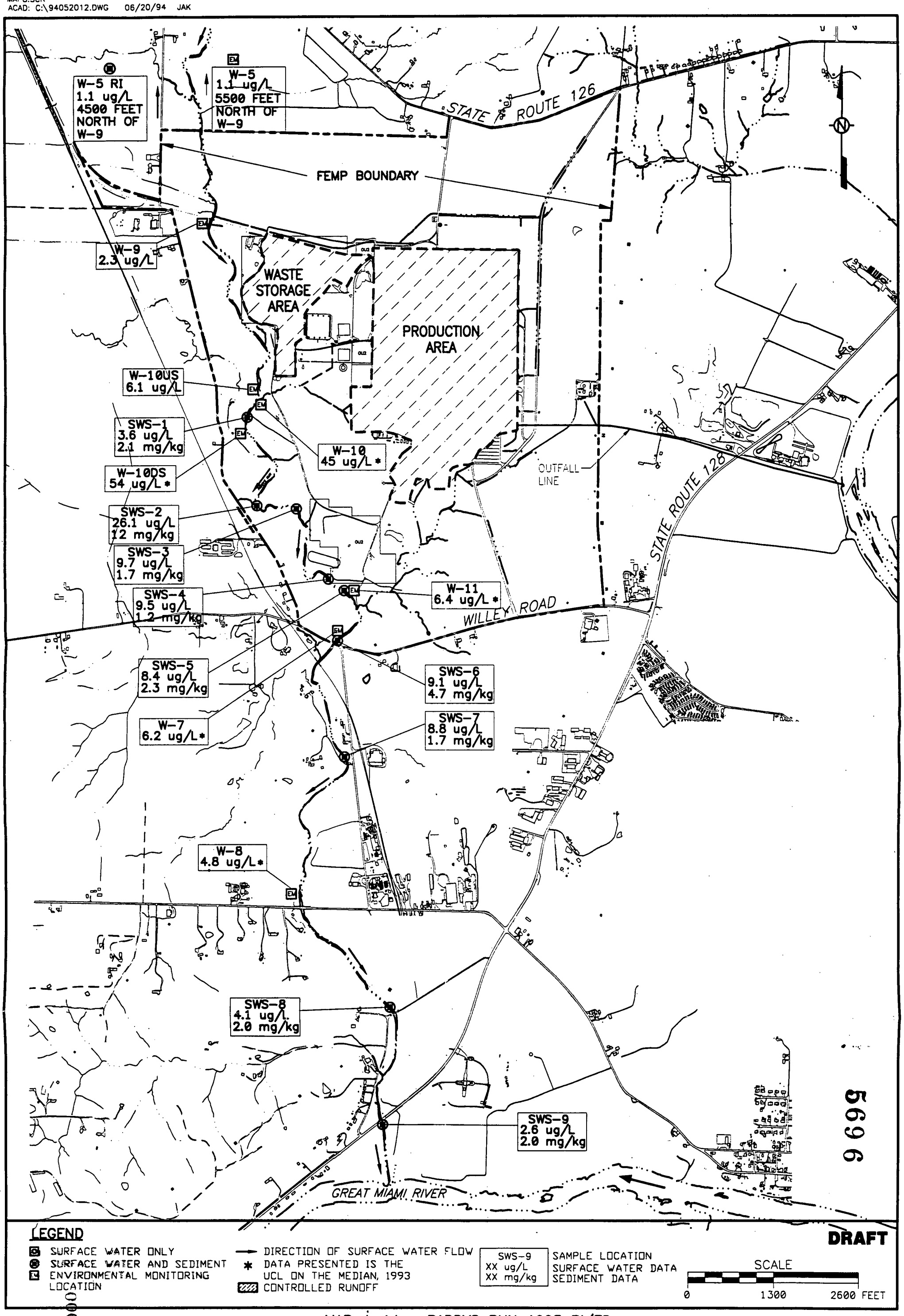
- SURFACE WATER ONLY
- DIRECTION OF SURFACE WATER
- GENERAL DIRECTION OF SURFACE RUNOFF
- CONTROLLED RUNOFF AREA
- SURFACE DRAINAGE

SCALE: 0 — 100 — 200 FEET

DRAFT

FIGURE 4-13
EAST DRAINAGE AREA
1993 RI/FS SURFACE WATER TOTAL URANIUM DATA

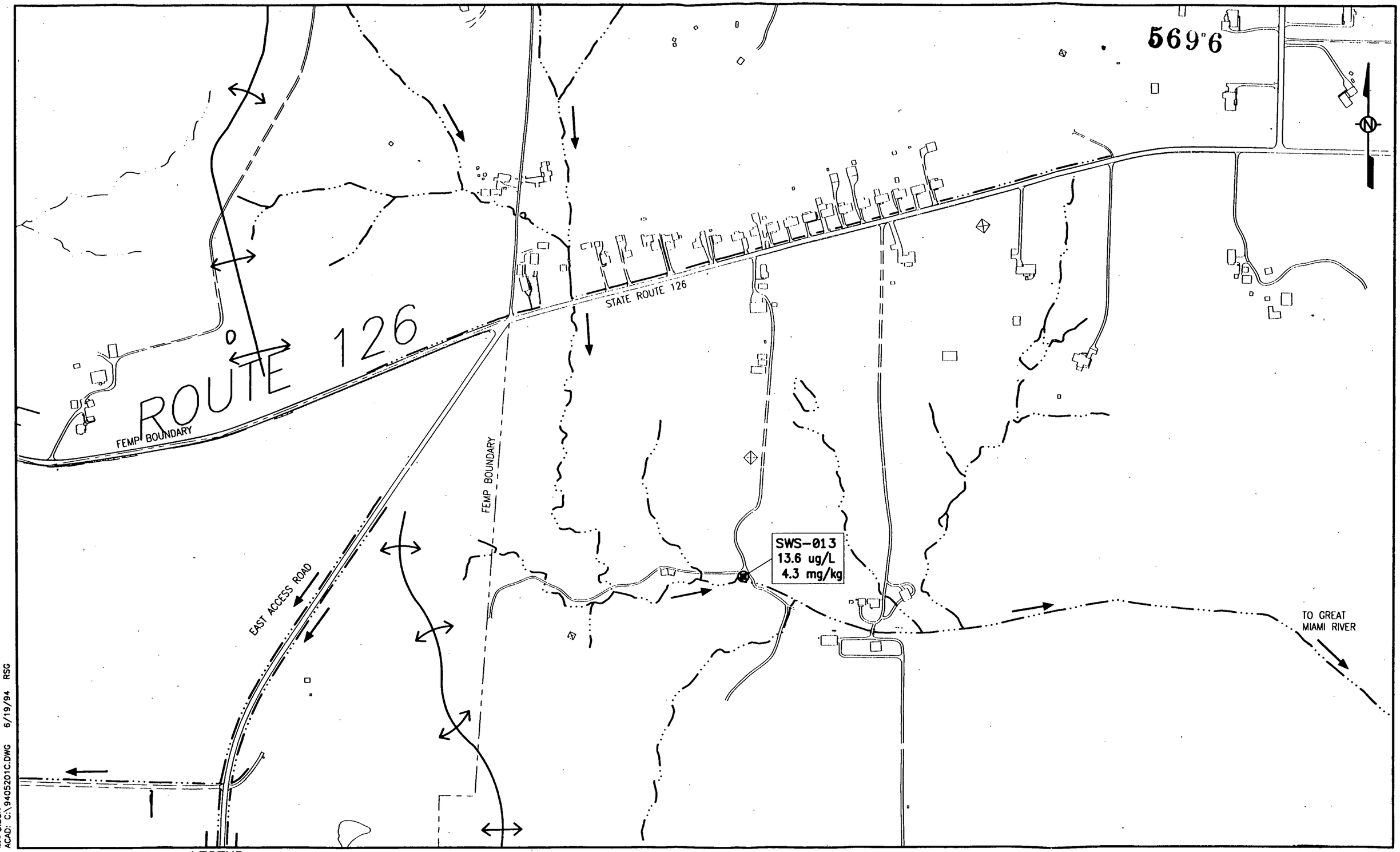
MAP8.SCR
ACAD: C:\94052012.DWG 06/20/94 JAK



MAP 4-14 PADDYS RUN 1993 RI/FS
SURFACE WATER AND SEDIMENT TOTAL URANIUM DATA

9696

000872



MAP3.SCR
ACAD: C:\9405201C.DWG 6/19/94 RSG

LEGEND

- SURFACE WATER AND SEDIMENT
- DIRECTION OF SURFACE WATER
- DRAINAGE DIVIDE

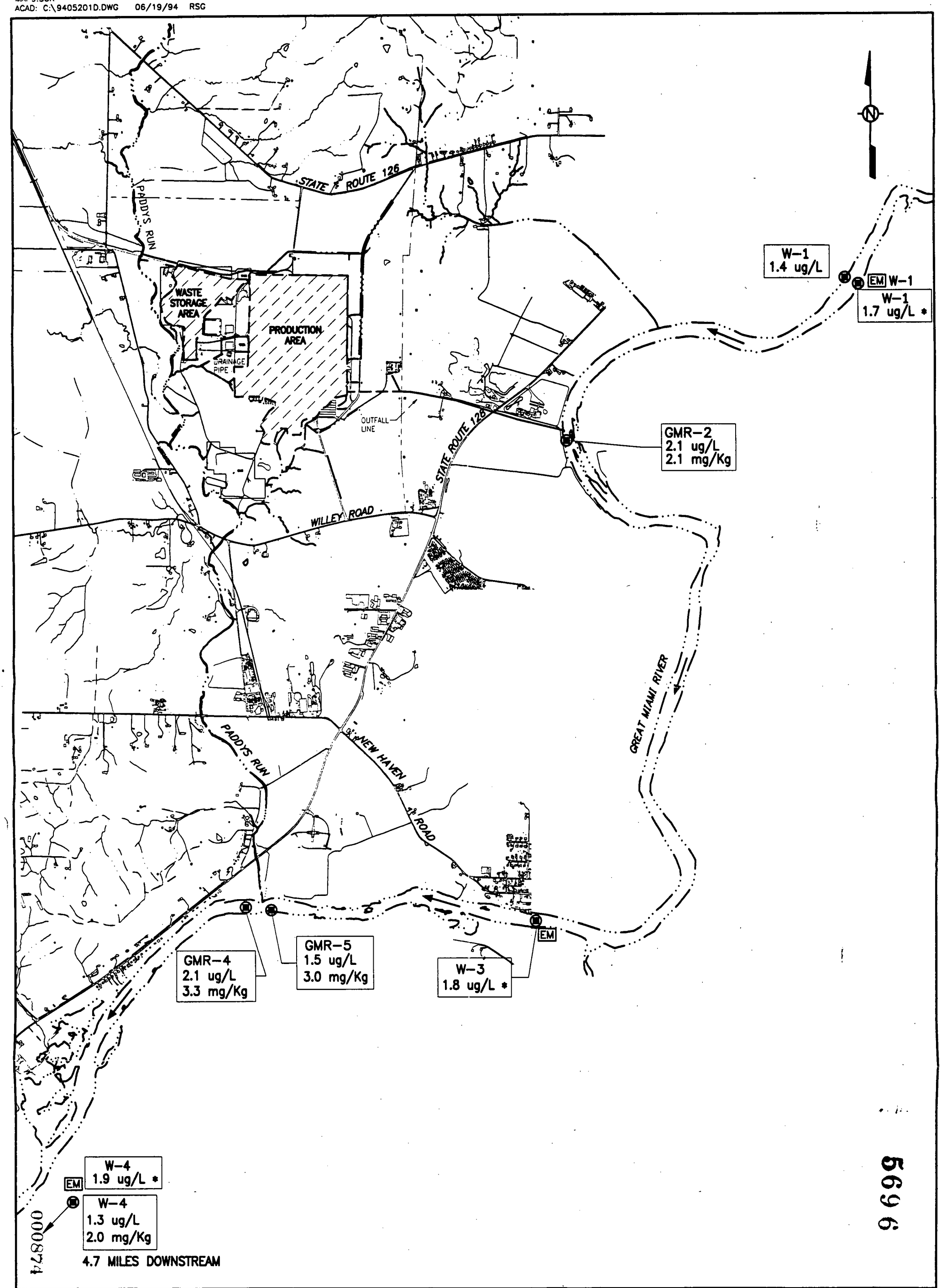
DRAFT

SCALE
0 300 600 FEET

FIGURE 4-15
NORTHEAST DRAINAGE AREA
1993 RI/FS SURFACE WATER AND SEDIMENT TOTAL URANIUM DATA

000873

MAP9.SCR
ACAD: C:\9405201D.DWG 06/19/94 RSG



LEGEND
- SURFACE WATER ONLY
- SURFACE WATER AND SEDIMENT
- EM ENVIRONMENTAL MONITORING LOCATION
- DIRECTION OF SURFACE WATER
- CONTROLLED RUNOFF AREA

* DATA PRESENTED IS THE UCL ON THE MEDIAN, 1993

DRAFT

SCALE 0 2000 4000 FEET

FIGURE 4-16
GREAT MIAMI RIVER
1993 RI/FS SURFACE WATER AND SEDIMENT TOTAL URANIUM DATA

000874

5696

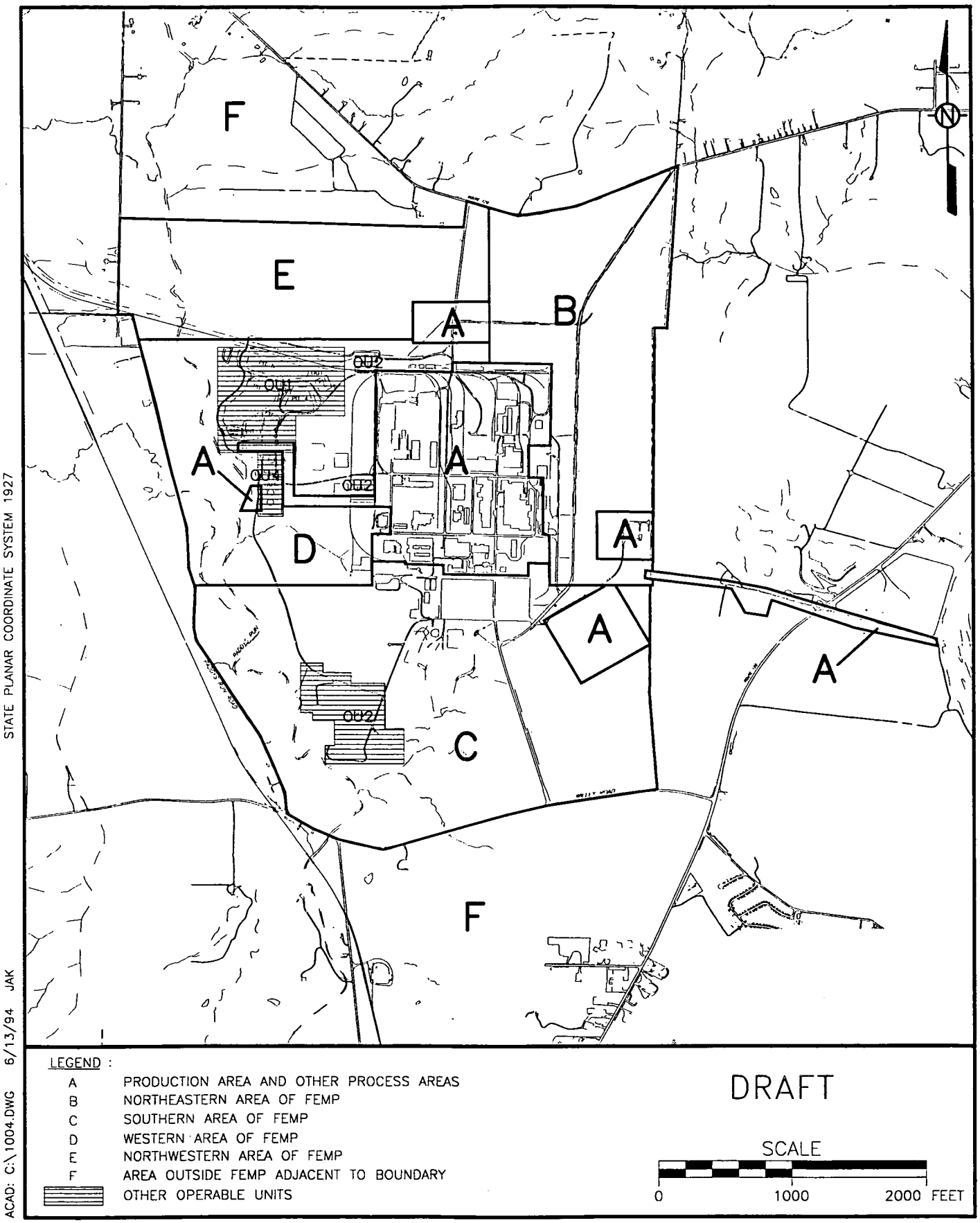


FIGURE 4–17. FEMP GEOGRAPHIC AREAS FOR SOIL

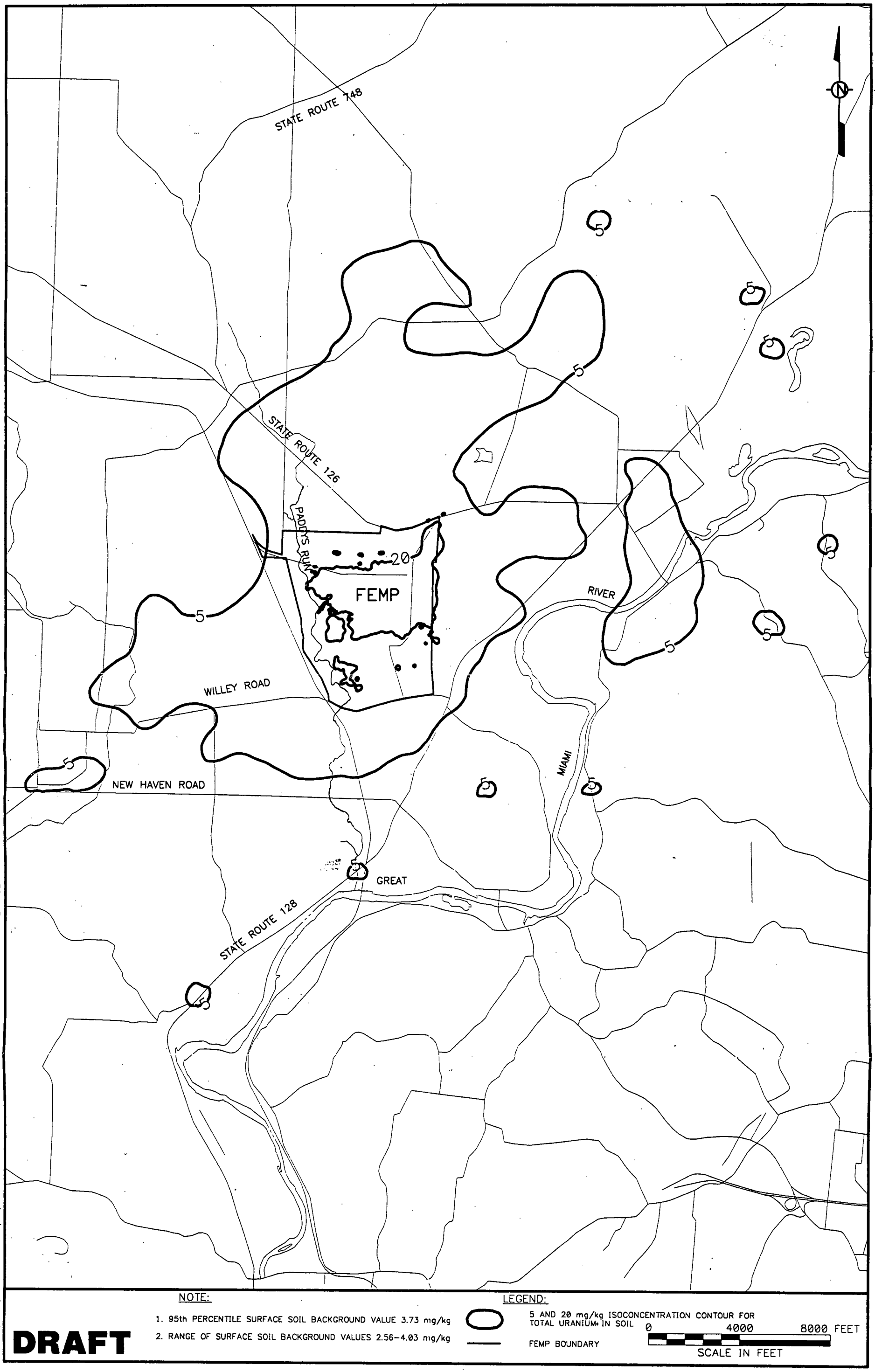
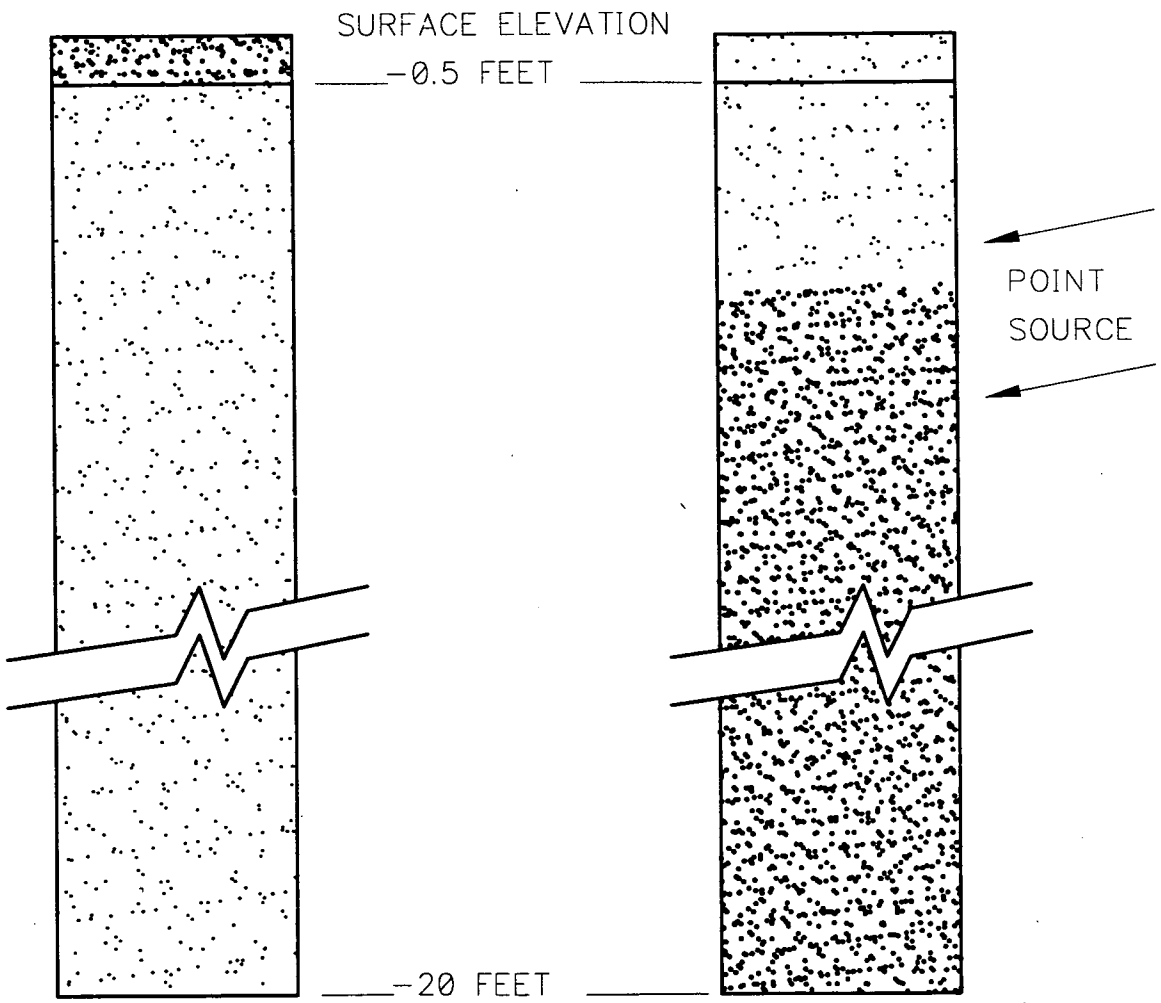


FIGURE 4–18: 5 AND 20 mg/kg ISOCONCENTRATION CONTOUR FOR TOTAL URANIUM IN SOIL, OU5, FEMP



LEGEND:

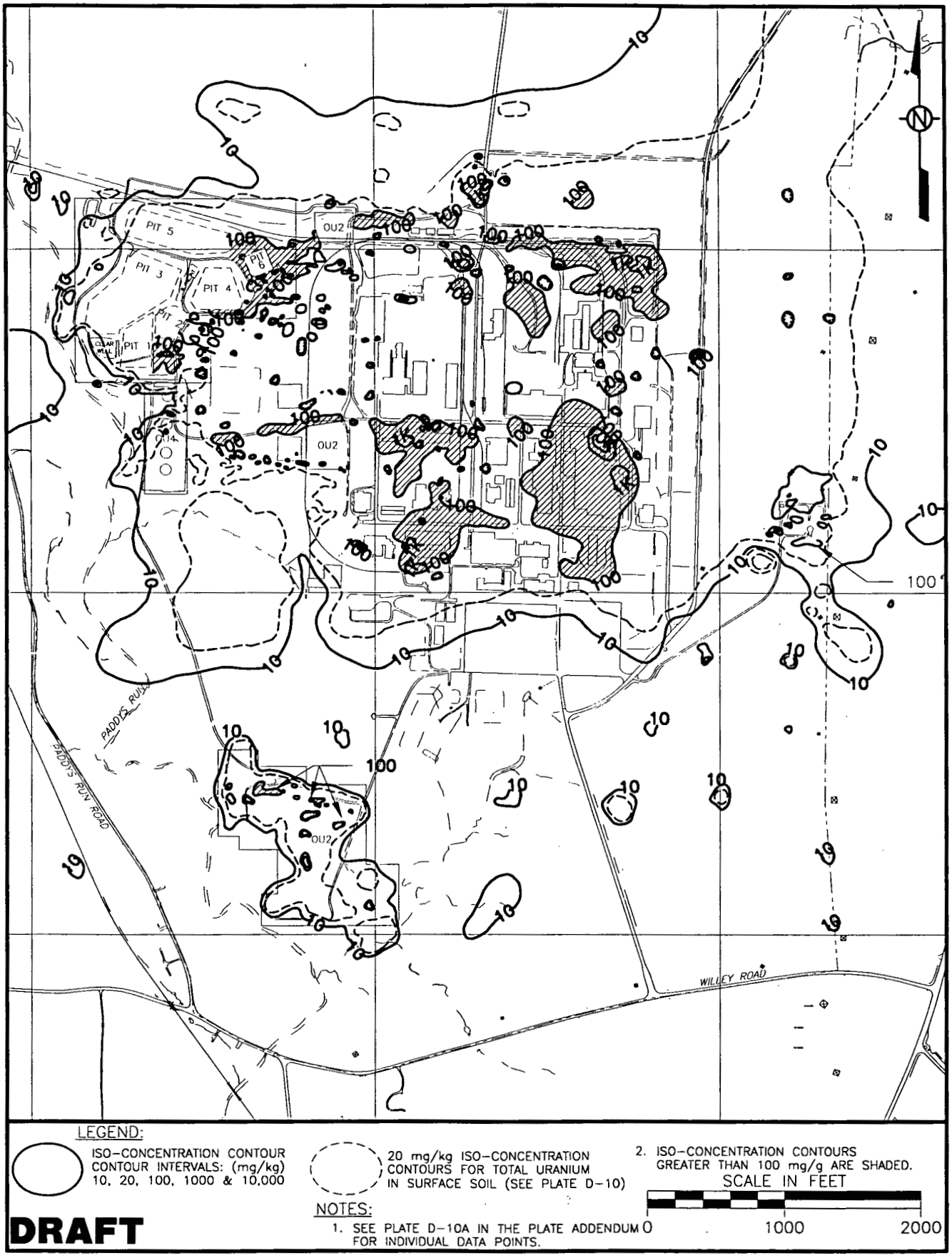
CONTAMINATED SOIL

UNCONTAMINATED SOIL

DRAFT

ACAD: W:/DATA/CADD/4P94/fig463.DWG 06/16/94 MLS

FIGURE 4-19. CONCEPTUALIZATION OF URANIUM DISTRIBUTION IN SOIL CONSIDERING POINT-SOURCE AND AIRBORNE RELEASE MECHANISMS



ACAD: W:/DATA/CADD/4P94/s102aa.DWG 6/18/94 MB STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-20 . VALIDATED TOTAL URANIUM, SURFACE SOIL, 0-0.5 FOOT

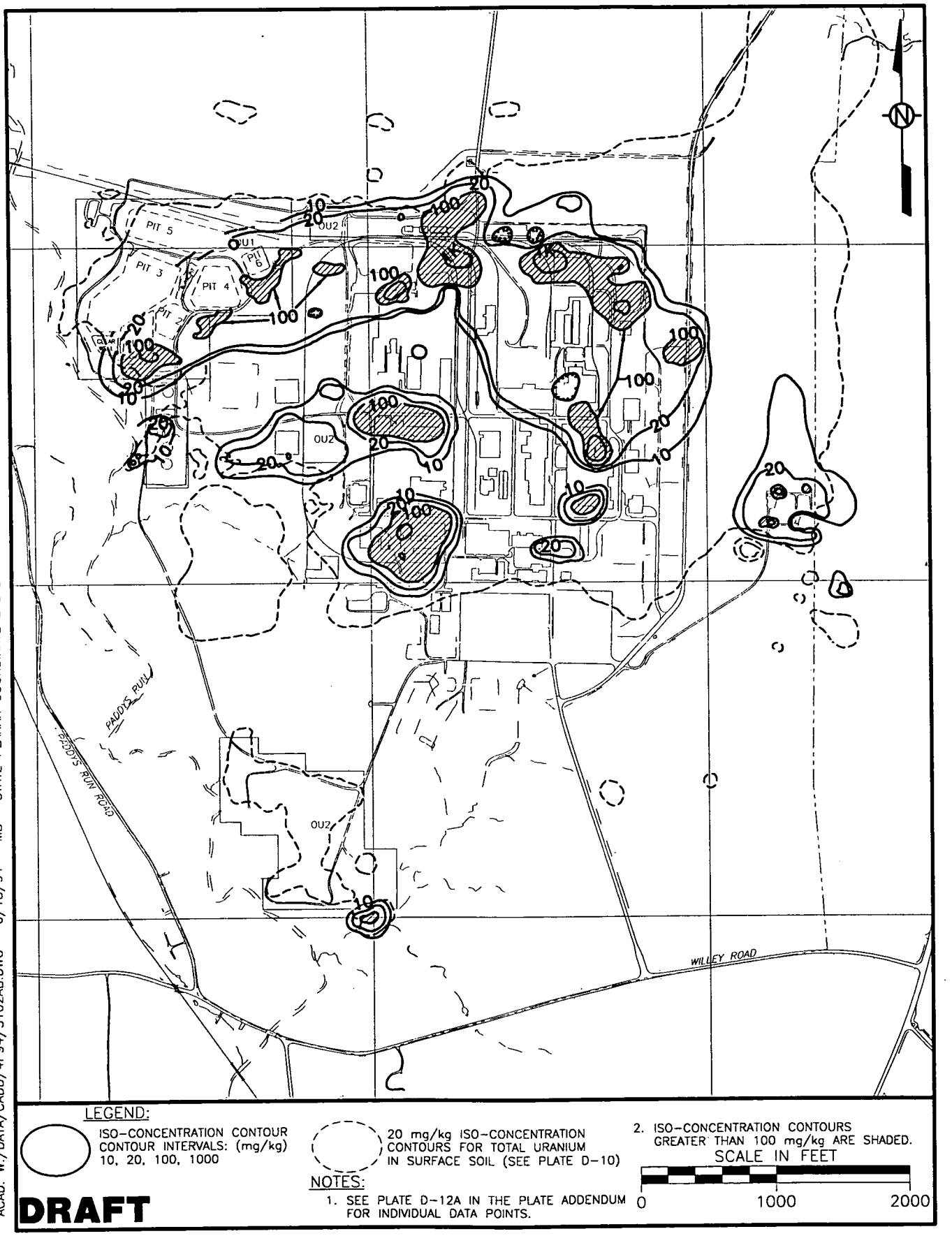


FIGURE 4-21. VALIDATED TOTAL URANIUM, SURFACE SOIL, 0.5-1.0 FEET

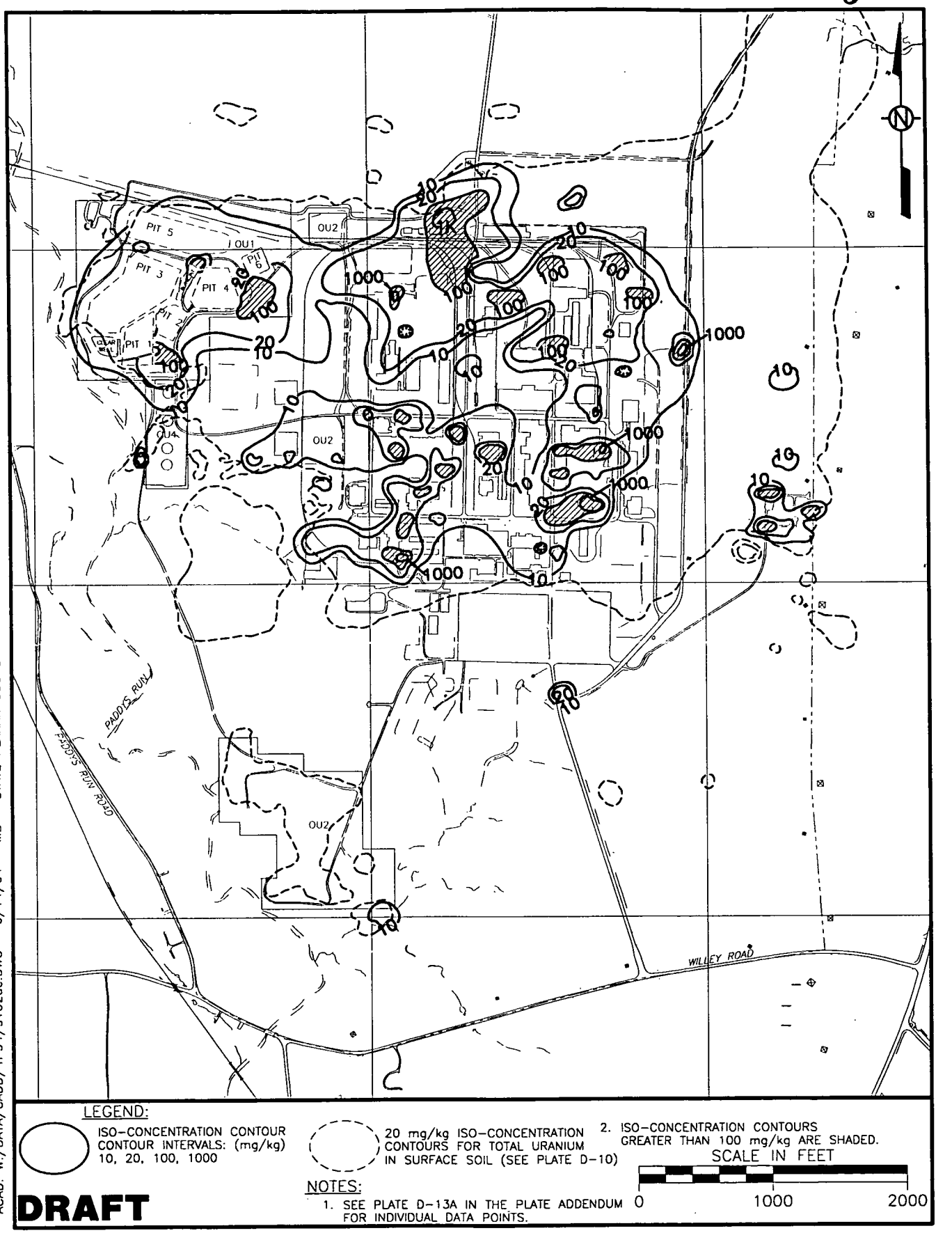


FIGURE 4-22. VALIDATED TOTAL URANIUM, SURFACE SOIL, 1.0-1.5 FEET

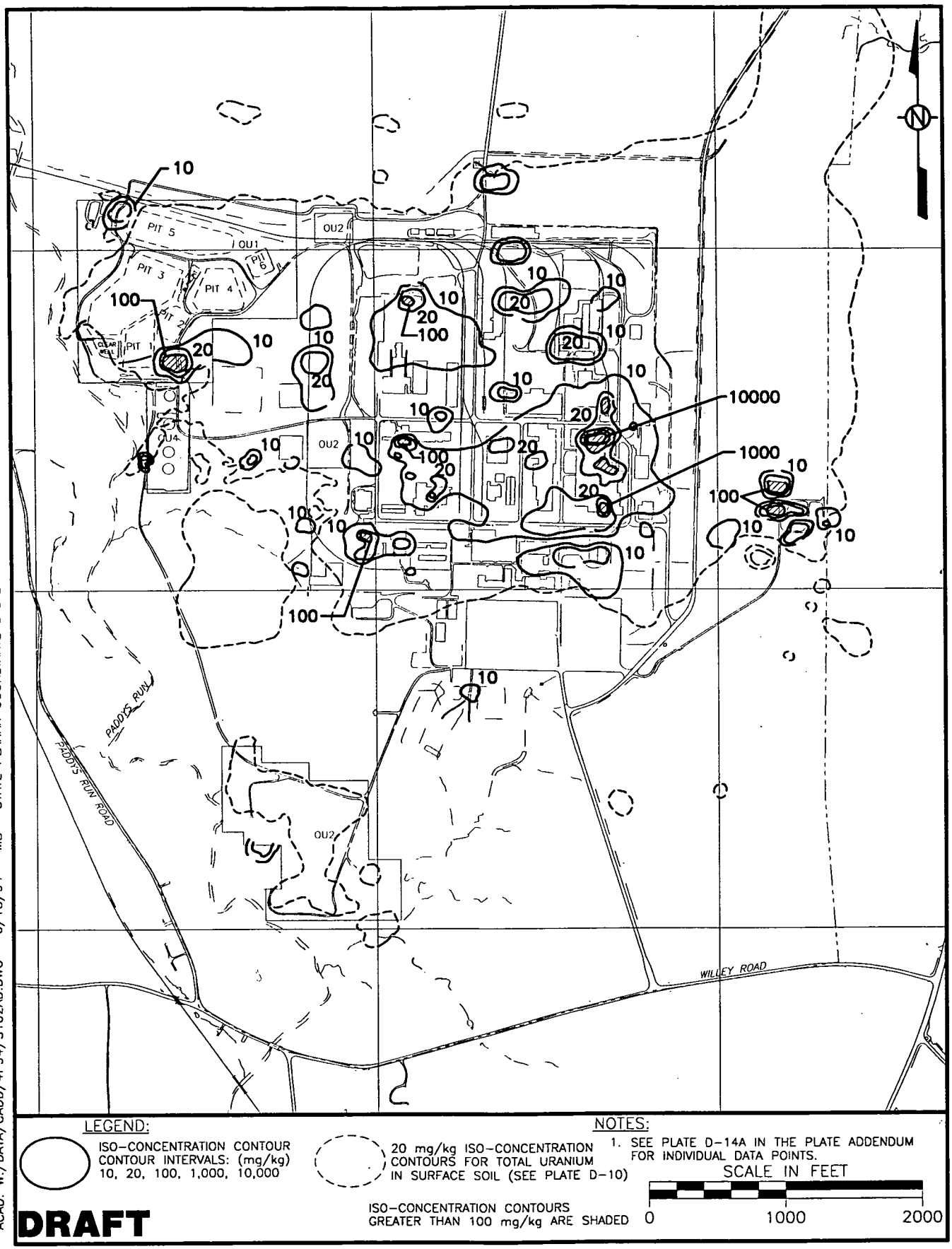


FIGURE 4-23. VALIDATED TOTAL URANIUM, SUBSURFACE SOIL, 1.5-3.0 FEET

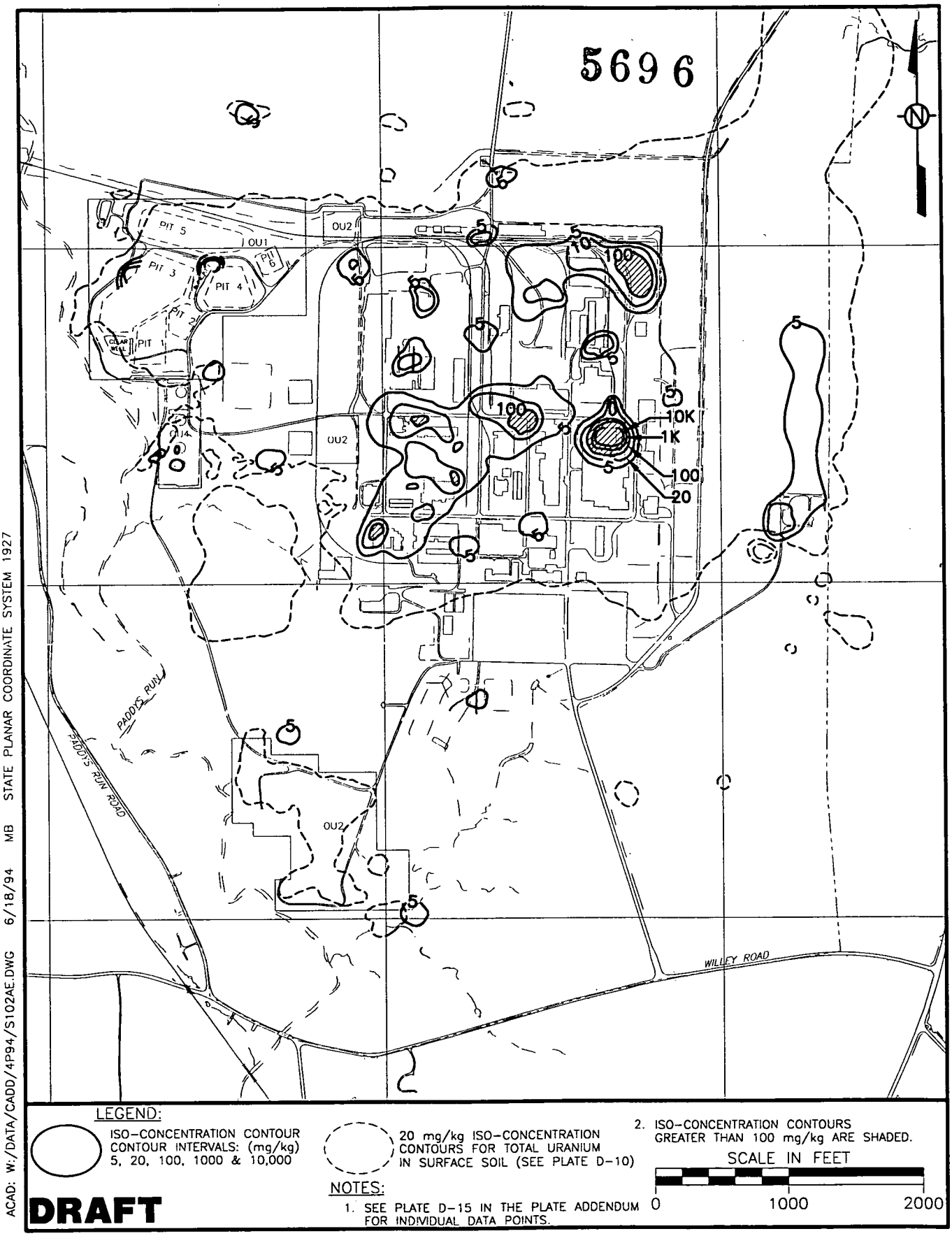


FIGURE 4-24. TOTAL URANIUM, SUBSURFACE SOIL, 3.0-5.0 FEET

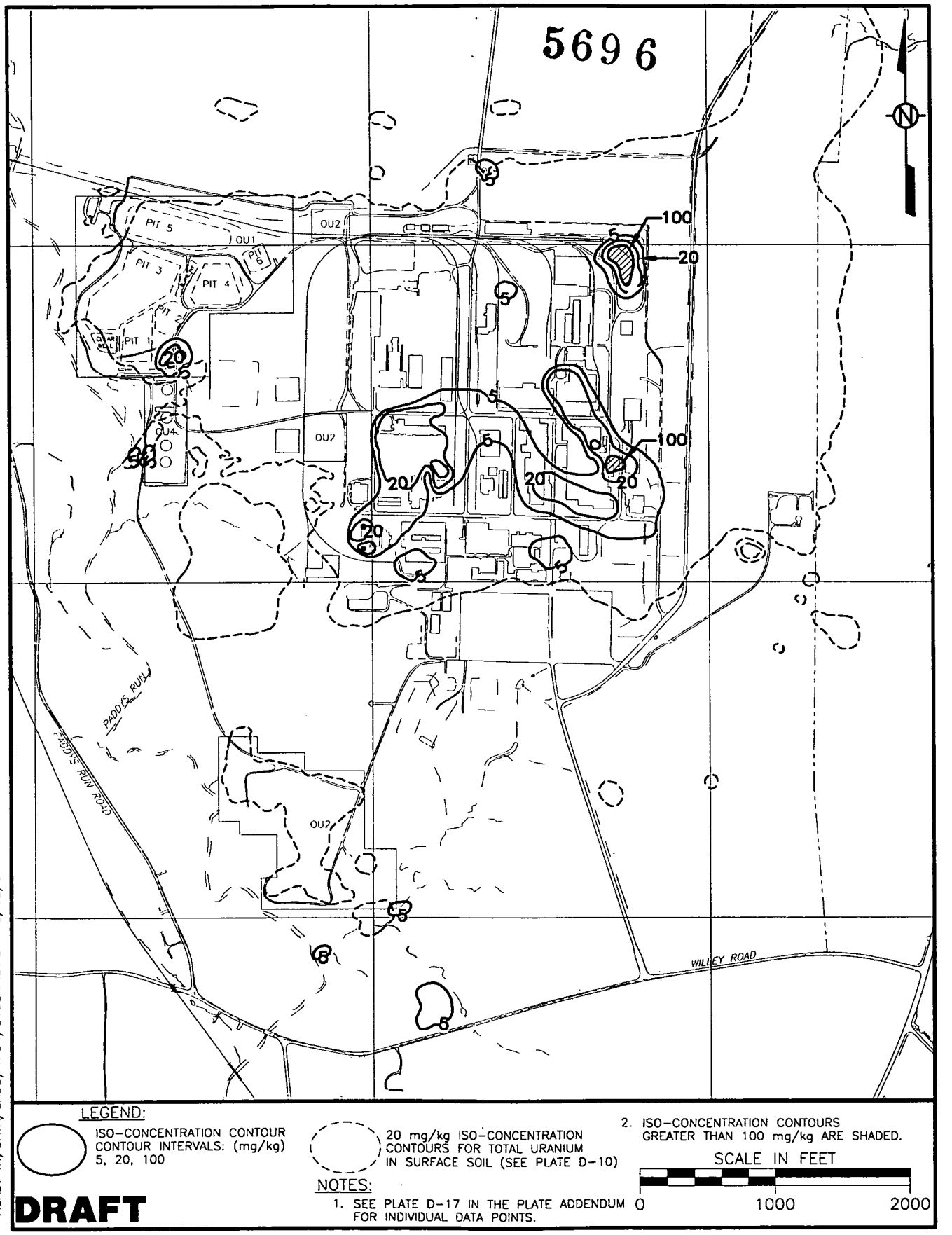


FIGURE 4-25. TOTAL URANIUM, SUBSURFACE SOIL, 5.0-10.0 FEET

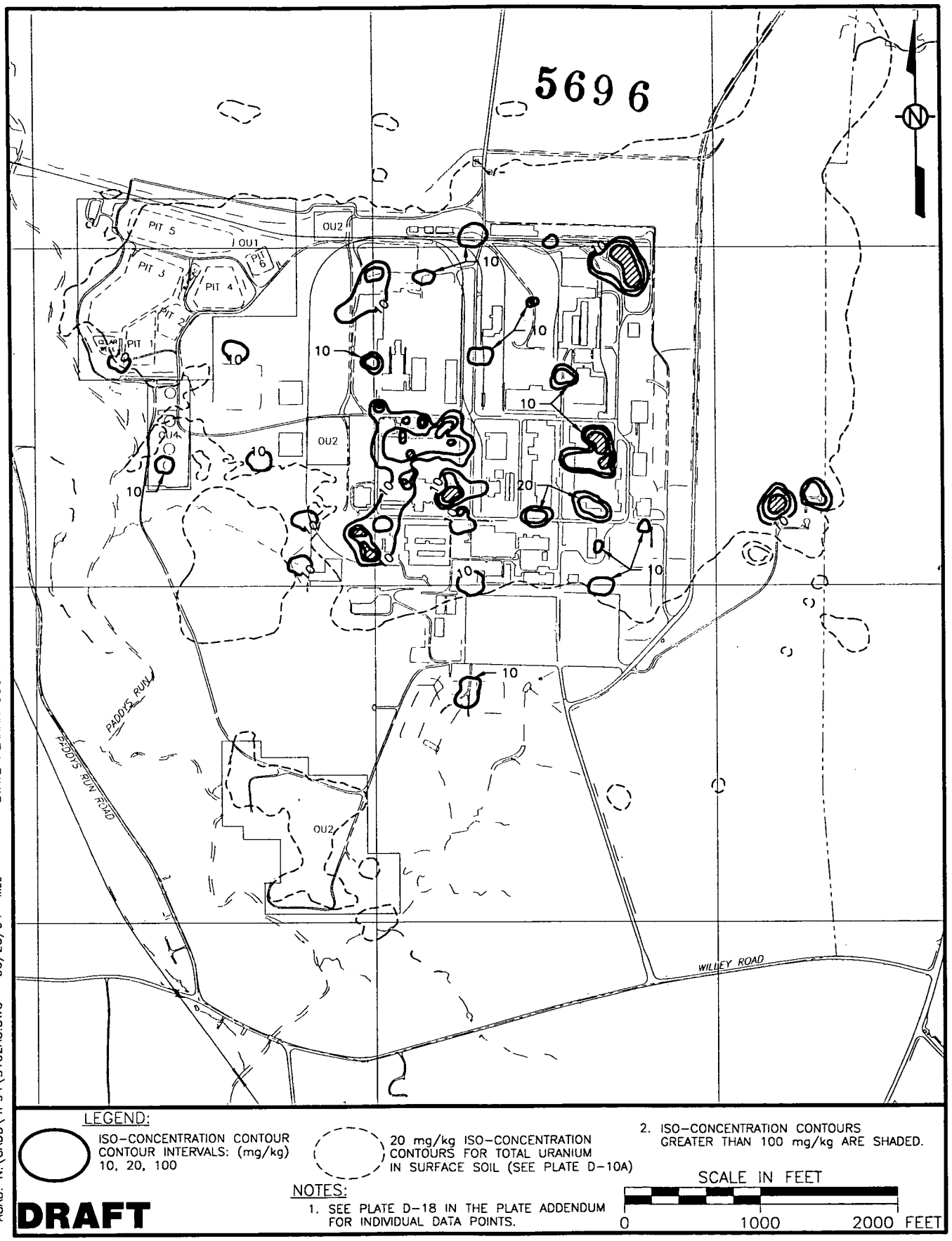


FIGURE 4-26. TOTAL URANIUM, SUBSURFACE SOIL, 10.0-15.0 FEET

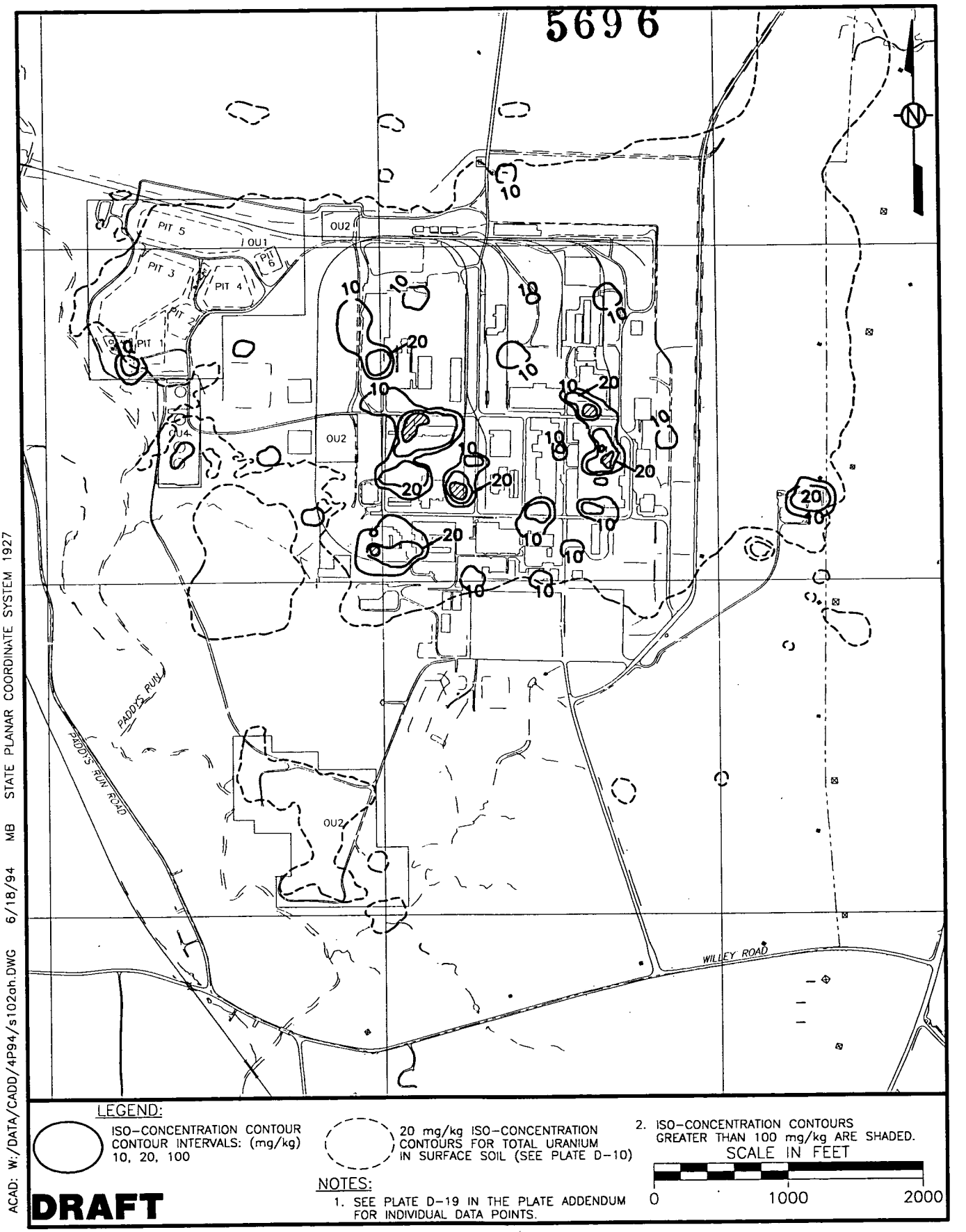


FIGURE 4-27. TOTAL URANIUM, SUBSURFACE SOIL, 15.0-20.0 FEET

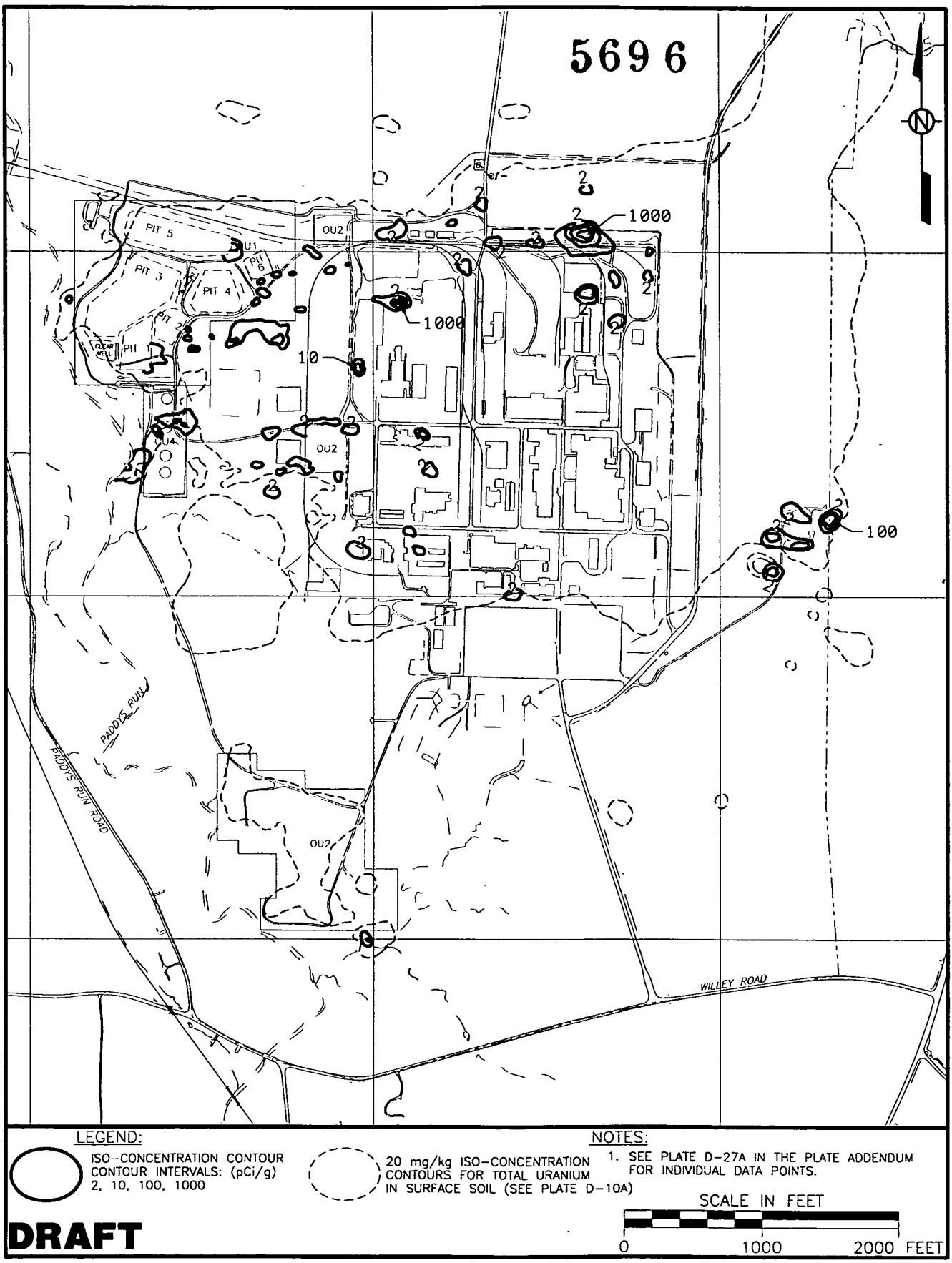


FIGURE 4-28. VALIDATED RADIUM-226, SURFACE SOIL, 0-0.5 FOOT

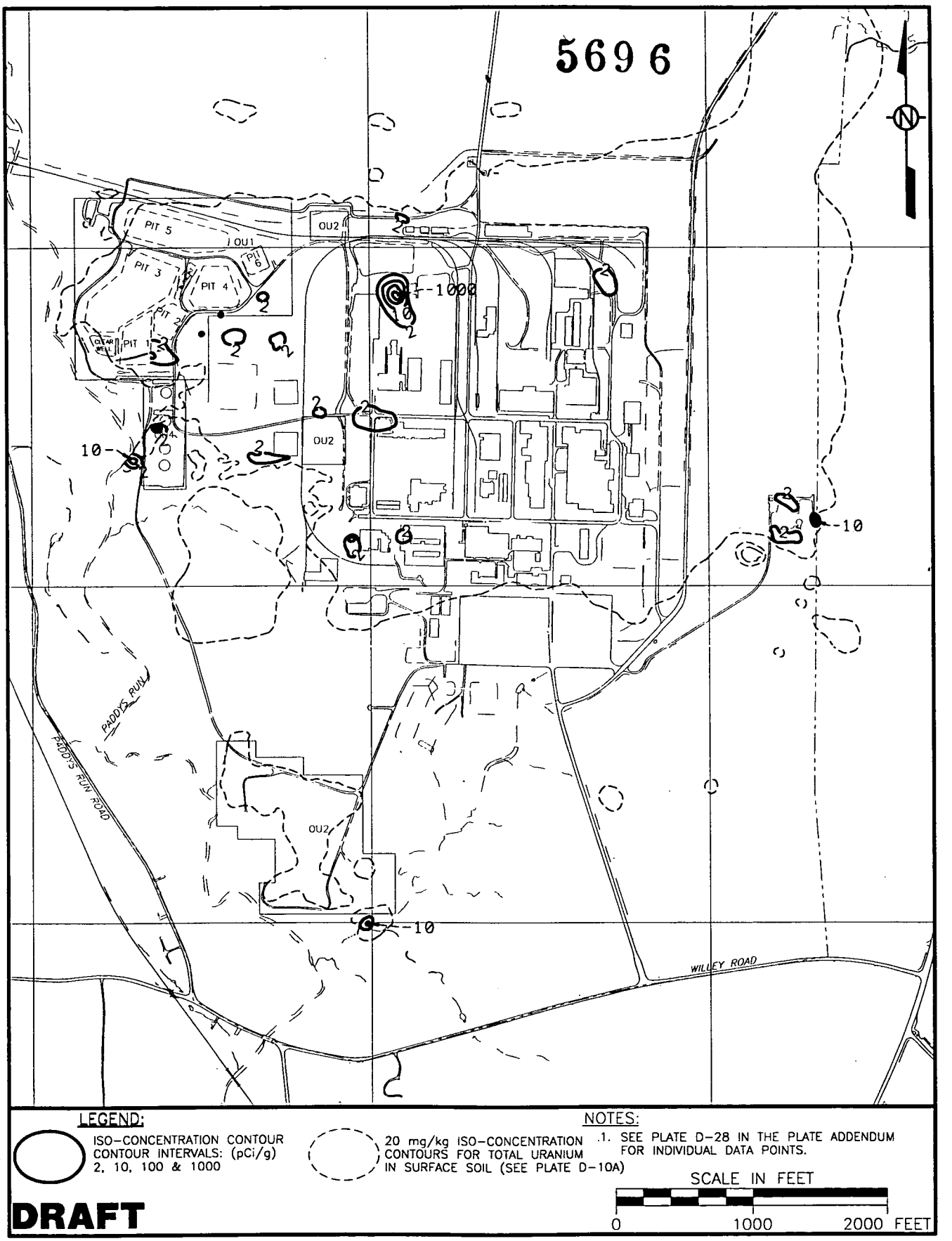


FIGURE 4-29. RADIUM-226, SURFACE SOIL, 0.5-1.0 FOOT

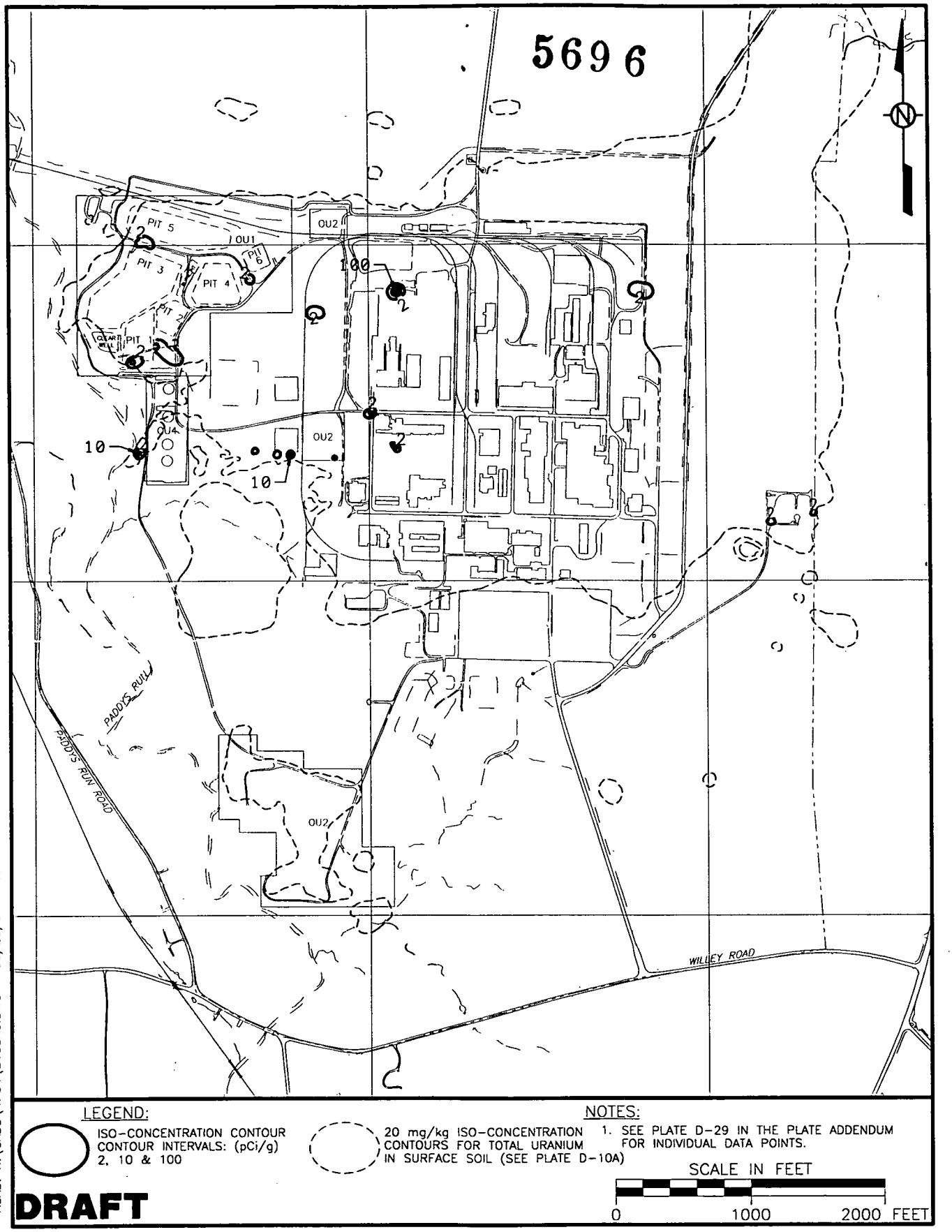


FIGURE 4-30. RADIUM-226, SURFACE SOIL, 1.0-1.5 FEET

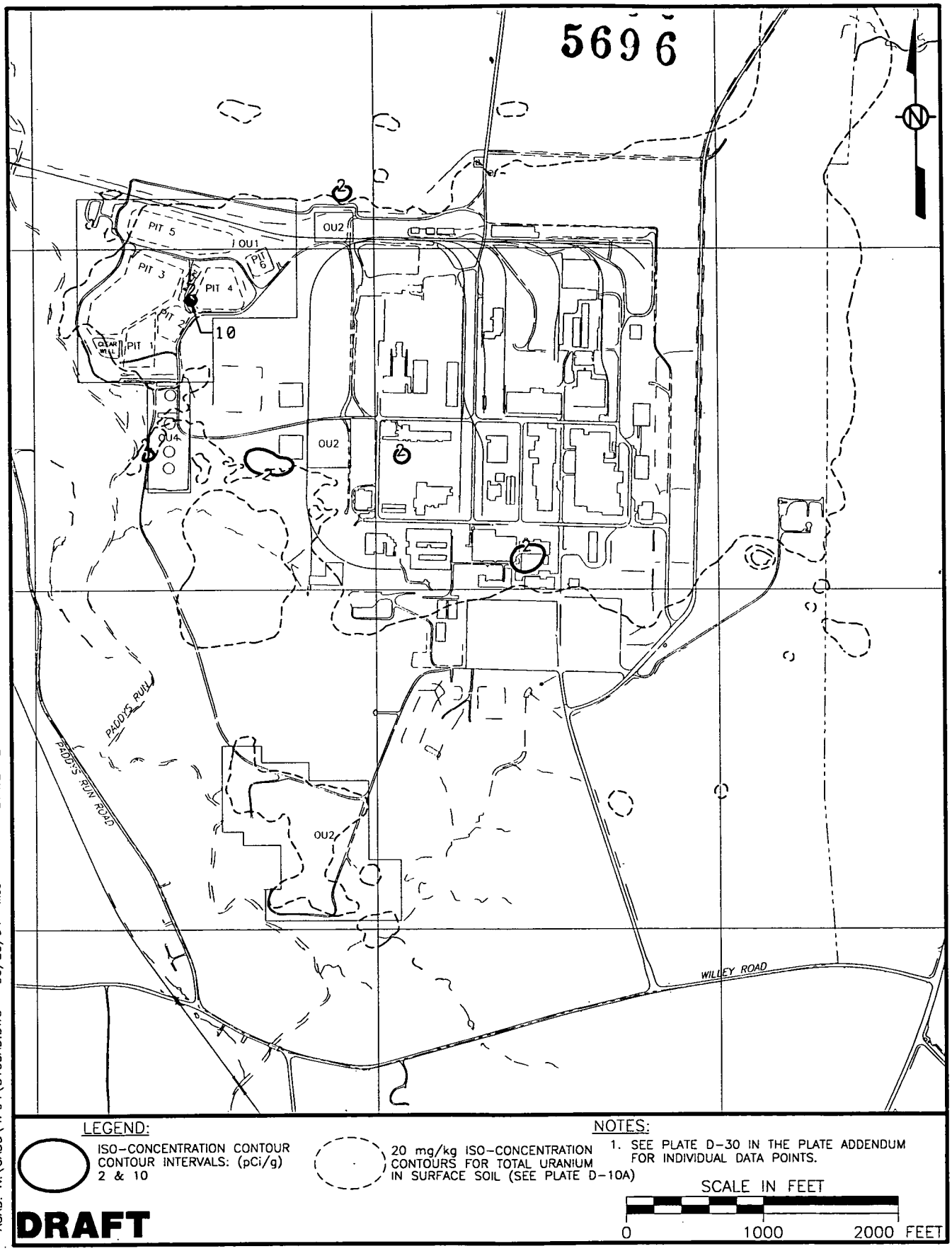


FIGURE 4-31. RADIUM-226, SUBSURFACE SOIL, 1.5-3.0 FEET

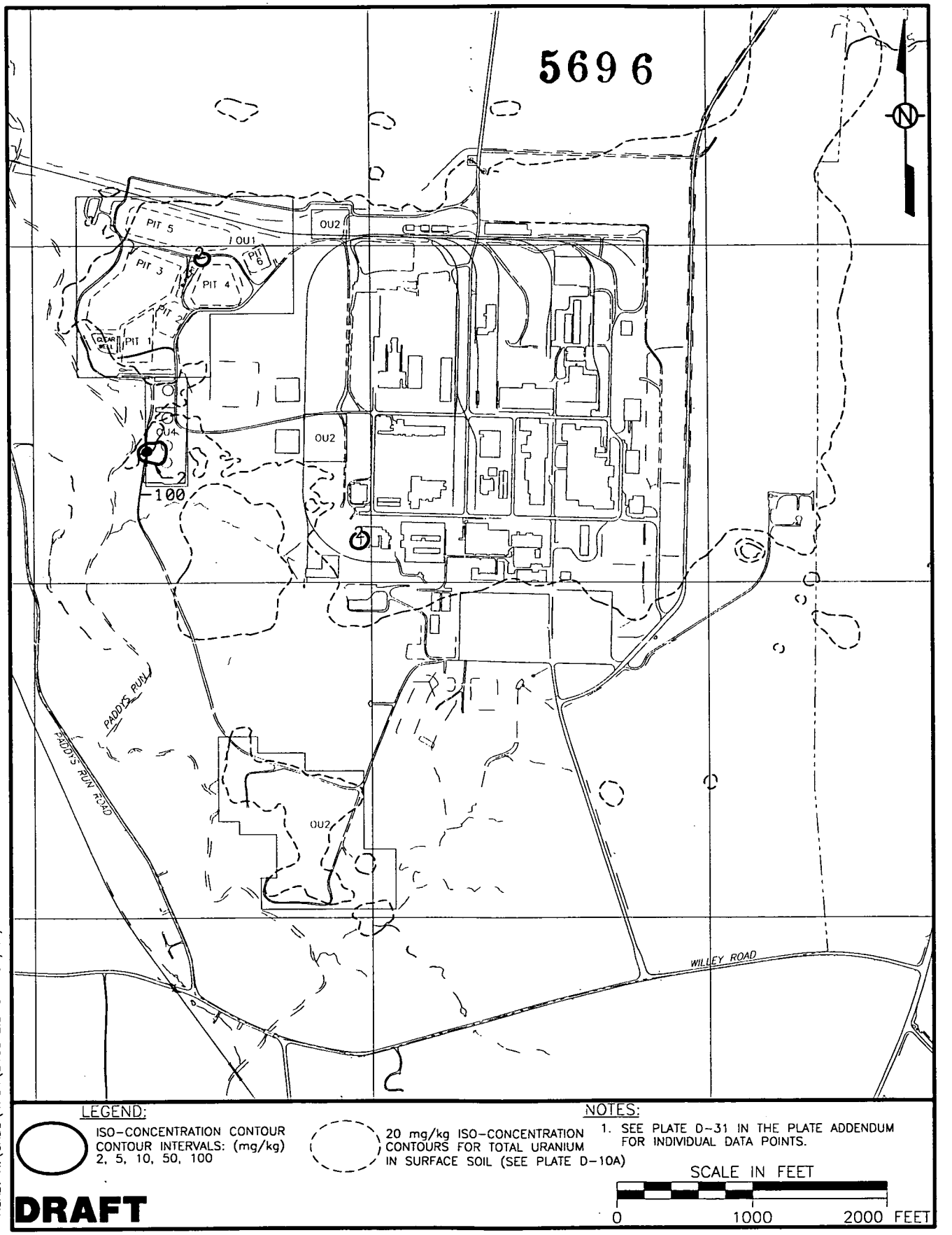


FIGURE 4-32. RADIUM-226, SUBSURFACE SOIL, 3.0-5.0 FEET

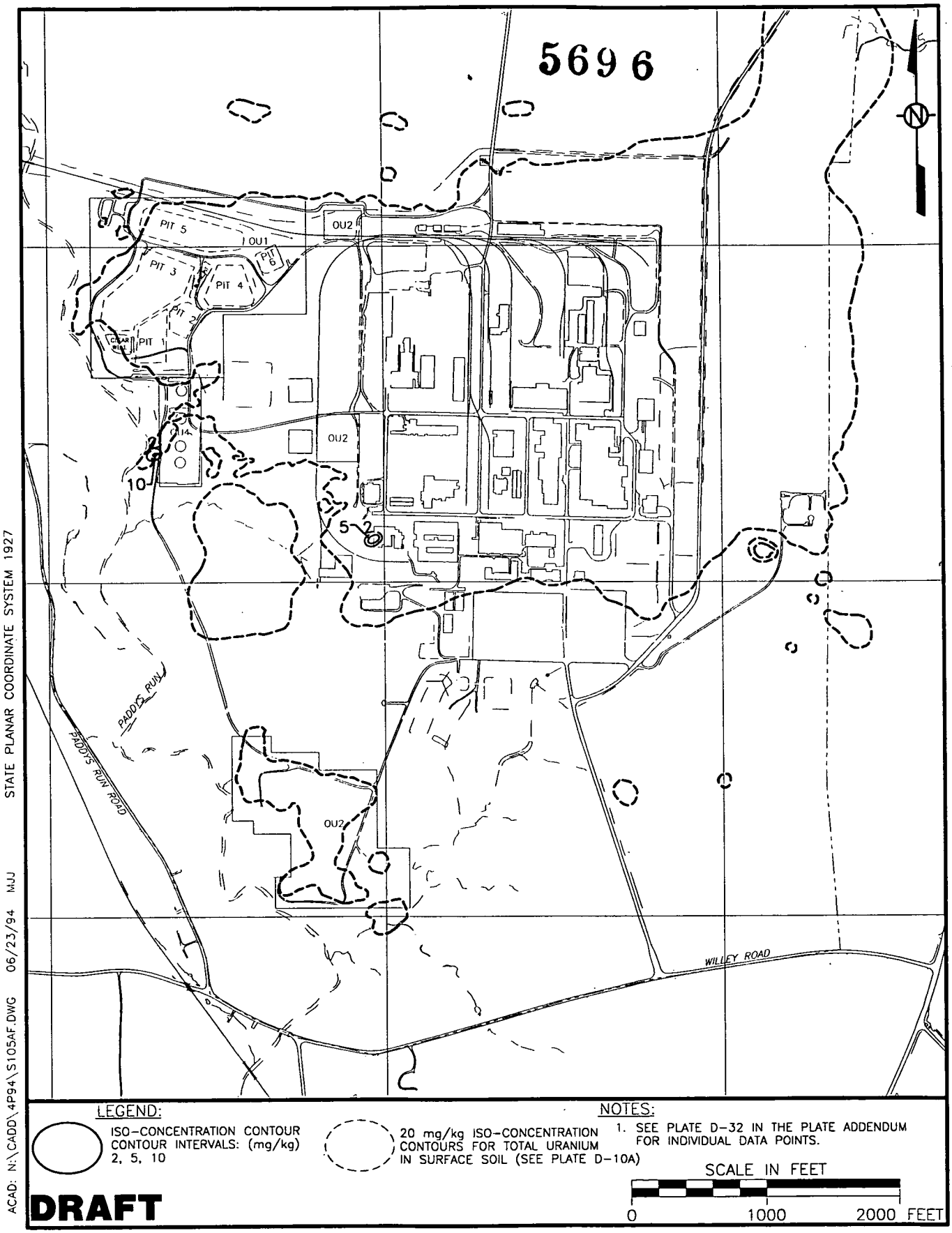


FIGURE 4-33. RADIUM-226, SUBSURFACE SOIL, 5.0-10.0 FEET

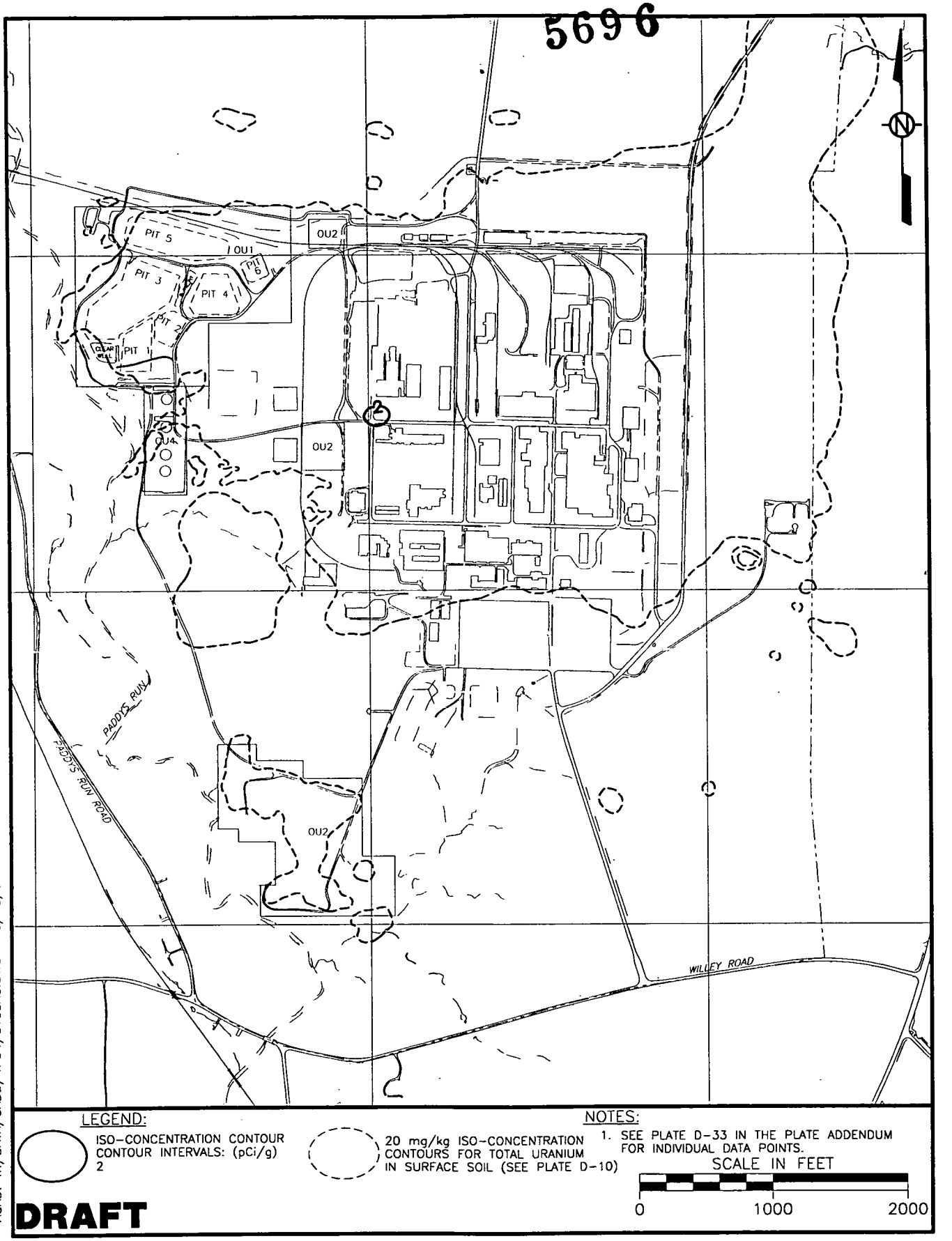


FIGURE 4-34. RADIUM-226, SUBSURFACE SOIL, 10.0-15.0 FEET

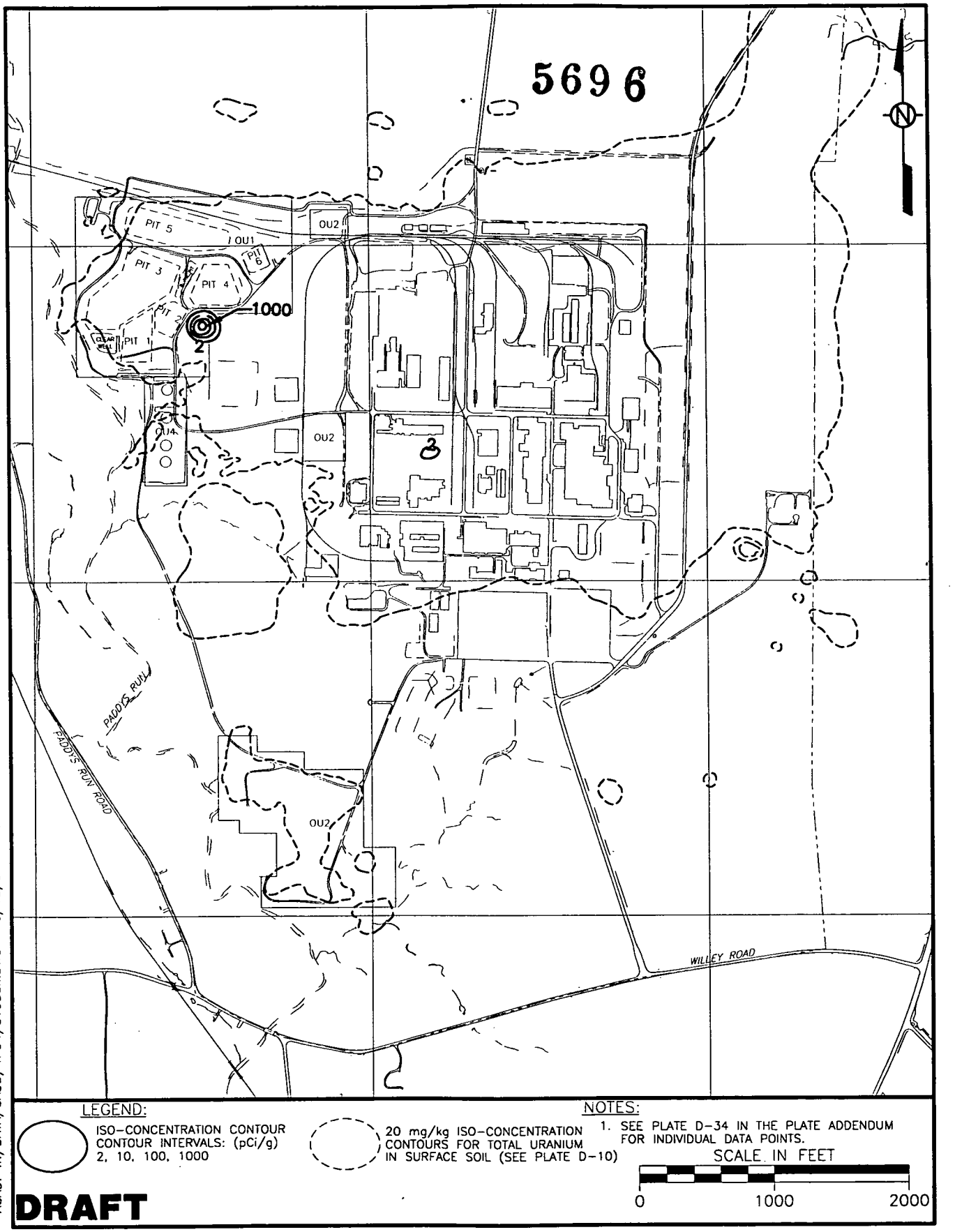


FIGURE 4-35. RADIUM-226, SUBSURFACE SOIL, 15.0-20.0 FEET

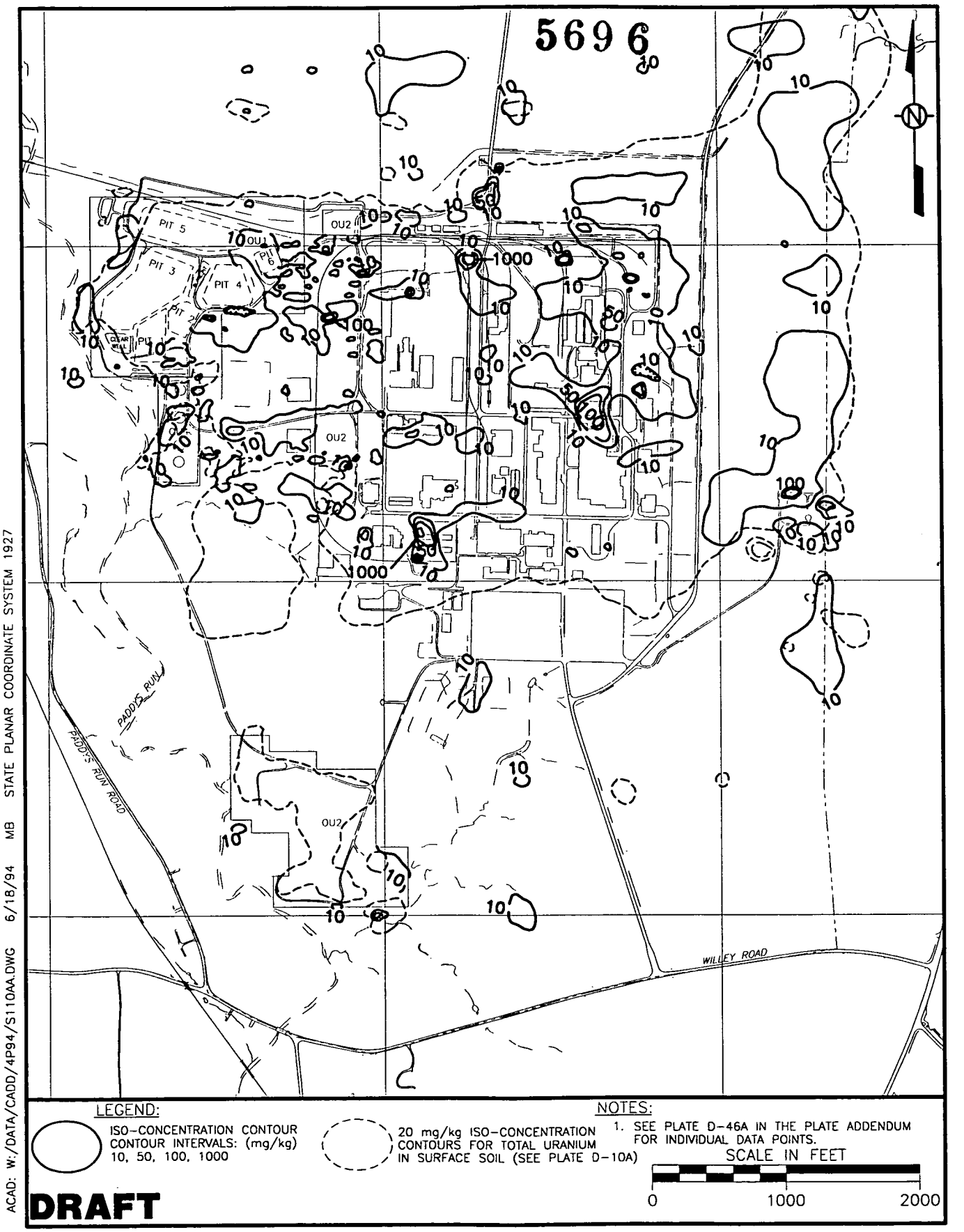


FIGURE 4-36. VALIDATED TOTAL THORIUM, SURFACE SOIL, 0-0.5 FOOT

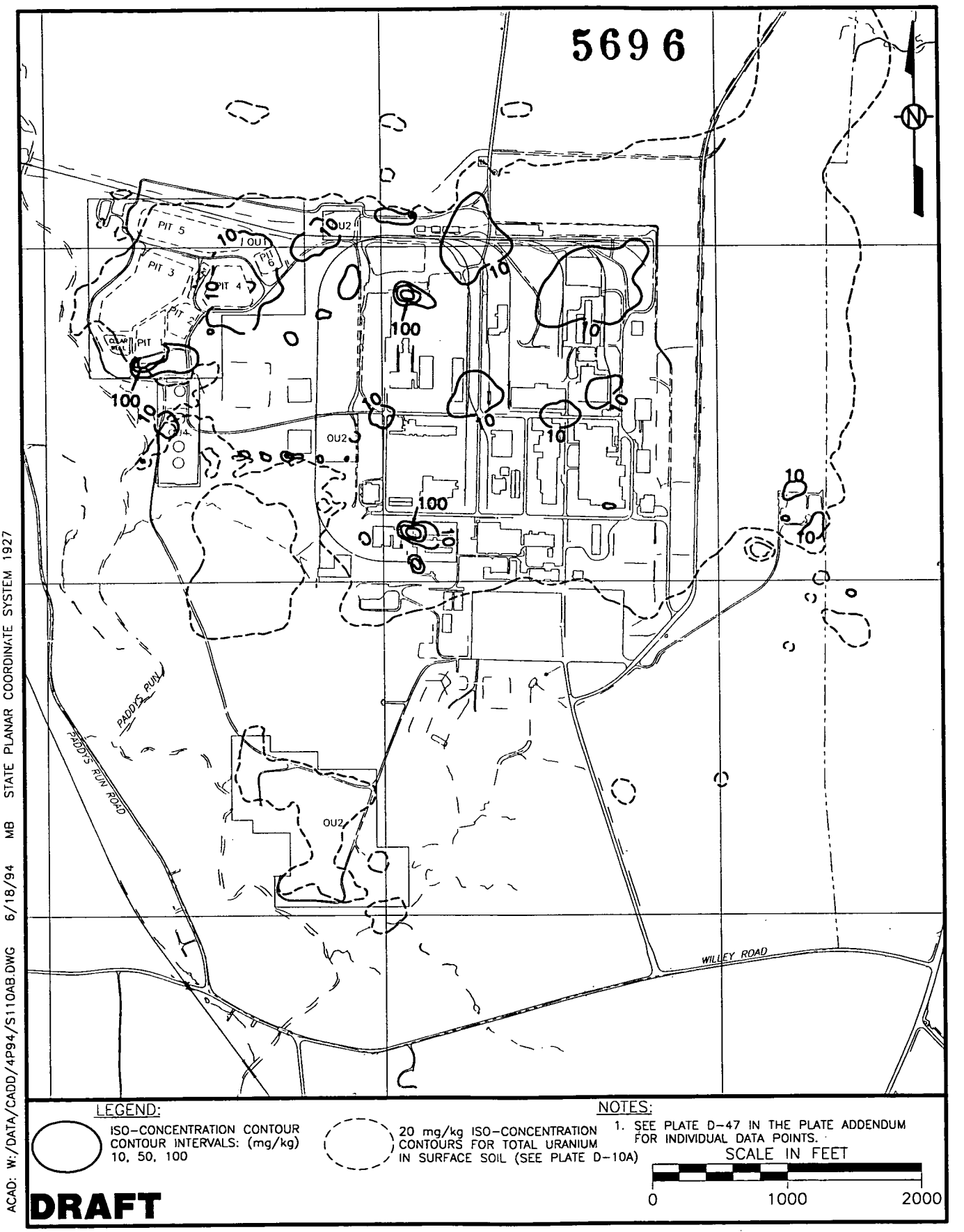
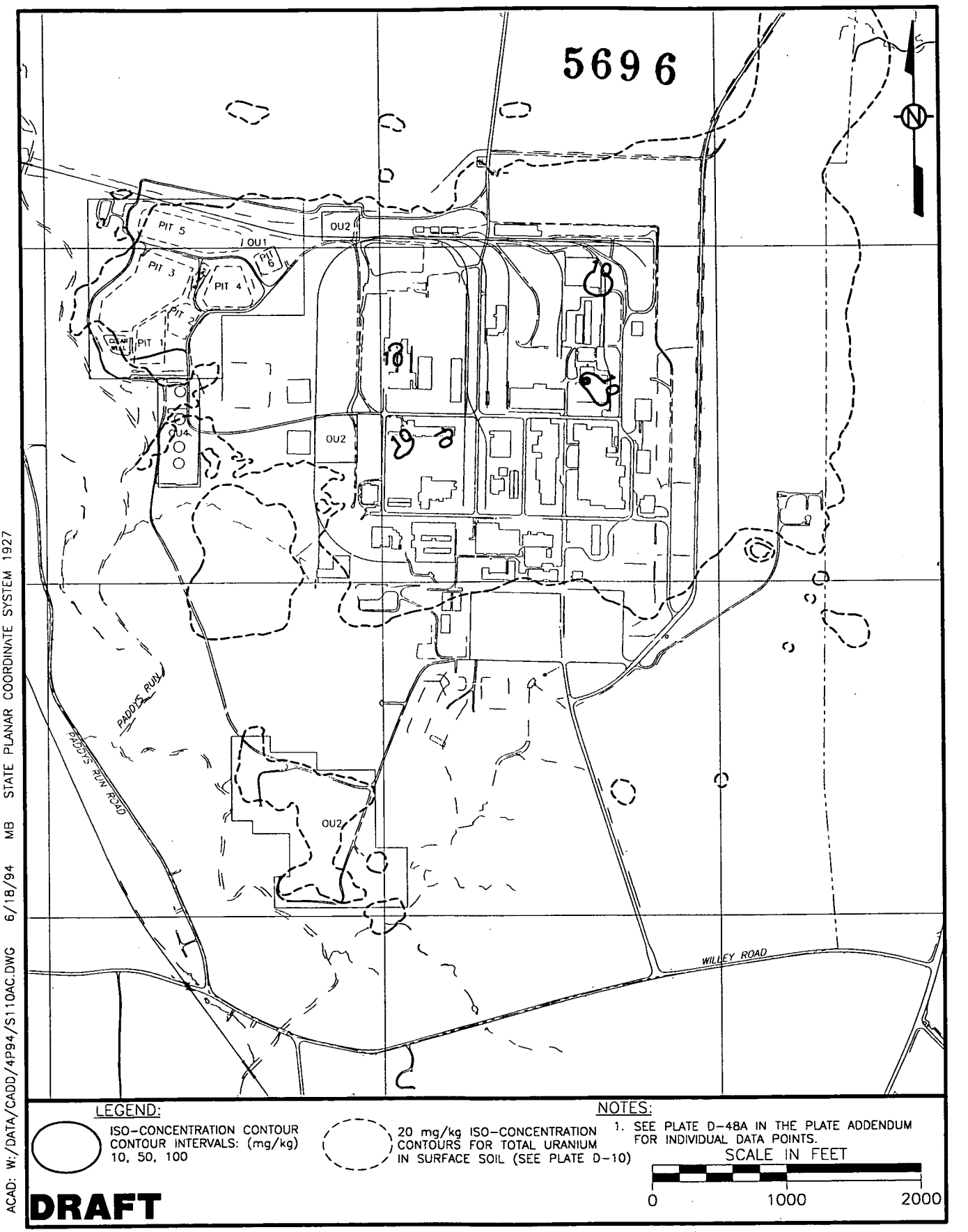


FIGURE 4-37. VALIDATED TOTAL THORIUM, SURFACE SOIL, 0.5-1.0 FOOT



ACAD: W:/DATA/CADD/4P94/S110AC.DWG 6/18/94 MB STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-38. VALIDATED TOTAL THORIUM, SURFACE SOIL, 1.0-1.5 FEET

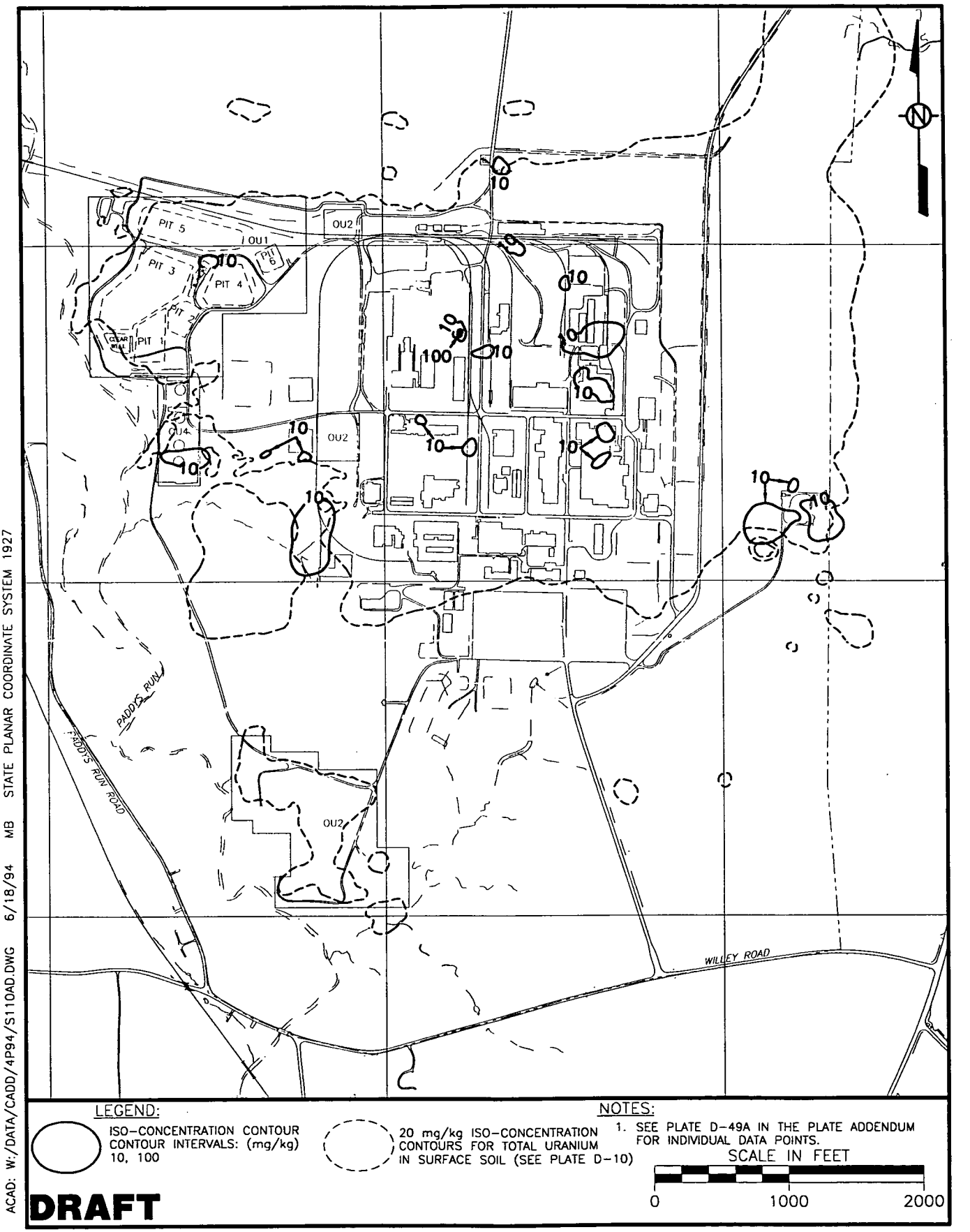
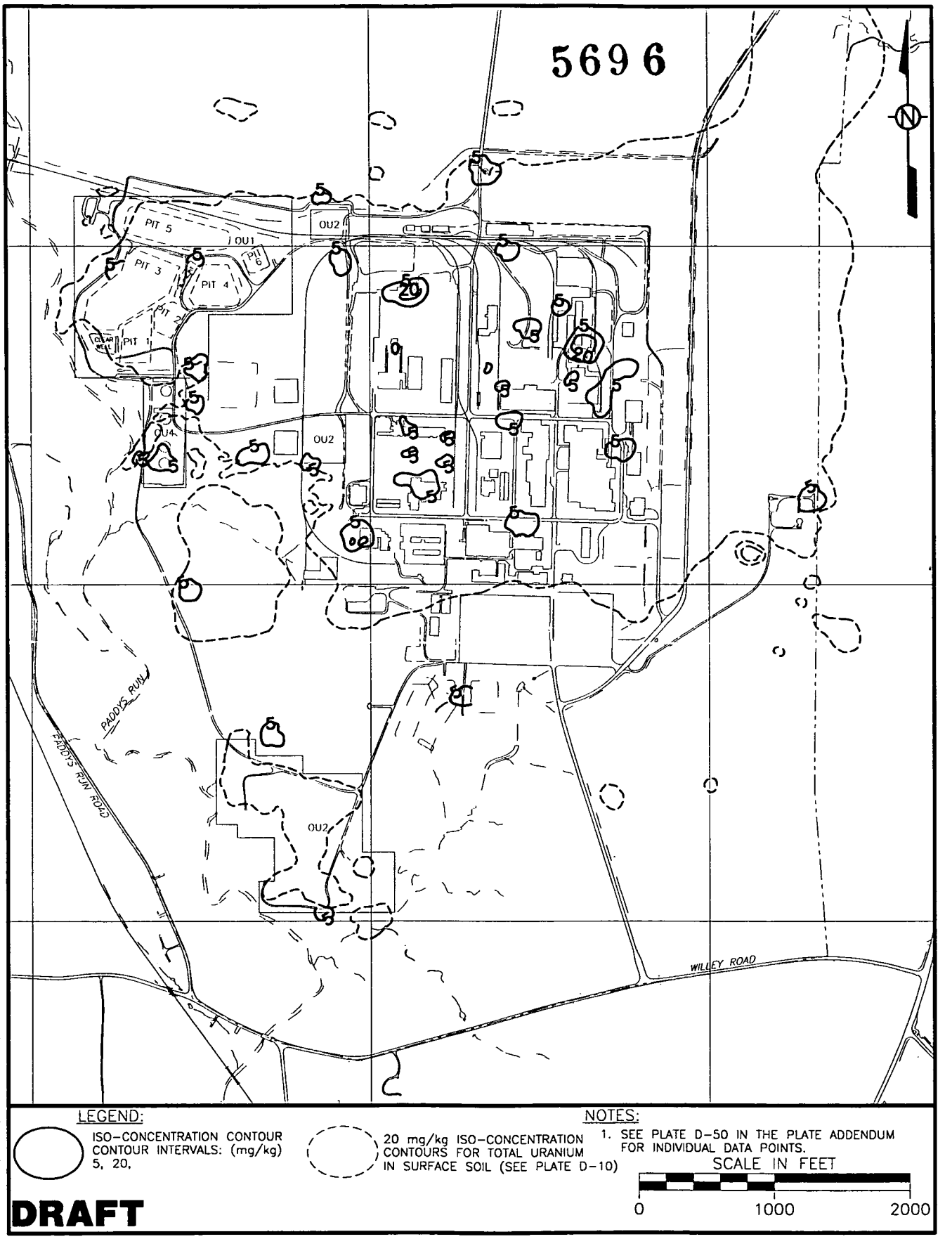


FIGURE 4-39. VALIDATED TOTAL THORIUM, SUBSURFACE SOIL, 1.5-3.0 FEET



ACAD: W:/DATA/CADD/4P94/S110AE.DWG 6/14/94 MB STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-40. TOTAL THORIUM, SUBSURFACE SOIL, 3.0-5.0 FEET

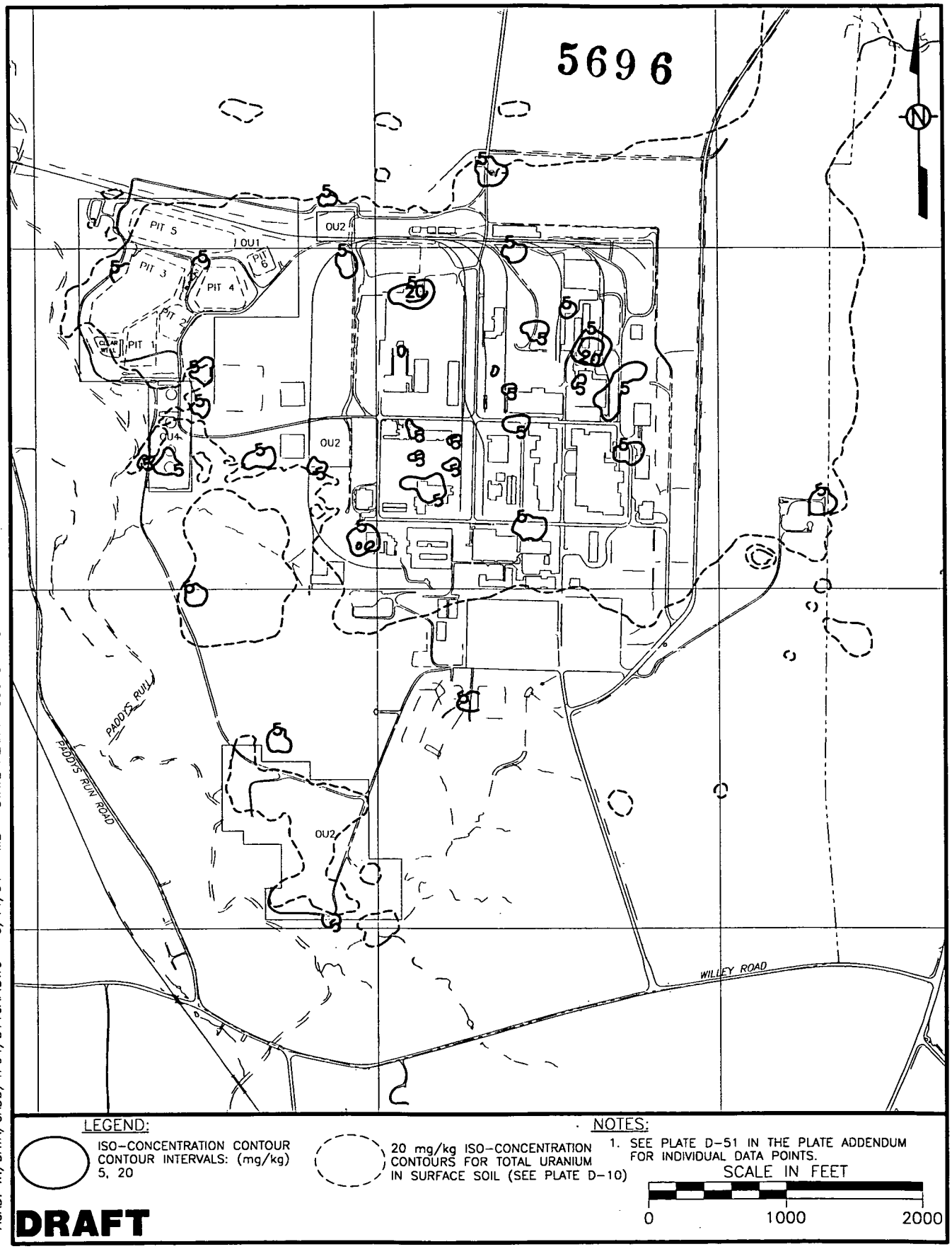


FIGURE 4-41. TOTAL THORIUM, SUBSURFACE SOIL, 5.0-10.0 FEET

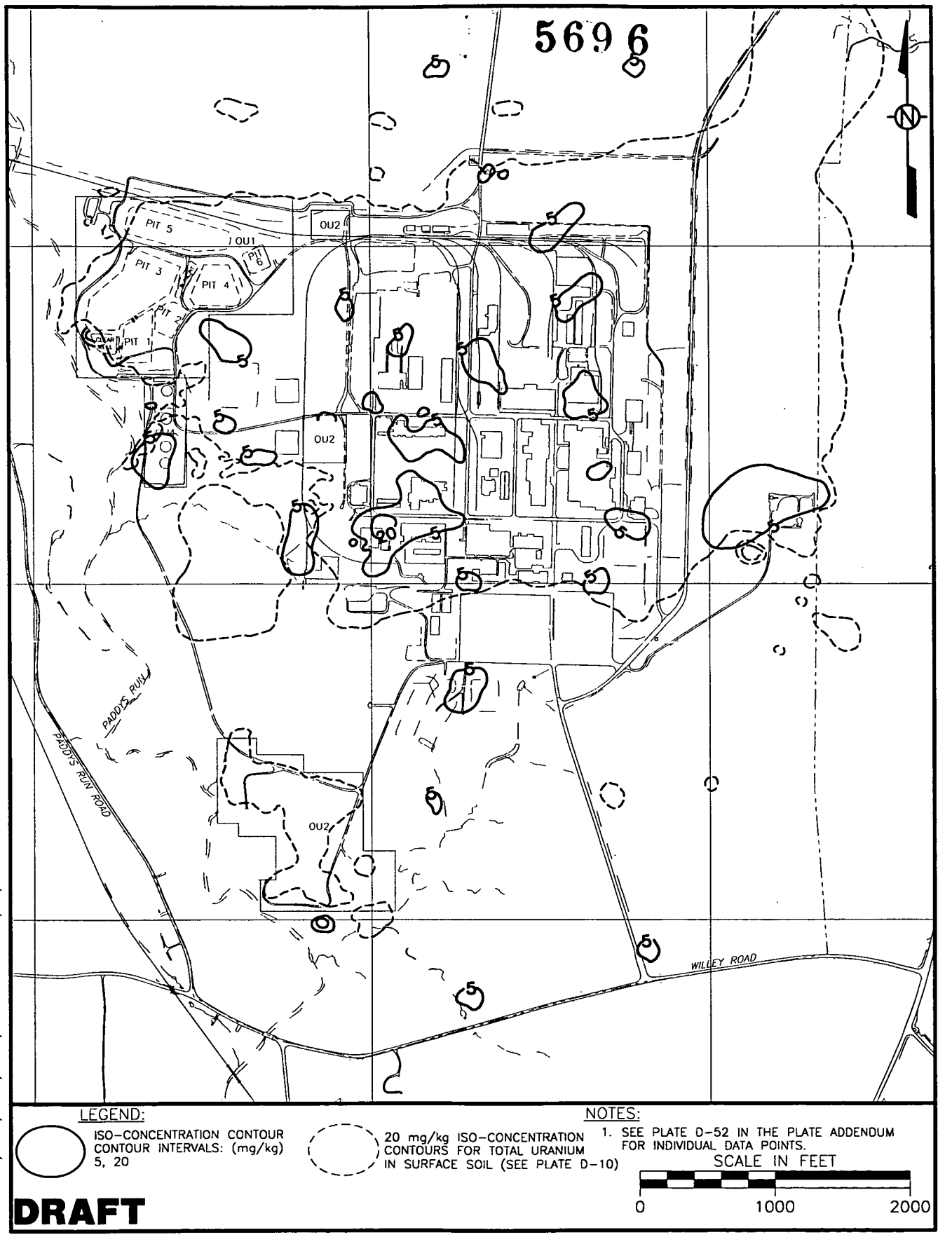
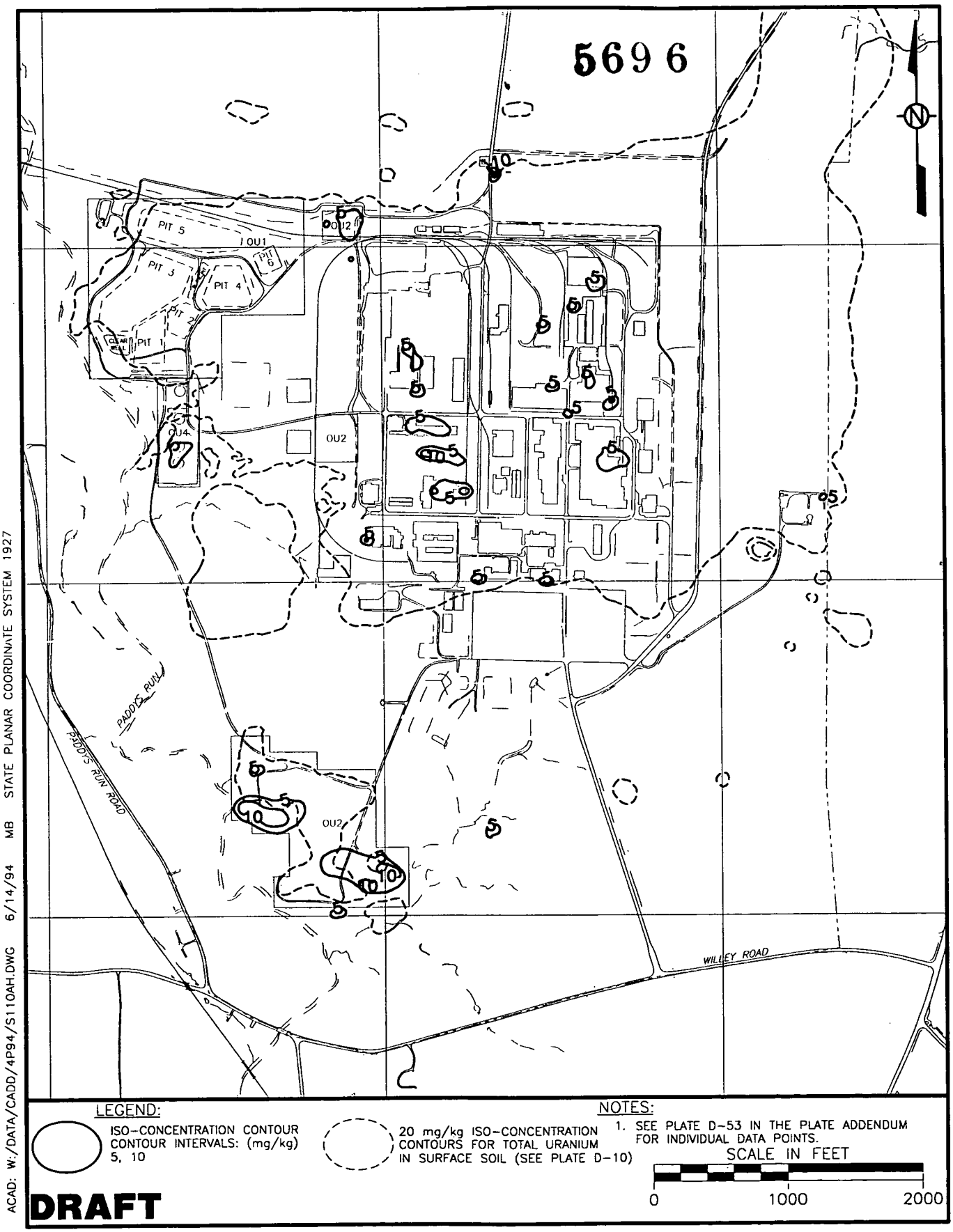
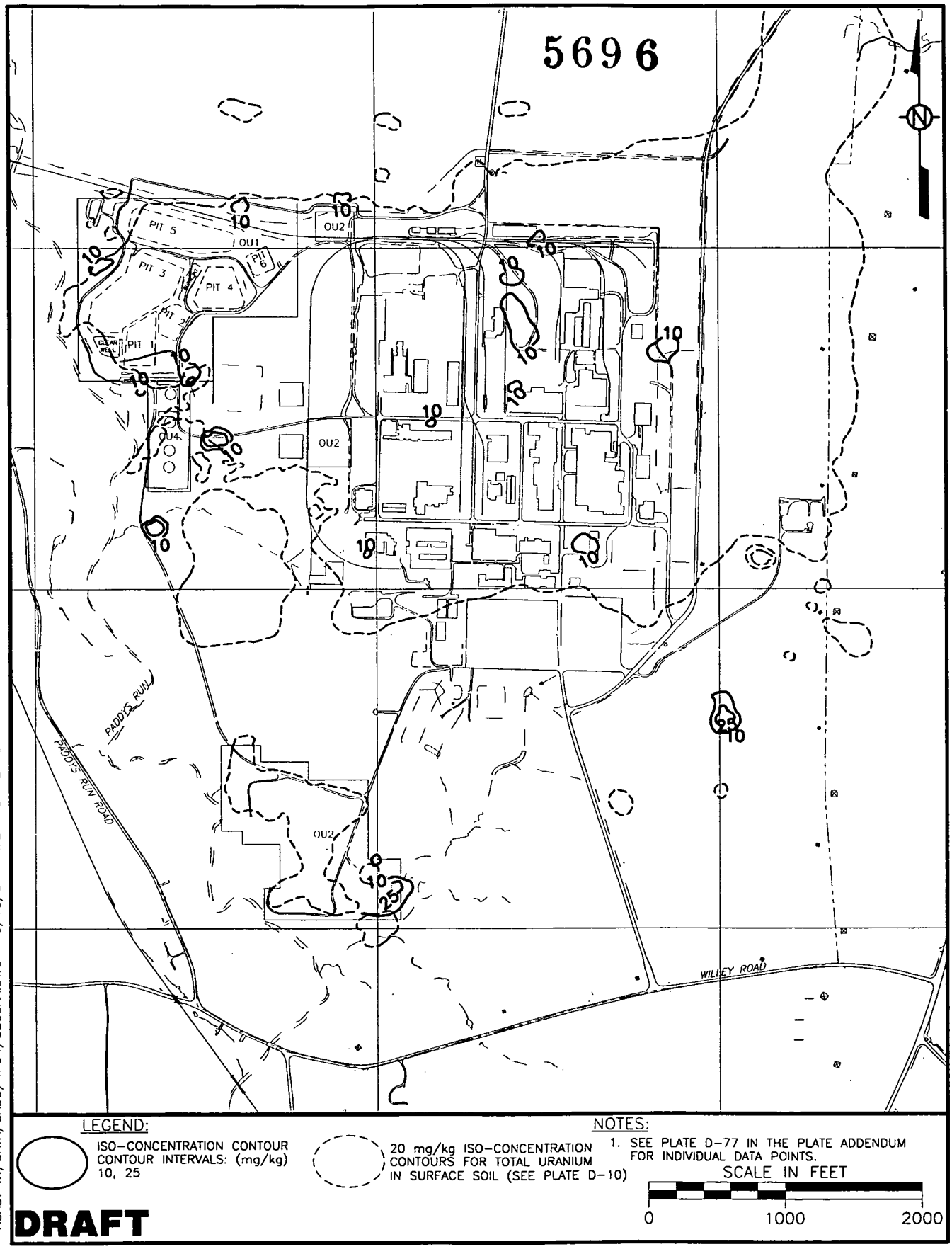


FIGURE 4-42. TOTAL THORIUM, SUBSURFACE SOIL, 10.0-15.0 FEET



ACAD: W:/DATA/CADD/4P94/S110AH.DWG 6/14/94 MB STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-43. TOTAL THORIUM, SUBSURFACE SOIL, 15.0-20.0 FEET



ACAD: W:/DATA/CADD/4P94/S203AA.DWG 6/18/94 MB STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-44. ARSENIC, SURFACE SOIL, 0-0.5 FOOT

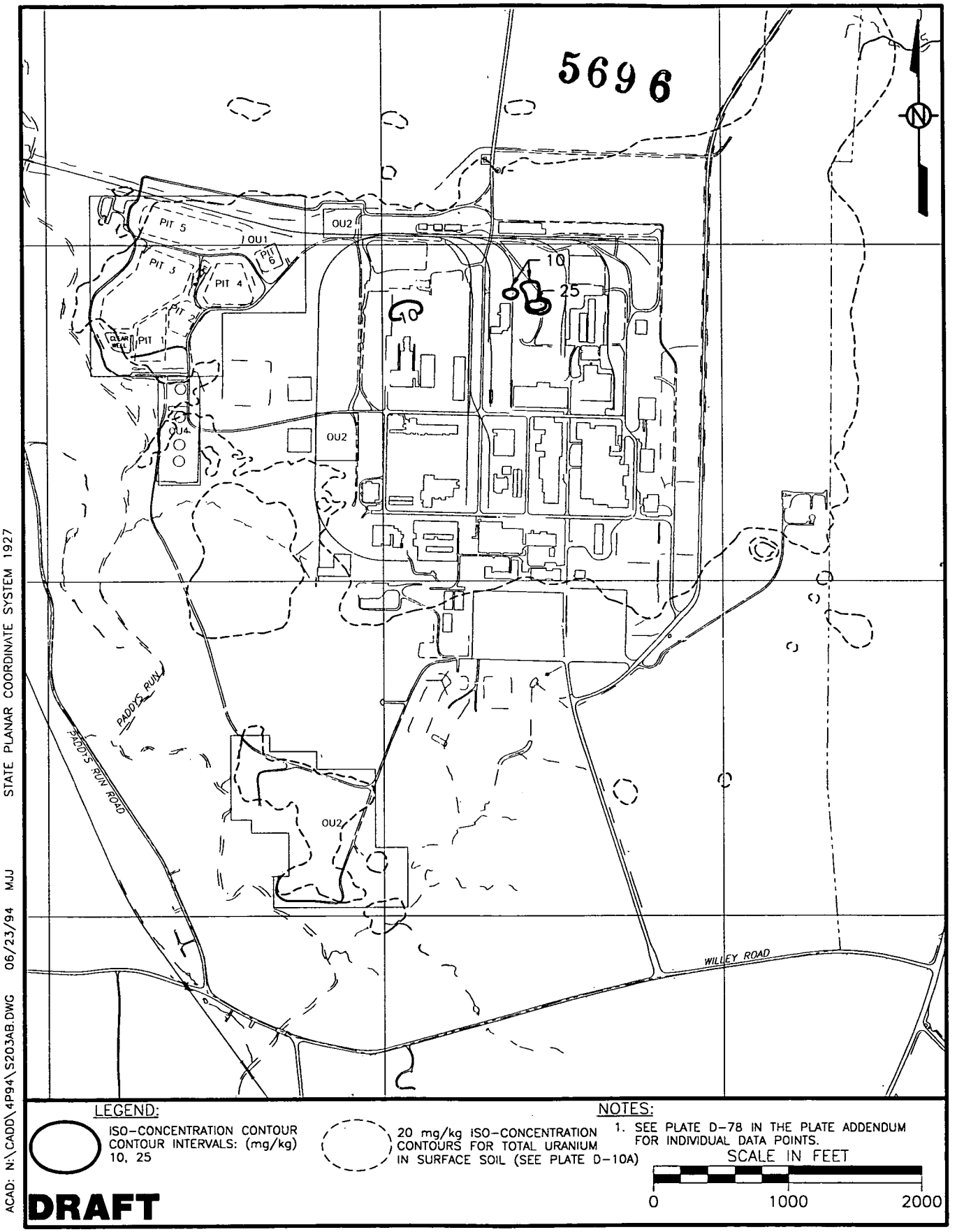


FIGURE 4-45. ARSENIC, SURFACE SOIL, 0.5-1.0 FOOT

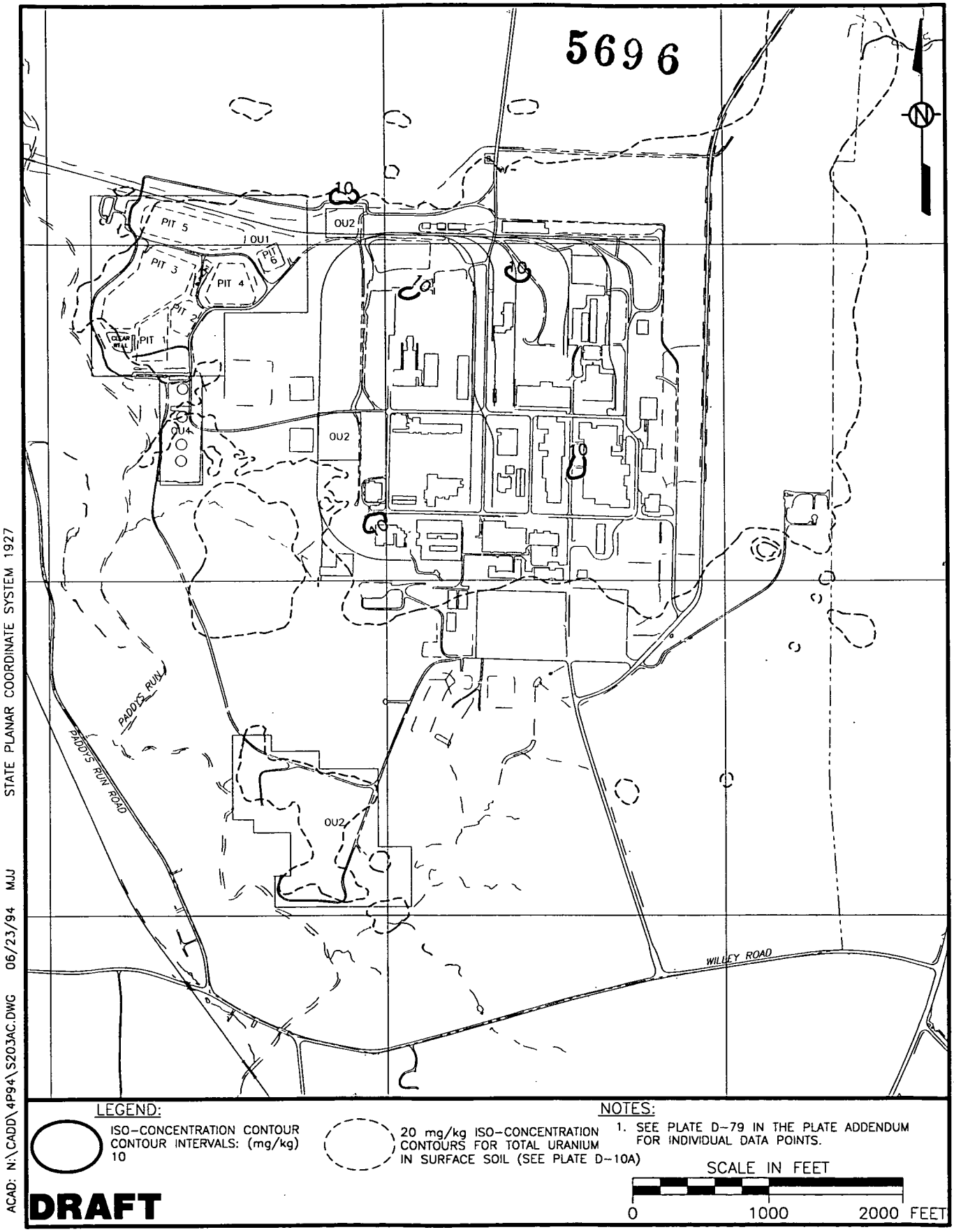
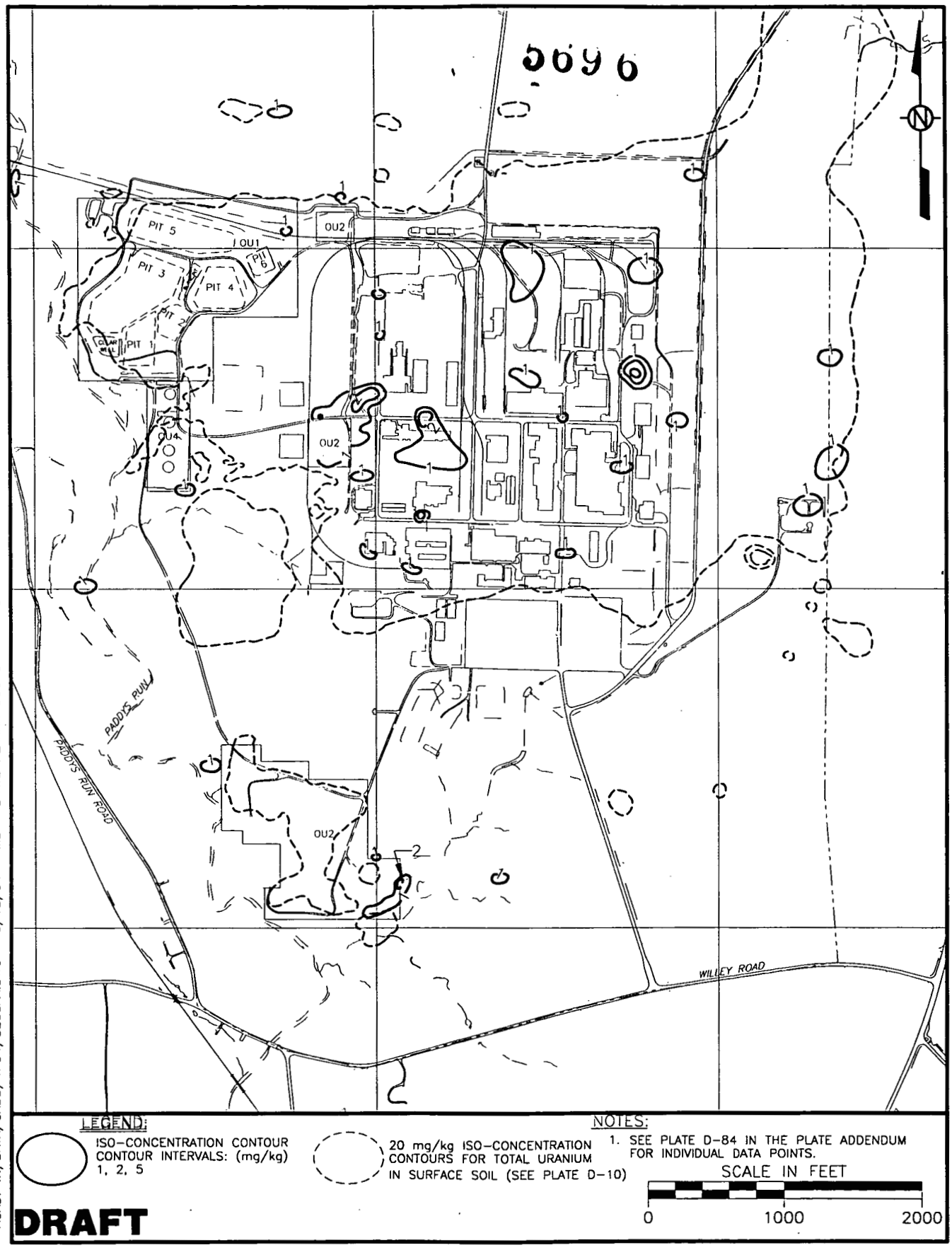


FIGURE 4-46. ARSENIC, SURFACE SOIL, 1.0-1.5 FEET



ACAD: W:/DATA/CADD/4P94/S205AA.DWG 6/18/94 MB STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-47. BERYLLIUM, SURFACE SOIL, 0-0.5 FOOT

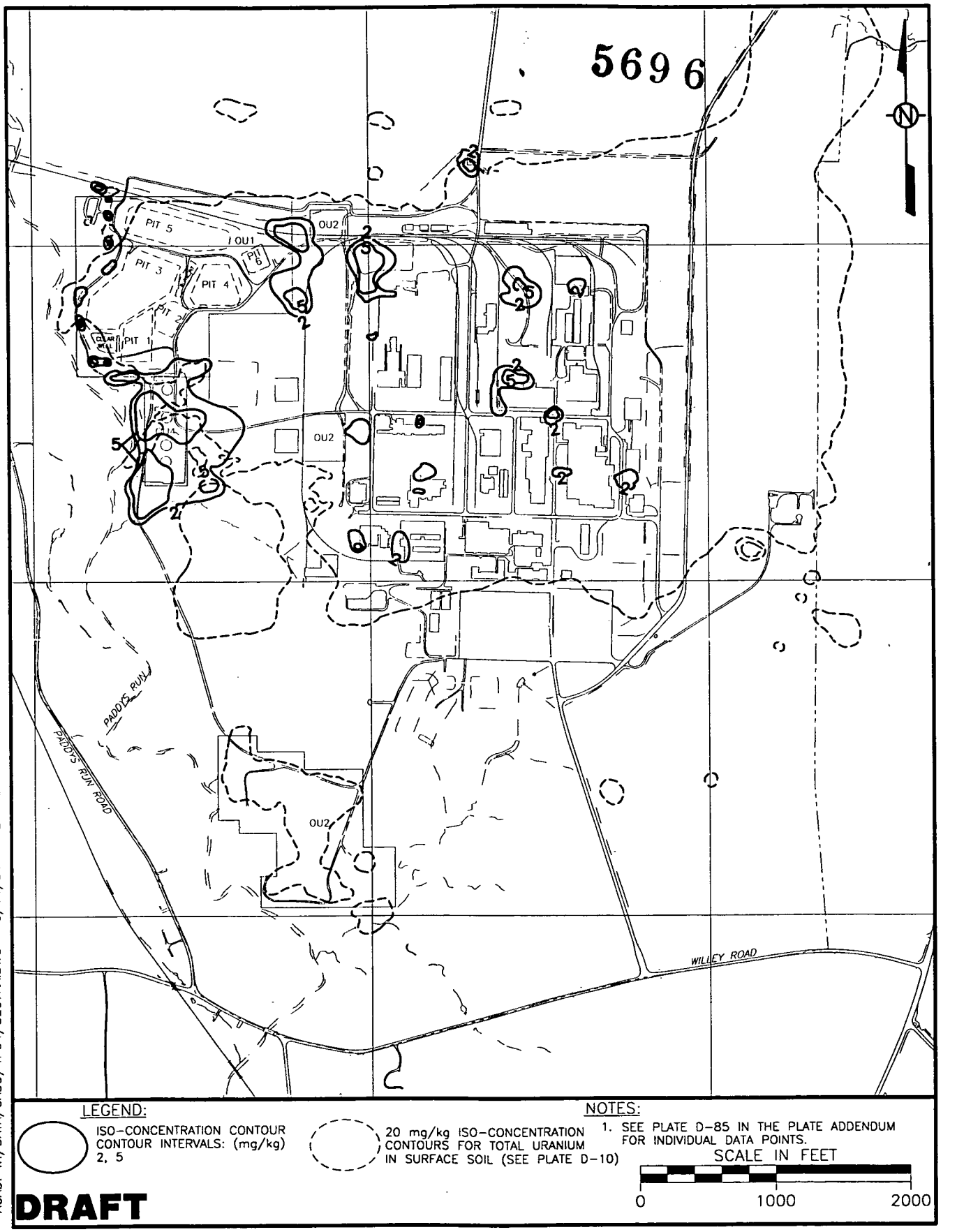
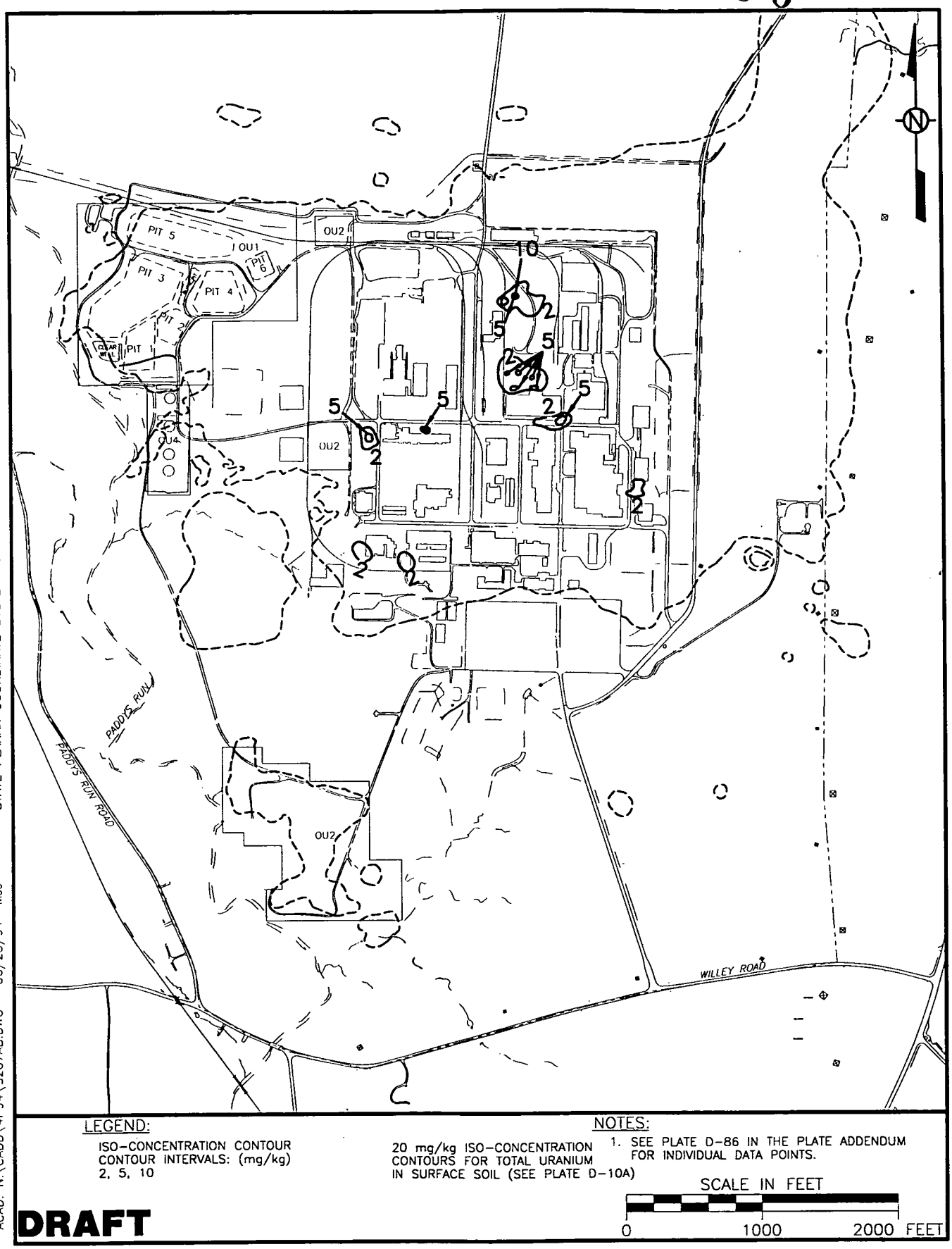


FIGURE 4-49. CADMIUM, SURFACE SOIL, 0-0.5 FOOT



LEGEND:

ISO-CONCENTRATION CONTOUR
CONTOUR INTERVALS: (mg/kg)
2, 5, 10

20 mg/kg ISO-CONCENTRATION CONTOURS FOR TOTAL URANIUM IN SURFACE SOIL (SEE PLATE D-10A)

NOTES:

1. SEE PLATE D-86 IN THE PLATE ADDENDUM FOR INDIVIDUAL DATA POINTS.

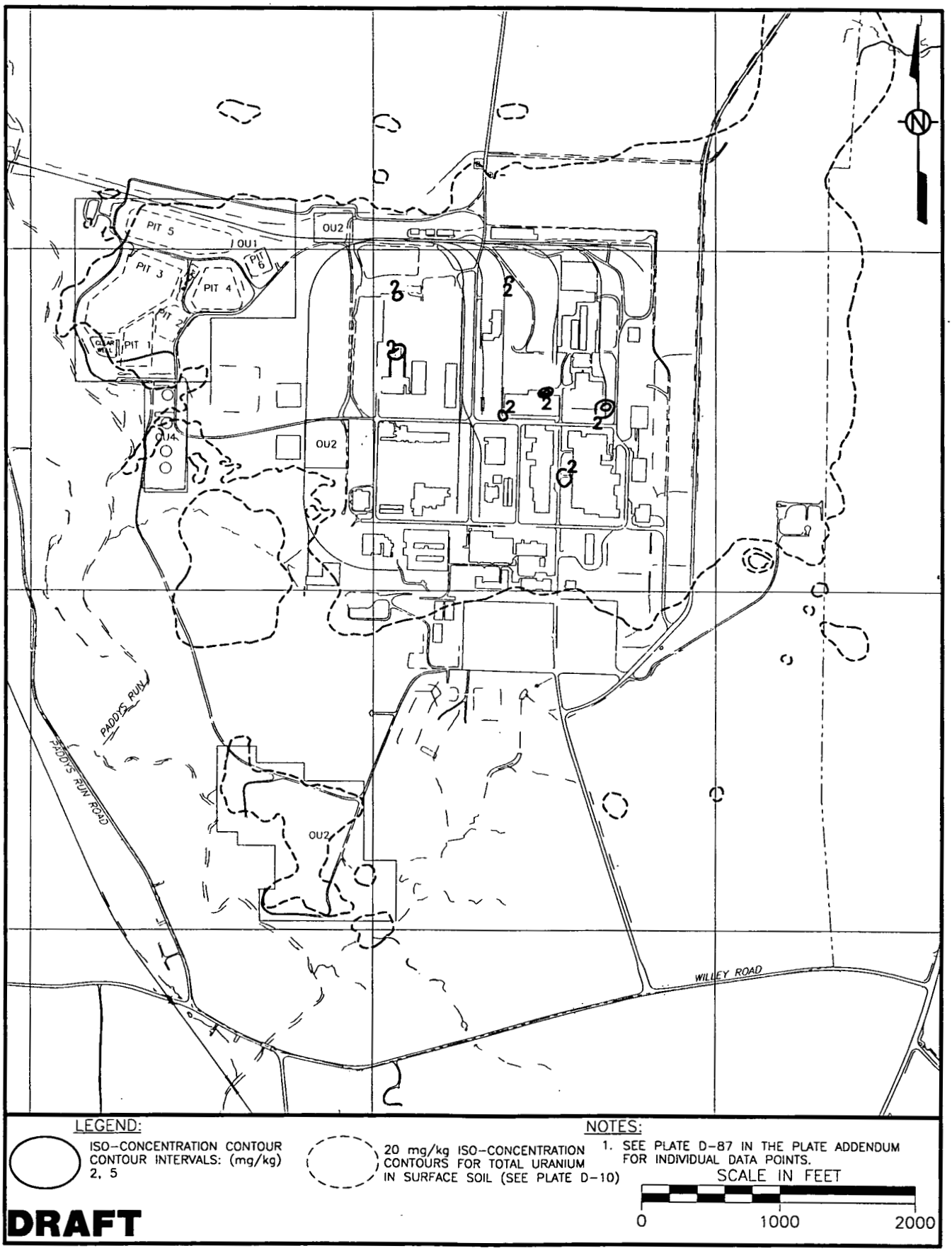
SCALE IN FEET

0 1000 2000 FEET

DRAFT

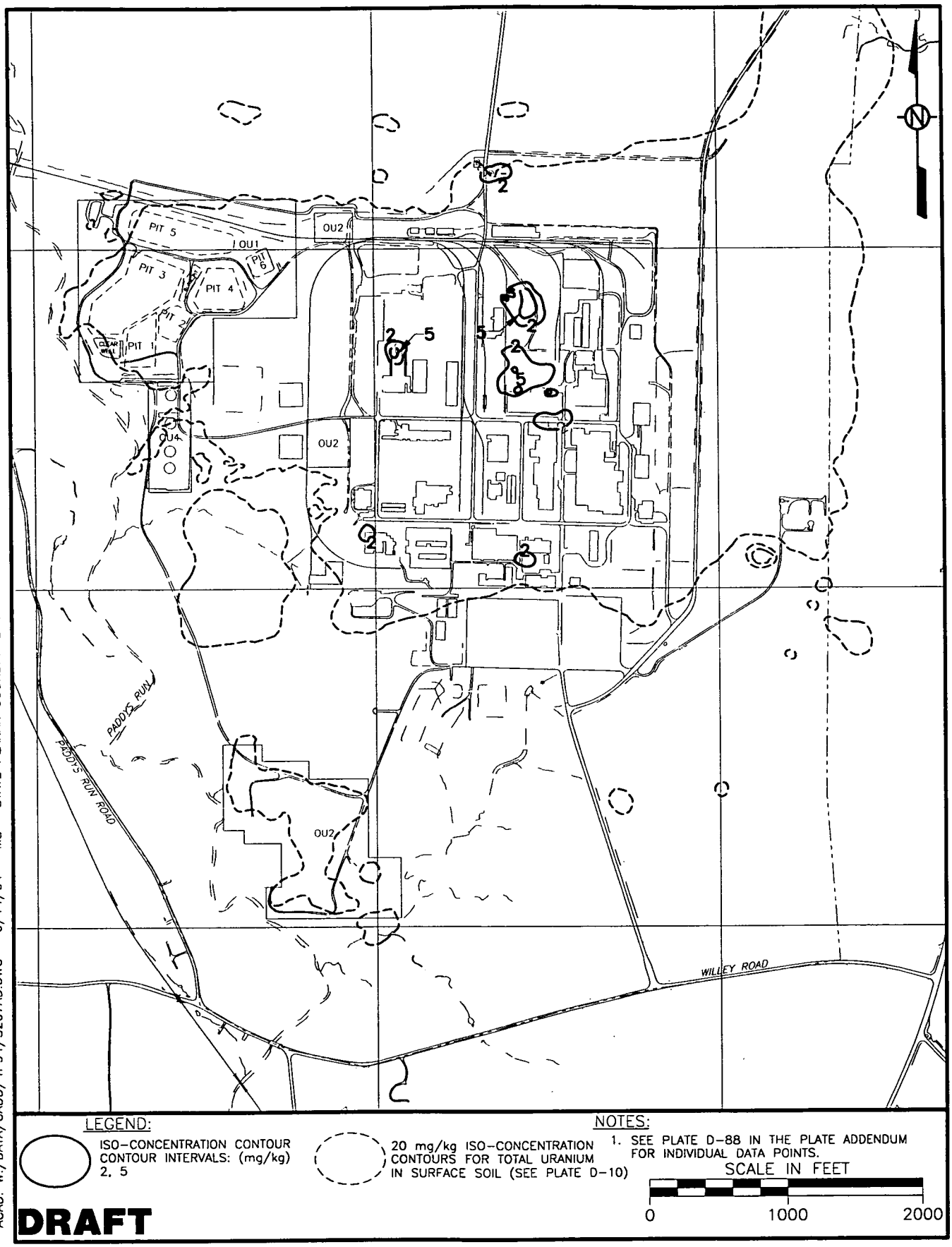
ACAD: N:\CADD\4P94\S207AB.DWG 06/23/94 MJJ STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-50. CADMIUM, SURFACE SOIL, 0.5-1.0 FOOT



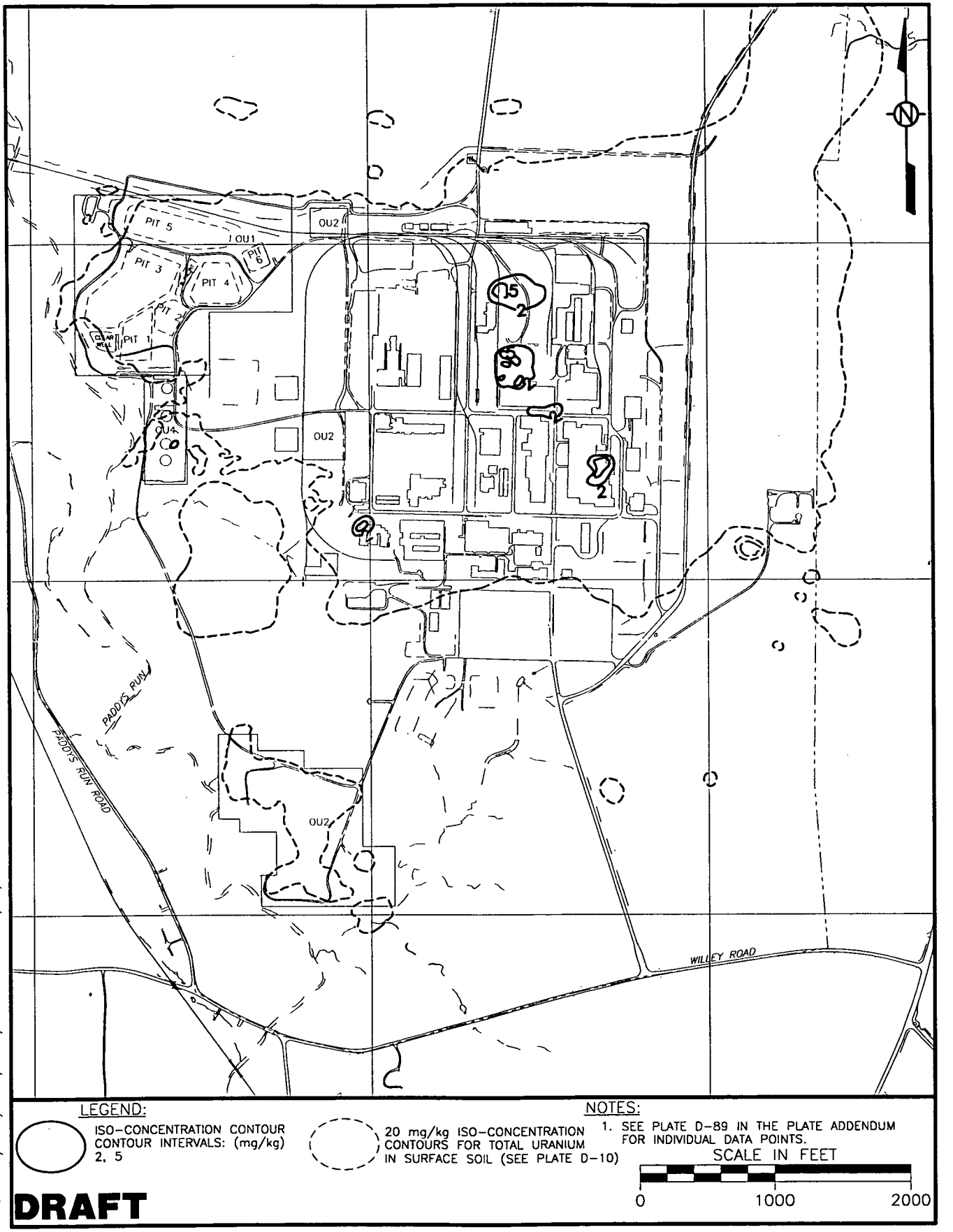
ACAD: W:/DATA/CADD/4P94/S207AC.DWG 6/18/94 MB STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-51. CADMIUM, SURFACE SOIL, 1.0-1.5 FEET



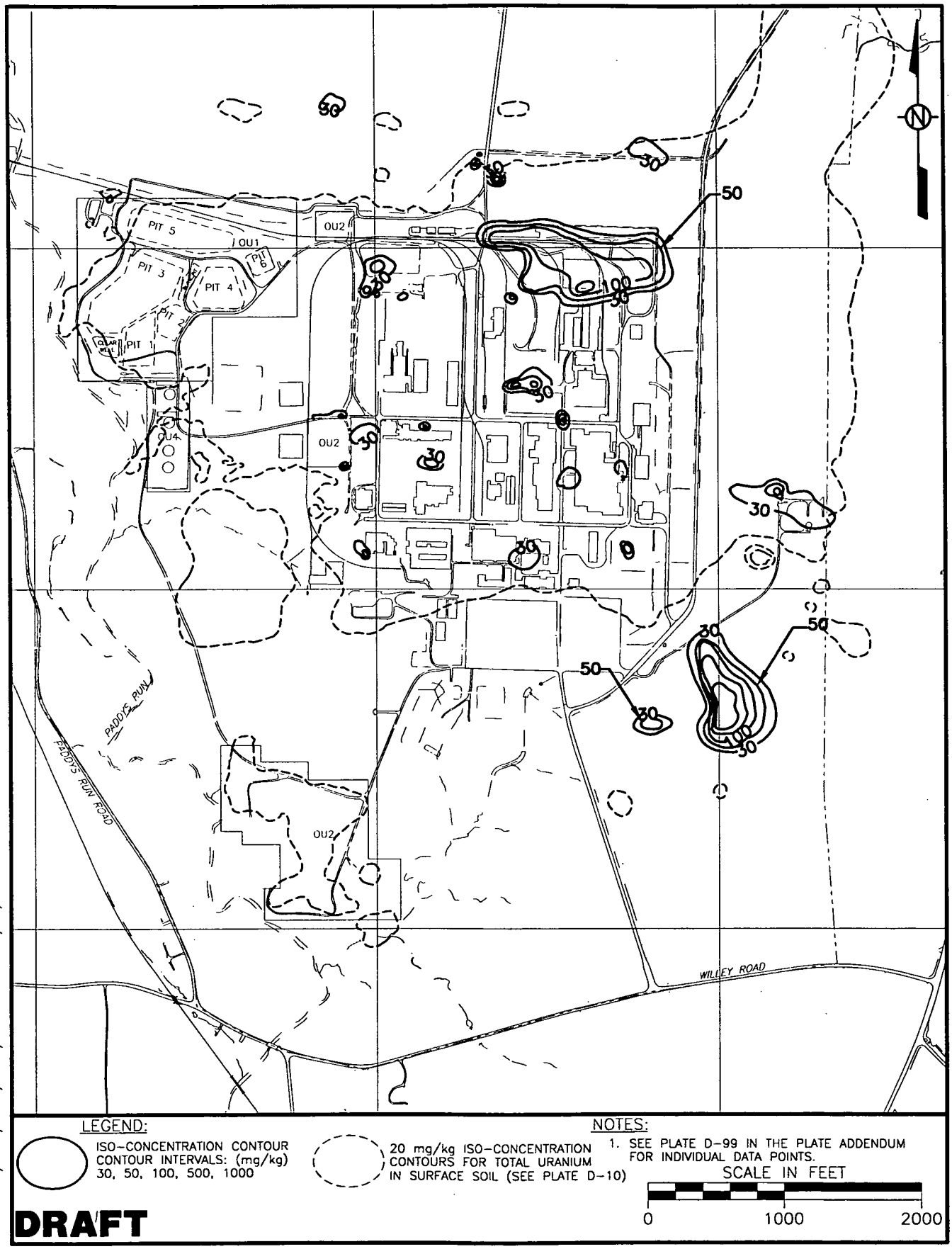
ACAD: W:/DATA/CADD/4P94/S207AD.DWG 6/14/94 MB STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-52. CADMIUM, SUBSURFACE SOIL, 1.5-3.0 FEET



ACAD: W:/DATA/CADD/4P94/S207AE.DWG 6/18/94 MB STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-53. CADMIUM, SUBSURFACE SOIL, 3.0-5.0 FEET



ACAD: W:/DATA/CADD/4P94/S215A.DWG 6/18/94 MB STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-54. LEAD, SURFACE SOIL, 0-0.5 FOOT

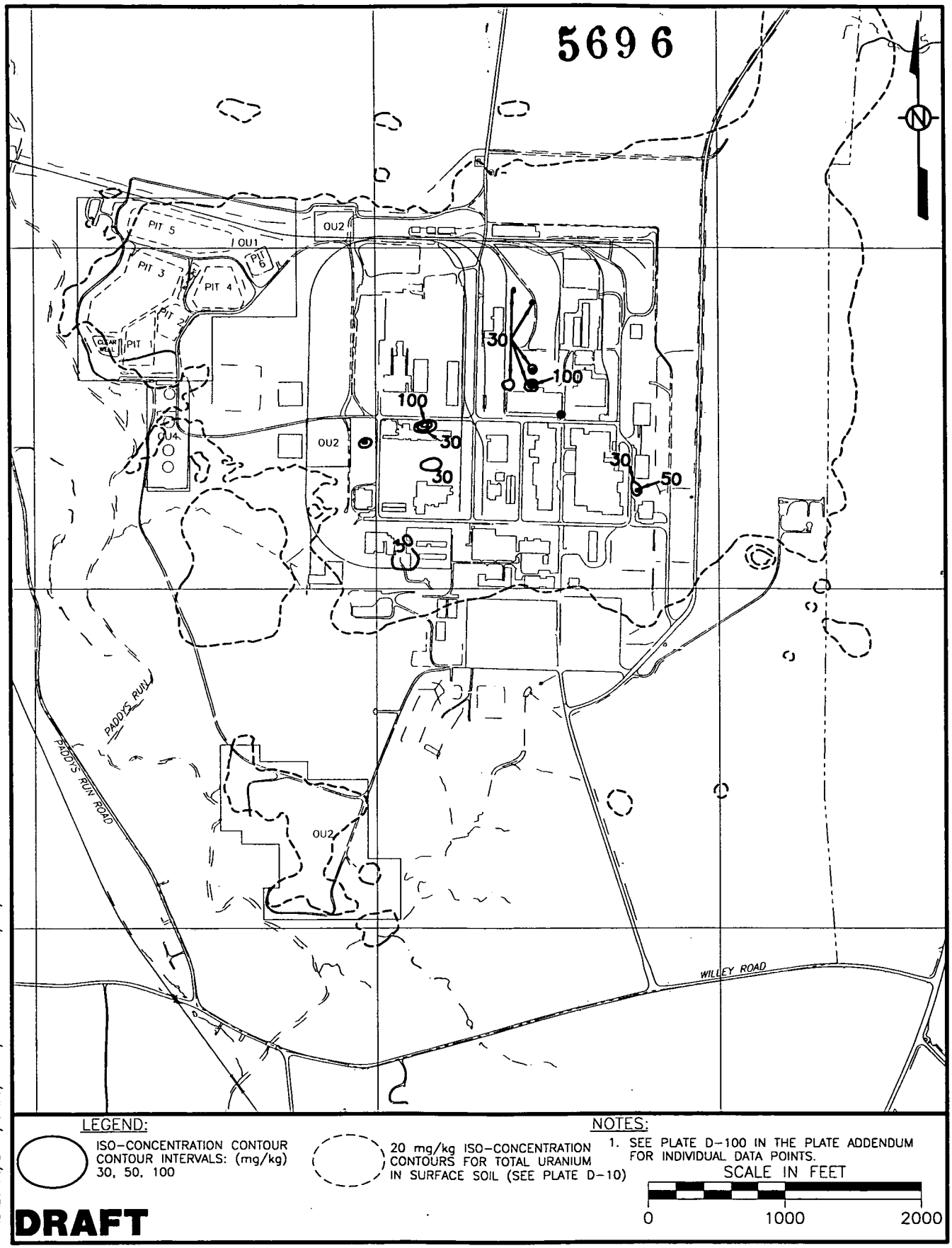
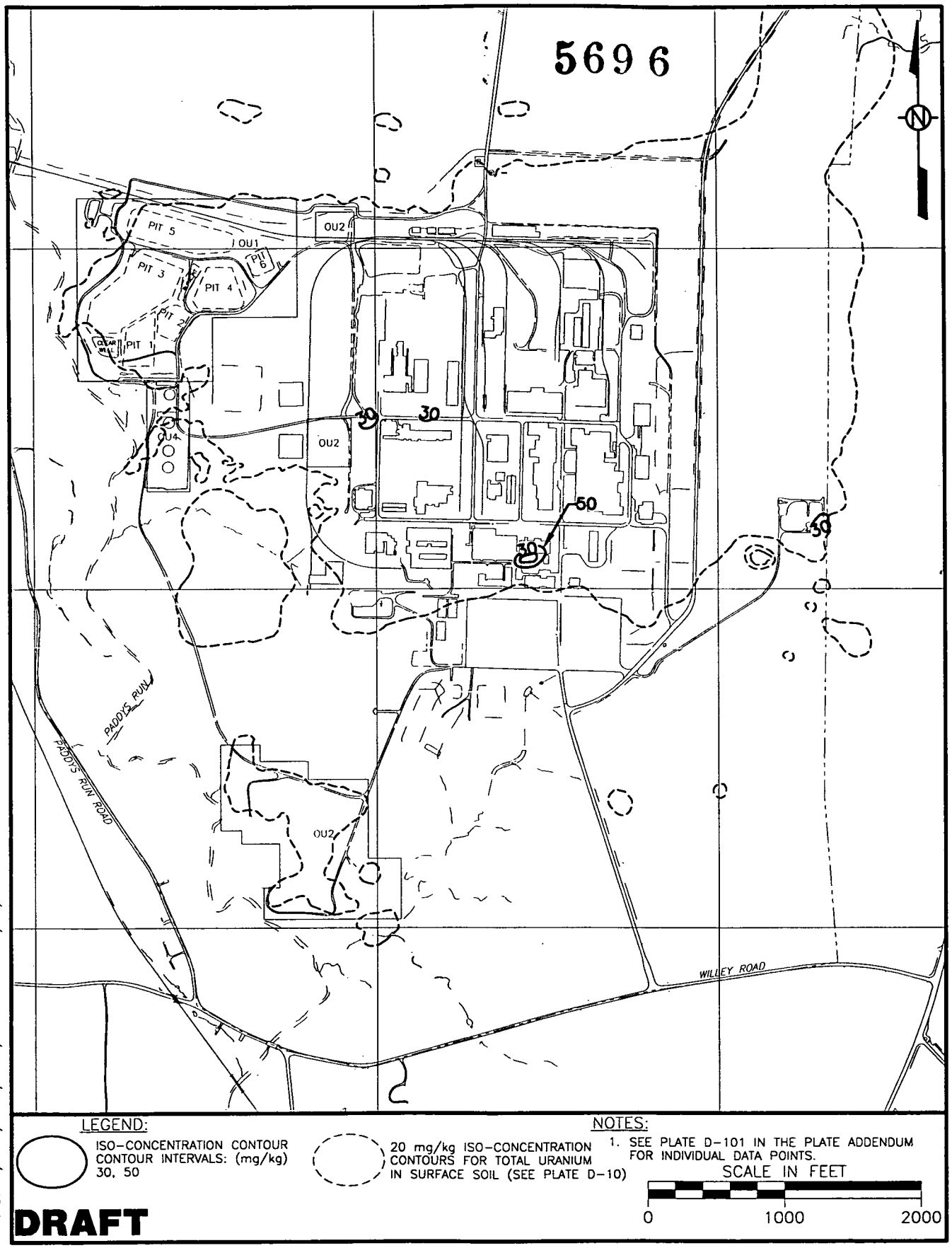
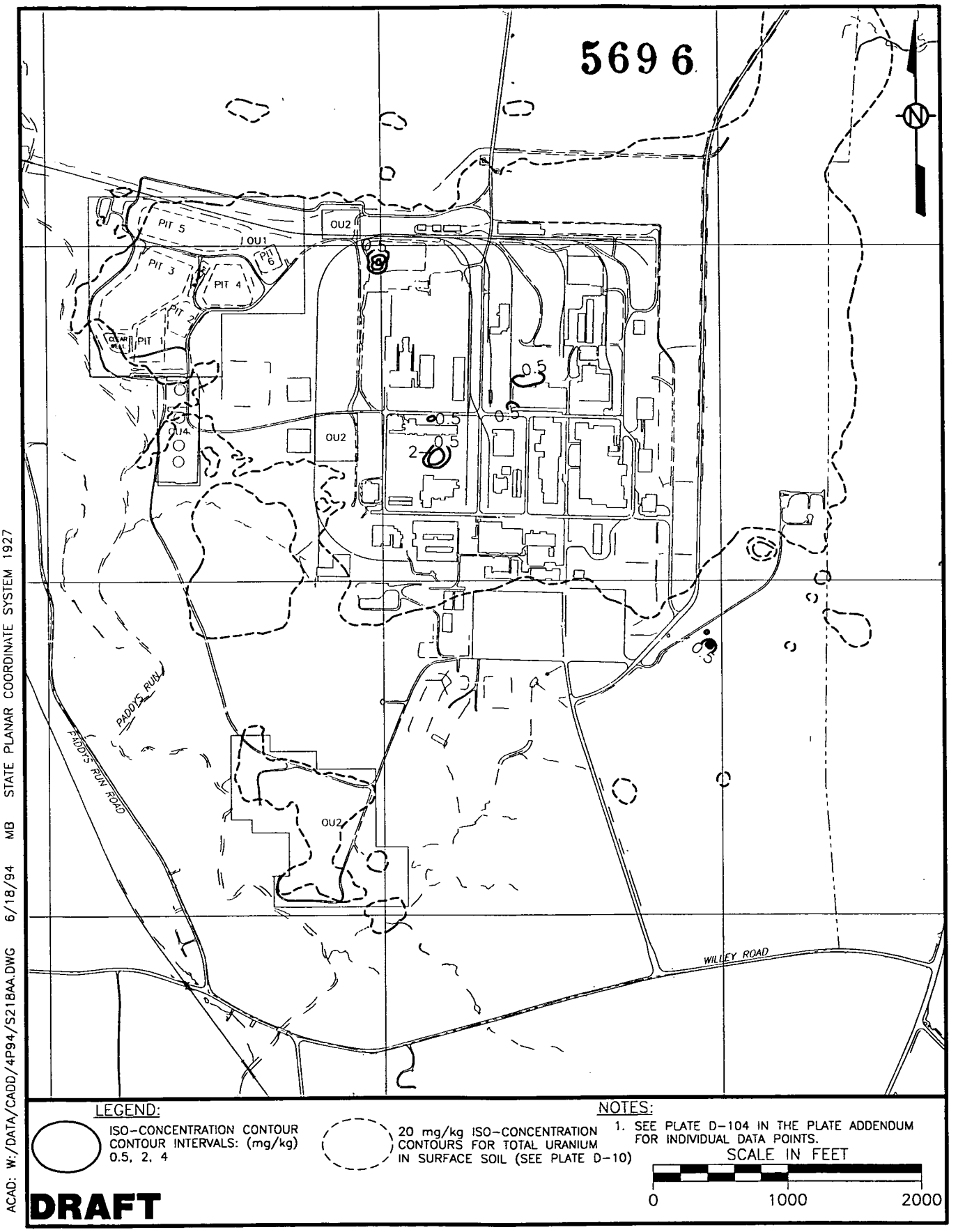


FIGURE 4-55. LEAD, SURFACE SOIL, 0.5-1.0 FOOT



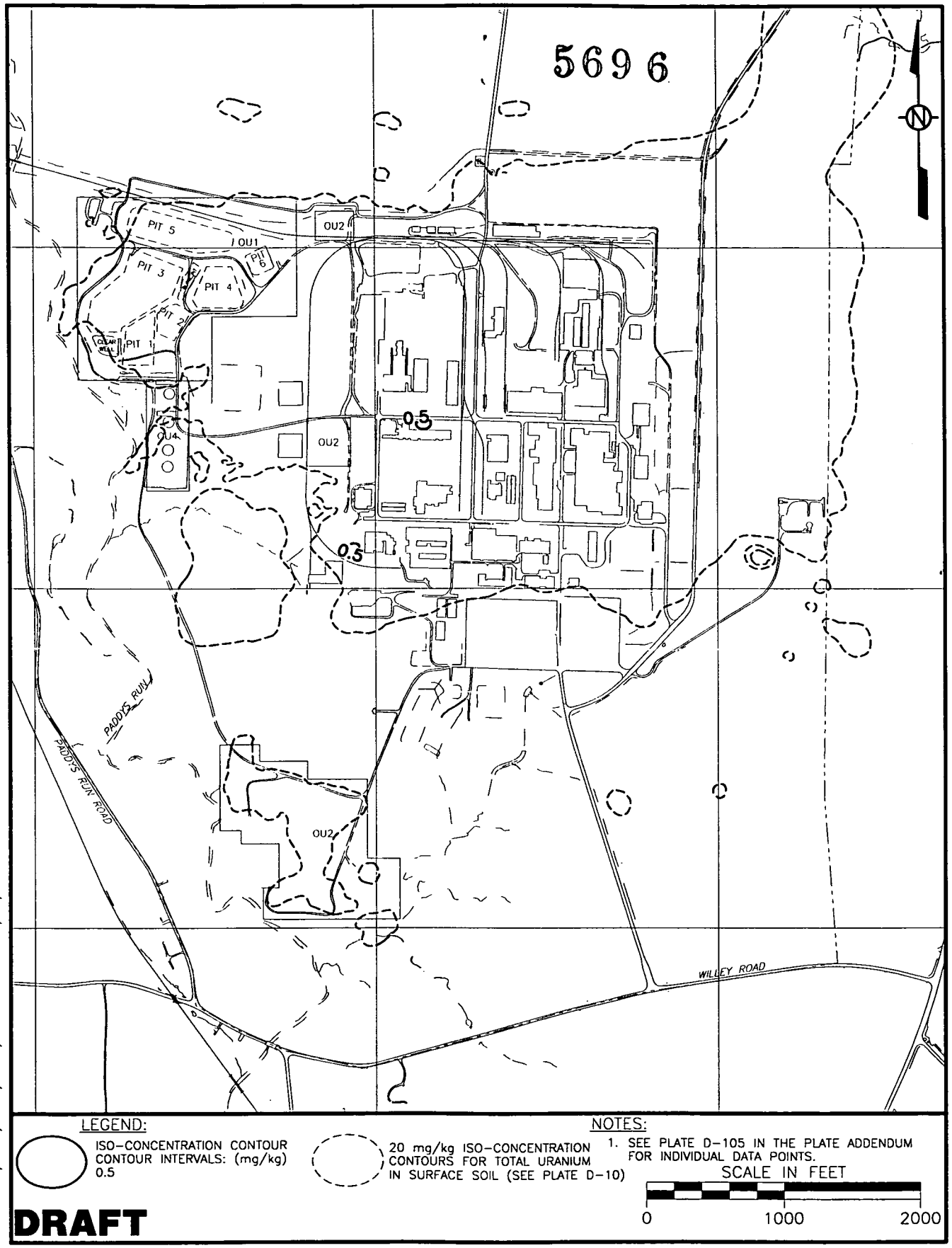
ACAD: W:/DATA/CADD/4P94/S215C.DWG 6/18/94 MB STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-56. LEAD, SURFACE SOIL, 1.0-1.5 FEET



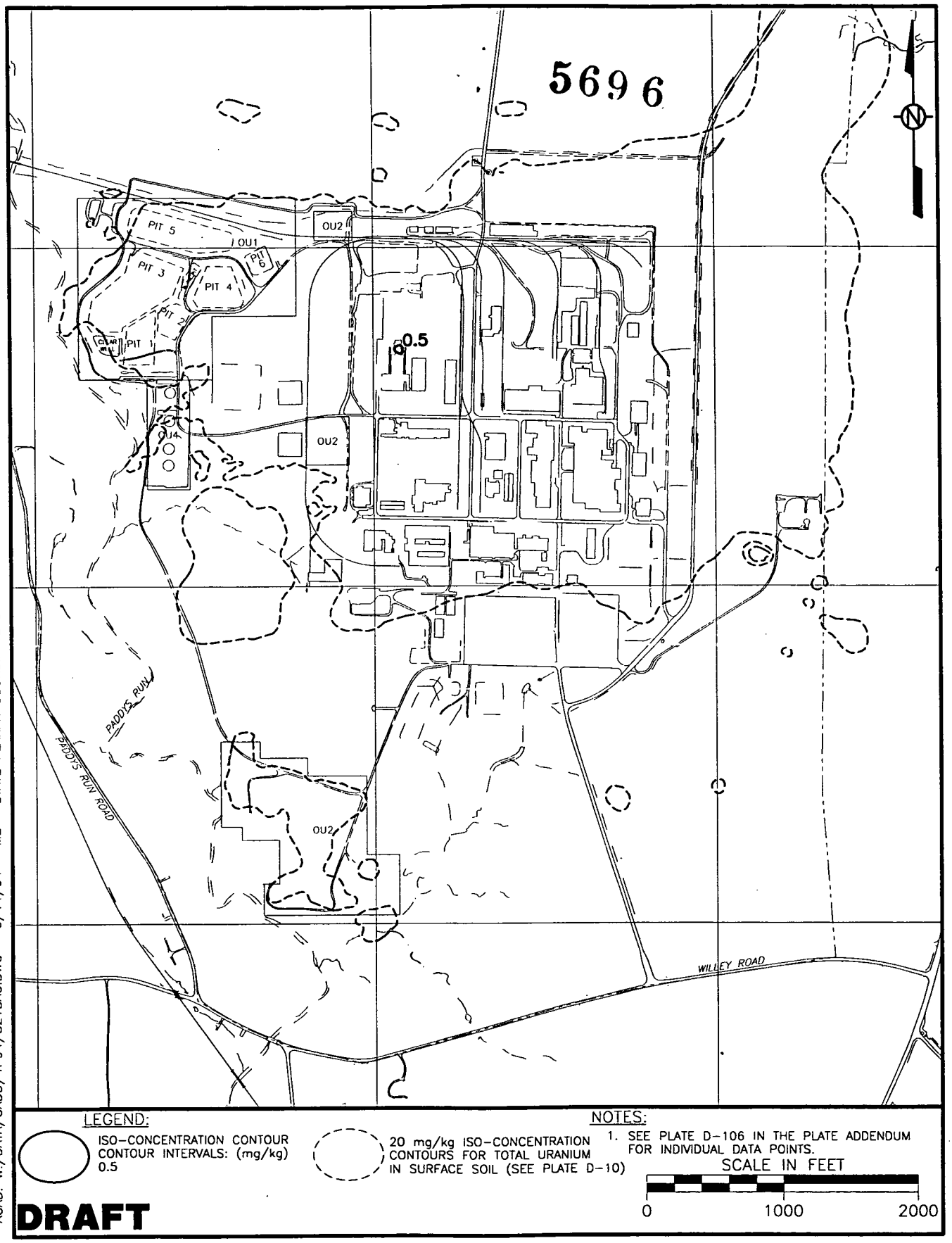
ACAD: W:/DATA/CADD/4P94/S21BAA.DWG 6/18/94 MB STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-57. MERCURY, SURFACE SOIL, 0-0.5 FOOT



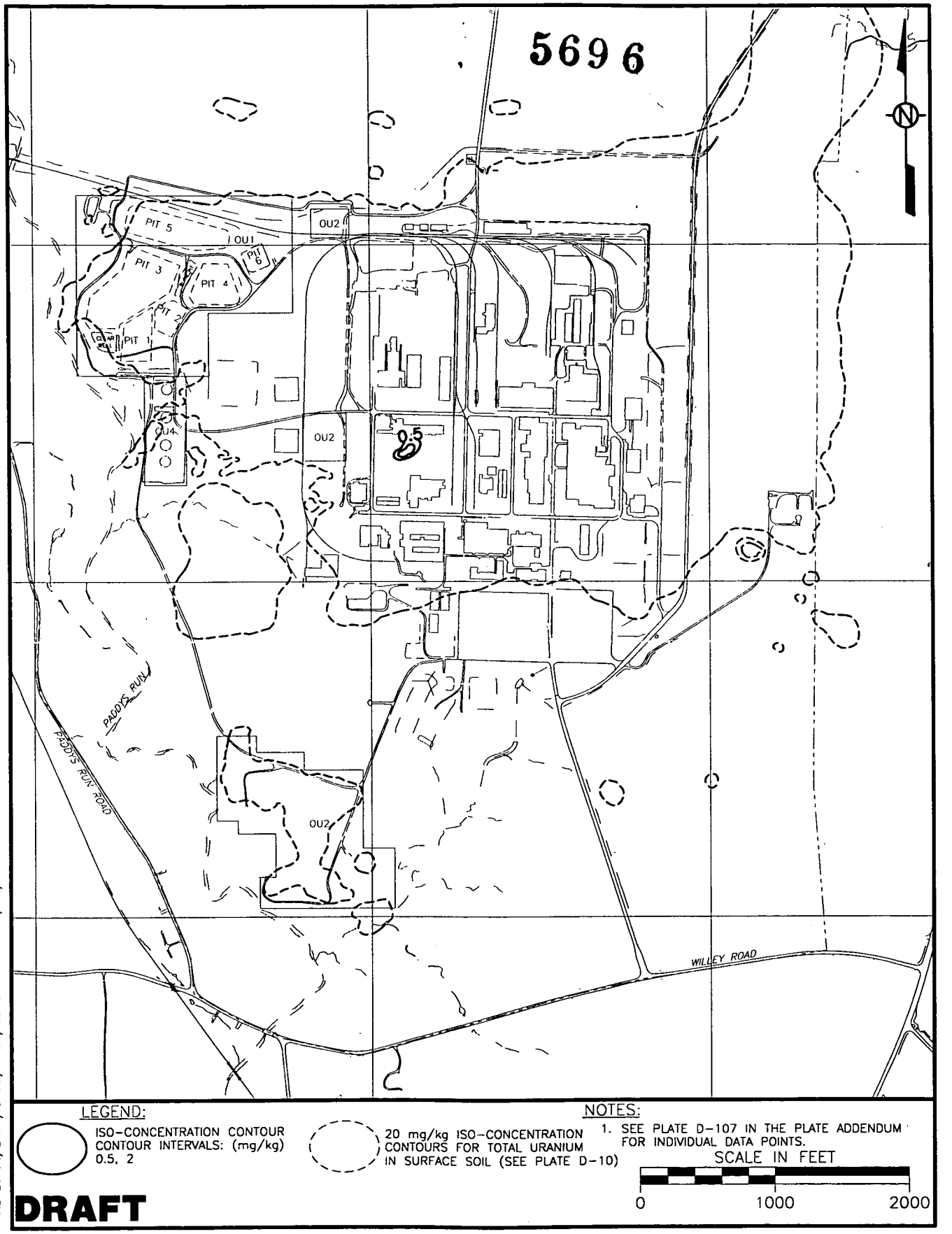
ACAD: W:/DATA/CADD/4P94/S218AB.DWG 6/18/94 MB STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-58. MERCURY, SURFACE SOIL, 0.5-1.0 FOOT



ACAD: W:/DATA/CADD/4P94/S218AC.DWG 6/14/94 MB STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-59. MERCURY, SURFACE SOIL, 1.0-1.5 FEET



ACAD: W:/DATA/CADD/4P94/S218AD.DWG 6/18/94 MB STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-60. MERCURY, SUBSURFACE SOIL, 1.5-3.0 FEET

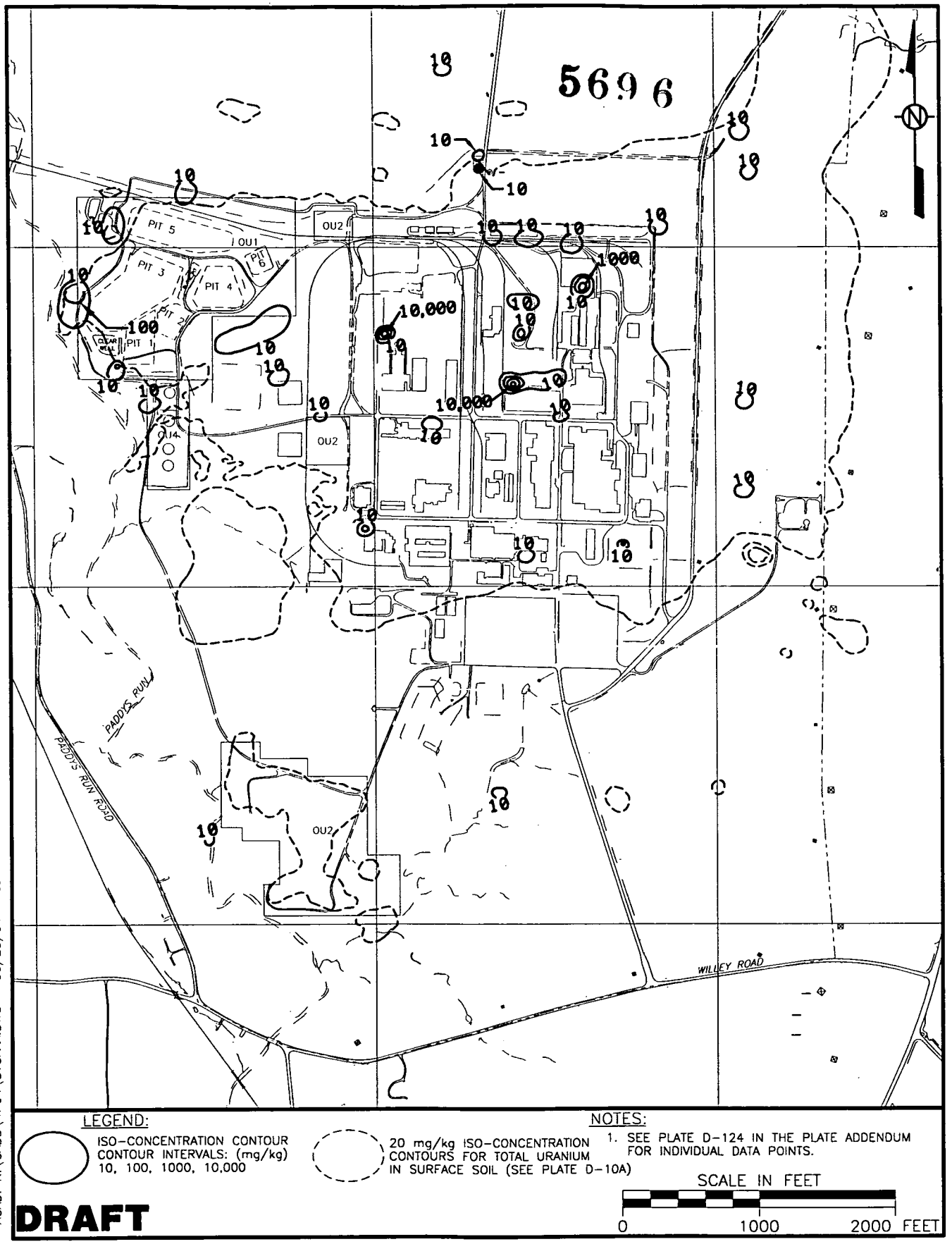


FIGURE 4-61. VOAs, SURFACE SOIL, 0-0.5 FOOT

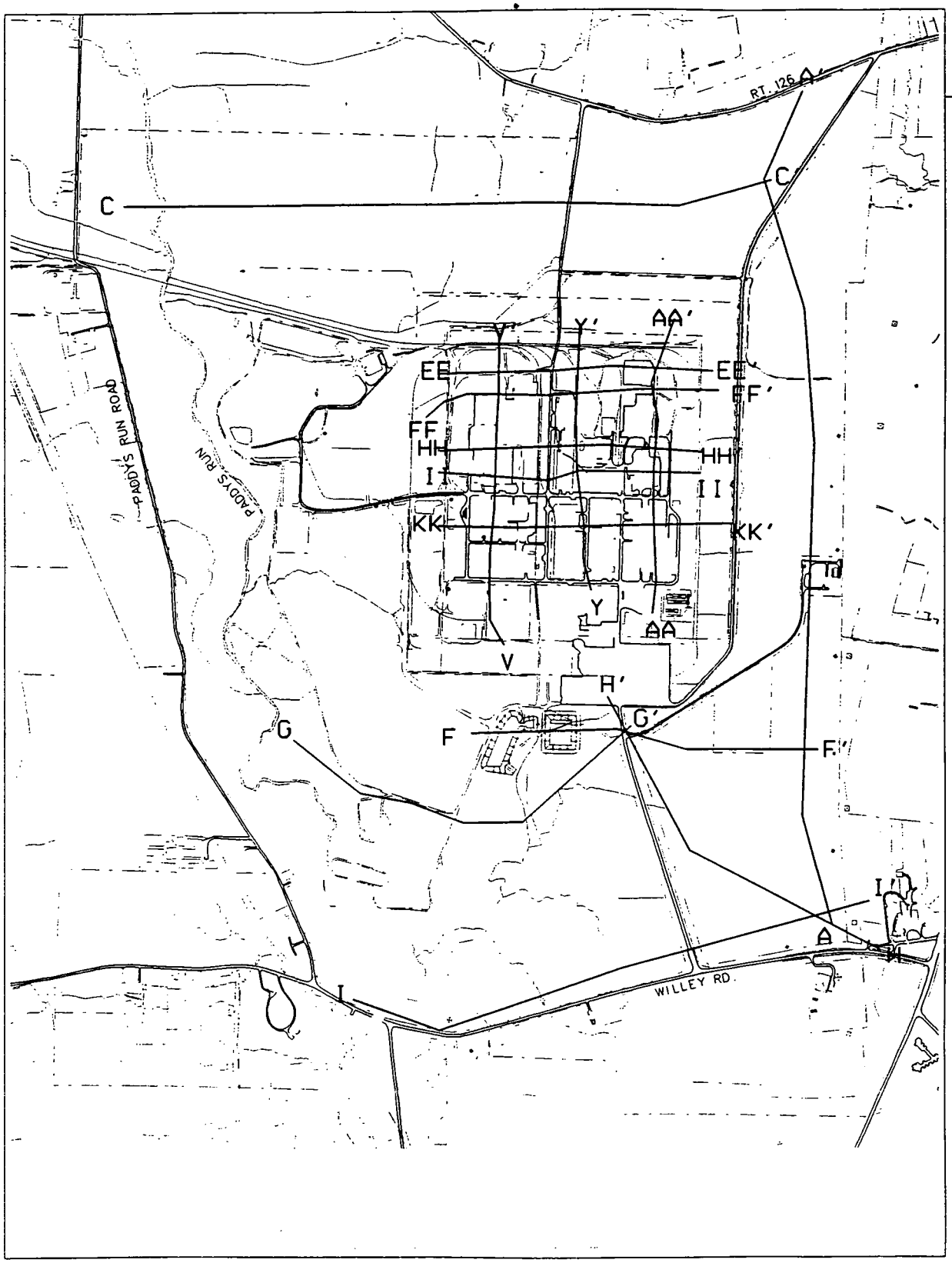
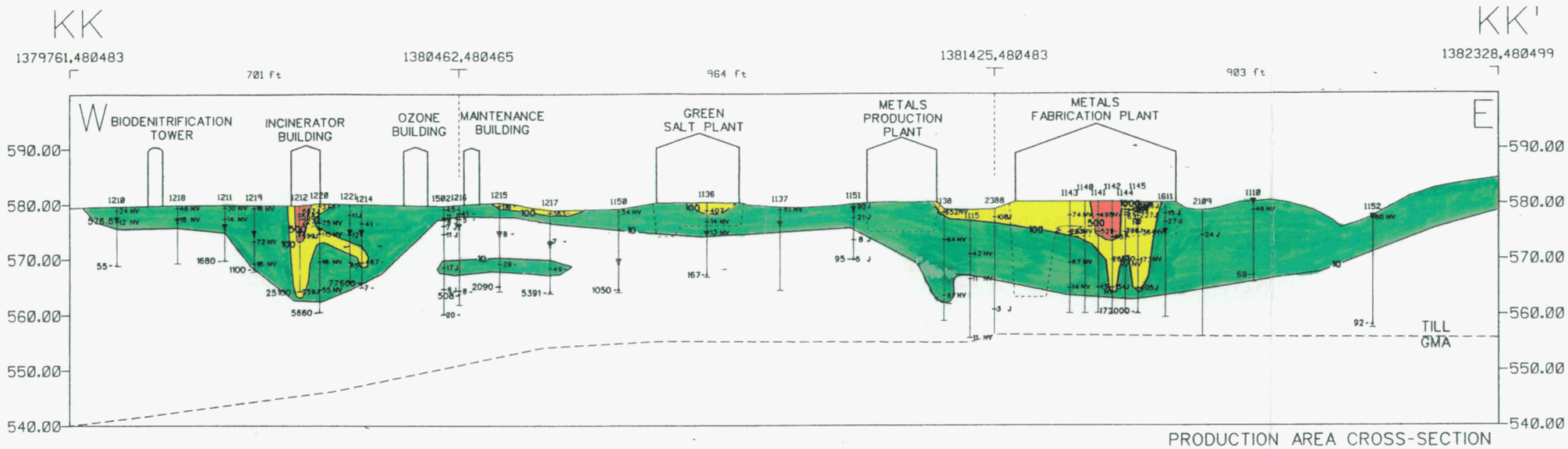


Figure 4-62 Locations Of Cross Sections Depicting Total Uranium In Soil

SCALE

1300 650 0 1300FEET

DRAFT



PRODUCTION AREA CROSS-SECTION

LEGEND:

- ⊥ 27.1 — MAXIMUM TOTAL URANIUM IN WATER (ug/L)
- ┼ 77.1 — MAXIMUM TOTAL URANIUM IN SOIL (mg/kg)
- —— 10 —— TOTAL URANIUM ISOPLETH FOR SOILS (PPM)
- — — — — TILL / GREAT MIAMI AQUIFER (GMA) BOUNDARY
- 1771 — MONITORING WELL NUMBER / BORING NUMBER
- ▼ — MAXIMUM WATER ELEVATION

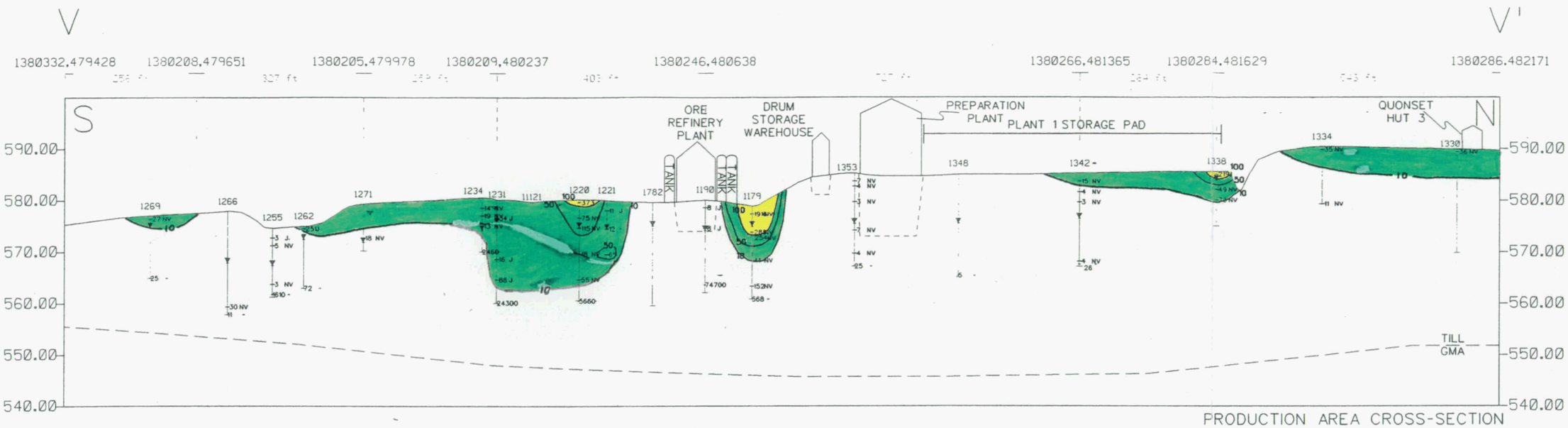
TOTAL URANIUM CONCENTRATION, mg/kg

- GREATER THAN 10,000
- 1000 TO 10,000
- 500 TO 1000
- 100 TO 500
- 10 TO 100

DRAFT

/USR/ERMA/:RIB5/DGN/SEC/GEO/DPTH/

Figure 4-63
TOTAL URANIUM IN GLACIAL OVERBURDEN



PRODUCTION AREA CROSS-SECTION

LEGEND:

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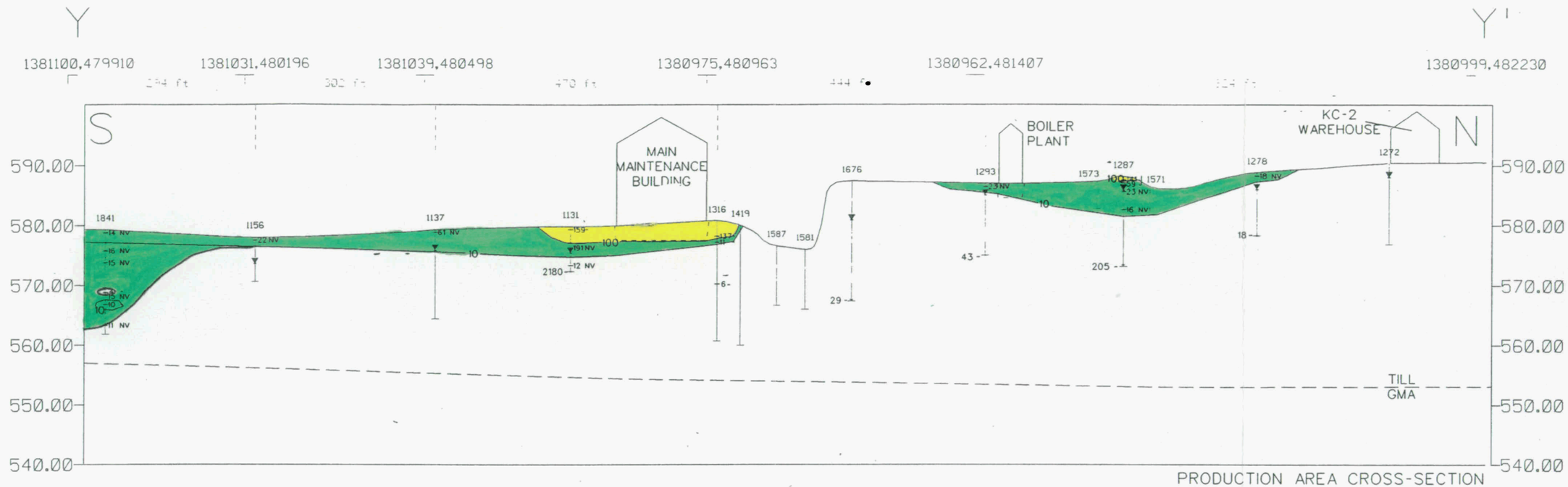
- 77.1 — MAXIMUM TOTAL URANIUM IN SOIL (mg/kg)
- 10 — TOTAL URANIUM ISOPLETH FOR SOILS (PPM)
- TILL / GREAT MIAMI AQUIFER (GMA) BOUNDARY
- 1771 — MONITORING WELL NUMBER / BORING NUMBER
- MAXIMUM WATER ELEVATION

TOTAL URANIUM CONCENTRATION, mg/kg

- GREATER THAN 10,000
- 1000 TO 10,000
- 500 TO 1000
- 100 TO 500
- 10 TO 100

DRAFT

Figure 4-64
TOTAL URANIUM IN GLACIAL OVERBURDEN



LEGEND:

- 27.1 — MAXIMUM TOTAL URANIUM IN WATER (ug/L)
- 77.1 — MAXIMUM TOTAL URANIUM IN SOIL (mg/kg)
- 10 — TOTAL URANIUM ISOPLETH FOR SOILS (PPM)
- TILL / GREAT MIAMI AQUIFER (GMA) BOUNDARY
- 1771 — MONITORING WELL NUMBER / BORING NUMBER
- MAXIMUM WATER ELEVATION

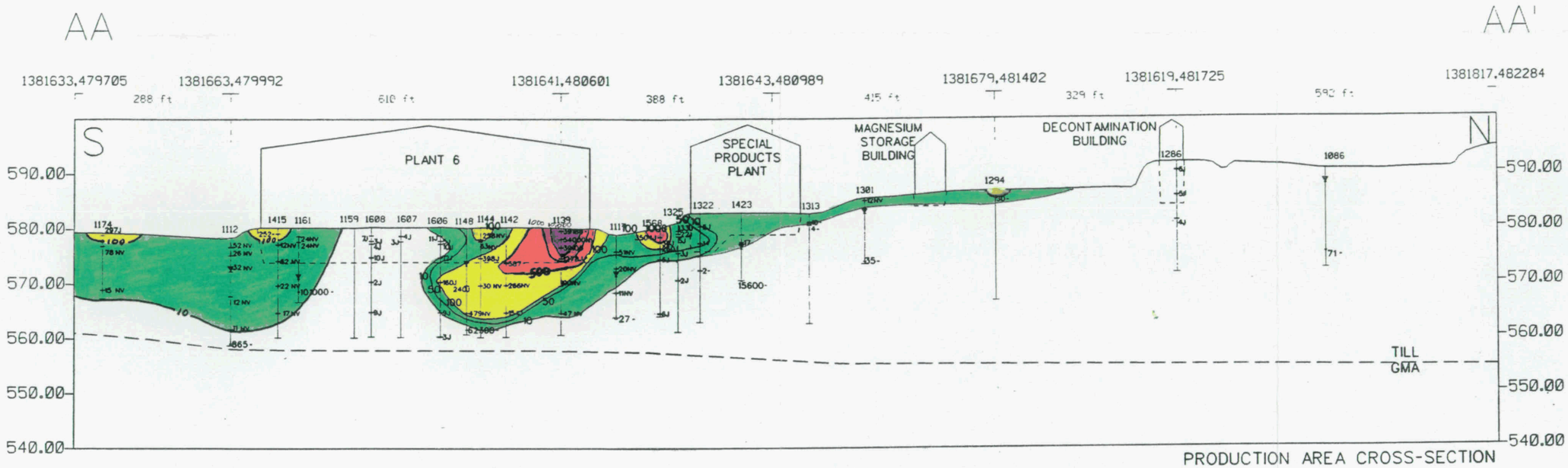
TOTAL URANIUM CONCENTRATION, mg/kg

- GREATER THAN 10,000
- 1000 TO 10,000
- 500 TO 1000
- 100 TO 500
- 10 TO 100

DRAFT

@FRED: /USR/ERMA/CRU5/DGN/SEC/GEO/DPTH/ PRODAR6.DGN

Figure 4-65
TOTAL URANIUM IN GLACIAL OVERBURDEN



PRODUCTION AREA CROSS-SECTION

LEGEND:

- ⊥ 27.1 — MAXIMUM TOTAL URANIUM IN WATER (ug/L)
- ┼ 77.1 — MAXIMUM TOTAL URANIUM IN SOIL (mg/kg)
- —— 10 —— TOTAL URANIUM ISOPLETH FOR SOILS (PPM)
- — — — — TILL / GREAT MIAMI AQUIFER (GMA) BOUNDARY
- 1771 — MONITORING WELL NUMBER / BORING NUMBER
- ▼ — MAXIMUM WATER ELEVATION

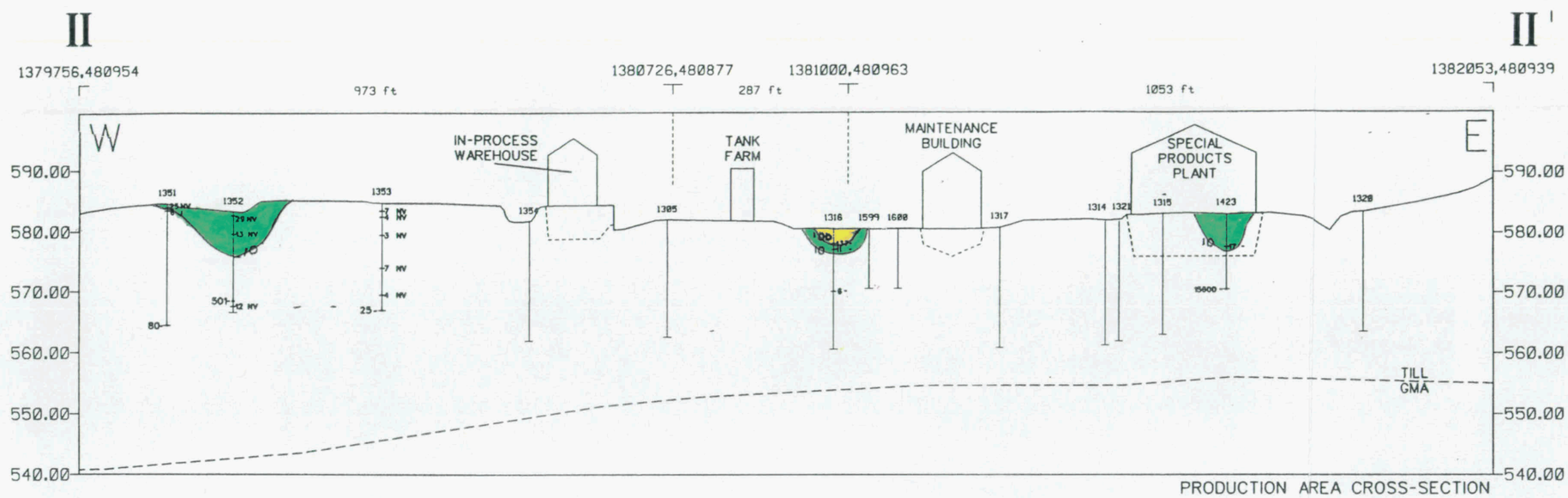
TOTAL URANIUM CONCENTRATION, mg/kg

- GREATER THAN 10,000
- 1000 TO 10,000
- 500 TO 1000
- 100 TO 500
- 10 TO 100

DRAFT

REFED: /USR/ERMA/CRU5/DGN/SEC/GEO/DPTH/

Figure 4-66
TOTAL URANIUM IN GLACIAL OVERBURDEN



LEGEND:

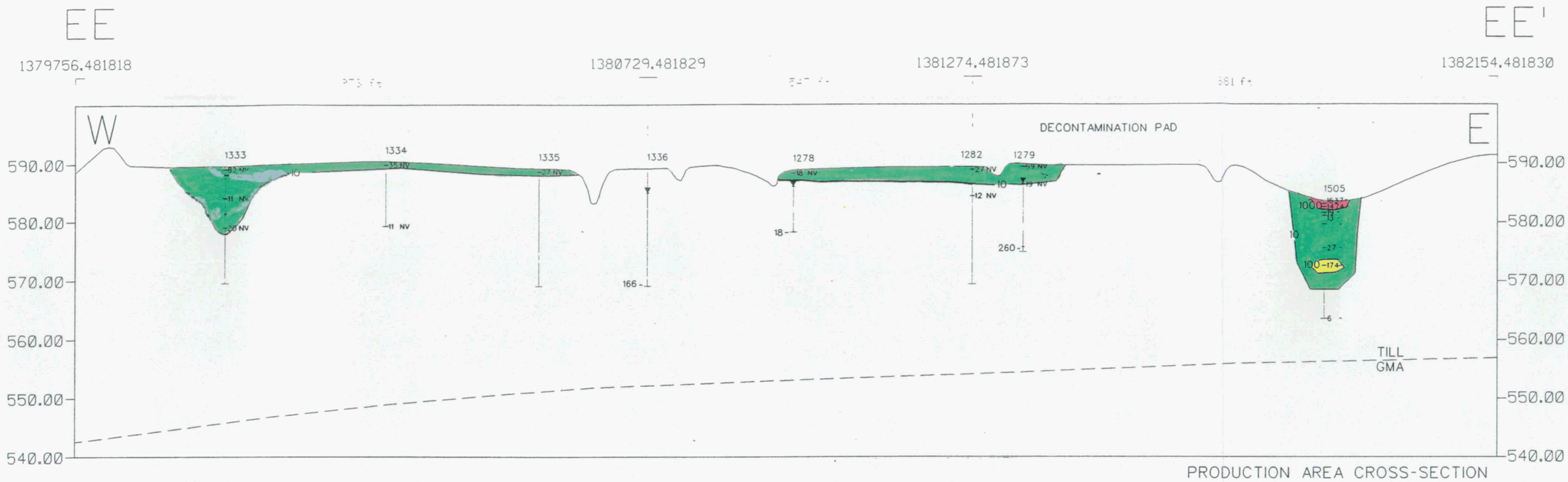
- 27.1 — MAXIMUM TOTAL URANIUM IN WATER (ug/L)
- 77.1 — MAXIMUM TOTAL URANIUM IN SOIL (mg/kg)
- 10 — TOTAL URANIUM ISOPLETH FOR SOILS (PPM)
- TILL / GREAT MIAMI AQUIFER (GMA) BOUNDARY
- 1771 — MONITORING WELL NUMBER / BORING NUMBER
- MAXIMUM WATER ELEVATION

TOTAL URANIUM CONCENTRATION, mg/kg

- GREATER THAN 10,000
- 1000 TO 10,000
- 500 TO 1000
- 100 TO 500
- 10 TO 100

DRAFT

Figure 4-67
TOTAL URANIUM GLACIAL OVERBURDEN



PRODUCTION AREA CROSS-SECTION

LEGEND:

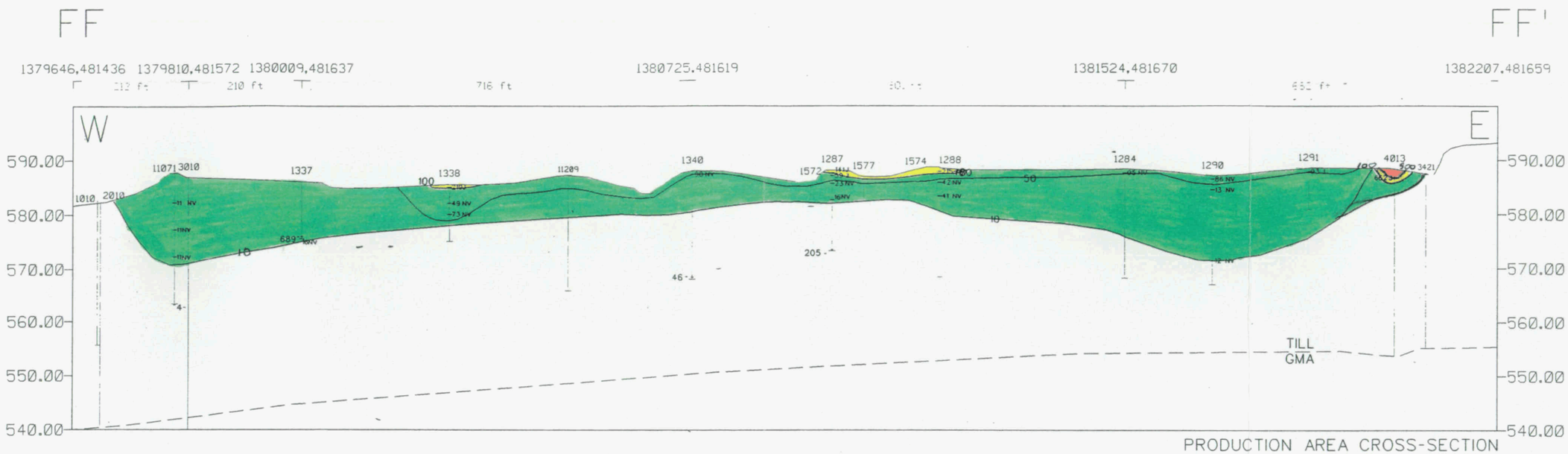
- ⊥ 27.1 — MAXIMUM TOTAL URANIUM IN WATER (ug/L)
- ┼ 77.1 — MAXIMUM TOTAL URANIUM IN SOIL (mg/kg)
- —— 10 —— — TOTAL URANIUM ISOPLETH FOR SOILS (PPM)
- — — — — — TILL / GREAT MIAMI AQUIFER (GMA) BOUNDARY
- 1771 — MONITORING WELL NUMBER / BORING NUMBER
- ▼ — MAXIMUM WATER ELEVATION

TOTAL URANIUM CONCENTRATION, mg/kg

- GREATER THAN 10,000
- 1000 TO 10,000
- 500 TO 1000
- 100 TO 500
- 10 TO 100

DRAFT

Figure 4-68
TOTAL URANIUM IN GLACIAL OVERBURDEN



LEGEND:

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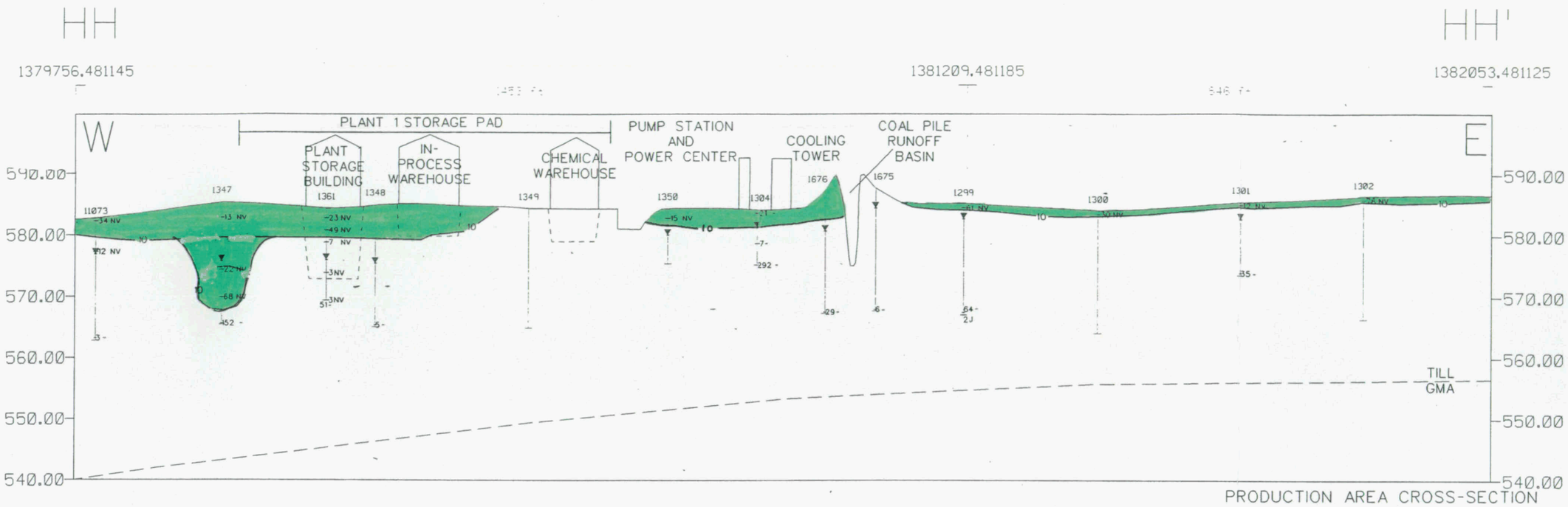
- 77.1 — MAXIMUM TOTAL URANIUM IN SOIL (mg/kg)
- 10 — TOTAL URANIUM ISOPLETH FOR SOILS (PPM)
- TILL / GREAT MIAMI AQUIFER (GMA) BOUNDARY
- 1771 — MONITORING WELL NUMBER / BORING NUMBER
- MAXIMUM WATER ELEVATION

TOTAL URANIUM CONCENTRATION, mg/kg

- GREATER THAN 10,000
- 1000 TO 10,000
- 500 TO 1000
- 100 TO 500
- 10 TO 100

DRAFT

Figure 4-69
TOTAL URANIUM GLACIAL OVERBURDEN



LEGEND:

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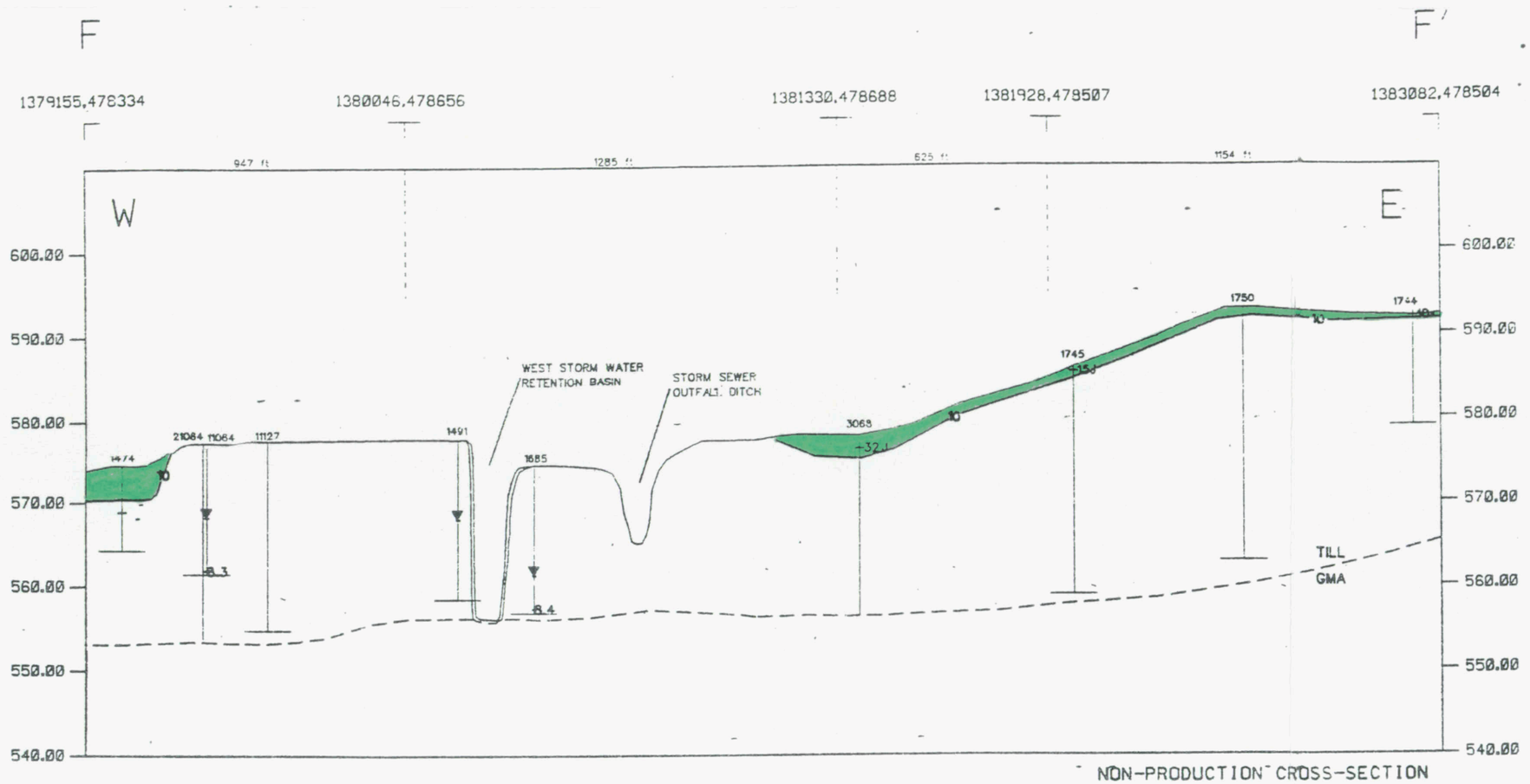
- 77.1 — MAXIMUM TOTAL URANIUM IN SOIL (mg/kg)
- 10 — TOTAL URANIUM ISOPLETH FOR SOILS (PPM)
- TILL / GREAT MIAMI AQUIFER (GMA) BOUNDARY
- 1771 — MONITORING WELL NUMBER / BORING NUMBER
- MAXIMUM WATER ELEVATION

TOTAL URANIUM CONCENTRATION, mg/kg

- GREATER THAN 10,000
- 1000 TO 10,000
- 500 TO 1000
- 100 TO 500
- 10 TO 100

DRAFT

Figure 4-70
TOTAL URANIUM IN GLACIAL OVERBURDEN



NON-PRODUCTION CROSS-SECTION

LEGEND:

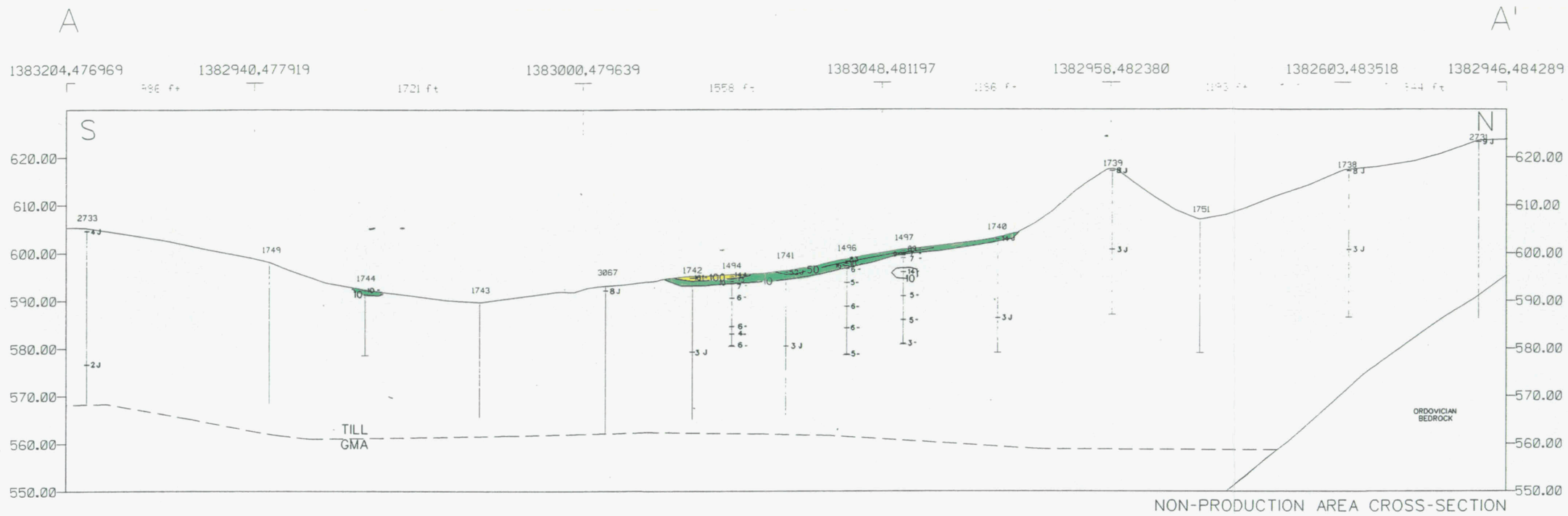
- 27.1 — MAXIMUM TOTAL URANIUM IN WATER (ug/L)
- 77.1 — MAXIMUM TOTAL URANIUM IN SOIL (mg/kg)
- 10 — TOTAL URANIUM ISOPLETH FOR SOILS (PPM)
- TILL / GREAT MIAMI AQUIFER (GMA) BOUNDARY
- 1771 — MONITORING WELL NUMBER / BORING NUMBER
- MAXIMUM WATER ELEVATION

TOTAL URANIUM CONCENTRATION, mg/kg

- GREATER THAN 10,000
- 1000 TO 10,000
- 500 TO 1000
- 100 TO 500
- 10 TO 100

DRAFT

Figure 4-71
TOTAL URANIUM IN GLACIAL OVERBURDEN



NON-PRODUCTION AREA CROSS-SECTION

LEGEND:

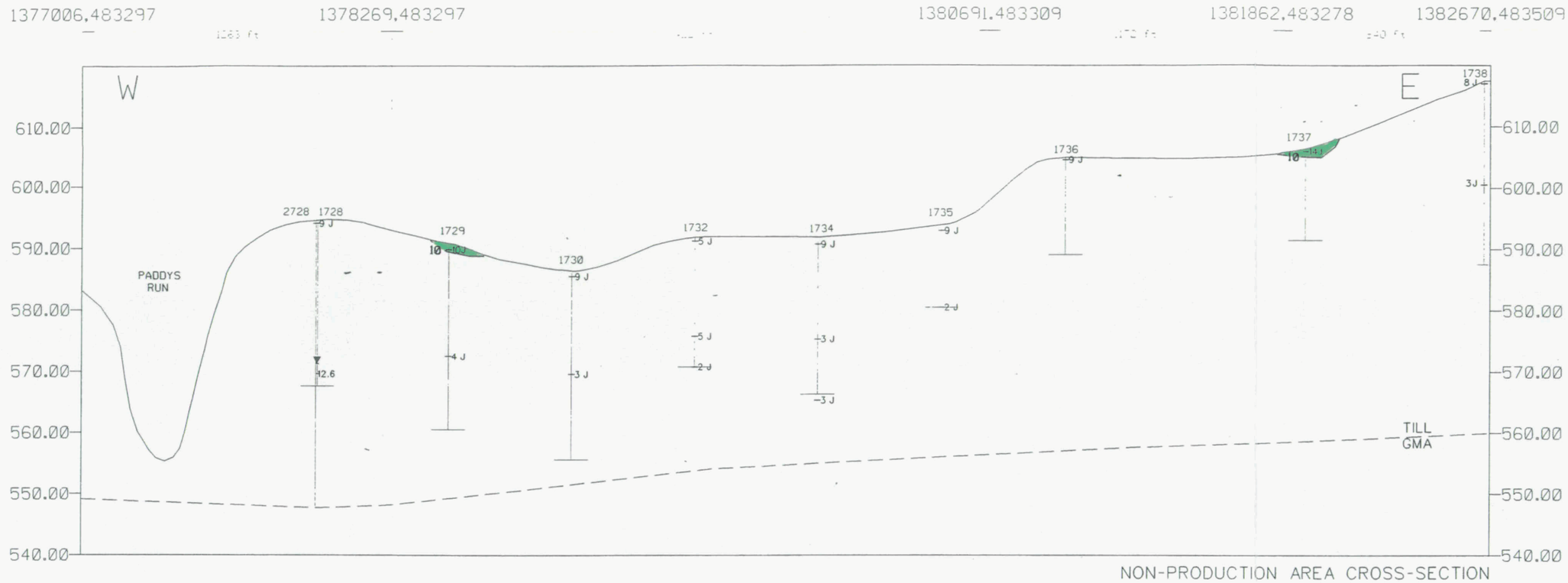
- 27.1 — MAXIMUM TOTAL URANIUM IN WATER (ug/L)
- 77.1 — MAXIMUM TOTAL URANIUM IN SOIL (mg/kg)
- 10 — TOTAL URANIUM ISOPLETH FOR SOILS (PPM)
- TILL / GREAT MIAMI AQUIFER (GMA) BOUNDARY
- 1771 — MONITORING WELL NUMBER / BORING NUMBER
- MAXIMUM WATER ELEVATION

TOTAL URANIUM CONCENTRATION, mg/kg

- GREATER THAN 10,000
- 1000 TO 10,000
- 500 TO 1000
- 100 TO 500
- 10 TO 100

DRAFT

Figure 4-72
TOTAL URANIUM IN GLACIAL OVERBURDEN



LEGEND:

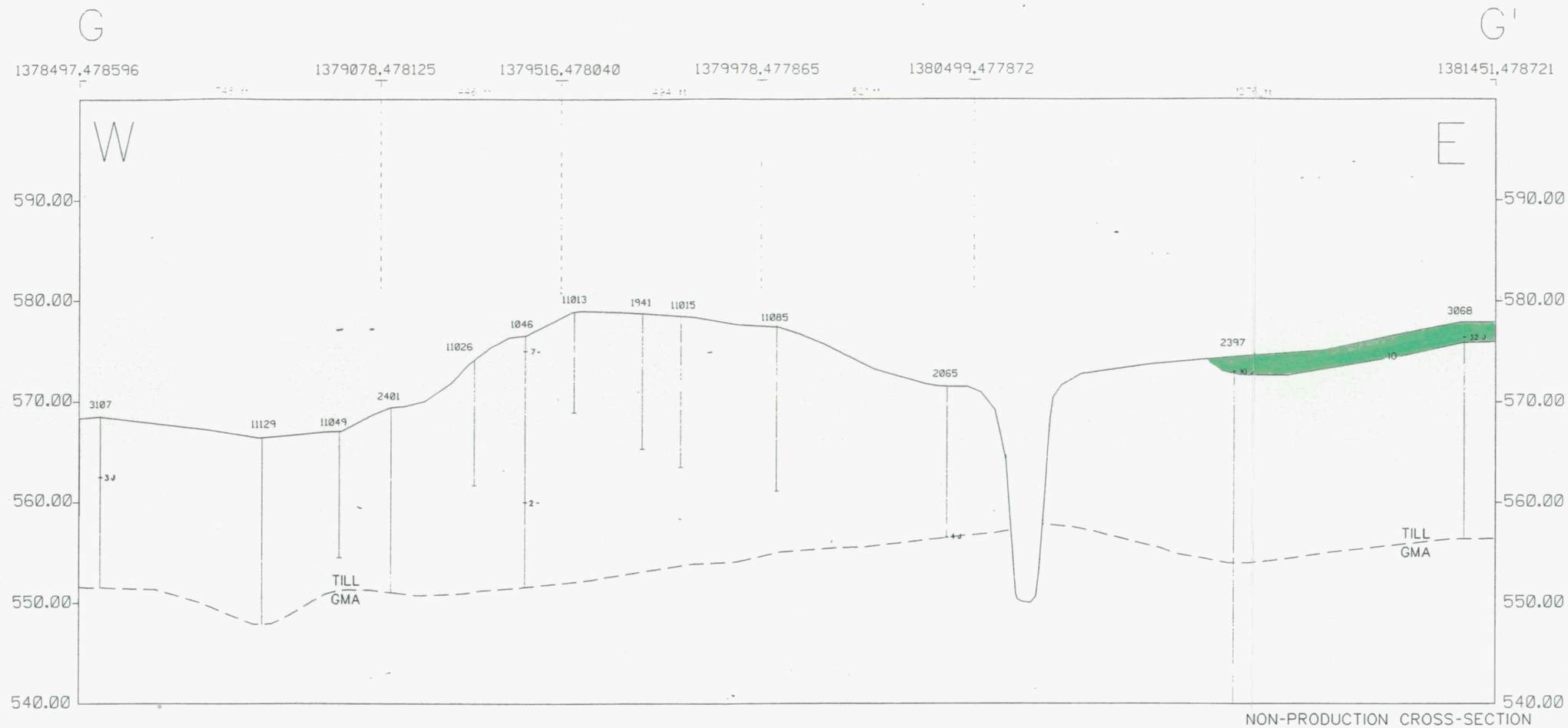
- ⊥ 27.1 — MAXIMUM TOTAL URANIUM IN WATER (ug/L)
- ┼ 77.1 — MAXIMUM TOTAL URANIUM IN SOIL (mg/kg)
- —— 10 —— TOTAL URANIUM ISOPLETH FOR SOILS (PPM)
- — — — — TILL / GREAT MIAMI AQUIFER (GMA) BOUNDARY
- 1771 — MONITORING WELL NUMBER / BORING NUMBER
- ▼ — MAXIMUM WATER ELEVATION

TOTAL URANIUM CONCENTRATION, mg/kg

- GREATER THAN 10,000
- 1000 TO 10,000
- 500 TO 1000
- 100 TO 500
- 10 TO 100

DRAFT

Figure 4-73
TOTAL URANIUM GLACIAL OVERBURDEN



LEGEND:

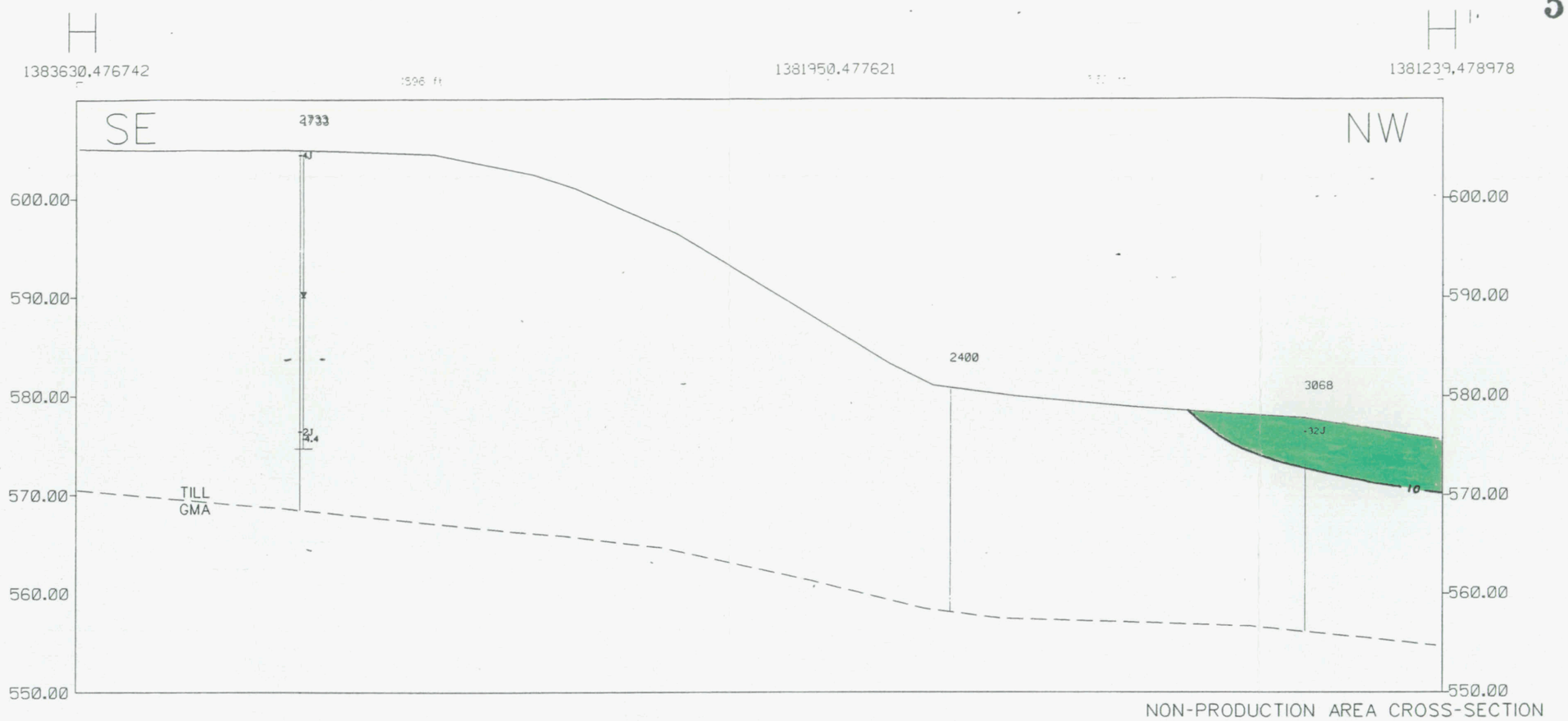
- 27.1 — MAXIMUM TOTAL URANIUM IN WATER (ug/L)
- 77.1 — MAXIMUM TOTAL URANIUM IN SOIL (mg/kg)
- 10 — TOTAL URANIUM ISOPLETH FOR SOILS (PPM)
- TILL / GREAT MIAMI AQUIFER (GMA) BOUNDARY
- 1771 — MONITORING WELL NUMBER / BORING NUMBER
- MAXIMUM WATER ELEVATION

TOTAL URANIUM CONCENTRATION, mg/kg

- GREATER THAN 10,000
- 1000 TO 10,000
- 500 TO 1000
- 100 TO 500
- 10 TO 100

DRAFT

Figure 4-74
TOTAL URANIUM GLACIAL OVERBURDEN



LEGEND:

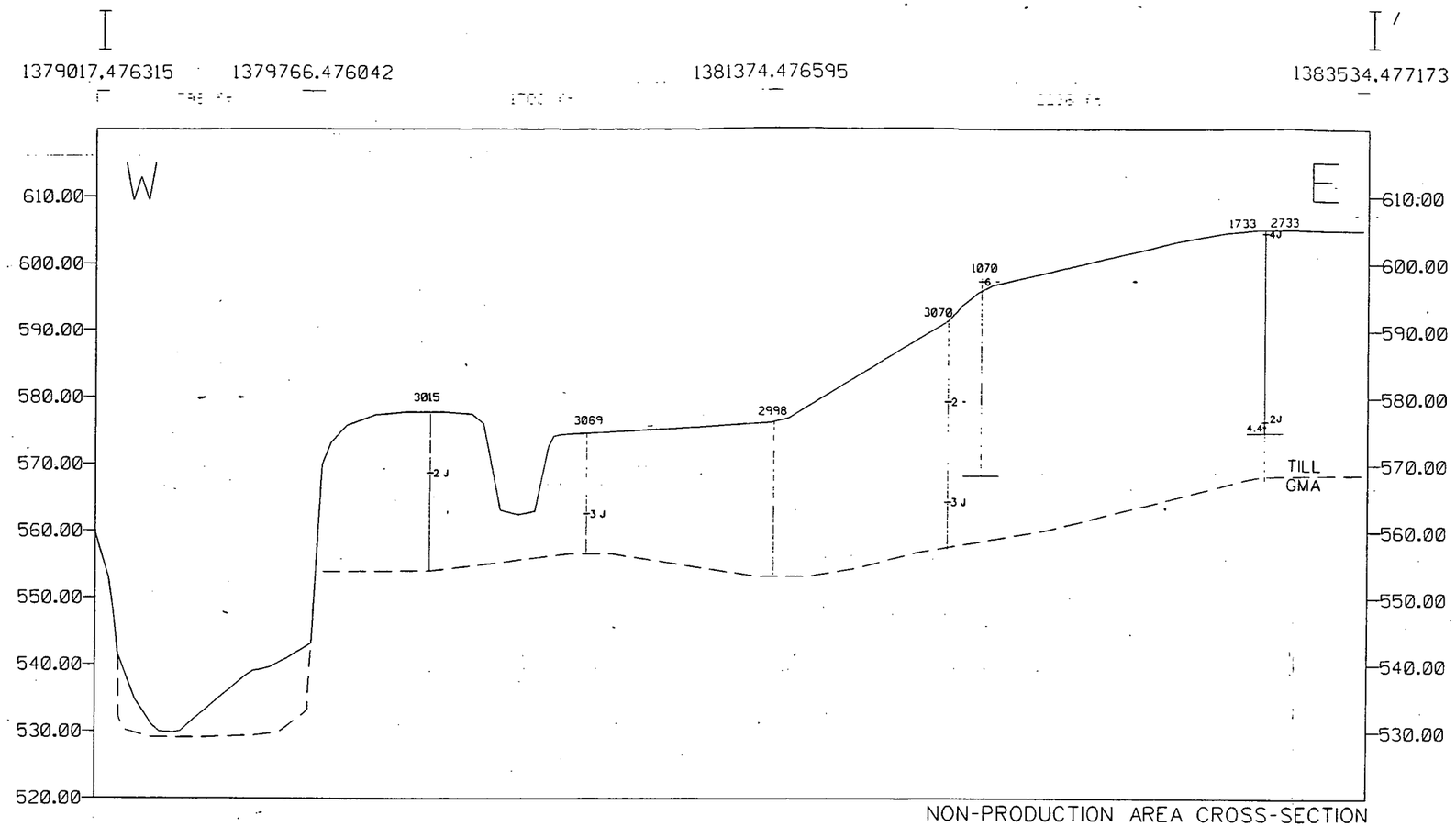
- 27.1 — MAXIMUM TOTAL URANIUM IN WATER (ug/L)
- 77.1 — MAXIMUM TOTAL URANIUM IN SOIL (mg/kg)
- 10 — TOTAL URANIUM ISOPLETH FOR SOILS (PPM)
- TILL / GREAT MIAMI AQUIFER (GMA) BOUNDARY
- 1771 — MONITORING WELL NUMBER / BORING NUMBER
- MAXIMUM WATER ELEVATION

TOTAL URANIUM CONCENTRATION, mg/kg

- GREATER THAN 10,000
- 1000 TO 10,000
- 500 TO 1000
- 100 TO 500
- 10 TO 100

DRAFT

Figure 4-75
TOTAL URANIUM IN GLACIAL OVERBURDEN



NON-PRODUCTION AREA CROSS-SECTION

LEGEND:

- 27.1 — MAXIMUM TOTAL URANIUM IN WATER (ug/L)
- 77.1 — MAXIMUM TOTAL URANIUM IN SOIL (mg/kg)
- 10 — TOTAL URANIUM ISOPLETH FOR SOILS (PPM)
- TILL / GREAT MIAMI AQUIFER (GMA) BOUNDARY
- 1771 — MONITORING WELL NUMBER / BORING NUMBER
- MAXIMUM WATER ELEVATION

TOTAL URANIUM CONCENTRATION, mg/kg

- GREATER THAN 10,000
- 1000 TO 10,000
- 500 TO 1000
- 100 TO 500
- 10 TO 100

DRAFT

Figure 4-76
TOTAL URANIUM GLACIAL OVERBURDEN

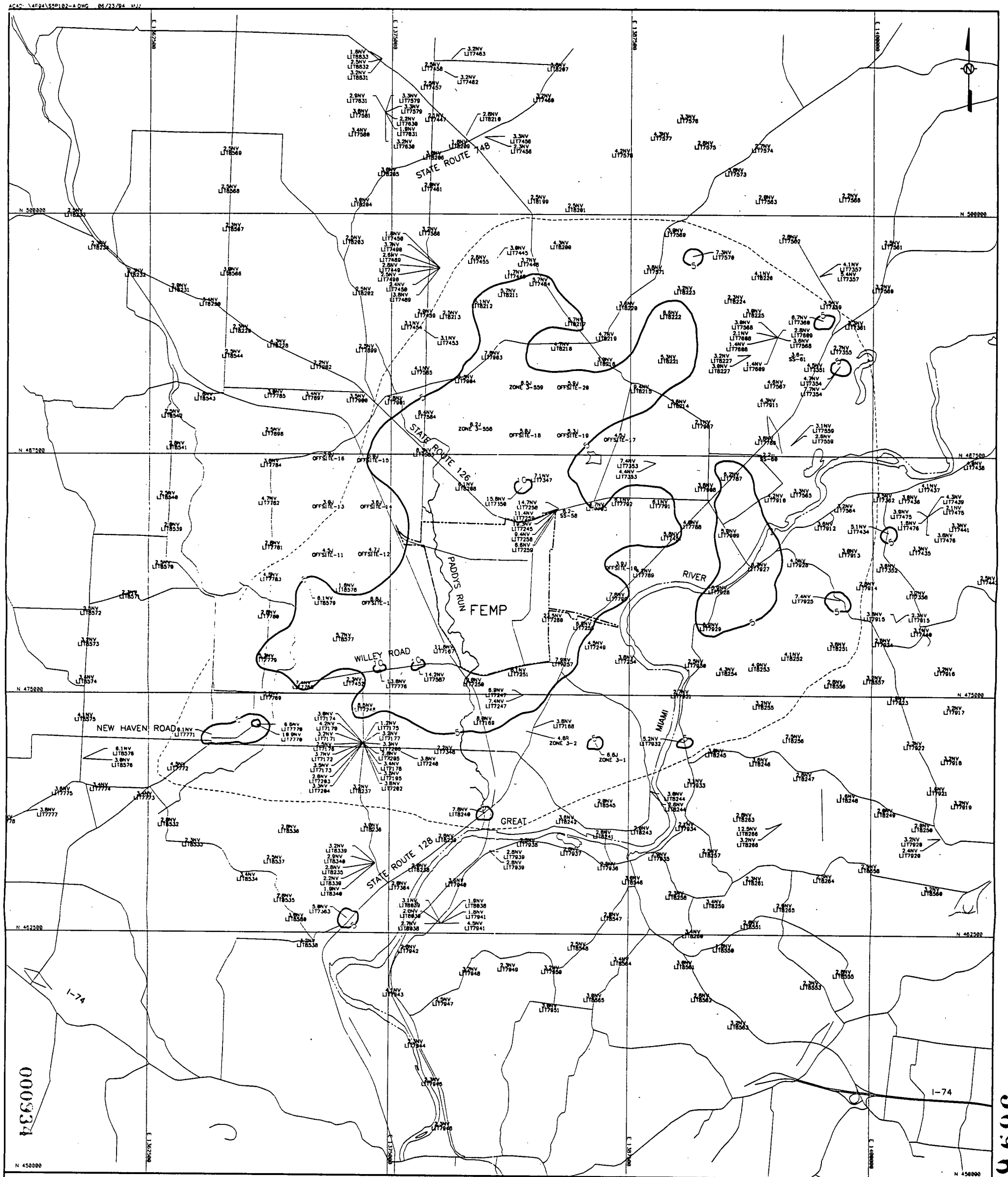


FIGURE 4-77. TOTAL URANIUM VALUES (mg/kg) OFF PROPERTY IN SURFACE SOIL AT 0-0.5 FEET, OU5, FEMP

000334

5696

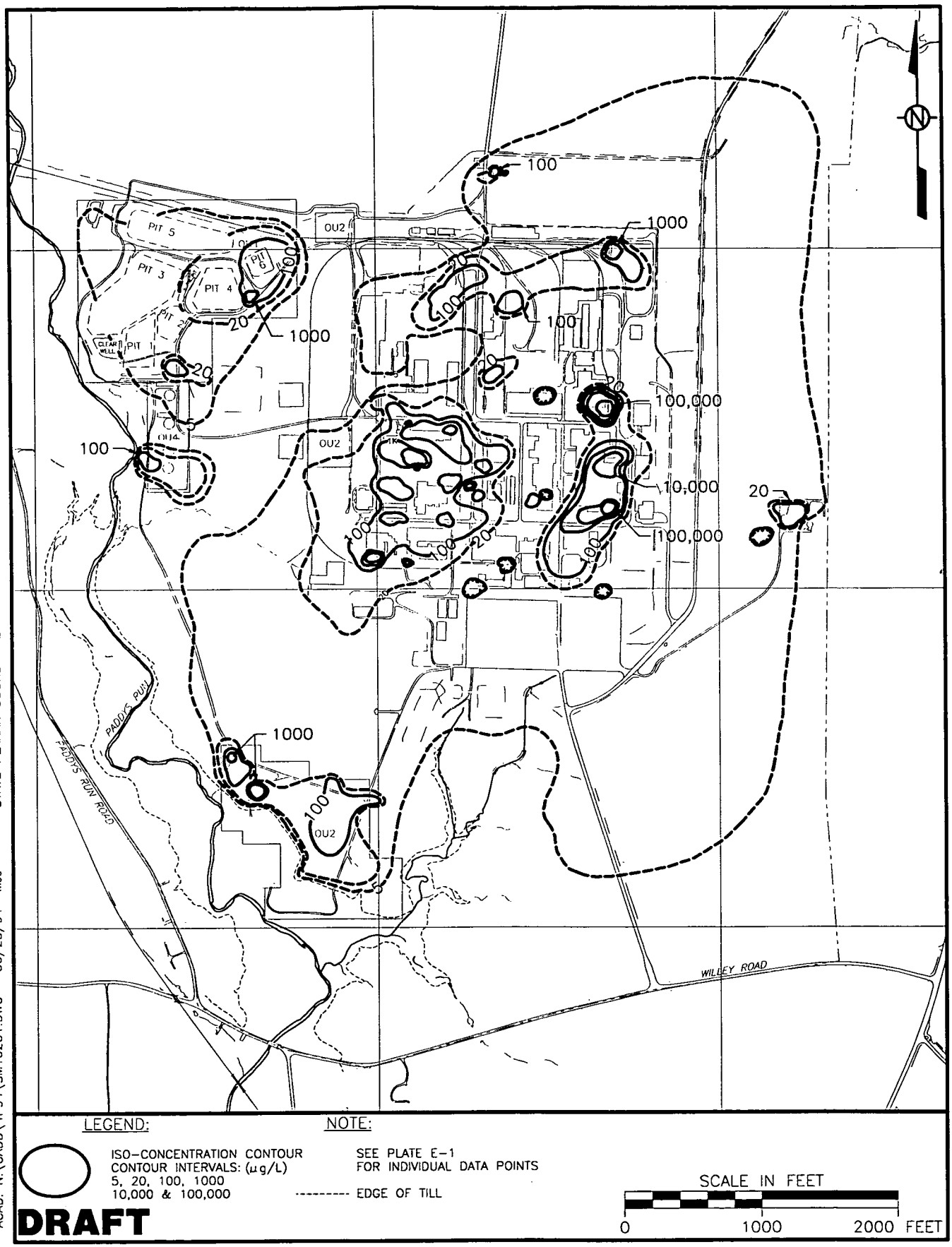


FIGURE 4-78. TOTAL URANIUM (µg/L) CONTAMINATION IN FEMP TYPE 1 WELLS – FILTERED SAMPLES, 1993 DATA SET

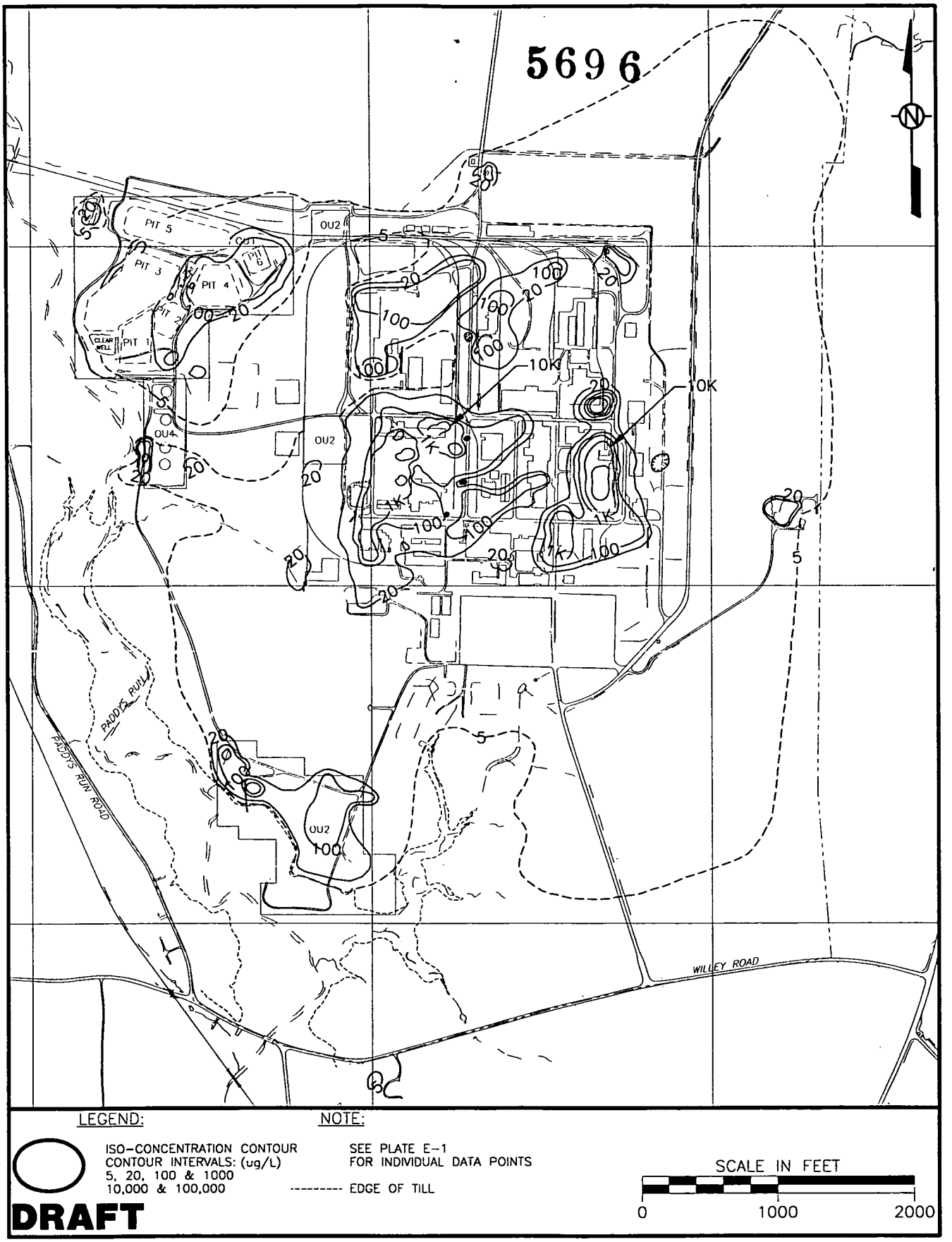


FIGURE 4-79. TOTAL URANIUM (ug/L) CONTAMINATION IN FEMP TYPE 1 WELLS - UNFILTERED SAMPLES, 1993 DATA SET

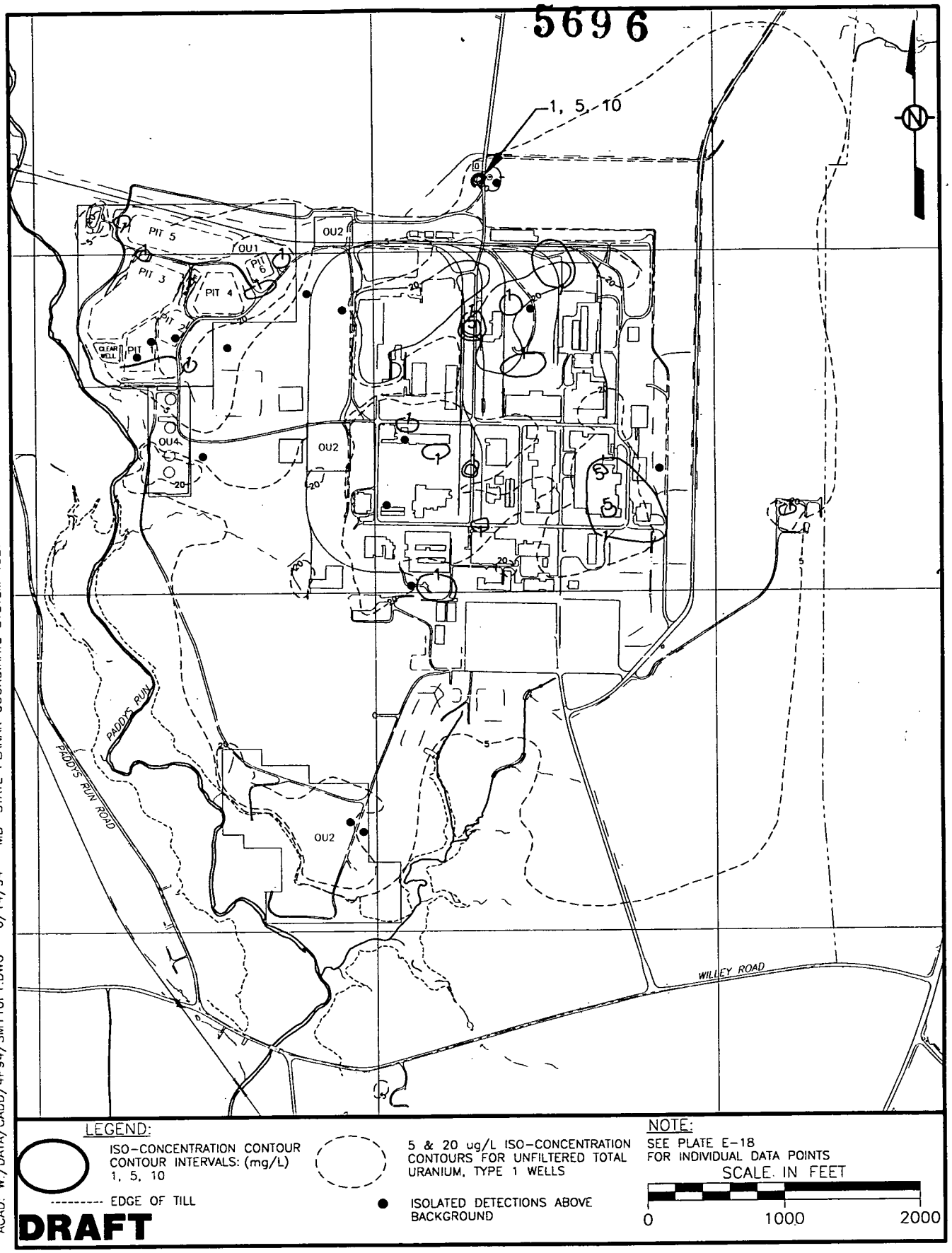
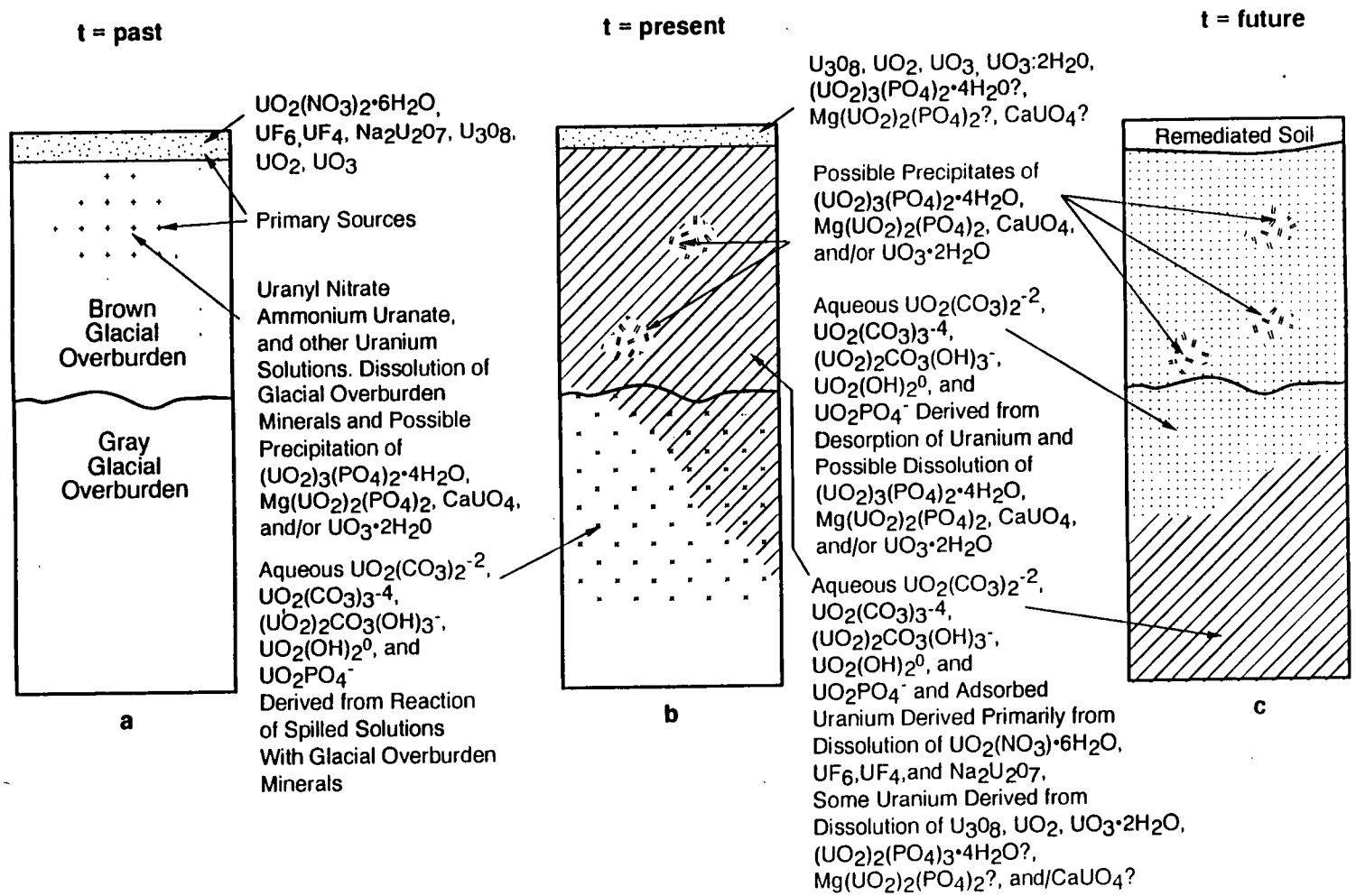


FIGURE 4-80. TOTAL THORIUM (ug/L) CONTAMINATION IN FEMP TYPE 1 WELLS - FILTERED SAMPLES, 1993 DATA SET

C:\AHSIZE.DWG 6/17/94 MRM

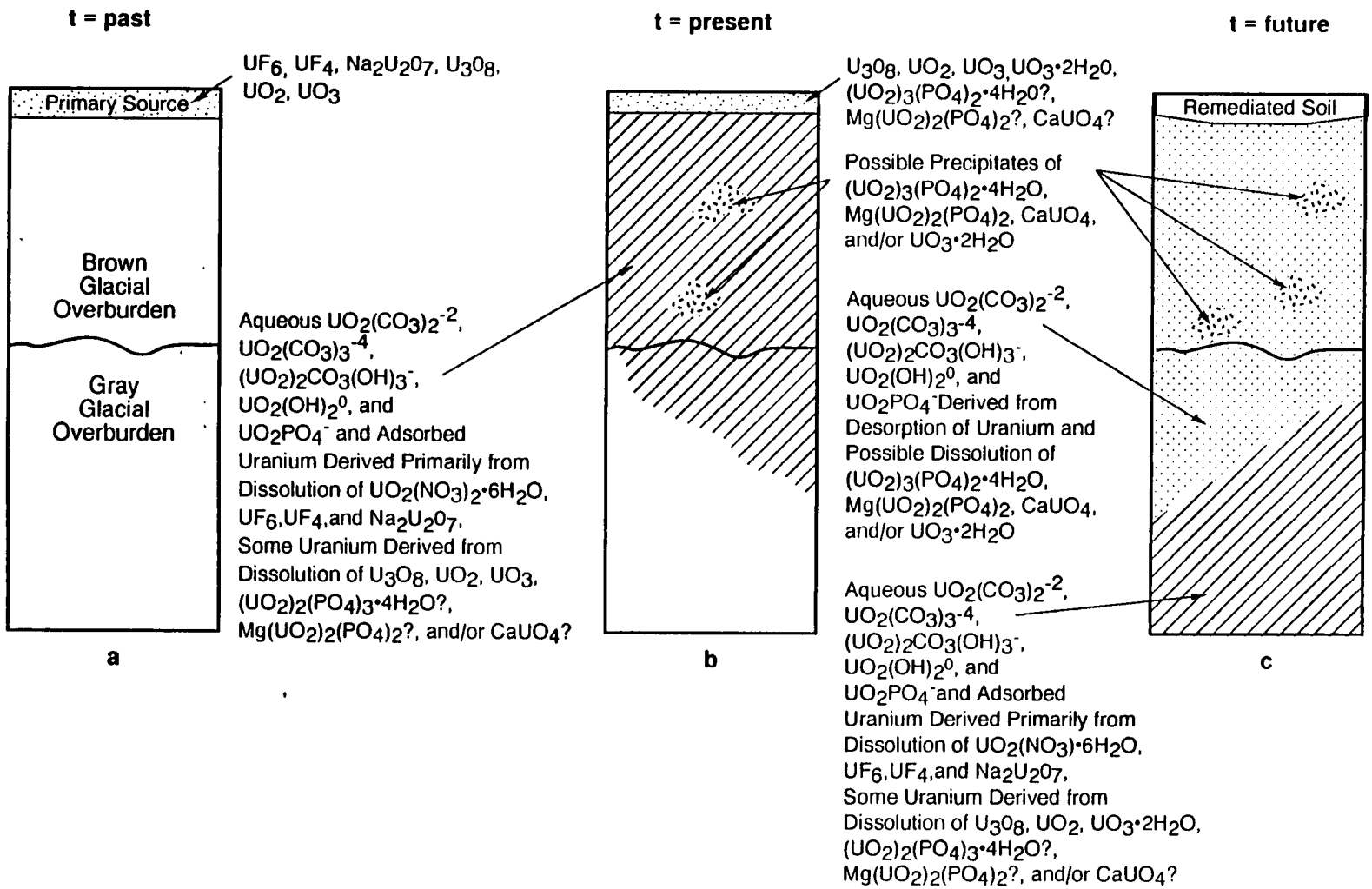


5696

000938

DRAFT

FIGURE 4-82. URANIUM DISTRIBUTION RESULTING FROM AQUEOUS AND PARTICULATE SOURCES



DRAFT

FIGURE 4-83. URANIUM DISTRIBUTION RESULTING FROM PARTICULATE SOURCES

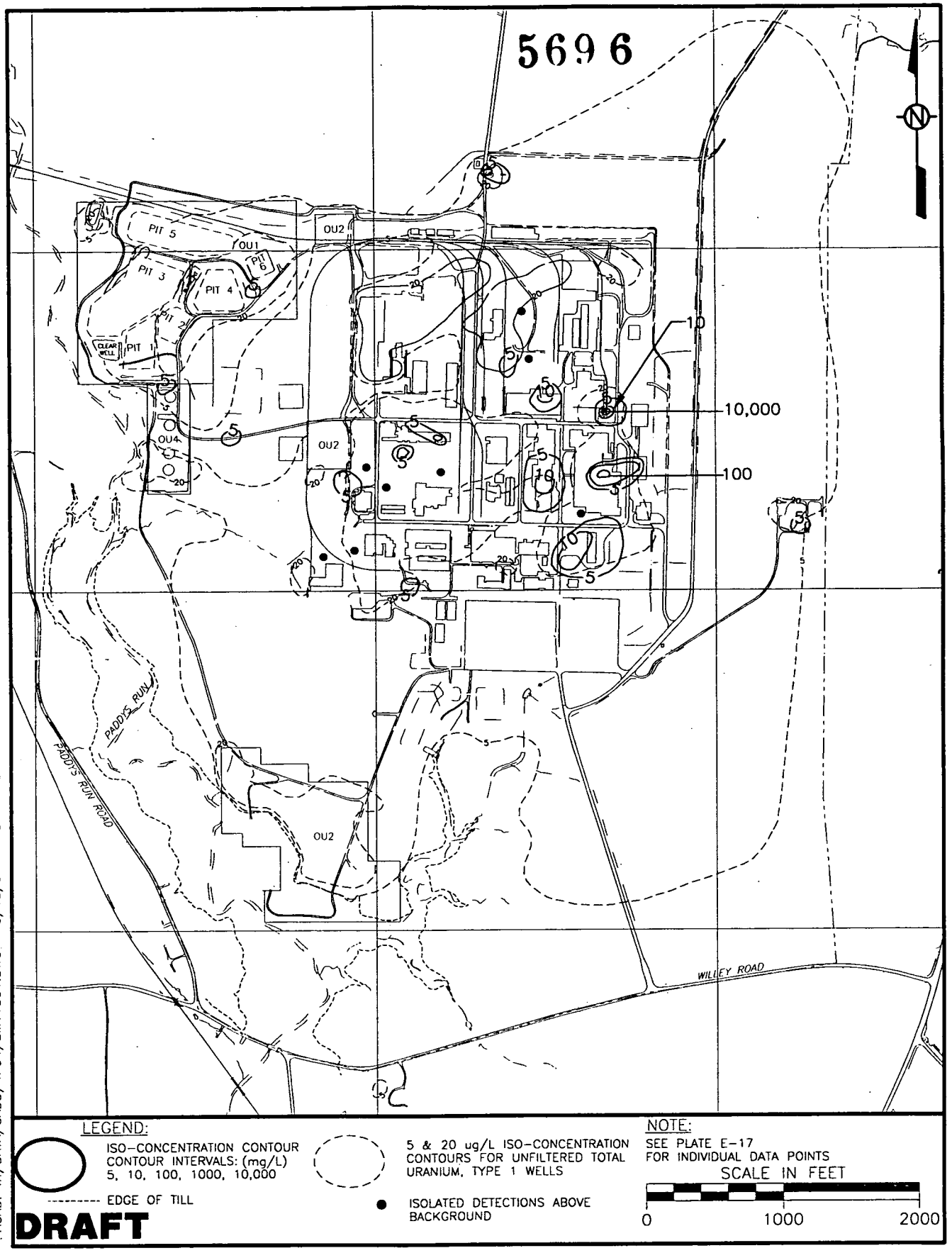
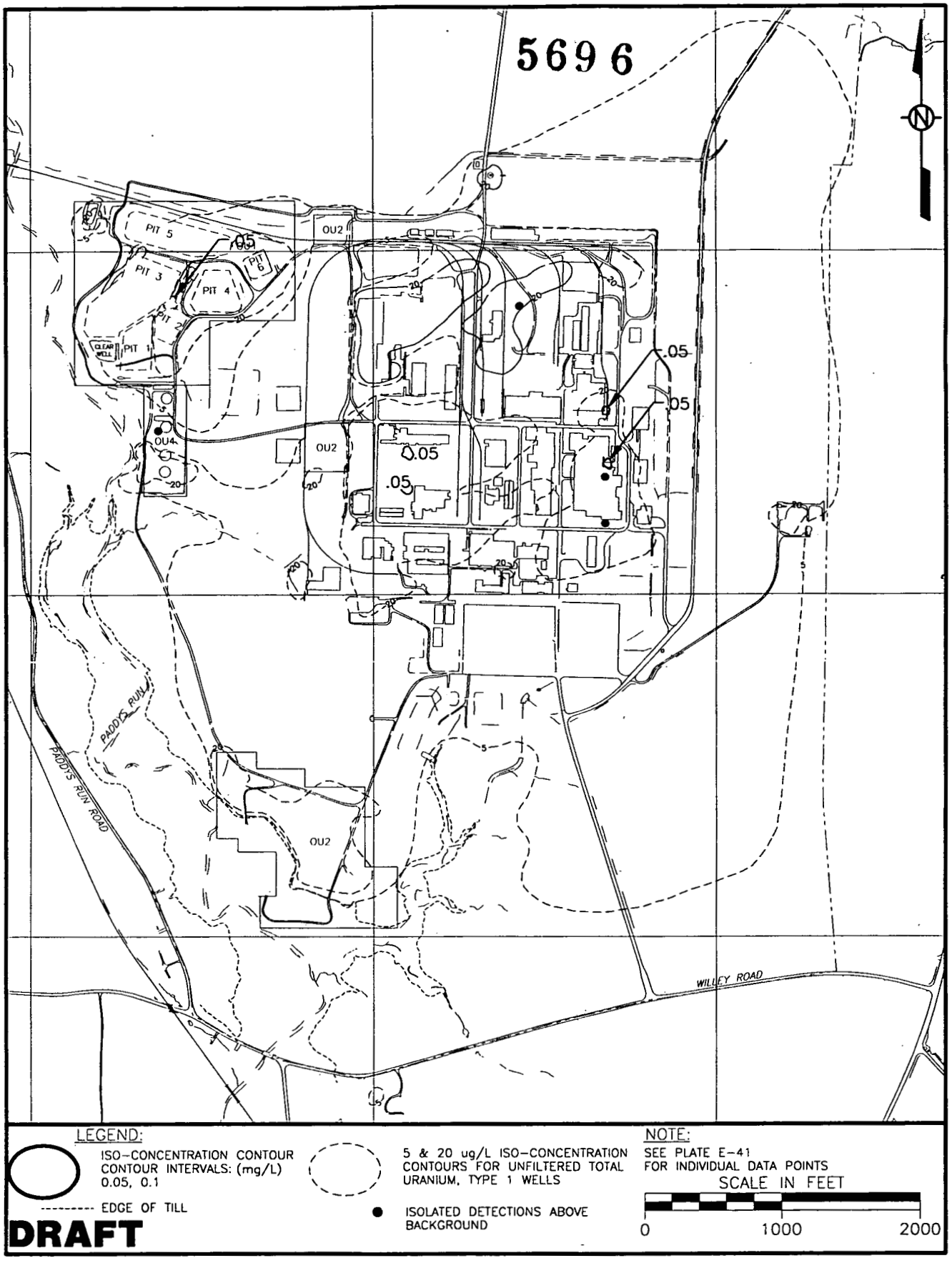


FIGURE 4-81. TOTAL THORIUM (ug/L) CONTAMINATION IN FEMP TYPE 1 WELLS - UNFILTERED SAMPLES, 1993 DATA SET



ACAD: W:/DATA/CADD/4P94/SM21OF1.DWG 6/16/94 MB STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-84. CHROMIUM (mg/L) CONTAMINATION IN FEMP TYPE 1 WELLS - FILTERED SAMPLES, 1993 DATA SET

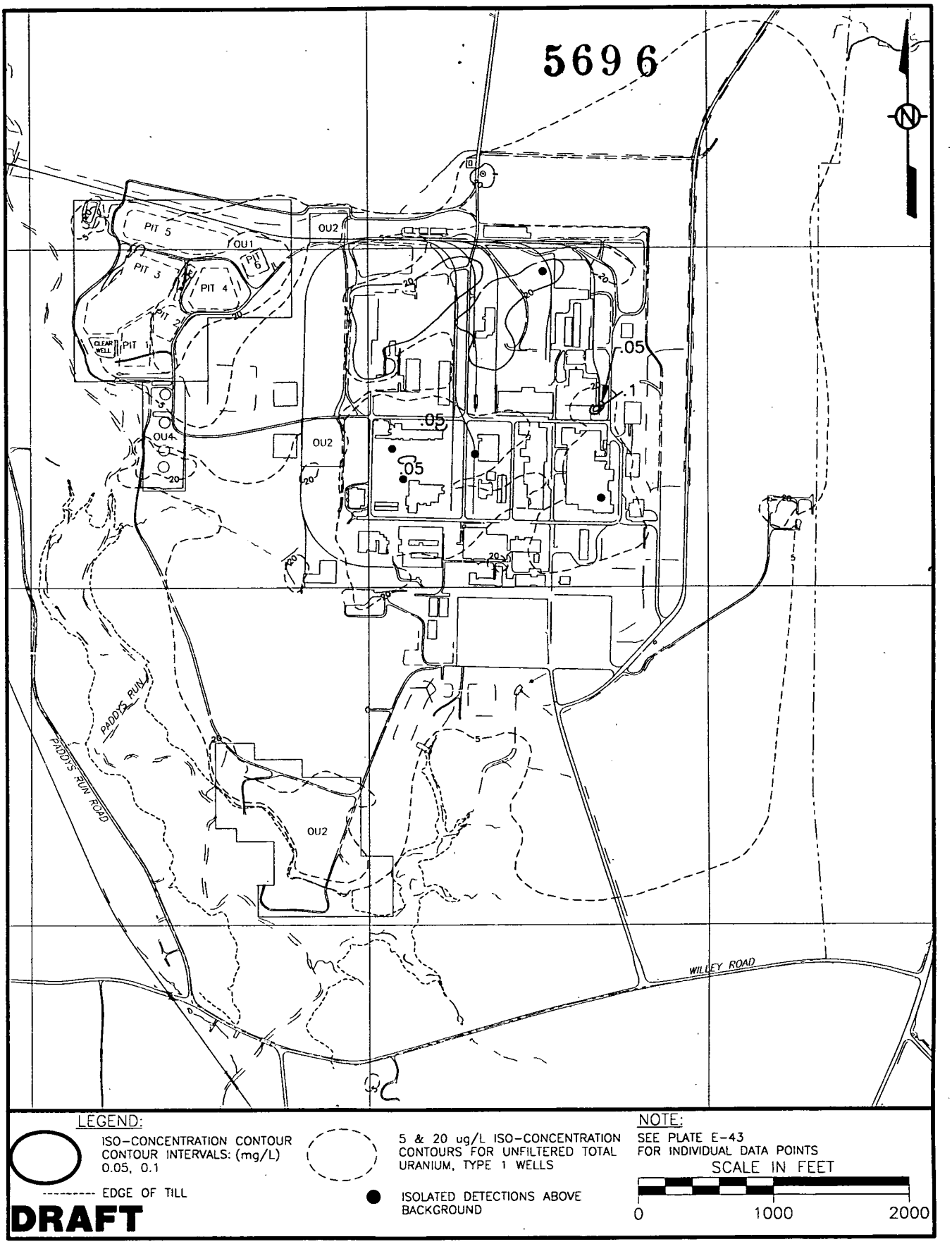


FIGURE 4-85. COPPER (mg/L) CONTAMINATION IN FEMP TYPE 1 WELLS - FILTERED SAMPLES, 1993 DATA SET

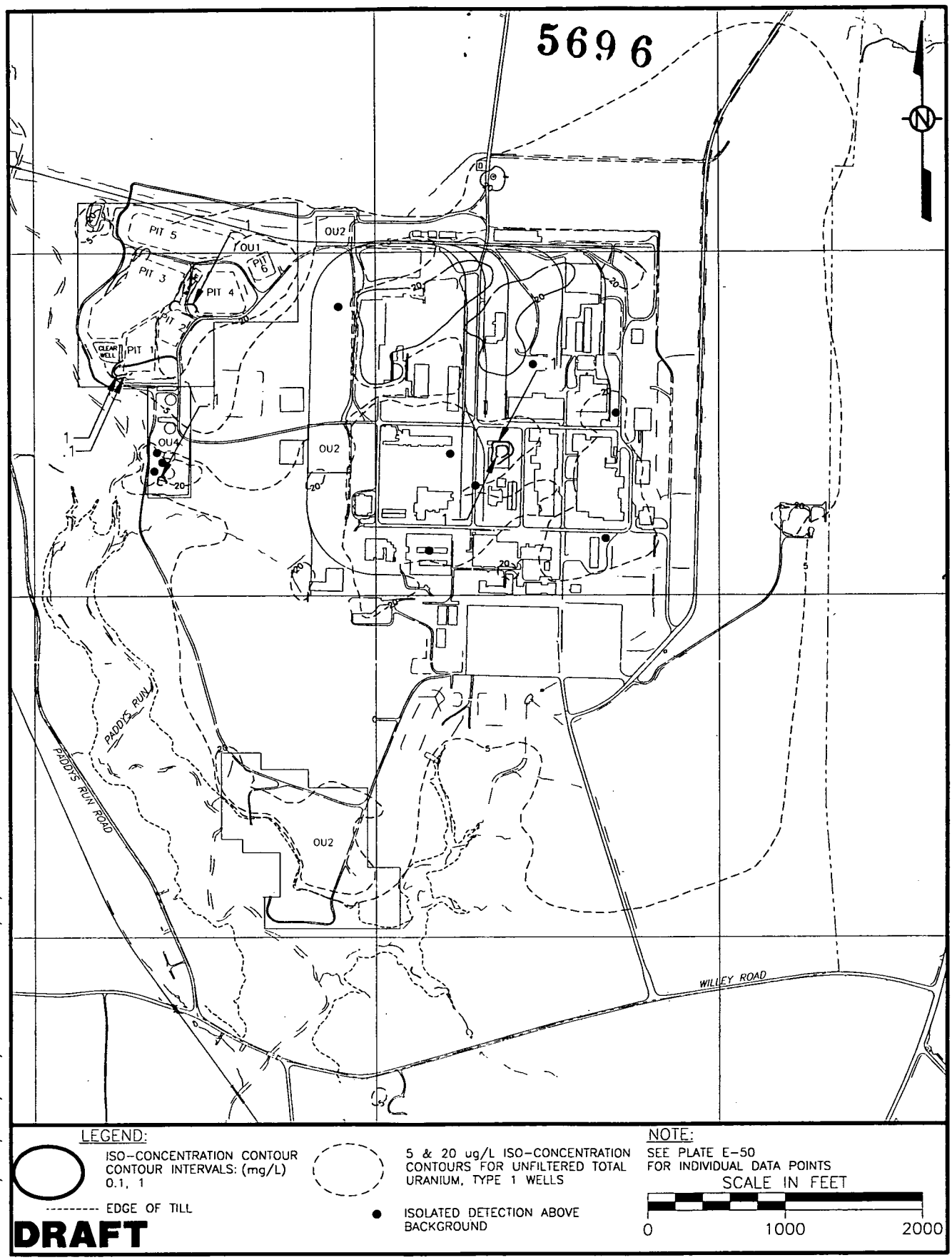


FIGURE 4-86. MOLYBDENUM (mg/L) CONTAMINATION IN FEMP TYPE 1 WELLS - FILTERED SAMPLES, 1993 DATA SET

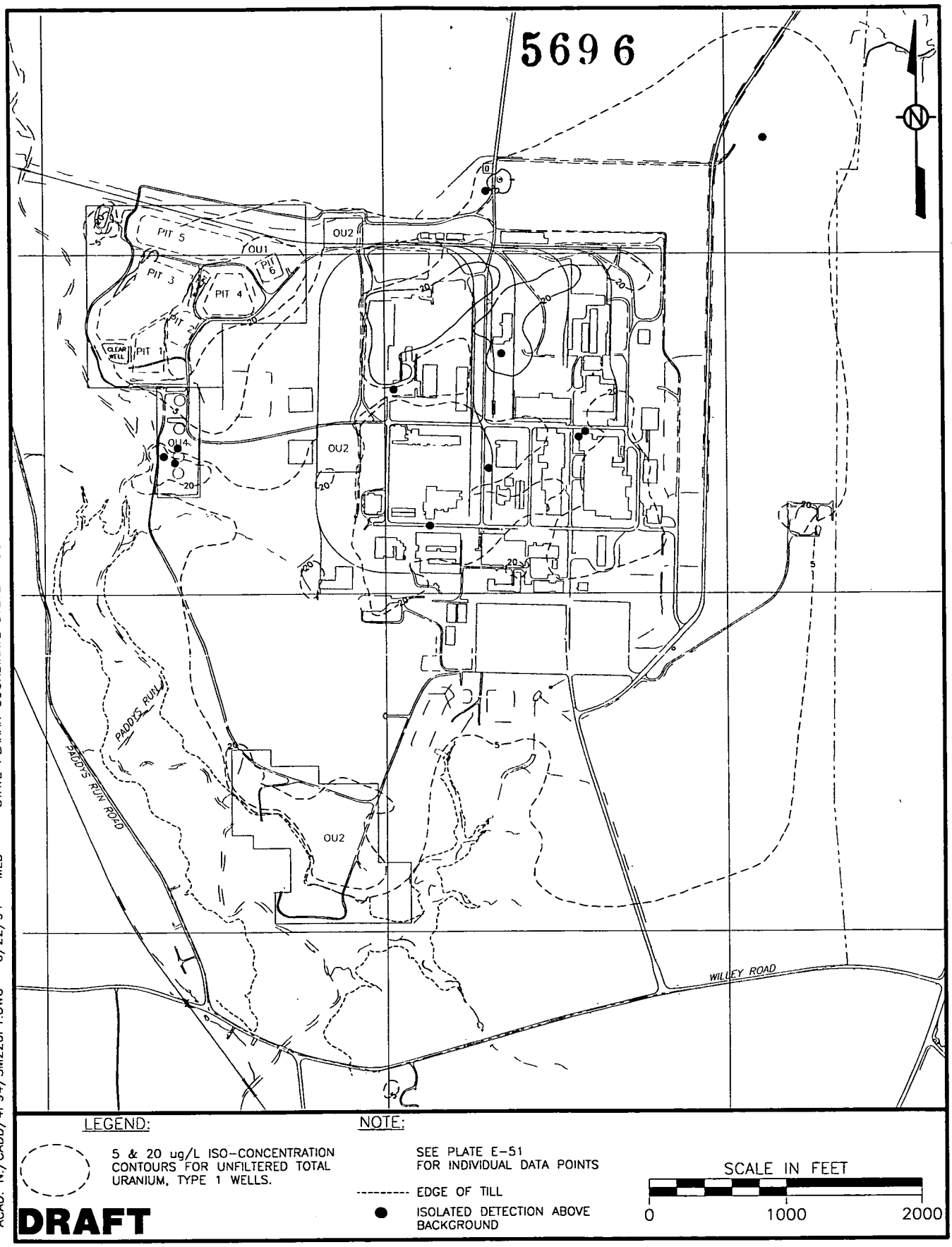


FIGURE 4-87. NICKEL (mg/L) CONTAMINATION IN FEMP TYPE 1 WELLS – FILTERED SAMPLES, 1993 DATA SET

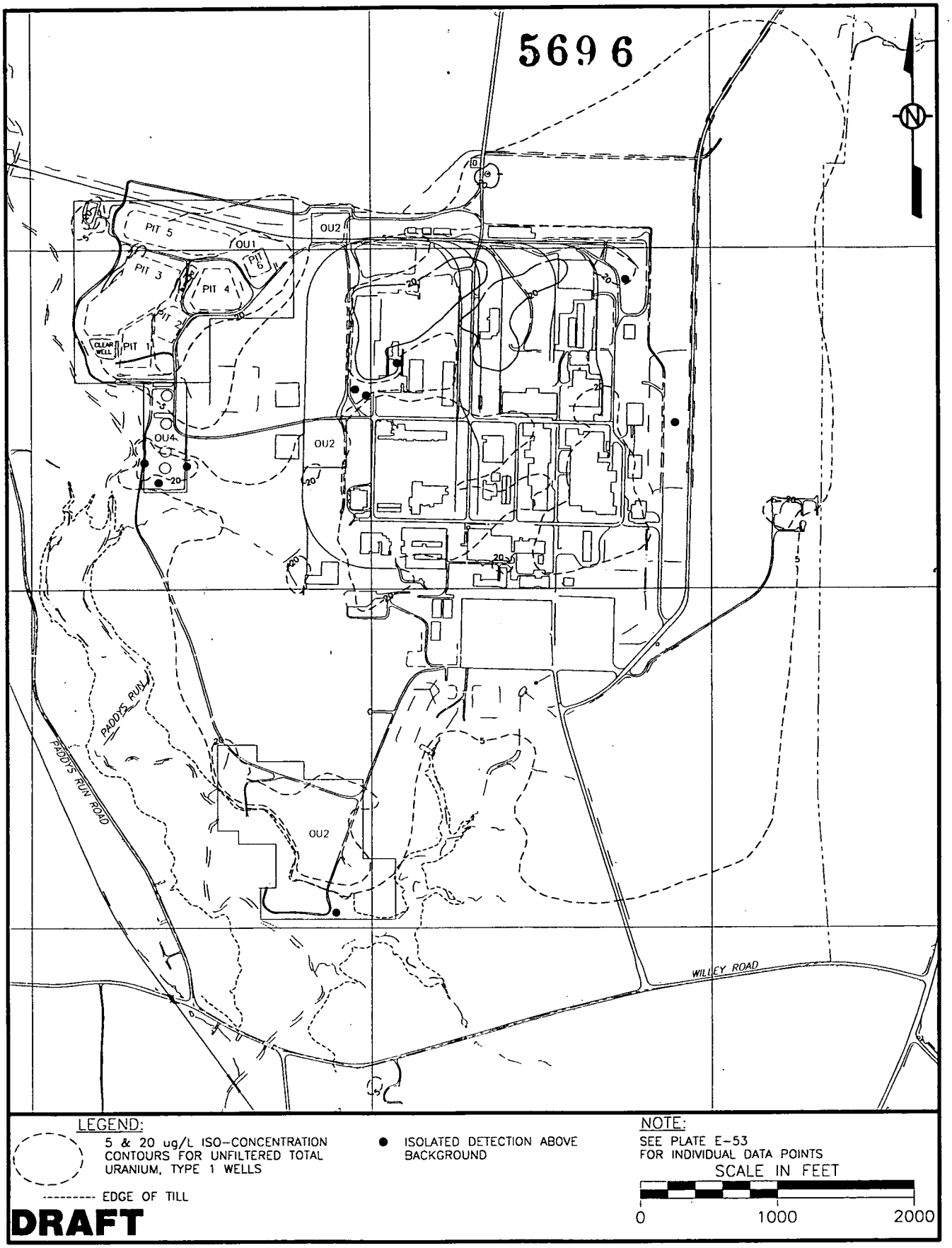


FIGURE 4-88. SELENIUM (mg/L) CONTAMINATION IN FEMP TYPE 1 WELLS – FILTERED SAMPLES, 1993 DATA SET

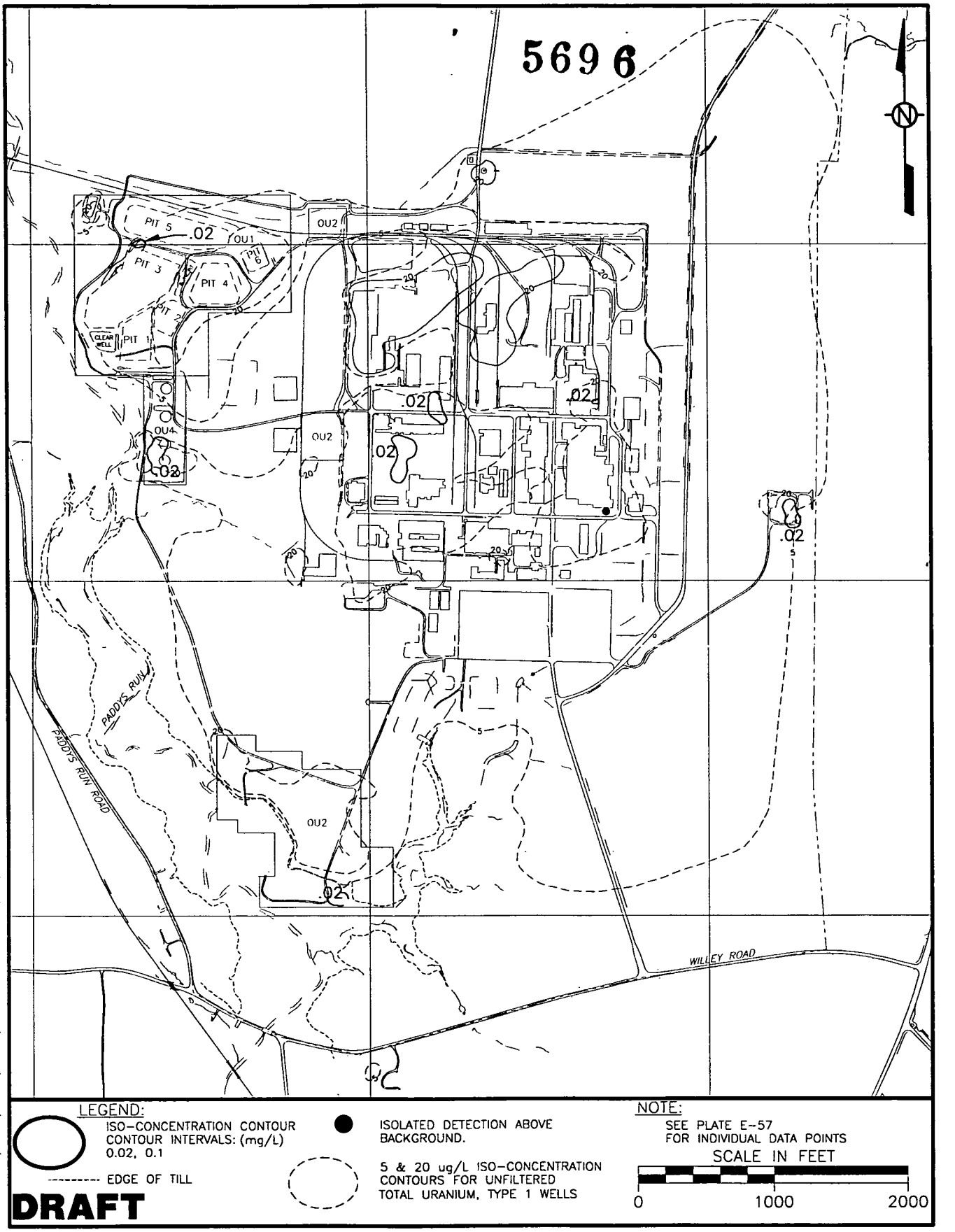


FIGURE 4-89. VANADIUM (mg/L) CONTAMINATION IN FEMP TYPE 1 WELLS – FILTERED SAMPLES, 1993 DATA SET

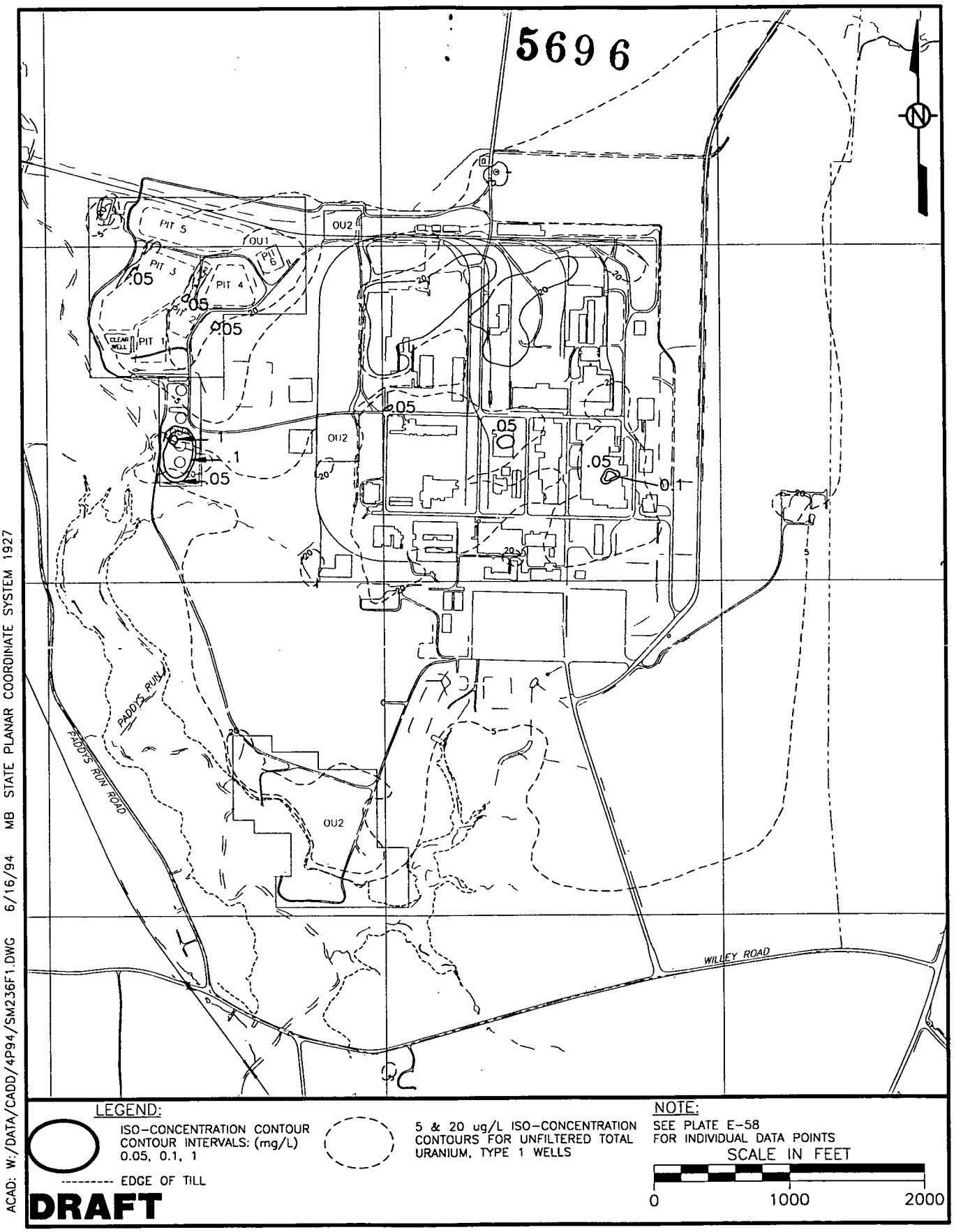


FIGURE 4-90. ZINC (mg/L) CONTAMINATION IN FEMP TYPE 1 WELLS – FILTERED SAMPLES, 1993 DATA SET

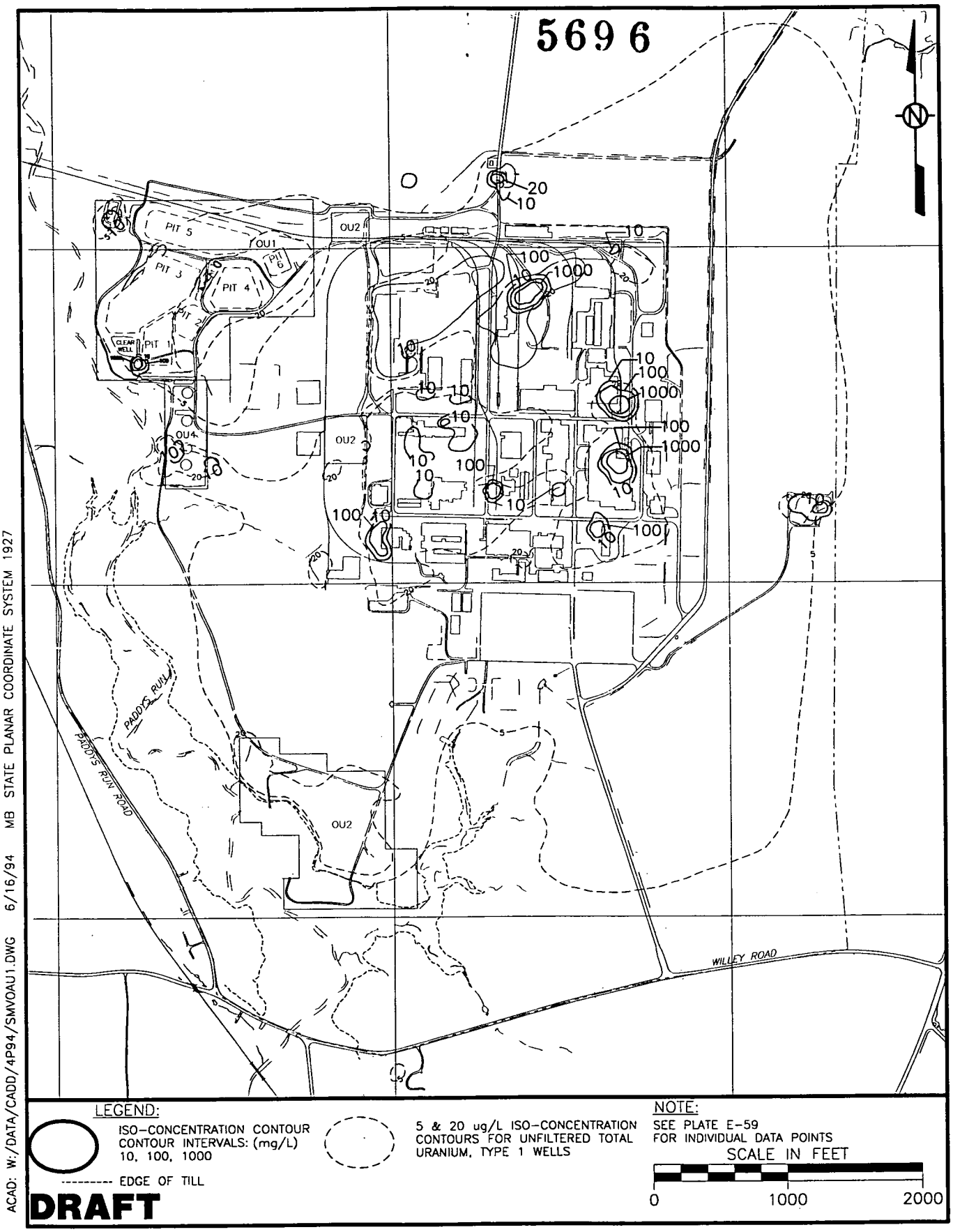


FIGURE 4-91. TOTAL VOC (ug/L) CONTAMINATION IN FEMP TYPE 1 WELLS - UNFILTERED SAMPLES, 1993 DATA SET

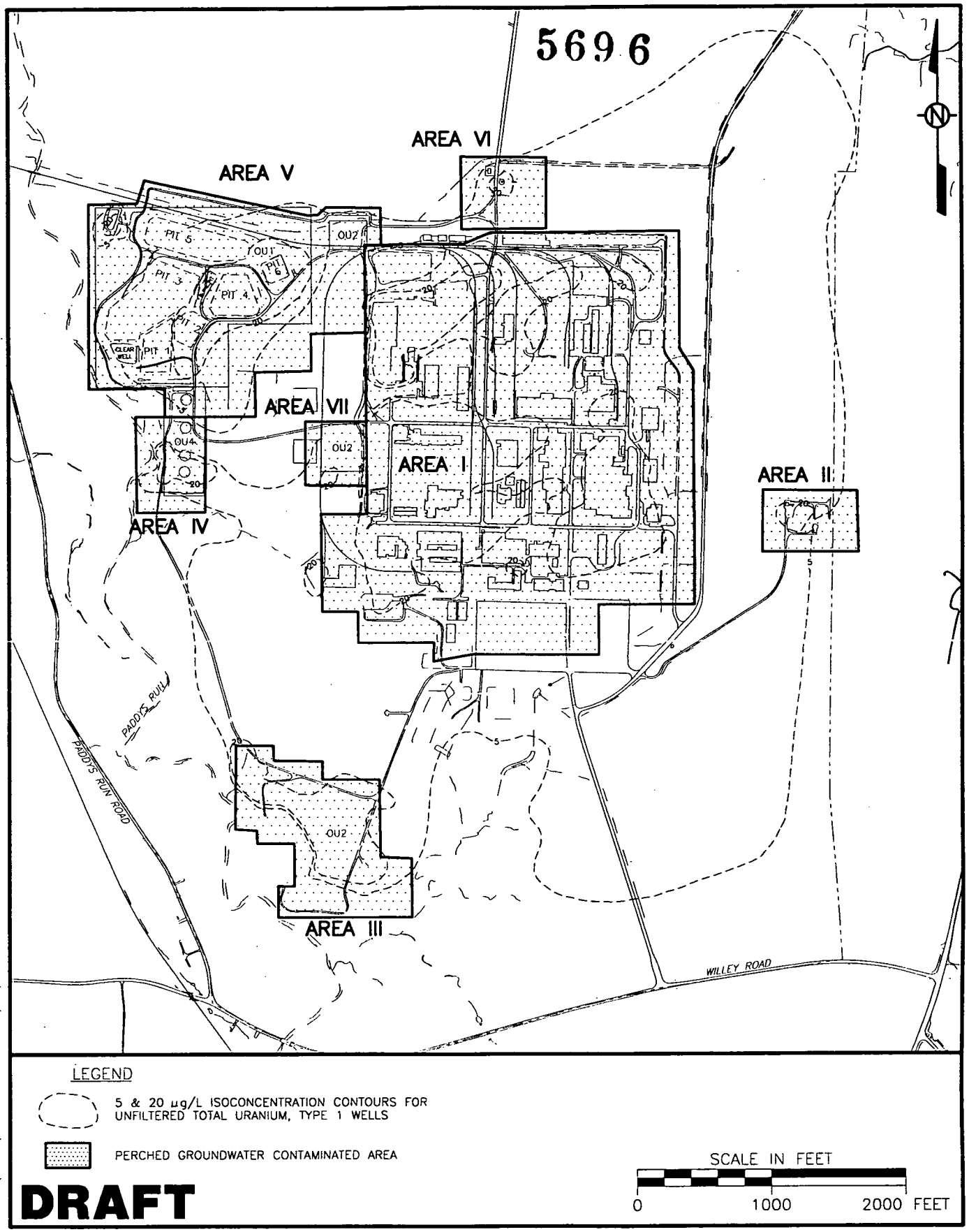


FIGURE 4–92. LOCATIONS OF PERCHED GROUNDWATER CONTAMINATED AREAS

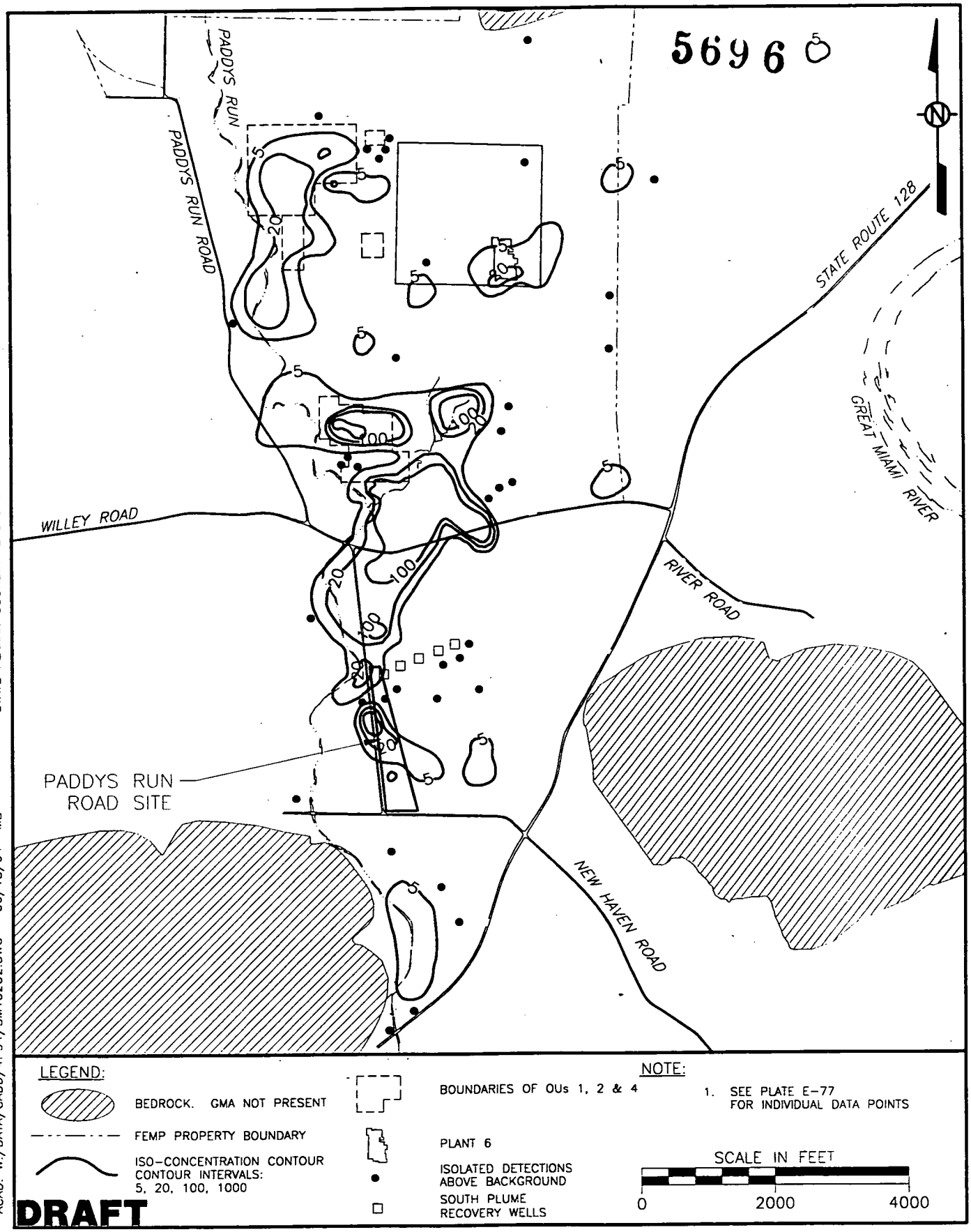
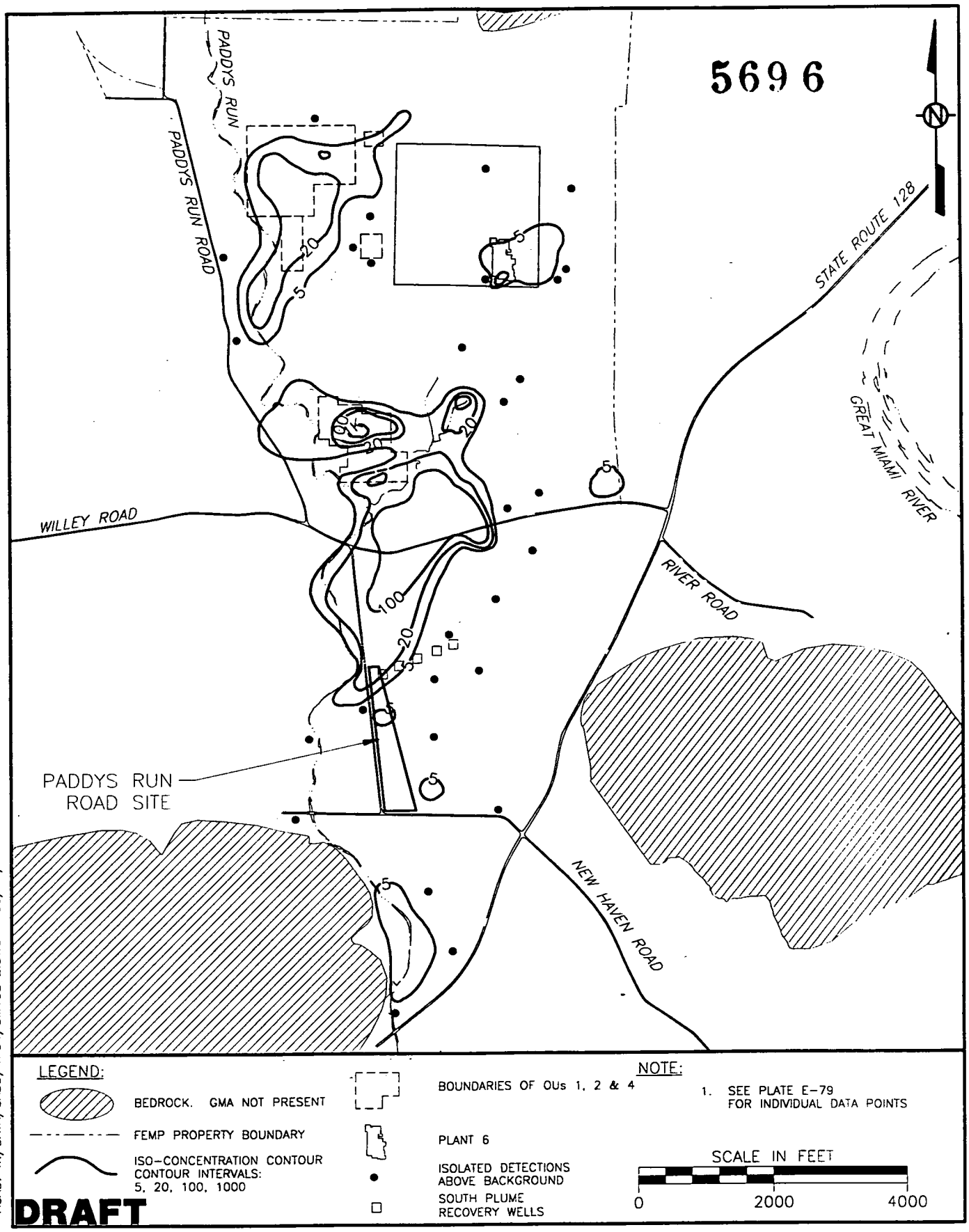


FIGURE 4-93 TOTAL URANIUM CONTAMINATION IN FEMP TYPE 2 WELLS – UNFILTERED SAMPLES, 1993 DATA SET



ACAD: W:/DATA/CADD/4P94/SM102F2.DWG 06/17/94 MB STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-94 TOTAL URANIUM CONTAMINATION IN FEMP TYPE 2 WELLS - FILTERED SAMPLES, 1993 DATA SET

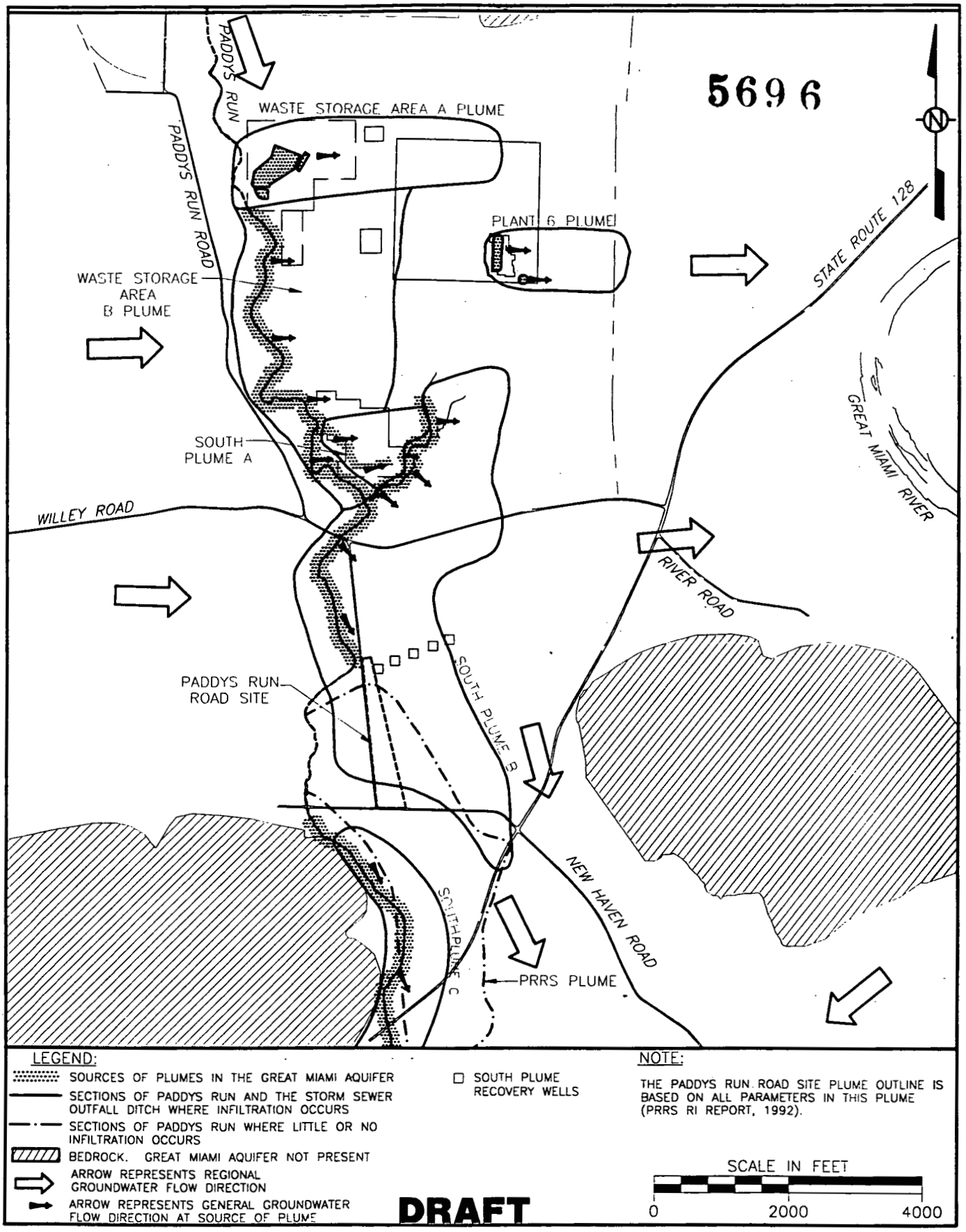


FIGURE 4-95 SCHEMATIC DEPICTION OF THE MAJOR FEMP AND PRRS PLUMES IN THE GREAT MIAMI AQUIFER

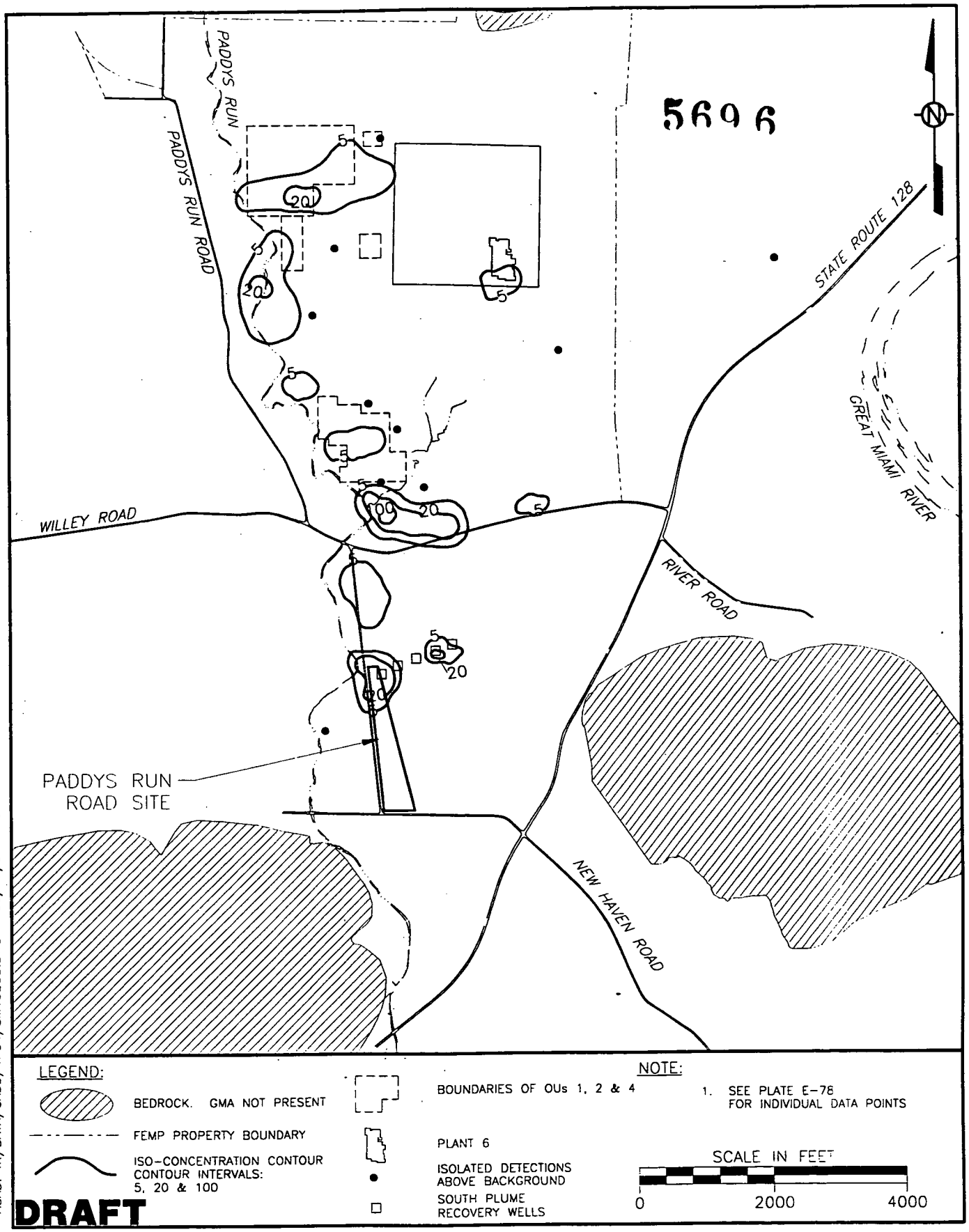


FIGURE 4-96 TOTAL URANIUM CONTAMINATION IN FEMP TYPE 3 WELLS – UNFILTERED SAMPLES, 1993 DATA SET

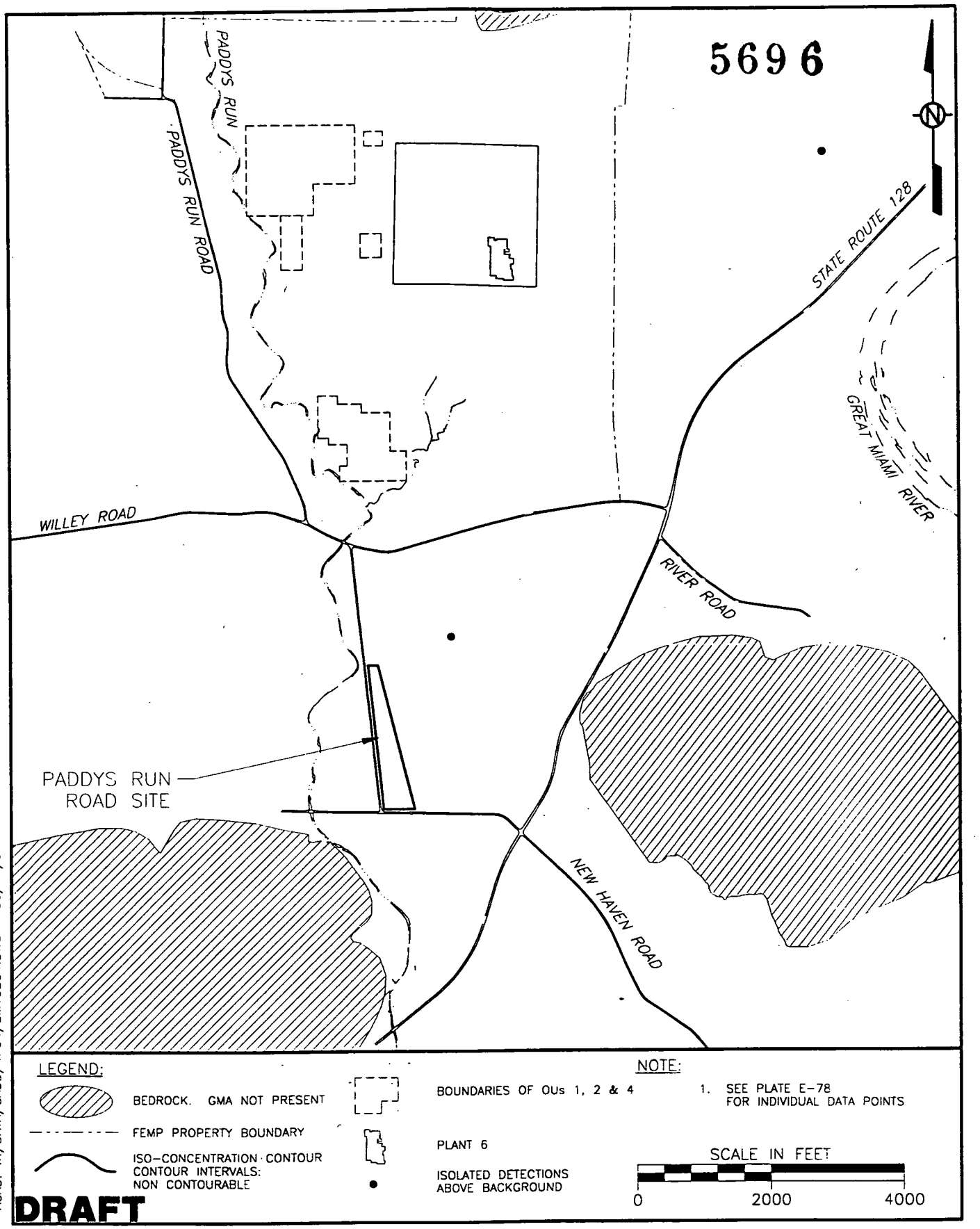


FIGURE 4-97 TOTAL URANIUM CONTAMINATION IN FEMP TYPE 4 WELLS – UNFILTERED SAMPLES, 1993 DATA SET

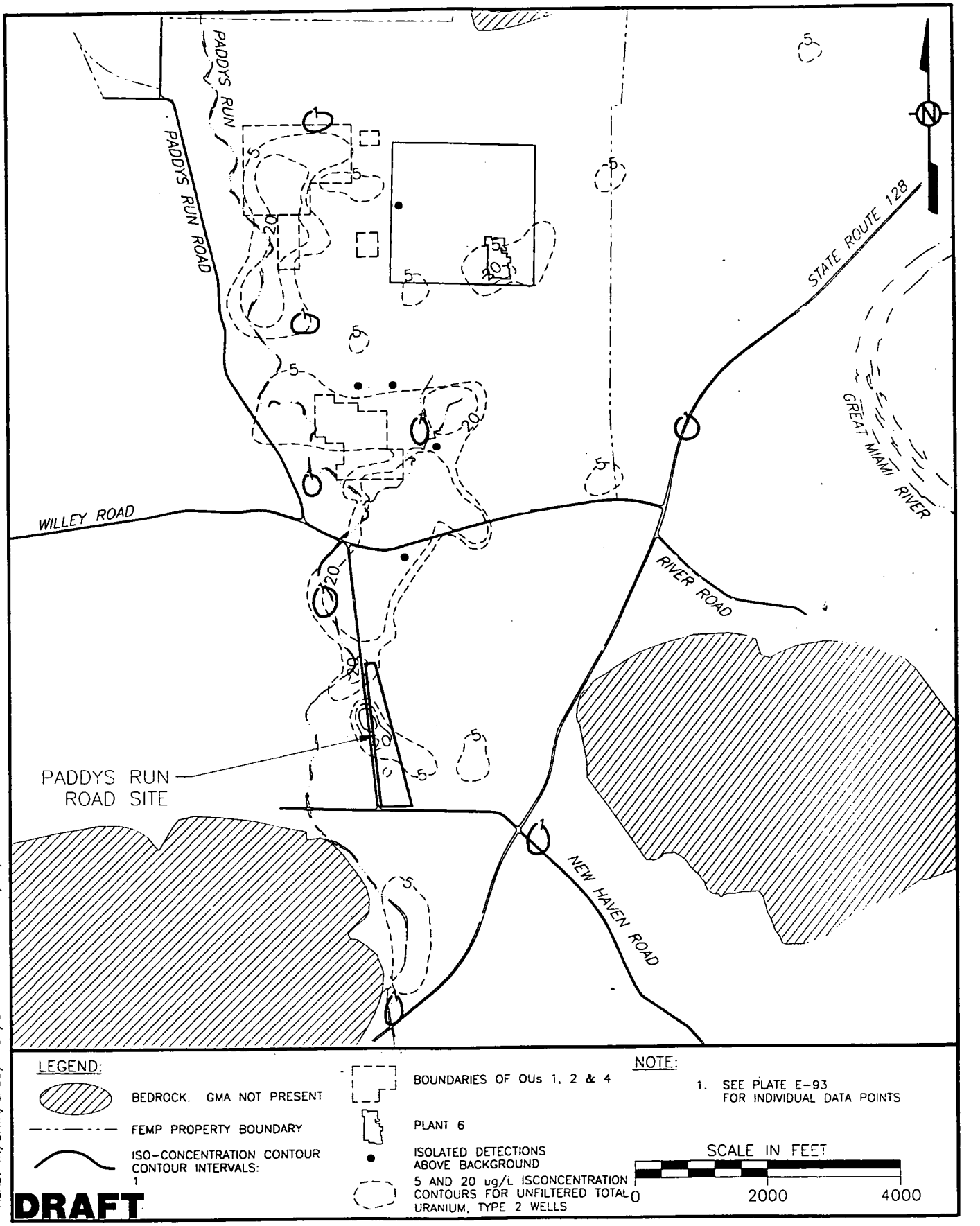
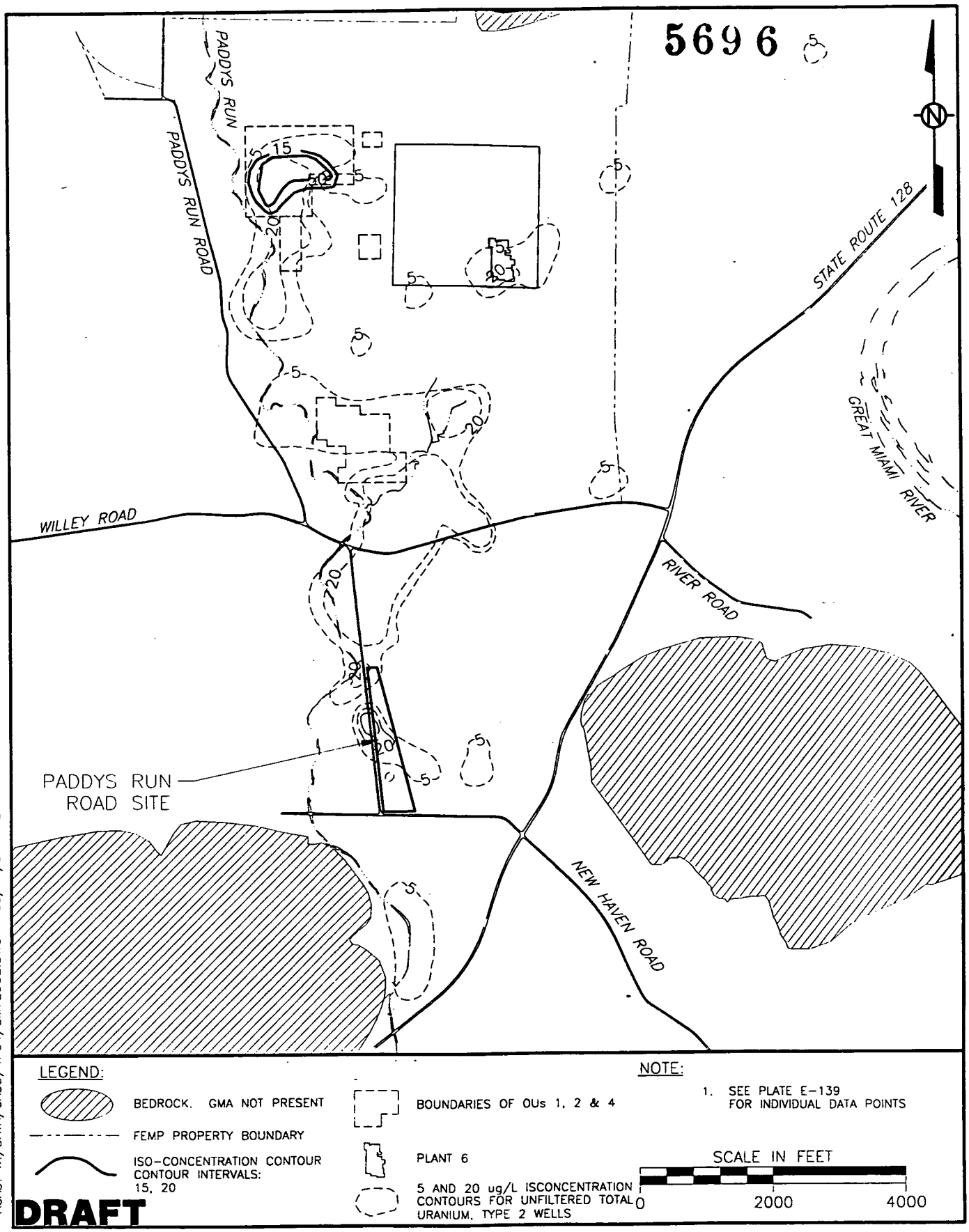


FIGURE 4-98 THORIUM-232 CONTAMINATION IN FEMP TYPE 2 WELLS - UNFILTERED SAMPLES, 1993 DATA SET



ACAD: W:/DATA/CADD/4P94/SM729U2.DWG 06/17/94 MB STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-99 NITRATE CONTAMINATION IN FEMP TYPE 2 WELLS - UNFILTERED SAMPLES, 1993 DATA SET

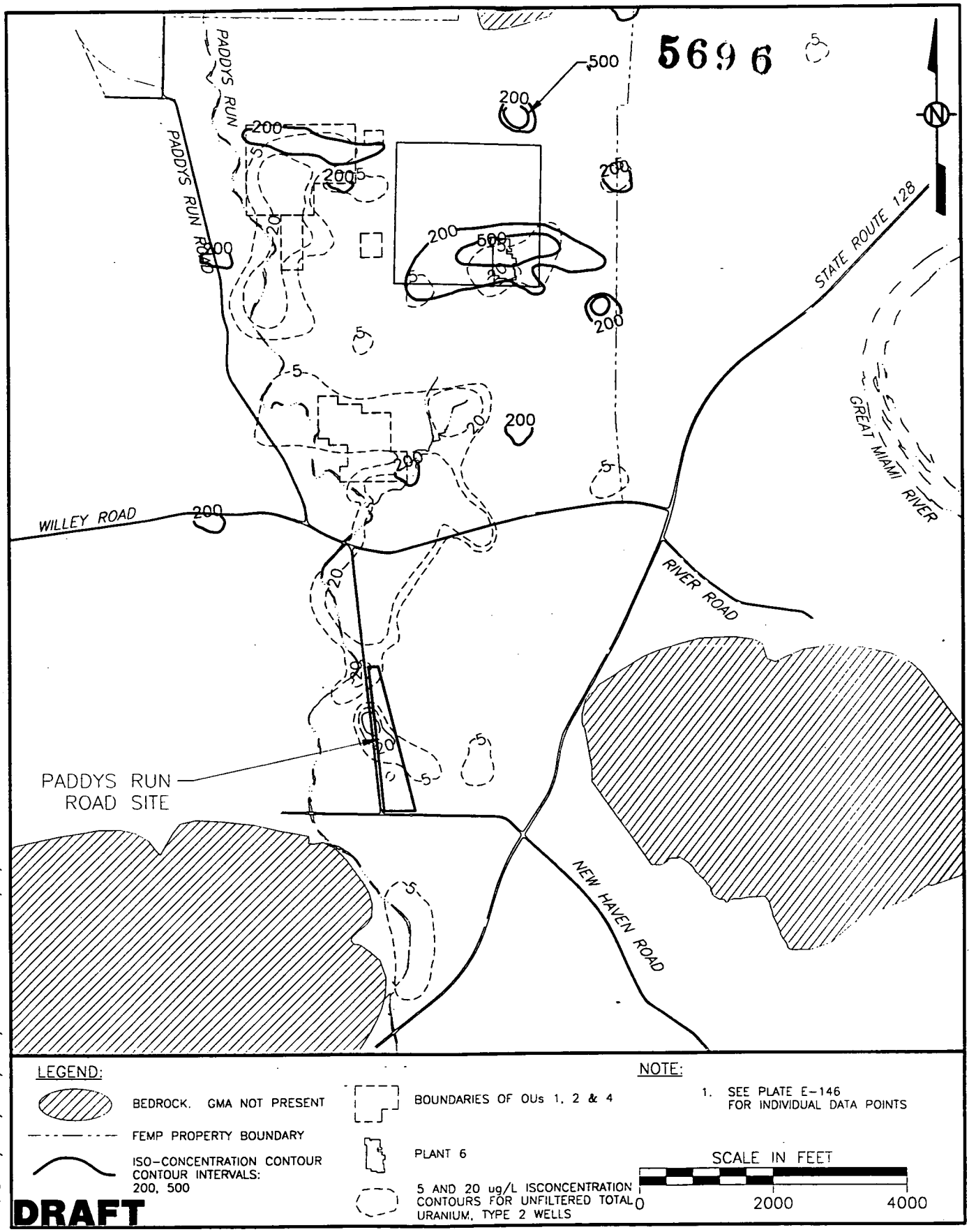
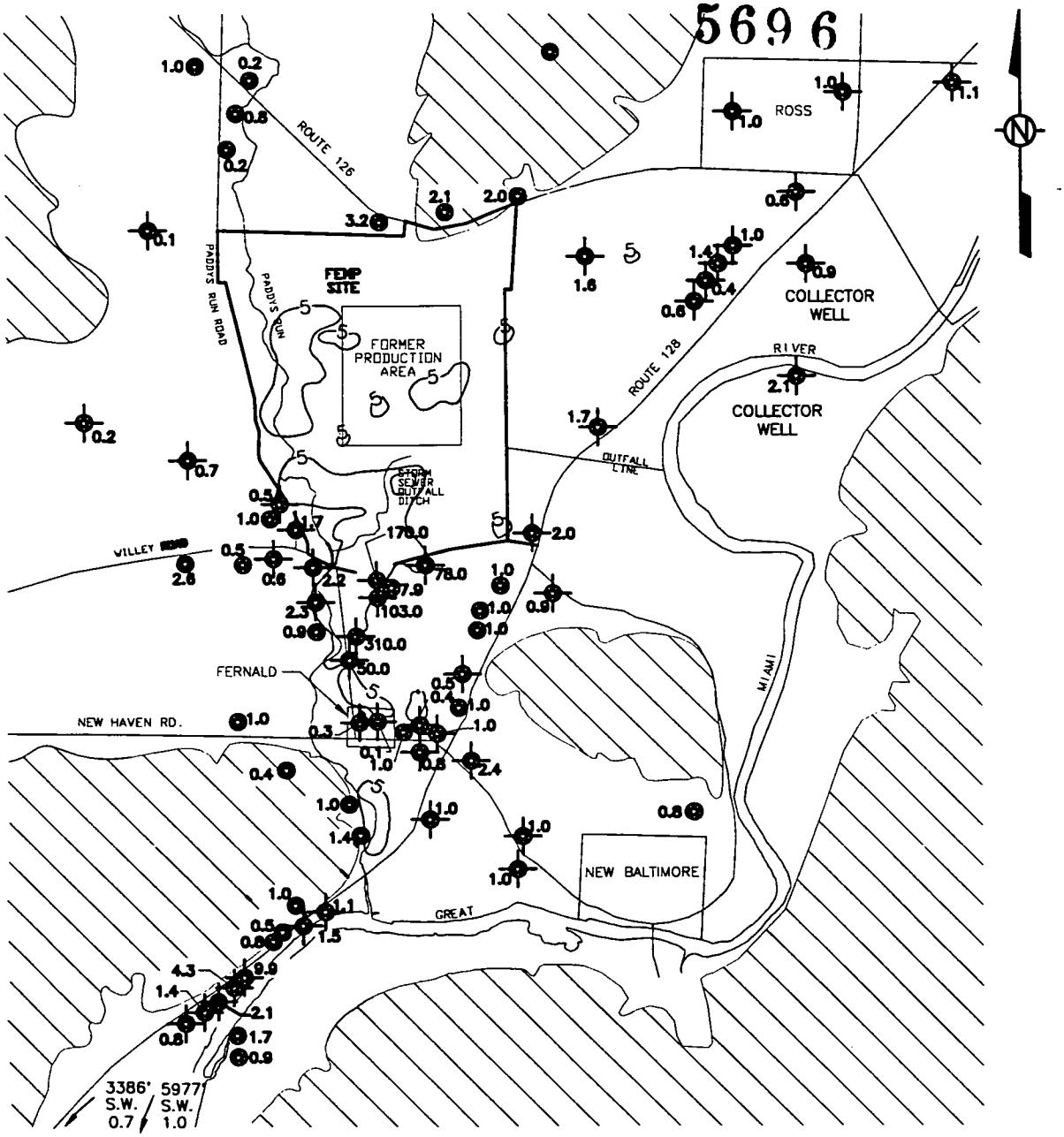


FIGURE 4-100 SULFATE CONTAMINATION IN FEMP TYPE 2 WELLS – UNFILTERED SAMPLES, 1993 DATA SET



LEGEND:

- 0.2 — WELL COMPLETED IN PERCHED ZONE OR BEDROCK, TOTAL URANIUM VALUE (µg/L)
- 0.7 — WELL COMPLETED IN THE GREAT MIAMI AQUIFER, TOTAL URANIUM VALUE (µg/L)
- FEMP PROPERTY BOUNDARY
- MUNICIPAL AREA
- BEDROCK
- 5 — 5 µg/L TOTAL URANIUM ISOCONCENTRATION CONTOURS IN GMA, TYPE 2 WELLS

NOTE:

1. INVENTORY INCLUDES RESIDENTIAL, COMMERCIAL, INDUSTRIAL, AGRICULTURAL, AND MONITORING WELLS.
2. COMPLETION DEPTHS AND CONSTRUCTION DETAILS FOR SOME WELLS ARE UNKNOWN.
3. THE MAXIMUM VALUE FROM 1993 DATA WAS SELECTED. IF 1993 DATA WERE UNAVAILABLE, THE MAXIMUM VALUE FROM THE MOST RECENT YEAR WAS SELECTED.
4. ALL ANALYSES PERFORMED AT FEMP ONSITE LAB.
5. WELL NUMBERS ARE SHOWN ON FIGURE A.1-4.

0 4000 8000
SCALE IN FEET

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STATE PLANAR COORDINATE SYSTEM 1927

W:\GMA\CADD\4P94\1CHERI1.DWG 6/23/94 MLS

FIGURE 4-101. TOTAL URANIUM CONCENTRATION (µg/L) DETECTED IN FEMP AREA PRIVATE WELLS-UNFILTERED SAMPLES, 1993 DATA

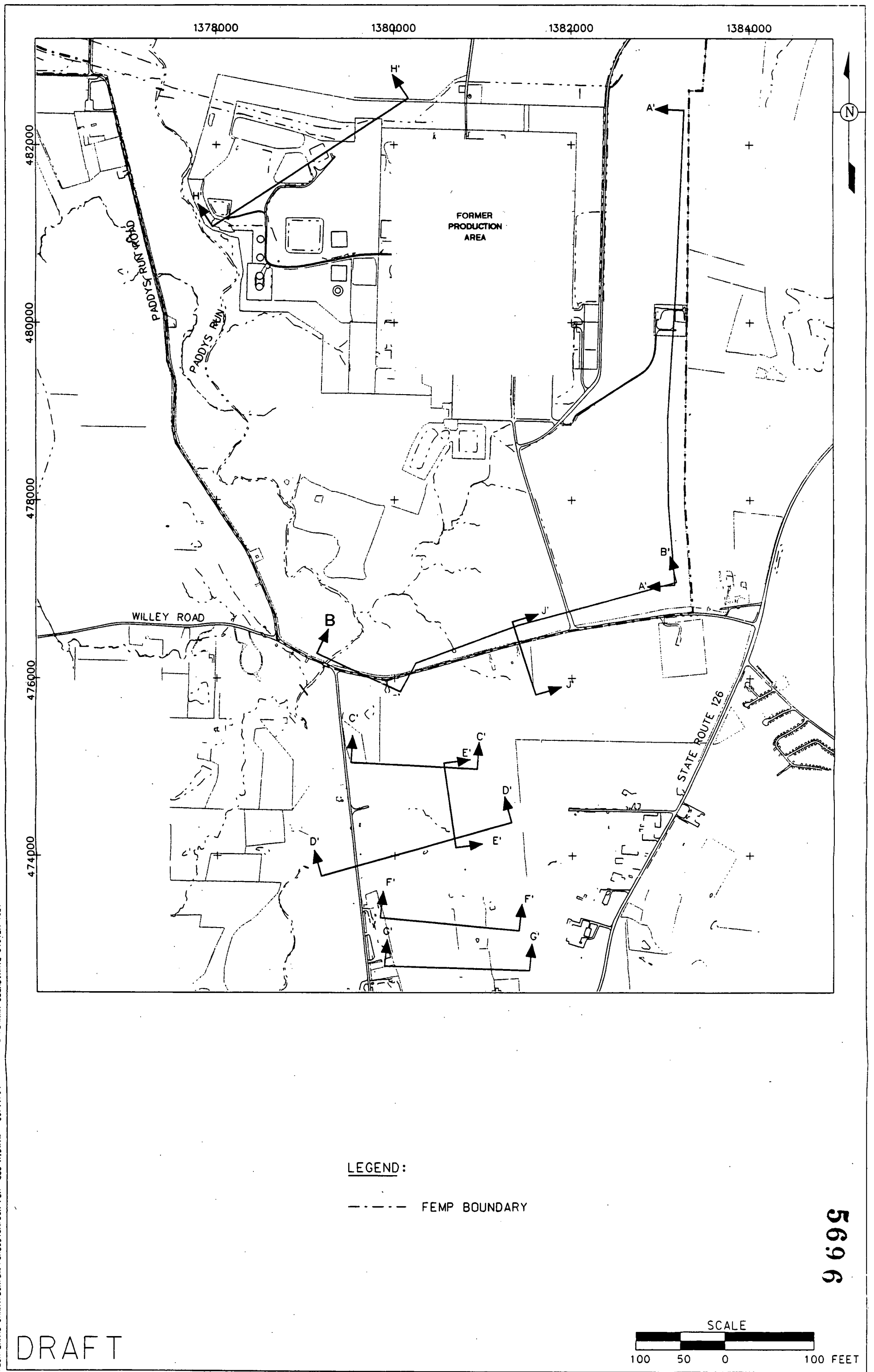
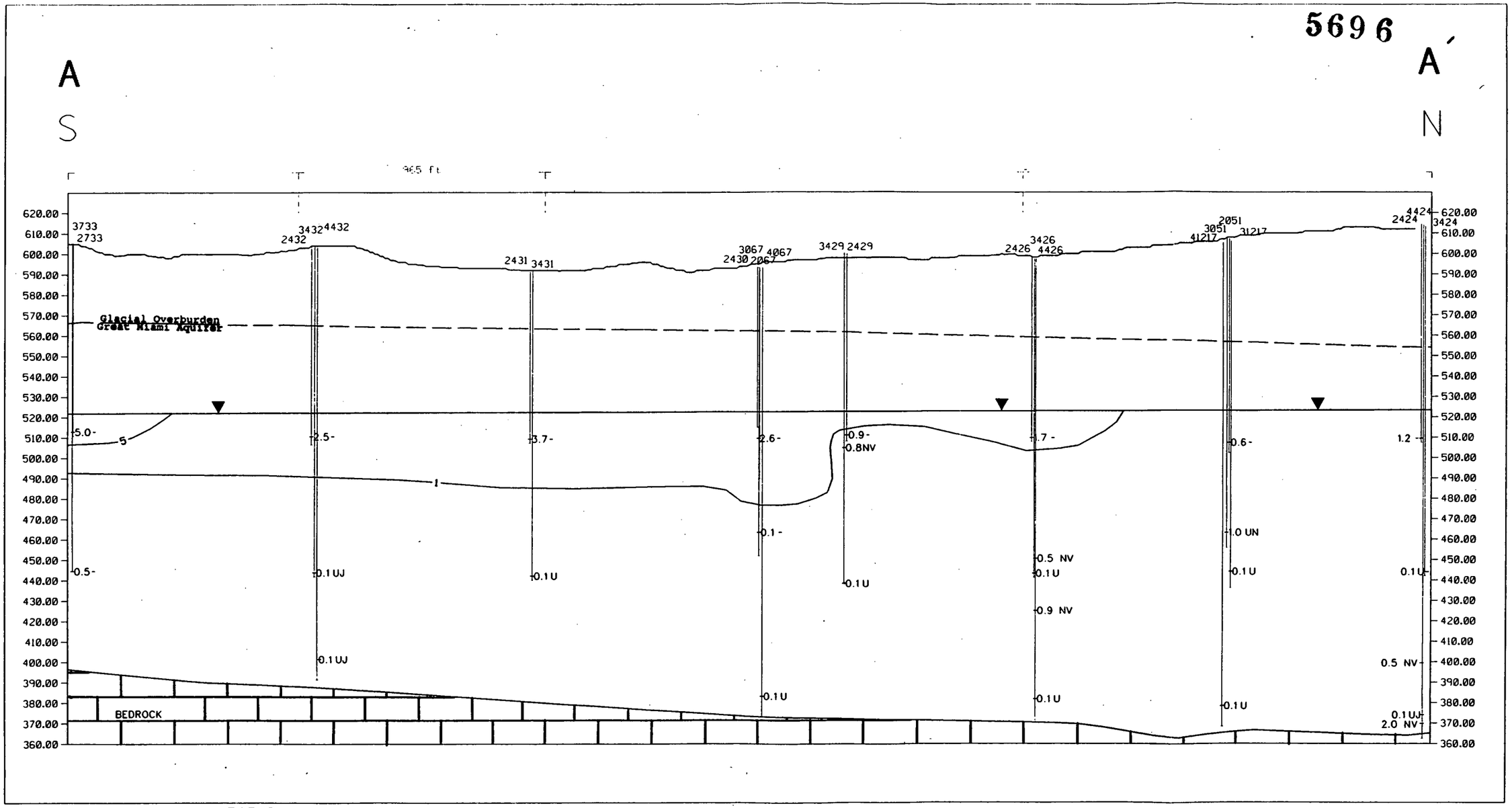


FIGURE 4-102 LOCATIONS OF CROSS- SECTIONS DEPICTING TOTAL URANIUM IN GROUNDWATER



LEGEND:

77.1 — TOTAL URANIUM IN GROUNDWATER (μg/L)

10 — TOTAL URANIUM ISOPLETH FOR GROUNDWATER (μg/L)

GLACIAL OVERBURDEN/ GREAT MIAMI AQUIFER BOUNDARY

1771 — MONITORING WELL/BORING NUMBER

WATER ELEVATION

NOTE: Uranium values are from unfiltered samples. The water elevations shown are estimated.

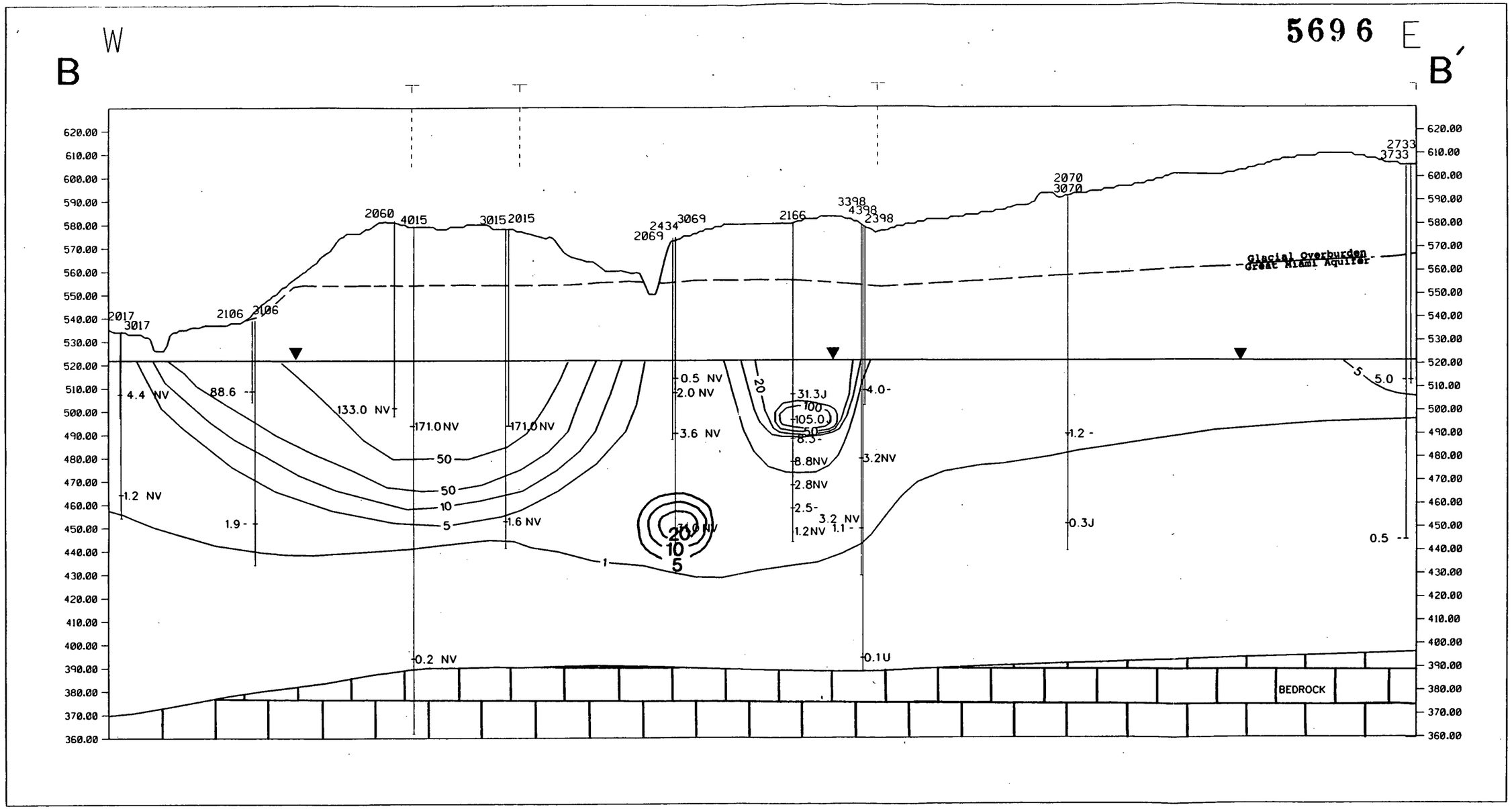
Data Qualifiers:
NV = nonvalidated
- = validated, not qualified
J = validated, estimated

SCALE
400 200 0 400 FEET

DRAFT

/ermo3/5grn1/dgn/sec/geo/dpth/tomoa.dgn FER OU5 RIDATA 6-17-94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-103. TOTAL URANIUM IN GROUNDWATER CROSS-SECTION A-A'



LEGEND:

77.1 — TOTAL URANIUM IN GROUNDWATER (μg/L)

10 — TOTAL URANIUM ISOPLETH FOR GROUNDWATER (μg/L)

GLACIAL OVERBURDEN/ GREAT MIAMI AQUIFER BOUNDARY

1771 — MONITORING WELL/BORING NUMBER

WATER ELEVATION

NOTE: Uranium values are from unfiltered samples. The water elevations shown are estimated.

Data Qualifiers:
NV = nonvalidated
\- = validated, not qualified
J = validated, estimated

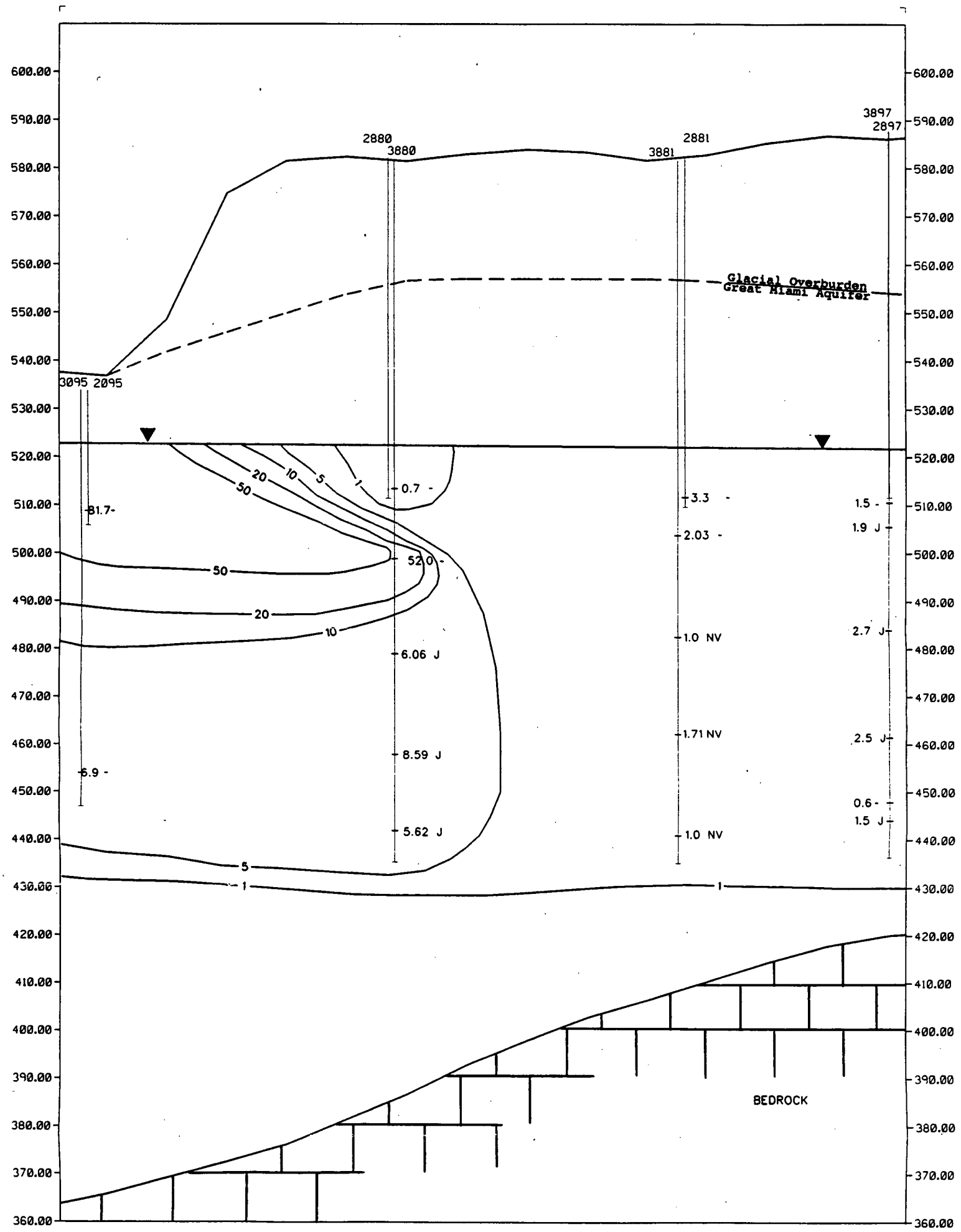
SCALE
350 175 0 350 FEET

DRAFT

/erma3/5arn1/dgn/sec/geo/dpth/tombb.dgn FER 005 RIDATA 6-17-94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-104 TOTAL URANIUM IN GROUNDWATER CROSS-SECTION B-B'

/armd3/5arn1/dgn/sec/geo/dpth/tomcc.dgn FER QUS RIDATA 6-17-94 STATE PLANAR COORDINATE SYSTEM 1927



LEGEND:

+ 77.1	TOTAL URANIUM IN GROUNDWATER (μg/L)
—— 10 ——	TOTAL URANIUM ISOPLETH FOR GROUNDWATER (μg/L)
- - - - -	GLACIAL OVERBURDEN/ GREAT MIAMI AQUIFER BOUNDARY
1771	MONITORING WELL/BORING NUMBER
▼	WATER ELEVATION

NOTE: Uranium values are from unfiltered samples. The water elevations shown are estimated.

Data Qualifiers:
NV = nonvalidated
- = validated, not qualified
J = validated, estimated

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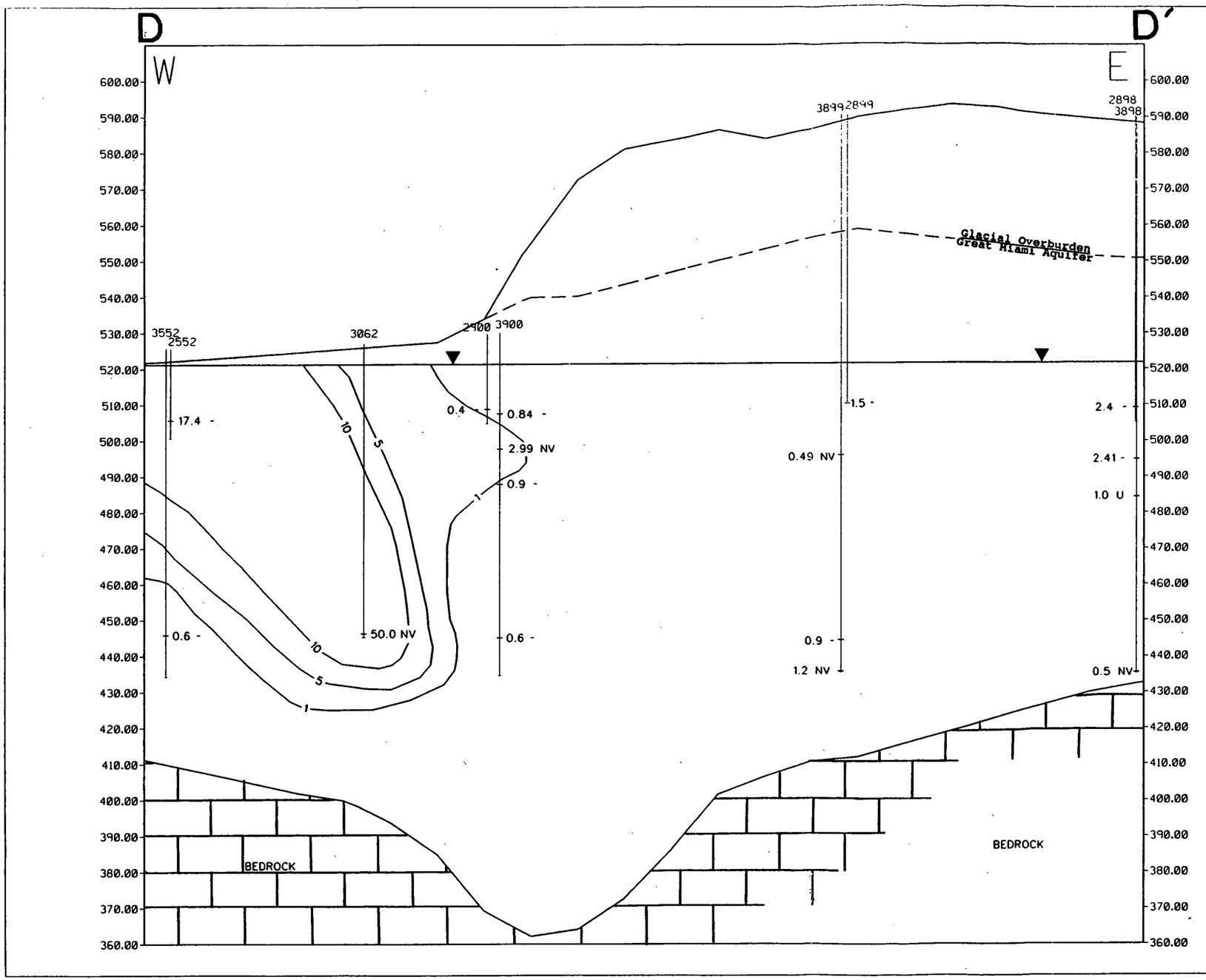
SCALE
200 100 0 200 FEET

FIGURE 4-105 TOTAL URANIUM IN GROUNDWATER CROSS-SECTION C-C'



NOTE: Uranium values are from unfiltered samples. The water elevations shown are estimated.

Data Qualifiers:
NV = nonvalidated
\- = validated, not qualified
J = validated, estimated

LEGEND:

+ 77.1	TOTAL URANIUM IN GROUNDWATER (μg/L)
—— 10 ——	TOTAL URANIUM ISOPLETH FOR GROUNDWATER (μg/L)
- - - - -	GLACIAL OVERBURDEN/ GREAT MIAMI AQUIFER BOUNDARY
1771	MONITORING WELL/BORING NUMBER
▼	WATER ELEVATION

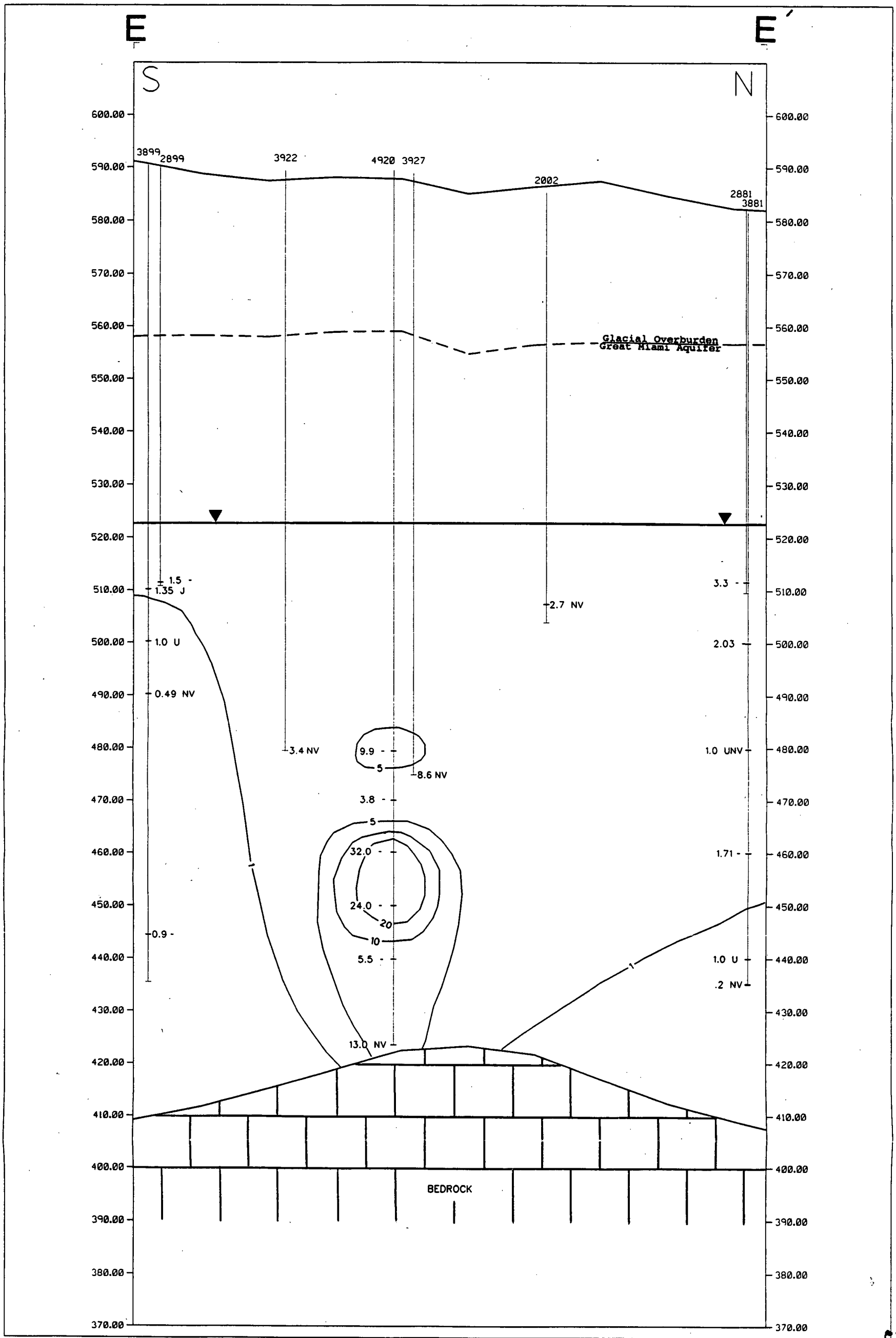
DRAFT

SCALE
250 125 0 250 FEET

/ermo3/5arn1/dgn/sec/geo/dpth/tomdd.dgn FER OU5 RIDATA 6-17-94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-106 TOTAL URANIUM IN GROUNDWATER CROSS-SECTION D-D'

/ermo3/5grn1/dgn/sec/geo/dpth/tomee.dgn FER OU5 RIDATA 6-17-94 STATE PLANAR COORDINATE SYSTEM 1927



LEGEND:

+ 77.1	TOTAL URANIUM IN GROUNDWATER (µg/L)	1771	MONITORING WELL/BORING NUMBER
—— 10 ——	TOTAL URANIUM ISOPLETH FOR GROUNDWATER (µg/L)	▼	WATER ELEVATION
- - - - -	GLACIAL OVERBURDEN/ GREAT MIAMI AQUIFER BOUNDARY		

NOTE: Uranium values are from unfiltered samples. The water elevations shown are estimated.

Data Qualifiers:
NV = nonvalidated
- = validated, not qualified
J = validated, estimated

SCALE
150 75 0 150 FEET

DRAFT

FIGURE 4-107 TOTAL URANIUM IN GROUNDWATER CROSS-SECTION E-E'

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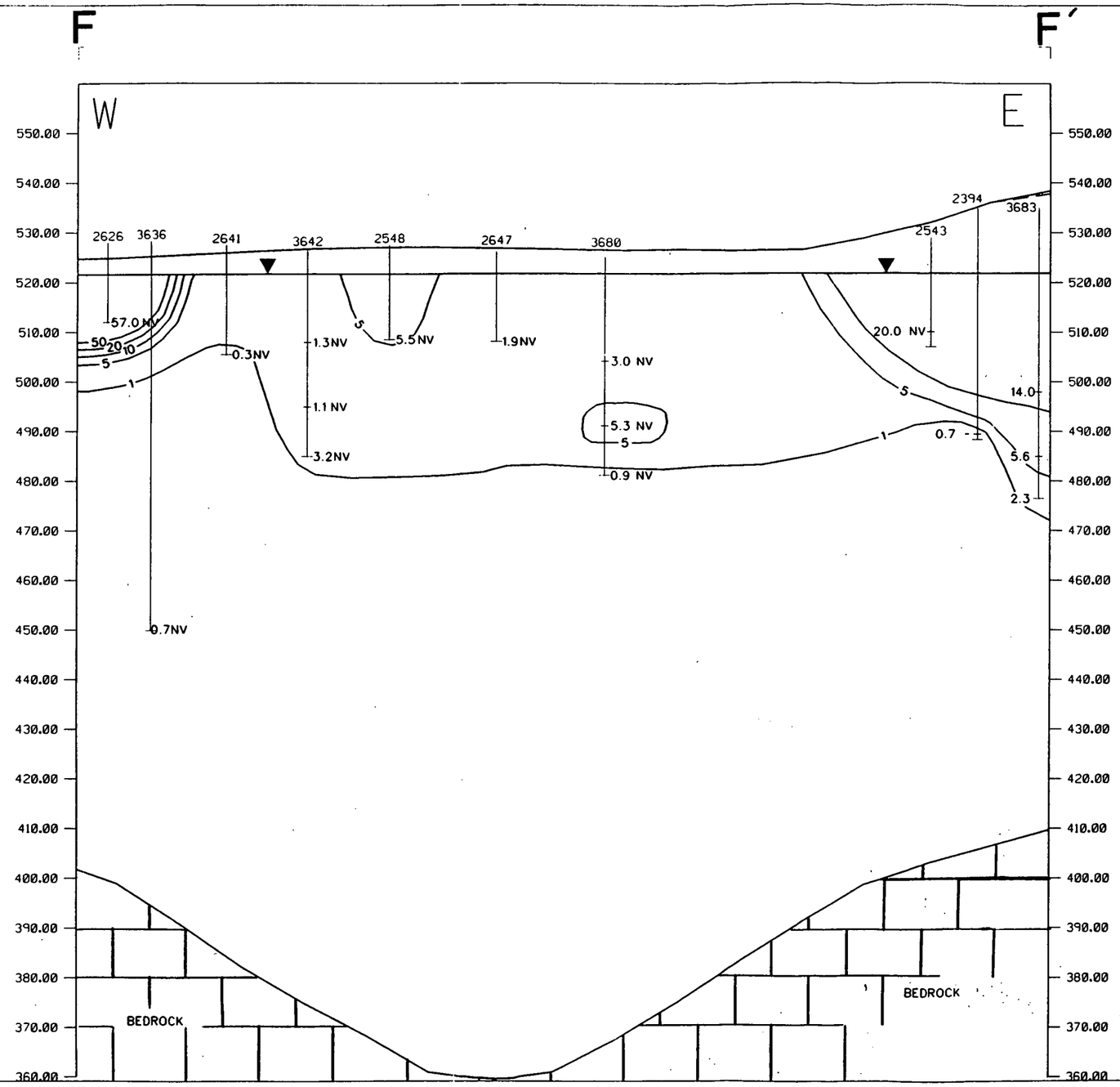


LEGEND:

77.1	TOTAL URANIUM IN GROUNDWATER (μg/L)
10	TOTAL URANIUM ISOPLETH FOR GROUNDWATER (μg/L)
1771	MONITORING WELL/BORING NUMBER
	WATER ELEVATION

NOTE: Uranium values are from unfiltered samples. The water elevations shown are estimated.

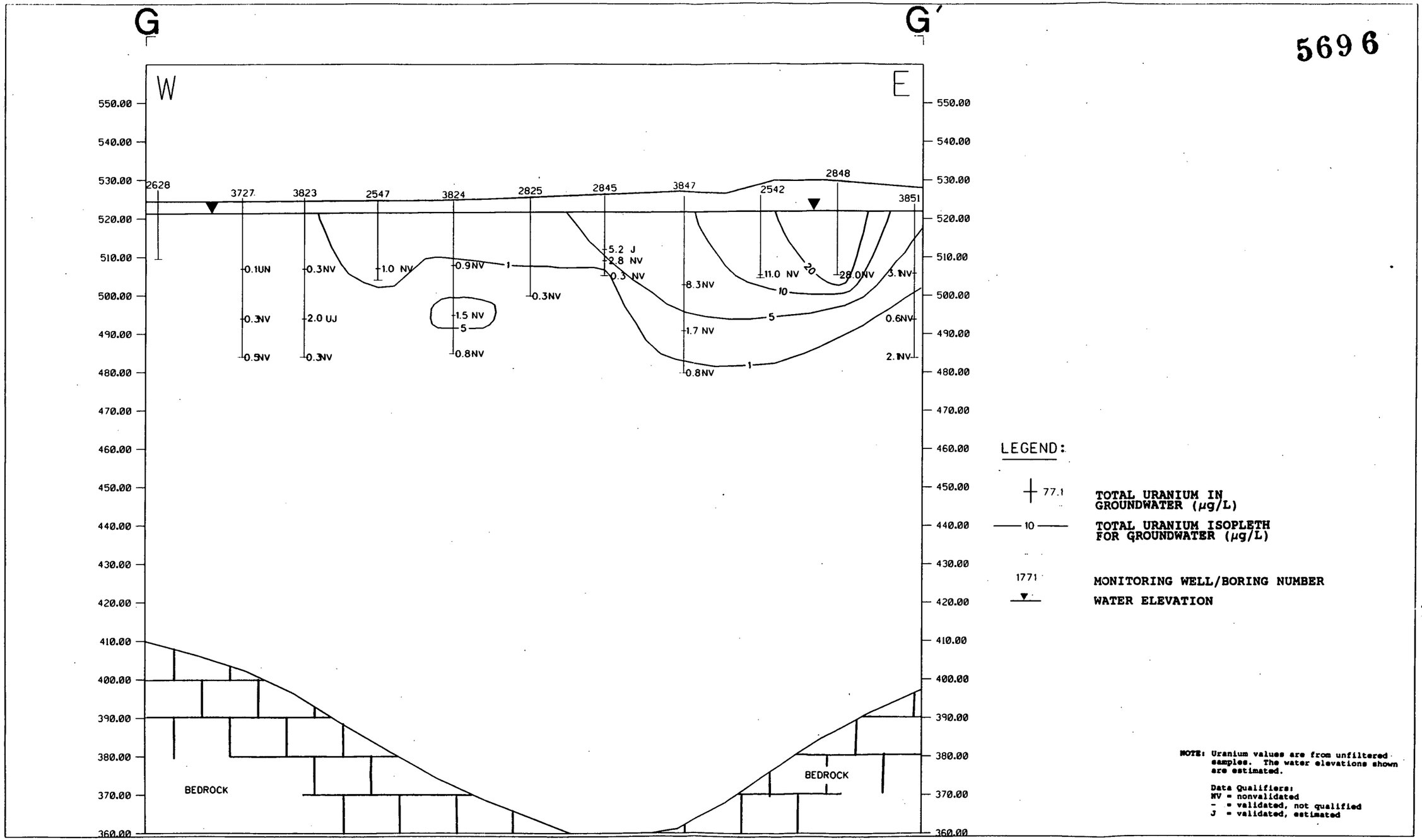
Data Qualifiers:
NV = nonvalidated
- = validated, not qualified
J = validated, estimated

SCALE
200 100 0 200 FEET

DRAFT

/erma3/5arn1/dgn/sec/geo/dpth/tomff.dgn FER OU5 RIDATA 6-17-94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-108 TOTAL URANIUM IN GROUNDWATER CROSS-SECTION F-F'



LEGEND:

77.1 — TOTAL URANIUM IN GROUNDWATER (μg/L)

10 — TOTAL URANIUM ISOPLETH FOR GROUNDWATER (μg/L)

1771 — MONITORING WELL/BORING NUMBER

▼ — WATER ELEVATION

NOTE: Uranium values are from unfiltered samples. The water elevations shown are estimated.

Data Qualifiers:
NV = nonvalidated
- = validated, not qualified
J = validated, estimated

SCALE
200 100 0 200 FEET

DRAFT

/erma3/5arn1/dgn/sec/geo/dpth/tomgg.dgn FER OU5 RIDATA 6-17-94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-109 TOTAL URANIUM IN GROUNDWATER CROSS-SECTION G-G'

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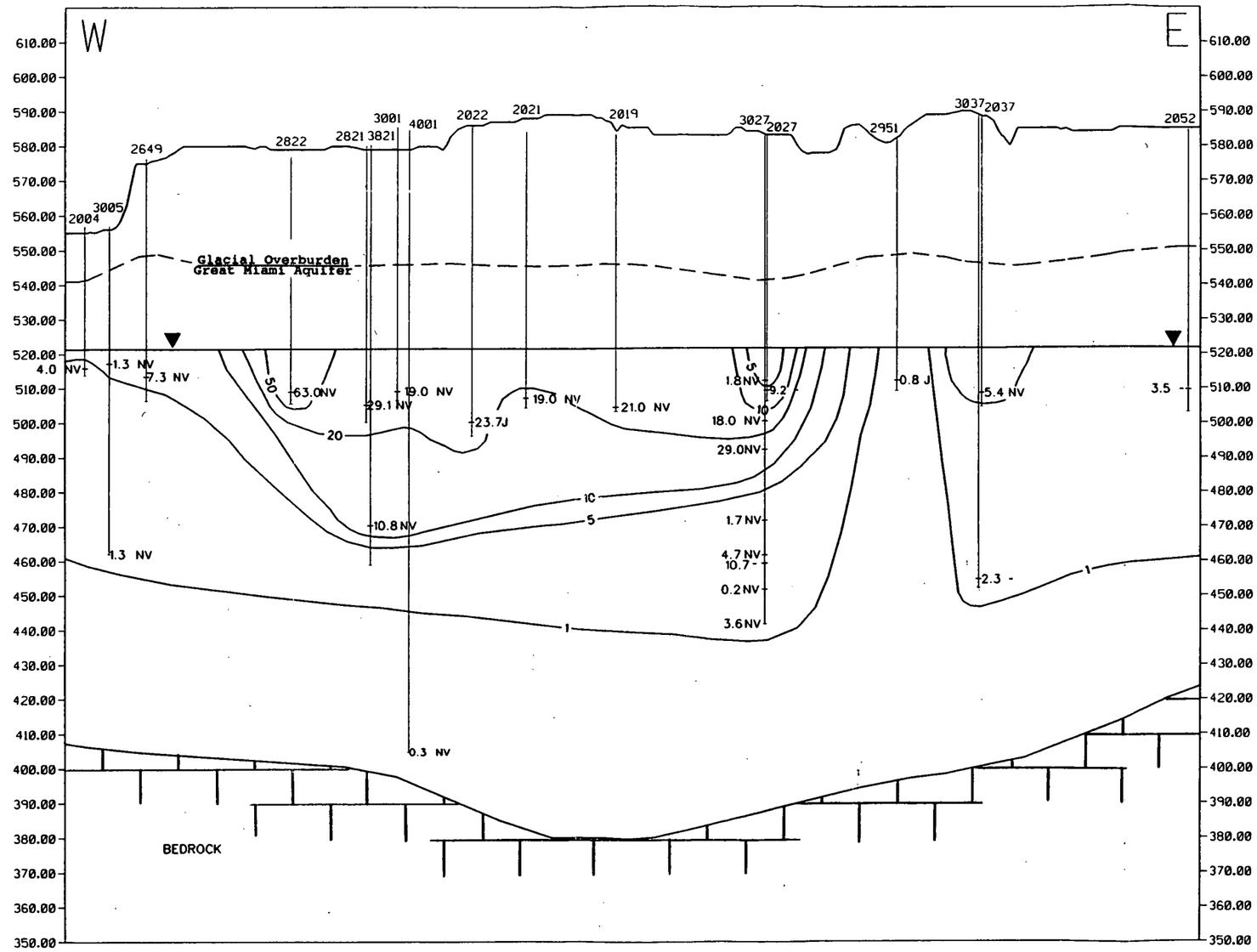

LEGEND:

+ 77.1	TOTAL URANIUM IN GROUNDWATER (μg/L)	1771	MONITORING WELL/BORING NUMBER
—— 10 ——	TOTAL URANIUM ISOPLETH FOR GROUNDWATER (μg/L)	▼	WATER ELEVATION
- - - - -	GLACIAL OVERBURDEN/ GREAT MIAMI AQUIFER BOUNDARY		

NOTE: Uranium values are from unfiltered samples. The water elevations shown are estimated.

Data Qualifiers:
NV = nonvalidated
\- = validated, not qualified
J = validated, estimated

SCALE
300 150 0 300 FEET

DRAFT

/erma3/5arn1/dgn/sec/geo/dpth/tomhh.dgn FER DU5 RIDATA 6-17-94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-110 TOTAL URANIUM IN GROUNDWATER CROSS-SECTION H-H'

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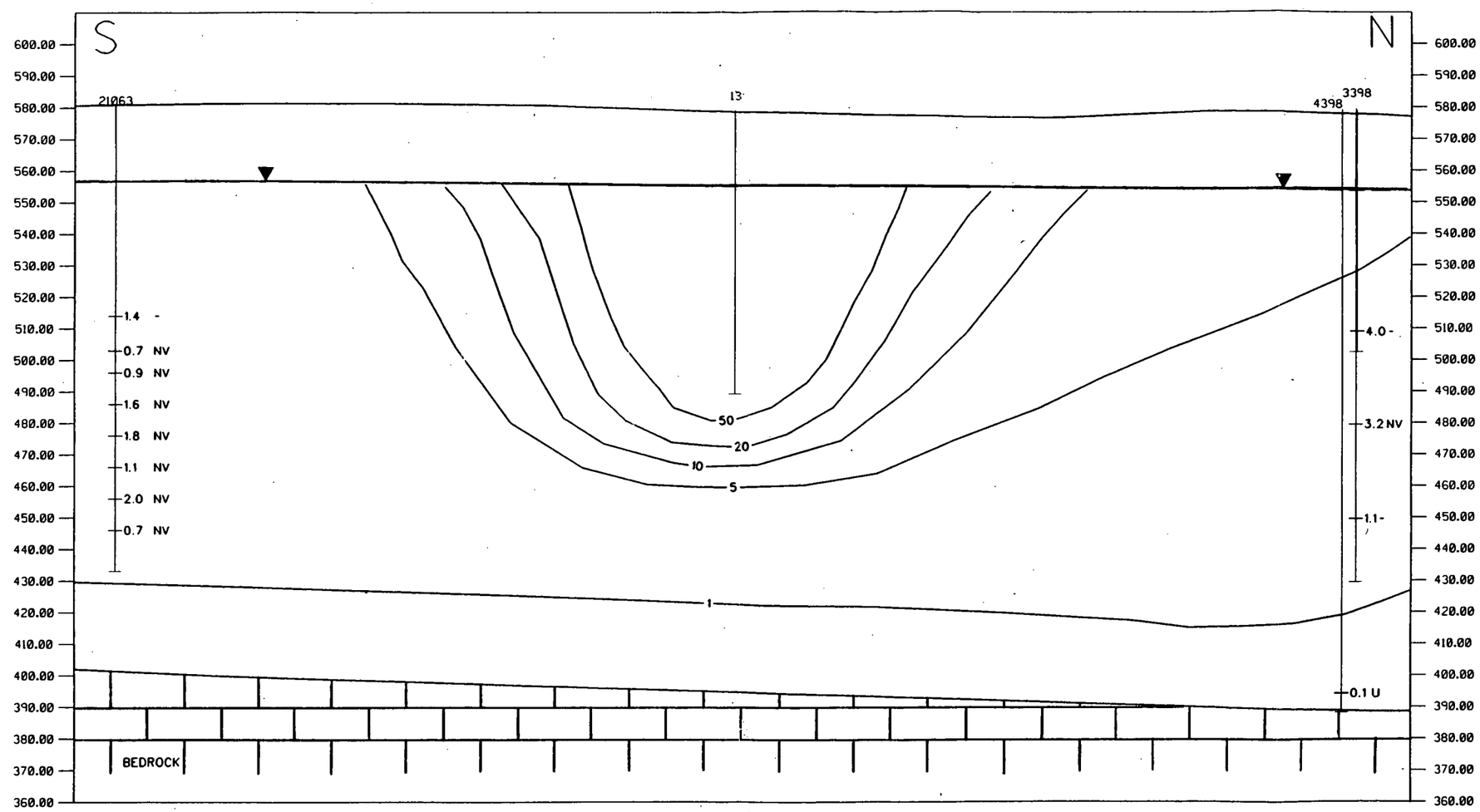


LEGEND:

77.1 TOTAL URANIUM IN GROUNDWATER (µg/L)

10 TOTAL URANIUM ISOPLETH FOR GROUNDWATER (µg/L)

GLACIAL OVERBURDEN/ GREAT MIAMI AQUIFER BOUNDARY

1771 MONITORING WELL/BORING NUMBER

WATER ELEVATION

NOTE: Uranium values are from unfiltered samples. The water elevations shown are estimated.

Data Qualifiers:
NV = nonvalidated
- = validated, not qualified
J = validated, estimated

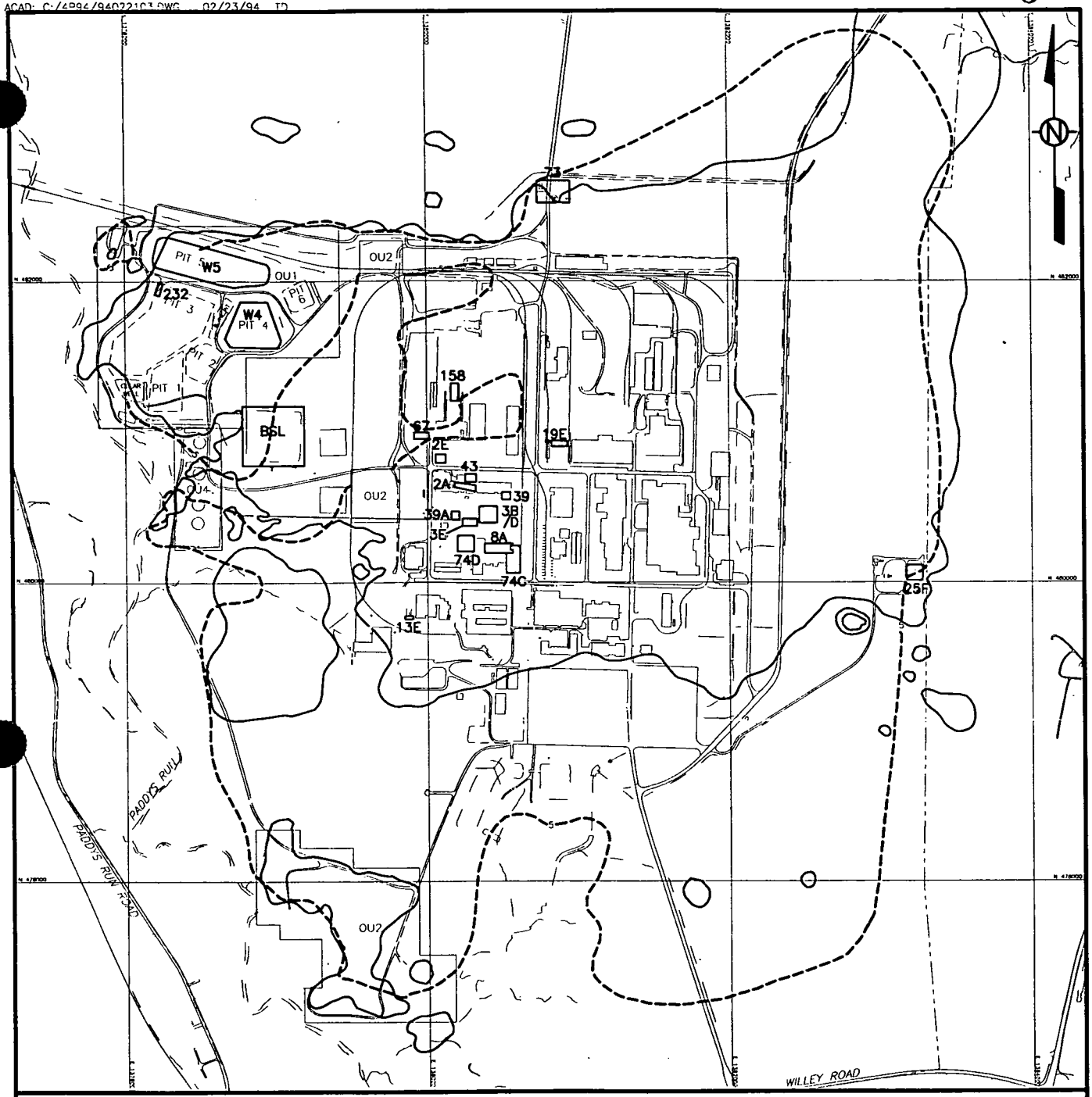
SCALE
80 40 0 80 FEET

DRAFT

/ermo3/5arn1/dgn/sec/geo/dpth/tomj.dgn FER OU5 RIDATA 6-17-94 STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 4-111 TOTAL URANIUM IN GROUNDWATER CROSS-SECTION J-J'

000968



LEGEND:

PERCHED GROUNDWATER PLUMES BENEATH HWMU AREAS (BASED ON 5 ug/L TOTAL URANIUM CONTOUR)

20 mg/kg TOTAL URANIUM SURFACE SOIL ISOCONCENTRATION CONTOUR

2A ORE REFINERY PLANT UNH TANKS
2E NFS UNH TANKS
43 UNH TANKS
3E HOT RAFFINATE BUILDING UNH TANKS
3B/3D NAR SYSTEM COMPONENTS
39 UNH TANKS
39A TRANE INCINERATOR
8A SCRAP RECOVERY PLANT
INCLUDES: BOX FURNACE
OXIDATION FURNACE
PRIMARY CALCINER
74C PLANT 8 EAST DRUM STORAGE PAD
74D PLANT 8 WEST DRUM STORAGE PAD

W4 WASTE PIT 4
W5 WASTE PIT 5
232 EXPERIMENTAL TREATMENT FACILITY

BSL BIOSURGE LAGOON
13E PILOT PLANT SUMP
158 WHEELABRATOR
67 PLANT 1 STORAGE BUILDING
19E TANK FARM SUMP
73 FIRE TRAINING FACILITY
25F SLUDGE DRYING BEDS

SCALE
0 1000 1600 FEET

FIGURE 4-112
LOCATION OF HWMUs TO BE CLOSED UNDER THE CERCLA PROCESS

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5.0 CONTAMINANT FATE AND TRANSPORT

The fate and transport models required to support the baseline risk assessment were developed and applied to predict contaminant movement from source areas to potential human or ecological receptors. Potential migration pathways through the environmental media over a 1000-year time frame were considered. The modeling provides the best forecast of likely contaminant migration to off-property locations which are not currently monitored and allows for future exposure predictions by extrapolating from known field data. The models, used in conjunction with monitoring data, predict contaminant concentrations at potential exposure locations over the 1000-year modeling time frame. Conservative assumptions were used in the models to provide a "reasonable worst case" picture of contaminant fate and transport. Some of the general modeling assumptions regarding the future conditions are summarized in Section 5.1.2.6.

Predicted future contaminant concentrations are based on currently unremediated and partially remediated (e.g., the ongoing South Groundwater Contamination Plume recovery well system) contaminant sources found in the Operable Unit 5 environmental media. The results of the fate and transport modeling of air, surface water, and groundwater pathways are used with measured current contaminant conditions in the Operable Unit 5 Baseline Risk Assessment (Section 6.0 and Appendix A) to estimate potential risks to human health and the ecological environment.

In general, Section 5.0 is an integrated summary of Appendix F, which presents more detailed discussions of pathway-specific modeling processes and results. Section 5.1 describes the overall objectives, assumptions, source area delineation, conceptual model, and modeling framework of the Operable Unit 5 contaminant fate and transport modeling. Section 5.2 discusses the contaminant conditions and characteristics found in the Operable Unit 5 source areas. Section 5.3 briefly presents the pathway-specific fate and transport models, modeling processes, and required modeling results. Section 5.4 summarizes the key modeling results by individual pathway and exposure point. Overall evaluations and summaries of the fate and transport modeling completed in Operable Unit 5 for each pathway are presented in Section 5.5. Appendix F and the Baseline Risk Assessment (Section 6.0 and Appendix A) contain more detailed information about the fate and transport modeling processes and the modeled impacts on environmental media or receptors.

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5.1 INTRODUCTION

Operable Unit 5 is defined as the environmental media within the boundaries of and surrounding the Fernald Environmental Management Project (FEMP) (see Section 3.0). Results of past investigations in the study area that characterize the environmental media are discussed in Sections 2.0, 3.0, and 4.0. From the standpoint of fate and transport modeling, Operable Unit 5 is more complex than those for other operable units due to the following factors:

- A large study area with different hydrogeologic units (i.e., glacial overburden, Great Miami Aquifer, Paddys Run, and Great Miami River) with various physical and geochemical conditions.
- Numerous large, separate source areas which, unlike other operable units, do not have readily definable boundaries for contaminant source characterizations.
- A large number of contaminants of concern, with a wide range of chemical characteristics, from other operable units at the FEMP.
- By far the largest amount of geological and analytical data to be evaluated and incorporated into the models.
- Complicated interactions and consistency issues among the multiple operable units at the FEMP.

Because of these complexities, new modeling tools and technical approaches not previously used by other operable units were necessary for Operable Unit 5 fate and transport modeling. The following six technical reports have been developed to provide more detailed information regarding the development and application of these modeling tools and approaches; the latest revisions of these reports are incorporated into this Operable Unit 5 RI Report by reference:

- Groundwater Modeling Report - Summary of Model Development (DOE 1993d).
- Groundwater Model Evaluation Report and Improvement Plan (DOE 1993c).
- Development and Application of the ECTran Model to Support the RI/FS at the FEMP (DOE 1993b).
- Surface Water Flow and Infiltration Model Summary Report (DOE 1994i).
- Glacial Overburden/Upper Great Miami Aquifer System Model Report (DOE 1994f).
- SWIFT Great Miami Aquifer Model - Summary of Improvements Report (DOE 1994j).

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The overall objectives, conceptual model, and modeling framework critical to Operable Unit 5 contaminant fate and transport modeling are summarized in this section. Rationale of contaminant source area delineation and assumptions about future conditions required to determine the modeling approach are also described.

5.1.1 Operable Unit 5 Remedial Investigation Modeling

As shown in Figure 5-1, the Operable Unit 5 remedial investigation/feasibility study (RI/FS) includes various fate and transport modeling tasks in different stages of the processes. The modeling presented in this report includes the supplemental modeling characterization and the baseline fate and transport modeling performed in the Operable Unit 5 remedial investigation (RI).

Together with the field data, the supplemental modeling characterizations were first conducted to define the cumulative impacts to Operable Unit 5 from Operable Units 1, 2, and 4 before their cleanups, thus defining the current contamination conditions at the FEMP. The past impacts from Operable Unit 3 to the environmental media were defined by directly using analytical data collected from soil, perched water, and groundwater in the Great Miami Aquifer underlying the former production area. Baseline fate and transport modeling was then conducted to predict future contamination conditions under the no-action scenario for Operable Unit 5.

Supplemental modeling characterization and baseline fate and transport modeling are two technically different types of modeling activities. Supplemental modeling characterization is conducted to analyze existing data or past conditions and data is available for evaluating model performance. Examples of this type of modeling include model calibration and simple spatial extrapolation of data. Baseline fate and transport modeling predicts future conditions according to assumptions about future scenarios. In general, environmental data covering long durations of time are not available to quantify the model accuracy. The accuracy and data requirements for these two types of modeling are different because of: their distinct objectives, uncertainties associated with the future hydrogeological conditions, and assumptions about future land-use scenarios. Conservative assumptions are used in the predictive model to provide a "reasonable worst case" picture of future contaminant migration. Most of the information required by the Operable Unit 5 baseline risk assessment was generated by predictive modeling.

5.1.1.1 Objectives

The assumptions and approaches of the fate and transport modeling for the Operable Unit 5 RI were influenced by the Operable Unit 5 baseline risk assessment and overall objectives of the RI.

The major objective of the fate and transport modeling for Operable Units 1, 2, 3, and 4 is to determine and/or justify the need to stop or reduce future contaminant loadings to the environmental media from the FEMP. The main objective of the fate and transport modeling for Operable Unit 5 is to determine the need for additional remedial actions to recover or contain contaminants that have already been released into the environmental media, after the source loadings have been stopped or reduced by the other operable units. The need for additional remedial actions will be based on the estimated future impacts to human and ecological receptors over a 1000-year time frame.

5.1.1.2 Environmental Media and Modeling Domain

The environmental media to be evaluated by the Operable Unit 5 fate and transport modeling include:

- Air in the vicinity of the FEMP
- The Great Miami Aquifer underlying and downgradient of the FEMP
- Surface water and sediment in the vicinity of the FEMP
- Surface and subsurface soils outside of Operable Units 1, 2, and 4 boundaries
- Uncapped surface soil within the Operable Units 1, 2, and 4 boundaries
- Perched groundwater outside of Operable Units 1, 2, and 4 areas.

The Operable Unit 5 fate and transport modeling domain encompasses these environmental media and an area large enough to cover all major potential contaminant receptor locations identified in the baseline risk assessment, as described in Section 5.1.2.5.

5.1.1.3 Definition of the Operable Unit 5 Baseline No-Action Scenario

The Operable Unit 5 RI will determine the need for future cleanup efforts after completion of remedial actions in other operable units. The baseline fate and transport modeling tasks only need to simulate the migration of contaminants under the no-action scenario. However, due to the on-going environmental management activities in Operable Unit 5 and the 1000-year time frame considered in the RI, the no-action or, more appropriately, "no-further-action" scenario requires clarification.

Because the storm water management systems and removal actions currently in operation at the FEMP are not expected to continue for 1000 years, two distinct time steps are defined in the Operable Unit 5

no-action scenario. The "baseline condition" looks at the first 70 years and includes current environmental management activities and existing levels of contamination in the environmental media without additional contaminant loading from other operable units. The "future condition" looks from 70 to 1000 years and begins after the assumed termination of on-going storm water management and removal actions. The 70-year time frame was chosen because it is usually used as a normal human lifetime and is used in the risk assessment. Seventy years is also a reasonable time frame for continual government control and completion of required remedial actions for the FEMP and the Great Miami Aquifer. Table 5-1 summarizes the assumptions for both the baseline and future conditions used to define the no-action scenario for Operable Unit 5.

5.1.1.4 Integration with Other Operable Units at the FEMP

The summary of the Operable Unit 5 baseline and future conditions listed in Table 5-1 indirectly defines future responsibilities and interactions among operable units at the FEMP. Past contaminant loadings from other operable units into the environmental media were included as contaminant sources and initial conditions in the Operable Unit 5 fate and transport modeling. Remedial actions by Operable Units 1, 2, 3, and 4 will significantly reduce future contaminant loadings from these areas when compared to existing contamination in the environmental media. Therefore, under the no-action scenario, the other operable units are assumed to be remediated and no simulation of continuous contaminant loadings from them were required in Operable Unit 5 baseline fate and transport modeling. Impacts of residual loadings from all operable units (including Operable Unit 5) after completion of the required remedial actions will be evaluated and quantified in the Operable Unit 5 Feasibility Study (FS).

5.1.2 Conceptual Model of Contaminant Migration

As an introduction to the overall modeling process, the following summary integrates all the pathway-specific conceptual models into a general description of the conceptual contaminant migration pathways for Operable Unit 5. Pathway-specific conceptual models are further explained in Section 5.3.

5.1.2.1 Baseline and Future Conditions

A description of the assumptions used to model baseline and future conditions is provided in this section. Figure 5-2 shows the locations of the operable units, current environmental management activities, and existing production wells discussed in this section.

Operable Units 1, 2, and 4

All major contaminant source loadings in the surface water and groundwater pathways to Paddys Run, the SSOD, and the Great Miami Aquifer are terminated. Most waste materials are assumed to have been removed and disposed of off site, capped in place, or stored in permanent on-property disposal facilities. After remediation, only minor amounts of residual contaminated soil remain in place and are exposed around the original source areas. Contaminant plumes in the Great Miami Aquifer are included as part of the initial Great Miami Aquifer conditions in the Operable Unit 5 baseline fate and transport modeling.

Operable Unit 3

All the above- and below-ground buildings and structures in the production area not related to waste water treatment are removed in the baseline condition. This assumption covers buildings in more than 90 percent of the area within the former production area. The contaminated soil currently under these buildings is exposed and becomes potentially mobile in the air and surface water pathways. Operable Unit 5 baseline contaminant sources include contaminated soil and contaminant plumes in perched water underlying the production area. Contaminant plumes in the Great Miami Aquifer due to past loadings from the production area are also included as part of the initial conditions.

Storm Water Runoff Control

Storm water runoff from the production, waste pit, and silo areas is collected in the existing retention basins, treated, and discharged under the National Pollutant Discharge Elimination System (NPDES) permit to the Great Miami River for the next 70 years (baseline condition). Surface runoff currently collected in the retention basins returns to its natural discharge pattern (e.g., to the storm sewer outfall ditch [SSOD], Paddys Run, and eventually the Great Miami River) without treatment after the first 70 years (future condition).

South Groundwater Contamination Plume Recovery Well System

The current South Plume recovery well system operates at a constant rate (i.e., five recovery wells each pumping 300 gallons per minute [gpm]) for 70 years (baseline condition) and then is turned off (future condition). Operation of this recovery well system is monitored according to the Design Monitoring Evaluation Program Plan (DOE 1993f). The pumped groundwater is considered part of the overall wastewater stream of the FEMP which is currently regulated under a discharge permit.

As the worst-case scenario, it is assumed that the estimated total mass of uranium contamination in the pumped groundwater will be discharged to the Great Miami River under the baseline condition.

Southwestern Ohio Water Company and Other Known Production Wells

Based on potential increased service demands, the future average total pumping rate for Southwestern Ohio Water Company (SOWC) wells is 25 million gallons per day (Mgd). This pumping rate represents a 39 percent increase from the current official pumping rate (i.e., 18 Mgd). All the other existing production wells, including the FEMP production well, operate at their current constant rates for 1000 years. It is assumed the FEMP production well will be continuously used by future on-property resident farmers beyond the first 70 years. There will be no new production wells that can significantly change groundwater flow conditions in the vicinity of the FEMP during the modeled time frame.

5.1.2.2 Contaminant Sources

By definition, the Operable Unit 5 environmental media do not have original contaminant sources. However, a large amount of contaminants have been released into the environmental media from other operable units in the past 40 years (Sections 1.2.3 and 1.3.7). Before environmental management activities were implemented around the contaminant source areas (e.g., removal actions described in Section 1.3.8), some contaminants had migrated away from their original sources and spread throughout a wide area. Therefore, Operable Unit 5 contaminant sources are contaminants currently existing in the environmental media outside other operable units. Operable Unit 5 sources do not include additional future loading from other operable units.

Operable Unit 5 sources include contaminated surface and subsurface soil, perched water in the glacial overburden, sediment along Paddys Run and the SSOD, and groundwater in the Great Miami Aquifer. From their original sources, contaminants migrated and will continue to migrate through the air, surface water, and groundwater pathways. Unlike other operable units, the extent of contaminated environmental media was not limited to the FEMP boundary. In addition to on-property contamination, Operable Unit 5 has off-property groundwater plumes (e.g., South Groundwater Contamination Plume).

Section 4.0 includes descriptions of the nature and extent of Operable Unit 5 contamination by media. Sections 5.2 and 5.3 conceptualize and quantify the understanding of Operable Unit 5 contaminant source areas and migration of contaminants into a multimedia fate and transport modeling framework.

5.1.2.3 Contaminant Migration Pathways

Contaminant transport from Operable Unit 5 sources may be along the following pathways:

- Surface water runoff:
  - Erosion of contaminated surface soil into Paddys Run and the SSOD
  - Flow of contaminated surface runoff water into Paddys Run and SSOD
  - Discharge of treated or untreated storm water and groundwater into the Great Miami River through the FEMP discharge outfall line.
- Groundwater transport:
  - Leaching of contaminants from contaminated soil through the vadose zone to the underlying Great Miami Aquifer
  - Infiltration of contaminated perched groundwater through the vadose zone to the underlying Great Miami Aquifer
  - Infiltration of contaminated surface water from Paddys Run and the SSOD to the Great Miami Aquifer
  - Natural and induced flow of groundwater in the Great Miami Aquifer which can carry dissolved contaminants and, potentially, contaminants adsorbed to colloidal particles of up to 2 microns in diameter
- Air emissions:
  - Volatilization of organic compounds, wind erosion of contaminated particulate matter, and the direct release of radon gas.

Because of the wide-reaching source areas and larger network of receptor locations/exposure points, the contaminant migration pathways of Operable Unit 5 cover a larger area and are more complex than other operable units at the FEMP.

5.1.2.4 Physical and Chemical Processes

Important physical and chemical processes that can significantly affect the future contaminant concentrations at potential receptor locations need to be simulated in the fate and transport models. Field investigations designed and conducted to characterize these processes are summarized in

Section 2.0. Figure 5-3 shows the major physical transport processes among different environmental media and chemical processes within each medium during the migration of a contaminant in the environmental media. These selected processes were quantified and simulated in Operable Unit 5 contaminant fate and transport modeling.

Model parameters required for describing the physical processes (i.e., air dispersion, air deposition, water infiltration, surface water flow, and groundwater flow) were defined by field data such as geotechnical tests, aquifer tests, field observations, and meteorological records (see Section 3.0). In the absence of field data, literature search results and model calibrations were used. The conceptualized physical environments (e.g., glacial overburden and Great Miami Aquifer) to be modeled that control the movements of water and air and thus the contaminant migrations are presented in Section 5.3 and Appendix F.

Model parameters required for describing the constituent-specific chemical processes (i.e., decay, leaching, adsorption, and desorption) and geochemical conditions of the media were defined by analytical data, laboratory tests such as batch tests, literature searches, and model calibrations. The persistence and fate and transport characteristics of Operable Unit 5 contaminants are described in Section 5.2.3.

5.1.2.5 Receptor Locations/Exposure Points

In addition to identifying locations of the maximum future on-property and off-property contaminant concentrations, future contaminant concentrations at specific sensitive locations (i.e., populated areas or potential exposure points where higher possibilities exist for future human exposure) were also evaluated. Figure 5-4 and the following list present these selected Operable Unit 5 receptor locations/exposure points:

- Air pathway:
  - Crosby Elementary School
  - Morgan Elementary School
  - Elda Elementary School
  - St. John Elementary School
  - Ross Middle/High School
  - Ross Country Day Nursery School
  - Knollman's dairy farm
  - Two locations south and east of the FEMP along the Great Miami River
  - Paddys Run Road
  - Village of Fernald

- Surface water pathway:
  - SSOD
  - Paddys Run
  - Great Miami River at the FEMP discharge outfall
  - Great Miami River at the mouth of Paddys Run
  - Drainage ditches at the FEMP

- Groundwater pathway:
  - FEMP production well
  - Knollman wells (Wells 12, 13, 14, and 26)
  - SOWC collection wells
  - Stricker's Grove well
  - Pottenger well (Well 34)
  - Monitoring Wells 2071, 2119, 2127, and 3127

In addition to the above listed off-property receptor locations, the FEMP was also divided into six risk assessment zones (as shown in Figure 5-5) based on the current site conditions. Future on-property and zone-specific contamination conditions as well as the off-property receptor locations were modeled and are evaluated in the Operable Unit 5 Baseline Risk Assessment, Appendix A.

5.1.2.6 Summary of General Assumptions

A number of assumptions regarding future conditions in the FEMP and Operable Unit 5 environmental media are described previously. Those assumptions as well as additional general assumptions which were used to simplify the conceptual model and contaminant fate and transport modeling of future contaminant migration in the environmental media are summarized below.

Future Activities

- The on-going environmental management activities (e.g., storm water runoff control, waste water treatment, discharge outfall, and South Plume recovery well system) at the FEMP will last for 70 years.

- Remedial actions by other operable units will be completed in relatively short time periods (i.e., less than 20 years).

- All the existing production wells, except the SOWC wells, will operate at current rates for 1000 years and there will be no new production wells that can significantly change flow conditions in the vicinity of FEMP. The SOWC wells will operate at the projected rate of 25 Mgd for 1000 years.

Hydrogeological and Meteorological Conditions

- Existing meteorological data (e.g., precipitation, wind speed and direction) is representative of the future conditions.
- Land surface conditions (e.g., vegetation, surface coverage and contours) outside of other operable units will not change significantly with time.
- Representative cross sections based on stratigraphy and zone-specific representative minimum barrier-layer (i.e., gray clay) thicknesses of the overburden can be used for determining future areal infiltration rates.
- General flow conditions (i.e., flow rate and direction) in the Great Miami River, Paddys Run, the Glacial Overburden, and Great Miami Aquifer remain relatively the same.
- Estimated steady state groundwater and surface water conditions can be used to represent the actual hydrogeological conditions which include seasonal fluctuations.
- The weathered zone in the glacial overburden is considered for estimation of infiltration rates allows higher infiltration rates.

Geochemical and Contamination Conditions

- Spatial distribution of uranium in soil is generally representative of other contaminants' distributions at the FEMP.
- Contaminant loadings into environmental media from other operable units during their remedial actions are negligible.
- Remedial actions by other operable units will significantly reduce future contaminant loading from these areas when compared to existing contamination in the environmental media.
- The weathered zone (i.e., the upper 10 to 15 feet) in the glacial overburden does not retard contaminant migration in the vertical direction.
- The general geochemical conditions in the environmental media do not change significantly with time.
- All the detected contaminant concentrations in Operable Unit 5 source areas are within solubility limits.

Although most of the general assumptions were made to simplify the modeling process, they also need to be conservative for risk assessment purposes. Conservative assumptions, such as no contaminant retardation or attenuation in the weathered zone, using minimum gray clay thickness for determining infiltration rates through overburden and no constraint on leachate concentrations by

theoretical solubility limits, were incorporated in the modeling to ensure that the future contaminant concentrations at the receptor locations were not underestimated. In addition to these general assumptions, other pathway- and model-specific assumptions are described further in the Appendix F.

5.1.3 Fate and Transport Modeling Framework

Fate and transport models were developed to predict the transport of contaminants within various media and to estimate the concentrations of contaminants to which potential receptors may be exposed. The fate and transport modeling processes involve many specific technical steps in order to satisfy all the requirements of the Operable Unit 5 baseline risk assessment; specific steps were taken to ensure that all the required information could be generated in reasonable amounts of time and with reasonable effort. For example, as part of the initial modeling process, screening of constituents of potential concern (CPCs) was performed to narrow the list of compounds to be carried through the later, detailed modeling process. The screening included comparisons of observed concentrations against various criteria (i.e., background concentrations, risk levels, travel time constraints, etc.,) as described in Section 5.3 and Appendix F.

As a brief introduction of the overall Operable Unit 5 contaminant fate and transport modeling, the following subsections describe the general technical steps of all the pathway-specific modeling and the two modeling tasks identified in Figure 5-1 (i.e., supplemental modeling characterization and baseline fate and transport modeling).

5.1.3.1 General Technical Steps

To quantitatively predict contaminant concentrations in all migration pathways, these steps were followed:

- Select significant (i.e., more than one positive detection above the background concentration) contaminants and contaminant source areas
- Present background information on the environmental setting for specific pathways
- Define the conceptual transport models for air, surface water, and groundwater based on a reasonable and conservative depiction of the current and future environmental setting
- Determine representative contaminant source concentrations and inventories for every source area

- Describe the screening processes used to reduce the number of constituents of potential concern
- Develop and apply pathway-specific and interpathway fate and transport models
- Compare modeling results with field data.
- Discuss the modeling process and results

5.1.3.2 Supplemental Modeling Characterization

Modeling was conducted to quantify the current contributions of contaminant sources from other operable units to the environmental media (especially in the subsurface environment) to supplement field measurements for defining the Operable Unit 5 source terms. The supplemental modeling characterizations, as shown in Figure 5-6, were essentially short-term (i.e., 40 years) fate and transport simulations of the past conditions using the Operable Unit 5 fate and transport models with contaminant source terms defined in previous RI reports for other operable units. The simulated distribution of contaminants include the areas directly beneath the waste storage and disposal areas where no field data was usually available. Combinations of field measurements and results of the modeling allowed Operable Unit 5 to more accurately account for all the contaminants which currently exist in the environmental media. Contributions of Operable Unit 3 to Operable Unit 5 sources are determined through field measurements because fate and transport modeling has yet to be performed for Operable Unit 3.

5.1.3.3 Contaminant Fate and Transport Modeling for Baseline Risk Assessment

The Operable Unit 5 baseline contaminant fate and transport modeling framework, as shown in Figure 5-7, incorporates all the Operable Unit 5 contaminant sources into the pathway-specific fate and transport models developed based on the conceptual model of contaminant migration, summarized in Section 5.1.2.

Results of the baseline fate and transport modeling represent future conditions due to the Operable Unit 5 contaminant sources under the no-action scenario. Conservative assumptions are used to provide a "reasonable worst case" picture of future contaminant migration.

5.1.3.4 Fate and Transport Models

As shown in Figures 5-6 and 5-7, the Operable Unit 5 RI used air transport, surface water transport, and groundwater transport models to support the supplemental modeling characterization and baseline

risk assessment. These models were developed based on physical and chemical processes (see Figure 5-3) in different contaminant migration media. In Figures 5-6 and 5-7, the soil media simulated in the air and surface water pathway is designated as surface soil. The reason for this designation is that only the top 6 inches and 1.5 feet of contaminated soil were usually incorporated in the air and surface water models, respectively. On the other hand, the entire volume of waste materials or contaminated soil in the overburden was considered in the groundwater pathway.

This subsection briefly summarizes the computer models used in the fate and transport modeling in each of the three major pathways. Additional information regarding the developments, capabilities, limitations, and applications of these site-specific models can be found in the remaining part of Section 5 and the Fate and Transport Modeling Appendix (i.e., Appendix F).

Air Transport Models

Air transport modeling was conducted for the baseline risk assessment in accordance with EPA guidance (EPA 1989c). Two emission models and an air dispersion model were used to estimate air emissions from each source and to calculate annual average concentrations and deposition rates at various receptor locations. One emission model predicts the quantity of exposed soil that would be resuspended by the wind, and the other emission model (RAECOM) estimates the flux of radon-222 (Rn-222) gas from soil containing radium-226 (Ra-226). Particulate-phase contaminants examined in the emission model include radionuclides, inorganic, and semivolatile organic contaminants. These models are listed in Table 5-2.

Surface Water Transport Models

Fate and transport modeling via surface water was conducted using the Surface Water Flow and Infiltration Model (SWF&IM) (DOE 1994i) developed for the FEMP. The SWF&IM is a combination of FEMP-specific hydrological conditions and several hydraulic and transport models used to simulate the various physical and chemical processes involved in the transport of contaminants from the surface soils into surface water, sediment and the Great Miami Aquifer. The models which comprise the SWF&IM and their connections are described in detail in the Surface Water Flow and Infiltration Model Report (DOE 1994i) and Appendix F.2 of this report. In addition, a summary of these models is presented in Table 5-3.

Groundwater Transport Models

The overall groundwater pathway includes contaminant transport in the glacial overburden, perched groundwater zone, and the Great Miami Aquifer. Each of these potential contaminant migration media has very distinct characteristics that can affect contaminant fate and transport. It is very difficult to incorporate all these characteristics and simulate the entire groundwater pathway by a single model. Therefore, multiple models were used to predict flow and contaminant transport in the overall groundwater pathway. The development of these models have been presented in a number of technical reports and are summarized in Appendix F.3. Table 5-4 lists these models for a quick summary.

5.2 CONTAMINATION IN THE ENVIRONMENTAL MEDIA

As described in Sections 2.0 and 4.0, various radionuclides, metals, and organic chemicals found at the FEMP during past sampling activities were evaluated in the Operable Unit 5 field studies. This section describes the process of selecting CPCs from all the chemicals found or expected in the Operable Unit 5 area, beginning with a review of the common predominant constituents identified by Operable Units 1, 2, and 4. Delineation of the conceptual Operable Unit 5 contaminant source areas, for baseline fate and transport modeling, was based on the distribution of these predominant constituents of concern (COCs) in the environmental media. The predominant COCs used to delineate the conceptual Operable Unit 5 source areas are uranium and its progeny. The source area definition in each pathway-specific fate and transport model was based on this general delineation with considerations of pathway-specific physical processes. All the available validated Operable Unit 5 data was then subjected to statistical analyses to determine the representative constituent-specific surface soil concentrations in every source area for all the constituents detected for the air and surface water pathways, separately. In addition to surface soil data, subsurface data from areas with deep contamination was also subjected to statistical analyses. Because of the limited validated data available, some unvalidated subsurface was used for the soils beneath Plants 2/3, 4, and 6. Finally these constituents were evaluated, before initiating the complex fate and transport modeling, through a sequence of screening procedures considering source-area-specific hydrogeological conditions and constituent-specific chemical properties and source concentrations. The final results of this process include: the delineation of conceptual Operable Unit 5 contaminant source areas for modeling; a list of constituents that have potentially nonnegligible contributions to the overall baseline risk and therefore require further evaluation by modeling; and information for source term determination in the fate and transport modeling.

To aid the discussion, the following acronyms are used to refer to constituents in different stages of the constituent screening, fate and transport modeling, and risk assessment described in this report:

- DC Detected constituent with at least one positive hit reported in the analytical database.
- COPC Constituent of preliminary concern is a DC with a concentration higher than the background concentration and toxicity screening level concentration.
- CPC Constituent of potential concern is a COPC that passes the travel time, decay, and vadose zone transport screening.
- COC Constituent of concern is a CPC that has been predicted to pose unacceptable impacts to human and/or environmental receptors.

CPCs are the constituents that require complete, detailed contaminant fate and transport modeling. The modeling results for CPCs were then used in the risk assessment to identify the COCs.

5.2.1 Common Predominant Constituents of Concern of Other Operable Units

The contaminants detected in Operable Unit 5 originated from other operable units. Many of these contaminants were identified as COCs in the baseline human health risk assessments conducted for Operable Units 1, 2 and 4. It is expected that predominant COCs commonly identified on a pathway-specific basis in these other operable units will also occur in Operable Unit 5. Therefore, common predominant COCs were selected over all pathways (i.e., air, surface water and groundwater) and over all operable units before evaluating Operable Unit 5 data for fate and transport modeling, by determining the percent contribution of each COC to the total risk. These COCs together with additional constituents identified in the Operable Unit 5 area (which also includes the soil and perched groundwater in the former production area) were evaluated in Operable Unit 5 media, namely air, surface water and groundwater, by modeling. Additional Operable Unit 5 CPCs were identified based on screening procedures to be described in Section 5.2.2. However, the list of common predominant COCs of other operable units provided an indication regarding what contaminants will cause most of the future impacts in the Operable Unit 5 environmental media. These COCs were also evaluated in the supplemental modeling characterization as shown in Figure 5-6.

The following subsection describes both the quantitative and qualitative aspects of the methods used in developing the list of common predominant COCs based on the results of the baseline risk assessments conducted for Operable Units 1, 2 and 4.

5.2.1.1 Common Predominant COC Selection Methods

As stated previously, the selection of common predominant COCs for each medium (air, surface water and groundwater) is based on the relative percent risk contribution from each carcinogenic and noncarcinogenic COC to the total risk across all operable units. Lists of carcinogenic and noncarcinogenic COCs are developed separately. The risks to one or more human receptors of concern, selected as being representative of reasonable maximum exposure (RME) scenarios for each environmental medium, are evaluated in this selection process.

It should be noted here that inclusion of Operable Unit 4 risk assessment results in this evaluation required that an assumption be made as to whether the K-65 silo structures fail in the future or remain intact. The risk assessment for Operable Unit 4 evaluated both scenarios; the evaluation of silo structural failure resulted in higher risks than those resulting from the evaluation of the silos remaining intact. In the former scenario, thorium-230 (Th-230) was identified as the predominant contributor to the total risks over all media in Operable Unit 4. For the purposes of identifying predominant COCs, it was assumed that the more realistic scenario representing future conditions is that the silo structures remain intact because a catastrophic failure of silo structure is not likely to happen.

The following steps discuss the screening and selection process applied to each constituent for evaluation in the Operable Unit 5 fate and transport modeling.

1) The first step in the COC screening process for each environmental medium is the qualitative comparison of risks, determined for each constituent, each human exposure pathway, and in each operable unit, to an incremental lifetime cancer risk (ILCR) of 10^{-7} for carcinogens and a hazard quotient (HQ) of 0.1 for noncarcinogens. A constituent (i) detected in medium (j) in operable unit (k) is selected as a carcinogenic COC candidate for fate and transport modeling if an ILCR calculated for that constituent exceeded 10^{-7} for at least one human exposure pathway. A constituent (i) detected in medium (j) in operable unit (k) is selected as a noncarcinogenic COC candidate for fate and transport modeling if a HQ calculated for that constituent exceeds 0.1 for at least one human exposure pathway.

2) All risks (carcinogenic or noncarcinogenic, as applicable) calculated for constituent (i) are summed over all human exposure pathways to obtain the total risk for that constituent in medium (j), operable unit (k). The risks summed over all pathways for constituent (i) included all risks, even those less than an ILCR of 10^{-7} and a HQ of 0.1. The summed risks for constituent (i) in medium (j) over all pathways in each operable unit are then added together, resulting in the total risk for constituent (i) in medium (j) over all exposure pathways and all operable units. This is done for all constituents passing the Step 1 criteria previously discussed.

3) The total overall risk for medium (j) across all detected constituents, all exposure pathways and all operable units is calculated for each operable unit from the results of the corresponding baseline human health risk assessment, then summing over all operable units.

4) Finally, the percent contribution of constituent (i) to the total overall risk (Step 3) is calculated by dividing the total risk level due to constituent (i) (derived in Step 2 above) by the total overall risk and multiplying by 100.

Spreadsheets showing the derivation steps discussed above are presented in Appendix F and summarized in Tables 5-5 through 5-7. Once the percent risk contributions of all constituents have been quantitatively determined, those constituents associated with the most predominant risk contributions across Operable Units 1, 2 and 4 (combined) are qualitatively identified as predominant COCs as parts of evaluation in Operable Unit 5 environmental fate and transport modeling. Tables 5-5, 5-6 and 5-7 present the common predominant COCs identified for the air, surface water and groundwater pathways, respectively, across all operable units. These tables also present the percent risk contributions of the COCs and all constituents as derived in Step 4 above.

5.2.1.2 Air Pathways

Table 5-5 shows that 14 common predominant COCs were identified for potential exposures across Operable Units 1, 2 and 4 via the air pathways. Four air pathways were evaluated in the baseline risk assessments for all operable units. These included inhalation and ingestion of dust-affected home-grown produce, ingestion of dust-affected meat products, and ingestion of dust-affected milk products. The future RME on-property farmer was selected as the receptor of concern for the air pathway.

The list of the 14 common predominant COCs includes eight carcinogenic COCs (Rn-222, Th-230, Th-232, uranium-234 [U-234], U-235/236, U-238, indeno(1,2,3-cd)pyrene, and polychlorinated biphenyls [PCBs]), five noncarcinogenic COCs (barium, cobalt, manganese, thallium, and total uranium), and arsenic, which is evaluated as both a carcinogen and a noncarcinogen. This list was generated by identifying those COCs associated with the greatest percent contribution to the total overall carcinogenic and noncarcinogenic risks across all operable units. Since the list of COCs exceeding the ILCR of 10^{-7} and the hazard quotient of 0.1 is somewhat large, a percent risk contribution of 0.5 percent was arbitrarily selected as the "cutoff" point below which no more COCs were added to the list of common predominant COCs.

The total overall ILCR across all operable units is 1.0×10^{-2} for the future RME on-property farmer. The total overall hazard index across all operable units is 8.4×10^{0} for the future RME on-property farmer. ILCRs summed over all pathways and operable units for selected common predominant carcinogenic COCs and percent risk contributions range from a minimum of 6.3×10^{-5} and 0.636 percent (PCBs) to a maximum of 4.7×10^{-3} and 47.3 percent (arsenic). HQs summed over all pathways and operable units for selected common predominant carcinogenic COCs and percent risk contributions range from a minimum of 1.6×10^{-1} and 1.91 percent (total uranium) to a maximum of 6.0×10^{0} and 71.6 percent (arsenic).

Tables F.1-IV-1 through F.1-IV-4 further breaks down the summary information in Table 5-2 and present the risk levels and HQs associated with each pathway evaluated for each operable unit. The air exposure pathway associated with the maximum carcinogenic risk levels across all operable units is inhalation. HQs could only be calculated for Operable Unit 1 (and not for Operable Units 2 and 4) because no noncarcinogenic constituents are detected at concentrations resulting in HQs exceeding 0.1. Of the four air exposure pathways evaluated in Operable Unit 1, the ingestion of home-grown produce results in the maximum hazard index.

5.2.1.3 Surface Water Pathways

Eleven common predominant COCs were selected for the surface water pathway during the evaluation of the carcinogenic and noncarcinogenic risks associated with radionuclides and chemicals in Operable Units 1, 2, and 4 (see Table 5-6). The carcinogenic risk, as indicated by the ILCR, and the noncarcinogenic risk, as determined by the HQ, were evaluated over all scenarios/receptors presented in each operable unit human health baseline risk assessment. A carcinogenic contaminant was selected as a COC if risk levels exceeded 10^{-7}. A noncarcinogenic contaminant was selected as a COC if corresponding HQs exceeded 0.1.

Tables F.2-VI-1 through F.2-VI-4 present risk levels for each surface water pathway evaluated for each operable unit. The worst case scenario in Operable Unit 1 involves the RME on-property farmer, future land use, future source term. Seven chemicals and radionuclides contribute to the carcinogenic risk. Cesium-137 (Cs-137), technetium-99 (Tc-99), U-238, U-234, strontium-90 (Sr-90) and arsenic are the main contributors. Only silver, through the ingestion of meat pathway, had a HQ greater than 0.1.

The Operable Unit 2 receptor with the greatest risk is the future expanded trespasser. Only one chemical/radionuclide presents a risk greater than 10^{-7}. The risk is driven by Th-228 via the ingestion of surface water. None of the chemicals or radionuclides has a HQ greater than 0.1.

Two COCs were selected for the surface water pathway during an evaluation of the carcinogenic and noncarcinogenic risks associated with radionuclides and chemicals in Operable Unit 4. The carcinogenic risk is driven by benzo(a)pyrene in the trespassing child, without access controls, current land-use scenario. In this same scenario for Operable Unit 4, the HQ of 0.1 is exceeded only by total uranium.

5.2.1.4 Groundwater Pathways

The carcinogenic risks, as indicated by ILCR risks, and the noncarcinogenic risks, as indicated by HQs were evaluated for all receptors presented in each operable unit's human health baseline risk assessment. A carcinogenic contaminant was selected as a groundwater pathway COC if risk levels exceeded 10^{-7}. A noncarcinogenic contaminant was selected as a COC if HQs exceeded 0.1. The risk levels and HQs were selected for consistency with the screening level methods used in the baseline risk assessment which met "reasonable worst case" requirements. Percent contributions to total risk or hazard index were calculated from each (Operable Units 1, 2, or 4) baseline risk assessment and listed in parentheses after the radionuclide or chemical. The pathways evaluated were ingestion of drinking water, ingestion of fruits and vegetables, ingestion of meat products, ingestion of milk, dermal contact while bathing, and inhalation of volatile organic compounds (VOCs).

The predominant groundwater COCs were selected during an evaluation of the carcinogenic and noncarcinogenic risks associated with radionuclides in Operable Units 1, 2, and 4 in the Great Miami Aquifer (see Table 5-7). The Great Miami Aquifer is considered representative of the groundwater used in the residential scenario. Ten COCs were selected as predominant Great Miami Aquifer groundwater COCs. The main contributors to carcinogenic risk are arsenic (62.8 percent), U-238+2D (33.0 percent), U-234 (4.43 percent), U-235/236 (0.892 percent), and Ra-226+8D (0.150 percent). Five radionuclides and chemicals are main contributors to the noncarcinogenic risk; total uranium (76.8 percent), arsenic (14.2 percent), antimony (4.15 percent), manganese (0.154 percent), and barium (0.111 percent). The receptor with the greatest risk is the future RME on-property farmer.

Tables F.3-IV-1 through F.3.IV-4 present risk levels for each groundwater pathway evaluated for each operable unit. In Operable Unit 1, the RME on-property farmer, future land use, future source term has the highest total risk which is driven by 13 chemicals and radionuclides. U-238 (32 percent), U-234 (3.8 percent), U-235 (0.9 percent), and arsenic (63.7 percent) are the significant drivers of the carcinogenic risk. Total uranium (79 percent), arsenic (14.7 percent), and antimony (4.3 percent) are drivers of the noncarcinogenic hazard index. In the perched zone groundwater of Operable Unit 1, the same receptor has the highest risk. Thirty-three chemicals and radionuclides contribute to the carcinogenic and noncarcinogenic risk. PCBs (51.6 percent), dioxins (2.7 percent), furans (7.7 percent), U-238 (26.3 percent), U-234 (6.6 percent), U-235/236 (1.2 percent), vinyl chloride (5.0 percent), and arsenic (1.8 percent) are the main drivers of carcinogenic risk. Total uranium (82.4 percent), molybdenum (10.8 percent), thallium (5.1 percent), antimony (1.1 percent), and arsenic (1.0 percent) are the main contributors to noncarcinogenic hazard.

In Operable Unit 2, the RME on-property farmer, future land use, future source term, has the highest total risk is driven by seven chemical and radionuclides. The main drivers of carcinogenic risk are U-238 (65 percent), U-234 (29 percent), and U-235/236 (1.6 percent) through the ingestion of meat, milk, and home-grown produce and the ingestion of groundwater pathways. Only total uranium (11 percent) contributes to the noncarcinogenic risk. It does so through the ingestion of groundwater, ingestion of home-grown produce and dermal contact with groundwater pathways. The receptor with the greatest risk from perched water in Operable Unit 2 is the perched water user, future land use, from the solid waste landfill. Carbazole (99.97 percent) is the primary contributor to carcinogenic risk with technetium-99 (0.034 percent) as a minor contributor.

The future land use, future source term, RME on-property farmer has the highest risk in Operable Unit 4 from groundwater. Four chemicals and radionuclides contribute to the risk. U-238 (59.3 percent), U-234 (37.2 percent), and U-235 (3.2 percent) contribute to carcinogenic risk through the ingestion of drinking water, vegetables/fruits, meat and milk; while total uranium (99.42 percent) is the only chemical with a HQ greater than 0.1 through the ingestion of drinking water and vegetables/fruits pathways. The Operable Unit 4 RME on-property resident farmer, future land use, future source term receptor has the greatest risk in perched groundwater. Twenty-seven chemicals and radionuclides contribute to the overall risk. Lead-210 (Pb-210) is the main contributor (98 percent) to carcinogenic risk and arsenic (67 percent), thallium (12.1 percent), cadmium (11.8 percent), and vanadium (4.6 percent) are the major contributors to noncarcinogenic risk.

5.2.2 Operable Unit 5 Constituents of Potential Concern

The nature and extent of Operable Unit 5 contamination were described in Section 4.0. Quantitative analyses of this information through the risk assessment process started with the selection of CPCs. The following subsections summarize the elements and the procedures followed in the Operable Unit 5 fate and transport modeling for selecting additional CPCs.

5.2.2.1 Contaminant Database

The analytical database used to define the nature and extent of Operable Unit 5 contamination includes samples collected throughout the vicinity of the FEMP in the following media: waste materials, surface and subsurface soils, perched groundwater, groundwater in the Great Miami Aquifer, storm water, surface water and sediment, air, and biota (see Sections 1.2.3 and 1.3.7). These data usually concentrated on locations of the known and suspected past contaminant releases in the production area or waste storage and disposal areas. Surface soil samples were also collected in a coarser sampling network throughout the FEMP and surrounding area. Data were collected under numerous programs for different purposes dating back to the mid-1980s. These data were used to define the contaminant source concentrations and initial contaminant conditions in the media during the fate and transport modeling. Table 5-8 summarizes the detected constituents in the Operable Unit 5 source areas.

In general, only validated data were acceptable for direct use in risk assessment. However, if certain unvalidated data were found to be consistent with the levels, trends, and extent of contamination indicated by available validated data, they were used in the fate and transport modeling as supplemental information for model development and calibration purposes.

5.2.2.2 Overall Constituent Screening Process

A constituent detected in the Operable Unit 5 area will not necessarily impact human health or the ecological environment in the vicinity of the FEMP. Because of their low toxicity levels or detected concentrations, some of the constituents can be safely screened out early in the risk assessment process. No further evaluation of these constituents is necessary. Some other detected constituents may have significant concentrations above acceptable toxicity levels in the sources but degrade rapidly in the environment and/or do not readily migrate. Only simple calculations are required to demonstrate the future impacts from these constituents. The complete, detailed fate and transport modeling processes are only necessary for the remaining detected constituents.

Due to the different physical processes that control contaminant migration in the environmental media, some constituents may be identified as CPCs in one migration pathway but not in other pathways, making it necessary to conduct the constituent screening in pathway-specific processes. As shown in Figures 5-8 and 5-9, the general screening process for the pathway-specific CPCs included comparisons of observed concentrations against various criteria (i.e., background concentrations, risk levels, travel time constraints, etc.). Figure 5-8 shows the screening process used in the surface water pathway; Figure 5-9 shows the screening process used in the groundwater pathway. These processes and screening in the air pathway are described in more detail in Section 5.3.

5.2.2.3 CPC Selection Criteria

The concentration criteria used in each pathway-specific screening process were developed based on 10^{-7} risk levels for carcinogenic constituents and 0.1 HQ levels for noncarcinogenic constituents. As shown in Figures 5-8 and 5-9, these criteria were compared to the measured or model-estimated contaminant concentrations in source materials, leachate through the glacial overburden and unsaturated sand and gravel before mixing with groundwater in the Great Miami Aquifer, and groundwater beneath Paddys Run and the SSOD, in different steps of the model screening.

5.2.2.4 Conceptual Operable Unit 5 Contaminant Source Areas

Figure 5-10 shows the delineation of conceptual Operable Unit 5 contaminant source areas developed by considering the distribution of total uranium contamination in the environmental media. Two-dimensional contouring and three-dimensional solid block modeling of uranium concentrations in the soil were both used in this process. It was assumed that the concentrations for other contaminants would generally follow the same pattern of uranium contamination. To verify this assumption, plots of surface soil concentrations for each constituent were reviewed and compared to the delineation of source areas based solely on uranium distribution. In general, the concentrations of all contaminants do follow the same pattern; areas of high contamination almost always fell in areas of high uranium contamination. In some cases the uranium delineation was modified (i.e., by subdividing larger areas into smaller source areas) to better match the pattern of contamination for all constituents.

The total uranium concentrations were plotted on a map of the FEMP and then contoured. Based on the uranium contours, the contaminant source areas were roughly divided into low, medium, and high contamination levels. The low range included values from background to 30 mg/kg of uranium, the medium from 30 to 150 mg/kg, and the high range of 150 mg/kg or higher. The 30 and 150 mg/kg

limits were chosen for convenience. The contour levels used to determine the ranges should not significantly effect the results because every area within each source area will be assigned a source concentration in the modeling following statistical procedures described in Appendix A, Attachment A-II. No valid surface soil sample results are excluded from the calculation of the source concentrations because of the source area delineation. The source areas were only used to group the data so that the concentration within each source area would be more uniform and more closely match the model assumption of uniform concentration within an area. Within the former production area, the delineation of the source areas did not strictly follow uranium concentration contours but also took into account locations of buildings and the historical use and purpose of various facilities.

Table 5-9 summarizes the general physical and chemical conditions in these conceptual contaminant source areas. The contaminants in the Operable Unit 5 area are generally confined in the surface soil (< 1.5 feet deep) except in localized places in the former production area (Table 5-9). This delineation of conceptual contaminant source areas was modified slightly during each pathway-specific fate and transport modeling process in order to incorporate pathway-specific physical transport processes. For example, the surface water drainage basin map was superimposed on the boundaries of the general conceptual source areas to provide a more detailed definition of surface contaminant source areas for the surface water runoff and transport modeling. Grouping of all the analytical data and statistical analyses on the data were conducted after these detailed source areas were separately defined for each pathway.

Source areas were developed so that source term determinations could be made for the modeling. The modeling results represent the combined impacts from all of the identified source areas in Operable Unit 5 within the modeling domain. A simpler division of the overall Operable Unit 5 area, shown in Figure 5-5 and further described in Appendix A, was also used in the risk assessment for on-property exposure scenarios under current and future conditions at the FEMP.

5.2.3 Persistence and Fate and Transport Characteristics of Contaminants

The migration of contaminants from source areas and their persistence in the environment are a function of both site characteristics and of the physical/chemical properties of the contaminants. Such properties include water solubility, tendency to transform or degrade (the compound's half-life), and chemical affinity for solids or organic matter (partition coefficient). Many geochemical reactions (e.g., sorption and precipitation) occur which affect constituent retardation, that affects the velocity of

the contaminant movement in a medium. In addition, radioactive and inorganic elements may undergo changes in their chemical forms (e.g., radioactive decay and formation of complexes). Unlike Operable Units 1, 2, and 4, however, it was not necessary to perform EQ3/6 geochemical modeling (which can determine the chemical-specific solubility limit) because Operable Unit 5 contaminants originated from waste storage and disposal areas in other operable units and are already in the environmental media. In general, there is no significant change of chemical conditions to be quantified, such as between the interfaces of waste storage units and the glacial overburden occurring when contaminants were first released from their original sources. Also, the concentrations of contaminants already in the Operable Unit 5 environmental media were assumed to be much lower than their solubility limits. Therefore, no theoretical solubility limits determined by EQ3/6 modeling were used to constrain the contaminant concentrations in Operable Unit 5 source areas. This is a conservative assumption because it allowed potentially higher leachate concentrations to migrate in the media. The revised process for determining the source leachate in the Operable Unit 5 baseline fate and transport modeling is shown in Figure 5-11. The EQ3/6 modeling results from other operable units are incorporated in the supplemental modeling characterizations for the non-Operable Unit 5 sources in the Operable Unit 5 fate and transport modeling.

5.2.3.1 Definitions of Common Transport Parameters

Major constituent-specific geochemical parameters required in the groundwater fate and transport modeling include: percent of extractable contaminant (K_e) in the sources, leaching coefficient (K_l) in the sources, solid-liquid partition coefficient (K_d) in the sources and the migration media, and retardation factor (R_d) in the migration media. The distinction between the parameters K_l and K_d is based on the type of contaminant solid that is present in the soil. For K_l, the contaminant may be present as particulate and adsorbed forms and the leaching coefficient measures contaminant mobilization due to both dissolution and desorption. The K_d is a measurement of solely adsorption/desorption equilibrium between soil and water and solid contaminant in excess of background is present only as adsorbed form (not precipitated). These parameters have significant impacts on the estimates of contaminant mass, concentrations, and loading and migration rates; therefore it is important that parameter values are properly assigned.

Source Leaching Coefficient (K_l)

In the Operable Unit 5 fate and transport model describing uranium migration in the glacial overburden, K_l was used to define the initial aqueous loading of uranium. Uranium K_l was

determined either by using laboratory tests or calculations of field data. The laboratory method used batch tests that mixed waste or contaminated soil with a distilled water solution adjusted to a pH of 5.6 with sulfuric acid. The K_l was calculated by dividing the uranium concentration on the solid (only uranium in excess of background) by the uranium concentration in solution. For the second method, the in situ leaching coefficient was determined by dividing the uranium concentration for the contaminated soil (only uranium in excess of background) by the uranium concentration in perched groundwater contacting the soil. Distribution of site-specific values of uranium K_l and K_d is discussed in Section 5.3.3.3 and Appendix F.3.

For other contaminants, K_d values in the media were used to approximate source K_l values. This is a very conservative approach for modeling to support the baseline risk assessment because, for any contaminant, K_l is at least as high as and usually higher than K_d by definition. Using the lower K_d value instead of K_l for a given source solid concentration, a higher source leachate concentration can be generated in the fate and transport model. As a result, a higher receptor concentration will be predicted.

Solid-Liquid Partition Coefficient (K_d)

Solid-liquid partition coefficients are used in fate and transport modeling to simulate the reversible adsorption/desorption processes of contaminants. K_d is commonly defined as the constant ratio between solid phase in excess of background and absorbed mass and dissolved phase concentrations of a chemical at equilibrium in fate and transport models (i.e., a linear isotherm). Therefore, chemicals with higher K_d values are more likely to be adsorbed onto soil materials and thus have less potential to migrate in the subsurface. K_d values for radionuclide and inorganic constituents are dependent on the medium types and conditions. K_d for an organic constituent is usually calculated using the constituent-specific octanol/water partition coefficient (KOW) and area-specific fraction of organic content (FOC) as shown in Appendix F.2.3.2.

Percent of Extractable Contaminant in the Waste Materials (K_e)

Although the adsorption/desorption process is usually considered to be reversible in fate and transport modeling, in general, the longer a contaminant remains adsorbed to the surface of a solid the more likely it is to be incorporated into the solid by surface reactions thereby making it no longer available for desorption under environmental conditions. Therefore, an estimate of the percent of extractable contaminant in the sources, which are usually solid phase waste or soil, is required to determine the

contaminant mass available for transport and leachate concentration. Although site-specific information has been collected for the K_e of uranium, K_e was not applied for any constituent (i.e., assumed as 100 percent) in the Operable Unit 5 RI modeling to be conservative. If K_e was applied in the modeling K_e and K_d would only have been determined for extractable portion.

Retardation Factor (R_d)

The contaminant travel time from a source area to the exposure points is one of the major concerns in risk assessment. For determining the contaminant travel time, the retardation factor is defined as the ratio between the groundwater flow velocity and chemical migration velocity through the soil matrix. Because most contaminants have higher tendencies to adsorb to soil than remain dissolved in water, they usually migrate slower than water in the subsurface environment. Therefore, R_d is usually greater than 1. In fate and transport modeling R_d is estimated by considering both the affinity of a contaminant to partition on to the solid (i.e., K_d) and the soil properties such as dry bulk density and moisture content of the soil.

Important chemical properties and how they affect contaminant behavior in the environmental media are described in following subsections for radionuclides, inorganics, and organics.

5.2.3.2 Radionuclide Constituents

Radionuclides undergo spontaneous transformations that involve the emission of particles and radiant energy. The resulting isotope may also be radioactive and undergo spontaneous decay or be a stable element which may no longer present carcinogenic risk caused by radiation. However, some stable elements still present a toxicological risk. The decay process can occur by various spontaneous mechanisms. Two of the more important decay modes are alpha decay and beta decay. The emissions produced by these decay modes consist of: alpha particles, beta particles, and gamma rays.

Alpha decay consists of the emission of an alpha particle from the nucleus of an atom. An alpha particle is composed of two protons and two neutrons and consequently has a charge of +2. Following radioactive decay by alpha emission, a different element is formed (e.g., Ra-226 becomes Rn-222) because the number of protons in the nucleus has changed. During beta decay a neutron is transformed into a proton and an electron. The electron is then expelled from the nucleus as a beta particle. The atomic number of the resulting progeny is increased by one, and the number of neutrons is decreased by one (e.g., Sr-90 becomes yttrium [Y]-90). The atom may be left in an

excited state; that is, the atom has excess energy that must be released. This energy can be emitted in several ways, including the formation of a gamma photon (ray) with a discrete energy.

Most of the radioactive materials present at the FEMP originated from natural sources such as pitchblende ore or ore concentrates and the radioactive elements present in these materials belong to three decay series (chains): the U-238 (uranium) series, the U-235 (actinium) series, and the Th-232 (thorium) series. If they are not subject to chemical or physical separation, the members of a series attain a state of radioactive equilibrium where the rate of decay of each nuclide is essentially equal to that of the nuclide that heads the series (the parent), leading to constant ratios of activity concentrations among the respective nuclides (parent and progeny). At the FEMP, radioactive equilibrium between various portions of these three decay chains does not always exist because of previous processing. In addition to chemical processes, physical processes were used to preferentially extract certain isotopes (same element but with differing numbers of neutrons in the nucleus, such as U-234, U-235 and U-238) from materials before their use at the FEMP (i.e., uranium that has been isotopically separated as part of fuel manufacturing). The isotopic ratios of these raw materials remained essentially unchanged during the chemical process conducted at the FEMP. More information was presented in Section 4.1 regarding the past operation.

As a result of different chemical processes used in different areas of the FEMP, there is a wide variance in the presence or absence of members of the decay chain, their concentrations, and the isotopic content of wastes. These differences can sometimes be used to identify the FEMP process that generated a waste contained in the storage areas. For example, natural uranium ore has a U-238/Th-230 activity ratio equal to 1. Uranium that has been refined (i.e., extracted from uranium concentrate leaving behind Th-230 and other contaminants) has a U-238/Th-230 activity ratio much greater than 1. Waste Pit 6 in Operable Unit 1 exhibits a U-238/Th-230 ratio which is much greater than 1, indicating that it was used primarily for the disposal of materials containing refined uranium. Waste Pits 3 and 5, by contrast, exhibit U-238/Th-230 ratios much less than 1. These pits were used for the disposal of raffinates from the FEMP refinery operations in Plant 2/3. These raffinates, which are the wastes remaining following the extraction of uranium from ores or uranium concentrates, contained only residual quantities of uranium but contained all of the Th-230 which was originally present in the ore or concentrate. The low U-238/Th-230 ratio of material in Waste Pits 3 and 5 indicates that much of the waste in these pits originated from the FEMP refinery.

The half-lives of some of the radionuclides of concern at the FEMP are measured in thousands of years. Exceptions are Sr-90 with a half-life of 29 years, Cs-137 with a half-life of 30 years, and Rn-222 with a half-life of four days.

Table 5-10 lists the major fate and transport parameters for radionuclide COPCs. These chemical-specific parameters were used in both the constituent screening and the baseline fate and transport modeling. Whenever possible (i.e., providing sufficient data and time) each detected radionuclide was modeled individually. However, the risk assessment usually evaluates human health risk based on impacts caused by chains of radionuclides rather than individual radionuclides. Modeling results for the parent of a decay chain or the total mass of all radionuclides in a decay chain were sometimes used to support the risk assessment directly. Proper scaling factor for determining the overall impacts caused by all radionuclides in a decay chain was used when only the parent radionuclide (e.g., U-238, U-235, and Th-232), head radionuclide of a sub-chain (e.g., Ra-226 in the U-238 decay chain), or total mass (e.g., total uranium) of a chain was modeled. These scaling factors are discussed in Section 6.0.

Because uranium is the predominant COC at the FEMP, a detailed discussion about the historical release of uranium and geochemical concepts of the subsurface total uranium distribution is provided as an attachment in Appendix F.3. The site-specific values of uranium geochemical parameters are also summarized in the discussion.

5.2.3.3 Inorganic Constituents

Inorganics do not degrade in the environment but they may undergo speciation, which is a change in chemical form. They may also react with soil or other solid surfaces by ion exchange, adsorption, precipitation, or complexation (combining of two compounds to form a new compound). These processes are affected by pH, oxidation-reduction conditions, and the type and amount of organic matter, clay, and hydrous oxides present. In turn, these factors are affected by the physical and biological properties of the environmental media.

Chemical speciation has a large impact on the solubility of inorganic materials and therefore their mobility in the environment. Chemical speciation, however, is very complex and difficult to distinguish in routine laboratory analysis. In general, the only distinction made in sampling and

analysis for inorganics is between total and filterable inorganics in water. The filterable inorganics represent the dissolved fraction, which is the more mobile and bioavailable fraction.

Table 5-11 lists the major fate and transport parameters for inorganic COPCs. These chemical-specific parameters were used in both the constituent screening and the baseline fate and transport modeling.

5.2.3.4 Organic Constituents

Organic contaminants may be degraded in the environment by various processes, including hydrolysis, oxidation/reduction, photolysis, or biodegradation. Degradation rates in various media can vary from minutes to years depending on the chemical and environmental conditions.

The mobility of an organic compound is affected by its volatility, partitioning between solids and water, water solubility, and concentration. Water solubility and the tendency to adsorb to particles or organic matter can correlate with retardation in groundwater transport. Chemicals with higher water solubilities and lower adsorption coefficients are expected to remain primarily in the dissolved phase and be transported at the same rate with the groundwater flow. Chemicals with lower water solubilities and higher adsorption coefficients are expected to remain primarily adsorbed to the surface of the soil and thus transportation with the groundwater would be very limited and at a much slower rate. Retardation factors in groundwater transport are discussed further in Appendix F. A general overview of the relative water solubility, tendency to adsorb to solids, and contaminant mobility for different categories of organic contaminants found in Operable Unit 5 is as follows:

- Volatile organic compounds:
  - High water solubility
  - High volatility
  - Low tendency to adsorb to solids
  - Generally transported dissolved in water or in air
  - Operable Unit 5 examples include 1,1-dichloroethene, carbon disulfide, chloroform, methylene chloride, 1,2-dichloroethene, trichloroethene, 1,1,2-trichloroethane, 1,1-dichloroethane, benzene, tetrachloroethene, and 2,4-dinitrophenol

- Semivolatile organic compounds:
  - Medium to low water solubility
  - Medium volatility
  - Medium to high tendency to adsorb to solids
  - Transport may occur dissolved in water, in air, or adsorbed to soil particles
  - Operable Unit 5 example includes carbazole

- Pesticides, PCBs, and dioxins:
  - Low water solubility
  - Low volatility
  - High tendency to adsorb to solids
  - Generally transported while adsorbed to soil particles
  - Operable Unit 5 examples include Aroclor-1254, alpha-chlordane, and heptachlor epoxide.

Table 5-12 lists the major fate and transport parameters for organic COPCs. These chemical-specific parameters were used in both the constituent screening and the baseline fate and transport modeling.

5.3 PATHWAY-SPECIFIC FATE AND TRANSPORT MODELING PROCESS

The following subsections summarize the fate and transport modeling processes of contaminants through air, surface water, and groundwater pathways. All the models used in the Operable Unit 5 contaminant fate and transport modeling are improved or newly developed according to a previously submitted overall model improvement plan (DOE 1993b) and the requirements of the Operable Unit 5 baseline risk assessment. Developments and applications of these models have also been presented to the U.S. and Ohio Environmental Protection Agencies (EPA and OEPA) in a series of technical information exchange meetings. Both technical defensibility of the models and consistency with previous modeling conducted for other operable units are emphasized in the Operable Unit 5 fate and transport modeling tasks. The concepts and data contained in the models are presented in Section 3.0. More details regarding technical steps for the contaminant fate and transport analyses are provided in Appendix F.

5.3.1 Air Pathway

Air emissions associated with Operable Unit 5 may involve different types of release mechanisms. If organic compounds are present within the surface soil, then volatilization of these compounds may occur. Radon gas that is generated as a result of radioactive decay of Ra-226 (a progeny of U-238) may be released. During periods of turbulent wind conditions, particles of contaminated surface soil can become resuspended in the air and may be inhaled by on- or off-property human receptors. The receptor grid for the air pathway modeling is shown in Figure 5-12. In the event that previously covered subsurface contaminant sources become uncovered, the transport of this material by wind erosion may also become a concern. The amount of material that may be suspended depends on wind speed and other site conditions such as soil moisture, particle size, and vegetative cover.

The air transport analysis conducted for Operable Unit 5 assesses the baseline risk caused by contaminant sources under baseline and future conditions and addresses the air quality portion of the environmental media not specifically addressed by Operable Units 1, 2, 3, and 4. This section provides an overview of the modeling protocol and assumptions, the model input data and the results of the air transport analysis for various COCs. Appendix F.1 contains further detail on the technical approach, calculation procedures, input data and model output associated with each land-use emission scenario discussed in Section 5.3.1.2.

5.3.1.1 Technical Approach

The air pathway analysis was conducted in accordance with EPA guidelines for air quality dispersion modeling and used on-site data whenever possible (as shown in Figure 5-13). When such data was not available, conservative assumptions were made so as not to underestimate the impact from the Operable Unit 5 sources. The method used to determine the maximum on- and off-property concentrations included three principal tasks.

The first task was to identify the contaminant class source areas of Operable Unit 5 and quantify the source term for each area. Contaminant classes included radionuclides, inorganics, organics and Ra-226. Second, downwind unit emission rate dispersion coefficients were calculated for each contaminant class and emission scenario using representative unit emission rates, meteorological data and receptor data using the ISCLT2 dispersion model. Then, unit emission rate dispersion coefficients were post-processed with contaminant-specific surface soil concentrations or activity levels to create tabular and graphical summaries to identify total contaminant concentrations at on- and off-property receptors.

5.3.1.2 Conceptual Model Emission Scenarios

The focus of attention for identifying Operable Unit 5 air pathway source areas was on locating those areas having elevated levels of contaminants that could be emitted from the surface soil layer. The potential release mechanisms involve volatilization, resuspension by way of wind erosion, and the release of radon gas from areas contaminated with Ra-226.

Two conceptual models were used in the air pathway analysis. The first conceptual model assumes that the current land use continues and that an 85 percent vegetative cover exists over the areas not covered by buildings, concrete, and gravel. The model also assumes that no remediation of Operable

Unit 5 has taken place beyond what has been completed to date. However, it is assumed that remediation has been completed for Operable Units 1, 2, 3, and 4 (e.g., contaminated buildings, concrete, and gravel in the former production area have been removed) and the contaminated soil currently under the production area buildings is exposed and an 85 percent vegetative cover has been established. The second conceptual model assumes an agricultural land-use scenario for Operable Unit 5 source areas. In the agricultural scenario, farming practices are consistent with local agricultural practices and an annual vegetative cover of 50 percent is assumed.

Drawings showing the spatial distribution of contaminant concentration or activity levels were reviewed to identify potential source areas and CPCs for the four classes of contaminants; radionuclides, inorganics, organics, and radon. Source areas for the radionuclide, inorganic, and organic contaminant classes were identified by defining areas having surface soil concentrations or activity levels in excess of contaminant-specific screening levels that were based on levels given in the document entitled "Risk Assessment Guidance for Superfund" (RAGS) (EPA 1989c). The RAGS screening levels were modified to add an inhalation pathway, increase the exposure from 30 to 70 years using calculated chemical dependent volatilization factors instead of RAGS default values, and decrease the systemic target hazard quotient (THQ) from 1.0 (RAGS standard) to 0.2. These modifications increased the conservativeness of the screening levels produced by the calculations. Screening levels for radon gas were derived from the regulation entitled "Federal Regulations on Standards for Management of Uranium Byproduct Materials Pursuant to Section 84 of the Atomic Energy Act of 1954," Subpart D, Section (2)i.

These modified screening levels were then used to identify source areas for the four classes of Operable Unit 5 CPCs in the air pathway. All surface soil samples (< 6 inches deep) found within each source area were used to develop statistically representative concentrations or activity levels for each source group area simulated in the air pathway modeling. The assigned concentration or activity level value for each source area was determined from either the maximum analytical values for the group or the upper confidence limit (UCL), depending on the number of samples in each source group and the distribution of the data.

5.3.1.3 Contaminant Emission Rates

The potential release mechanisms considered for air emissions from Operable Unit 5 included the volatilization of organic compounds, the wind erosion of contaminated surface soil particulate matter,

and the direct release of radon gas. Each of these pathways was evaluated in accordance with the objectives of the Operable Unit 5 baseline risk assessment and the conceptual model. The method used to calculate contaminant emission rates is also discussed below. Appendix F.1 contains additional details regarding emission rate calculations.

The potential for the long-term volatilization of organics from surface soil was evaluated from the information contained within the CPC database. Volatile organic compound contamination in surface soil was not found to be widespread. Isolated areas of contamination were characterized by only a few compounds and maximum concentration levels were all just slightly above the screening levels used to identify potential source areas. Also, over time the volatilization rate of these organics will decrease and should not be a significant source for the long-term scope of the risk assessment. As a result, the volatilization of organic compounds was not considered to be a significant release mechanism for organics; however, particulate transport of organics was modeled.

Radon

Radon is a gaseous radioactive decay product of Ra-226. In this analysis, radon gas emissions were assumed to come from contaminated surface soil areas having Ra-226 activity levels above the defined screening limit. Radon emission flux rates were calculated for all source areas using the RAECOM model, assuming no cover material. This assumption results in higher, more conservative emission flux rates. A list of the radon emission flux rates used in the air transport analysis is shown in Table 5-13. Further information regarding the calculation of radon flux rates is given in Appendix F.1.

Contaminated Particulate Matter

In calculating the wind erosion emission rate for each CPC in this analysis, it was assumed that the contaminants were a constituent of the particulate. Contaminant concentrations or activity levels for wind erosion source areas were assigned from the statistical data generated for each source area and associated contaminants. A listing of the contaminant surface soil activity levels or concentrations assigned to particulate matter source areas within each contaminant class are shown in Tables 5-13 through 5-15.

The procedure used for estimating particulate emissions due to wind erosion was based on the concept of "threshold friction velocity" (TFV). This specific method, recommended by the EPA for

estimating wind erosion rates from flat soil surfaces at hazardous waste sites, is described in Appendix F.1. The approach assumes that a minimum wind speed is required for the resuspension of particulate matter from the soil and that the emission rate is a function of two factors, specifically the TFV and the erosion potential of the soil. The lower the TFV, the higher the potential for erosion of the soil by the wind. Depending on the surface soil characteristics, areas can be classified as having either an "unlimited" or "limited" erosion potential.

Various steps are required in the wind erosion emission rate calculation process using the TFV concept. These steps are described in further detail in Appendix F.1, along with calculations showing the derivation of wind erosion emission rates for all source areas. In the current model scenario, all wind erosion source areas having an 85 percent vegetative cover were classified as having a limited erosion potential. In the agricultural scenario, wind erosion source areas were assumed to only have a 50 percent vegetative cover and were classified as having an unlimited potential.

5.3.1.4 Modeling Protocol

The air transport modeling was conducted using a specific modeling protocol that is consistent with EPA guidelines and with the Risk Assessment Work Plan Addendum (DOE 1992) and subsequent risk protocols, i.e., "Particulate Dispersion Modeling Protocol," issued in September 1993. The objective of this protocol is to use consistent and representative data to calculate maximum annual average concentrations for all contaminants in the current and agricultural emission scenarios. Technical issues addressed in the protocol are shown in Figure 5-14. A general overview of the modeling protocol is discussed below. The reader is referred to Appendix F.1 for more specific details regarding source emissions data, meteorological data, dispersion options, model input data and model assumptions.

On-Site Meteorological Data

Meteorological and climatological data are required as input for the ISCLT2 dispersion model, including wind speed, wind direction, atmospheric stability, ambient air temperature, and mixing height. The principal source of meteorological data was the on-site FEMP meteorological monitoring system installed in 1986. Other supplementary meteorological and climatological data, not available from the on-site system, was obtained from the National Weather Service (NWS) Office at the Greater Cincinnati-Northern Kentucky International Airport and from the James A. Cox International Airport at Dayton, Ohio. Climatological data regarding the annual average temperature and

precipitation was obtained from both the FEMP on-site station and the NWS office at the Greater Cincinnati-Northern Kentucky International Airport. Upper air data, in support of determining mixing heights, was obtained from the James A. Cox International Airport at Dayton, Ohio.

The format of the meteorological data required by the ISCLT2 model is in the STability ARray (STAR) format. The STAR format is a statistical meteorological data summary that gives the joint frequency distribution of six wind speed classes by 16 wind direction sectors (i.e., north, north-northeast, northeast, etc.), by six atmospheric stability categories (A through F). The STAR data used in the air pathway analysis for Operable Unit 5 was a composite of five years of on-site data that included meteorological data from 1987 through 1989, 1991, and 1992. The 1990 database was not used because of data recovery problems during this annual period; the meteorological tower was out of service for a 16-week period during 1990. This resulted in a data recovery rate of only 70 percent for 1990. EPA guidance suggests a minimum of 90 percent data recovery for any one year.

Modeling Approach

The ISCLT2 model was used to calculate annual average concentrations using a number of model options that allow the user to specify the atmospheric conditions of pollutant dispersion, the type of emission source and source emission parameters.

The selection of rural or urban dispersion coefficients for use in the ISCLT2 model was based on a land-use analysis. The land-use types within a 1.9-mile radius of Operable Unit 5 were estimated from a review of U.S. Geological Survey (USGS) maps and a site survey of the area. Based on the review, no more than 10 percent of the area within a 1.9-mile radius of Operable Unit 5 can be classified as industrial, commercial, or compact residential; so the area was classified as rural for the purpose of dispersion modeling and rural dispersion coefficients were selected for use in the modeling.

All source emissions were assumed to result from either the resuspension of contaminated particulate matter due to wind erosion or the release of radon gas. All Operable Unit 5 source areas were defined as area sources in the model and emission rates were in the units of grams or picocuries per second per square meter ($pCi/s/m^2$).

Because of the large number of contaminants that had to be addressed in this analysis, the modeling was initially done on a unit emission rate basis. Then, individual source concentration data for surface soil and waste materials was then used in conjunction with unit emission rate dispersion coefficients to calculate specific contaminant concentrations at all receptor locations.

Receptor Network

The maximum annual contaminant concentrations resulting from Operable Unit 5 emission sources were determined by having the ISCLT2 model calculate concentrations at a number of receptor locations in various directions and distances from the Operable Unit 5 areas. Receptor points included locations within and beyond the FEMP boundary.

A receptor grid covering approximately 3113 acres was used to determine the maximum on- and off-property concentrations for all emission scenarios. The receptor grid consisted of 5246 receptor locations having a uniform 164-feet spacing.

A discrete receptor network was also used to calculate annual average CPC concentrations for sensitive receptor locations. The discrete receptors included the following locations:

- Crosby Elementary School
- Morgan Elementary School
- Elda Elementary School
- St. John Elementary School
- Ross Middle/High School
- Ross Country Day Nursery School
- Knollman dairy farm
- Two locations south and east of the FEMP along the Great Miami River
- Paddys Run Road
- Village of Fernald

These locations are shown in Figure 5-4. Additional information regarding the air transport receptor network, including an illustration of the receptor grid, can be found in Appendix F.1.

5.3.1.5 Required Modeling Results

The required air transport modeling results include the maximum on- and off-property concentrations of CPCs within the overall modeling receptor network and at the above-listed discrete receptor locations.

5.3.2 Surface Water Pathway

Surface water runoff is a viable transport pathway for all the contaminated surface soil in Operable Unit 5. During a rainfall event, soil particles are dislodged by the impact of raindrops and the flow of runoff across the soil surface. The amount of soil erosion depends on rainfall intensity, slope length, slope steepness, vegetative cover, and erosion control practices in place. Contaminants adsorbed to the soil particles are also dissolved and transported into the runoff water and receiving surface water. Contaminated surface water also infiltrates into the Great Miami Aquifer through portions of the streambeds of Paddys Run and the SSOD where the streams have cut through the glacial overburden (Section 3.4). The top layer of soil in the vicinity of the FEMP property is composed of glacially deposited sediment. Surface sediment consists of relatively impermeable glacial overburden deposits (clay, sand, silt, and gravel). Underlying this layer are permeable glacial outwash deposits that form the water-bearing unit of the Great Miami Aquifer. Where the glacial overburden is absent, water readily infiltrates into the unsaturated outwash deposits due to their porous nature. The water-table elevation in the Great Miami Aquifer in and around the FEMP property is generally lower than the streambed elevation resulting in an unsaturated zone between the water table and the streambed. Significant amounts of water can infiltrate from the stream to the unsaturated glacial outwash deposits and then enter the Great Miami Aquifer. This migration is the basis for modeling the surface water as a possible pathway of contamination to the groundwater.

5.3.2.1 Conceptual Model and Modeling Framework

The following sections describe the conceptual model of the various processes in the movement of surface water and the associated movement of contaminants at the FEMP. The modeling tools used to simulate the movement of contaminants with the surface water are also described.

Conceptual Model of Surface Runoff

The Paddys Run drainage basin consists of land surfaces drained by streams and channels discharging to Paddys Run. As rain falls on the land, a portion of it becomes runoff while the rest of the rainfall either infiltrates directly into the ground or is lost due to evapotranspiration (see Section 3.2.4). The amount of rainfall which becomes runoff is dependent on the ground surface conditions. The runoff then collects and flows in the channels in the drainage basin, moving from small channels to successively larger channels until reaching the basin outlet. The flow in the channels can come from the runoff or can enter the stream from groundwater. The flow that originates from the groundwater

is baseflow. Paddys Run in the vicinity of the FEMP is often dry and contains little or no baseflow (Section 3.3).

For the reaches of Paddys Run and the SSOD which flow on top of the glacial overburden, infiltration is assumed negligible due to the low streambed permeability. Infiltration through the streambed will still occur where the stream is flowing on the less permeable glacial overburden; however, the greater majority of the infiltration will occur where the stream has cut into the glacial outwash deposits. The small amount which infiltrates into the glacial overburden can be neglected without affecting the overall results of the model. Therefore, within the reaches where glacial overburden is present, infiltration rates were not calculated. When Paddys Run cuts deep enough into the glacial outwash deposits so that the streambed elevation matches the water table elevation, infiltration again becomes negligible because the water elevations are in equilibrium. The water table elevation in the Great Miami Aquifer fluctuates during the year, so that the lateral extent of infiltration in the streambeds also fluctuates. After a storm event, significant infiltration can occur from the location where the streams cut into the glacial outwash deposits until the location where streambed elevation matches the average water table elevation. In order to simulate the infiltration of surface water into the streambeds of Paddys Run and the SSOD, the average groundwater elevation was used to set the bounds of the infiltration model. The average groundwater elevation under Paddys Run and the SSOD was determined by averaging water elevations in each of the Type 2 monitoring wells located along Paddys Run and the SSOD which have more than 20 data points available. Between well locations the water elevations were linearly interpolated to create an average water-table elevation profile under the streambeds. The infiltration of surface water through the streambeds of Paddys Run and the SSOD is affected by the head of water (depth) in the streams. The depth of flow in turn is affected by the flow generated by the storm runoff.

Conceptual Model of Contaminant Transport

The contaminants being transported with the surface water runoff are assumed to be washed off the surface soil on and around the FEMP. Contaminated groundwater can potentially enter the surface water from two sources, either the perched water zone or from the Great Miami Aquifer. The perched water is located in sand and gravel lenses situated above the relatively impermeable glacial overburden deposits. The perched water can enter the surface water via seeps located along Paddys Run and some of its tributaries. The contaminant loading of perched water seeping into the surface water is evaluated and discussed in Appendix F.3.7. This evaluation included all of the chemicals

either in the perched water or having the potential to enter the perched water at concentrations above screening levels. As discussed in Section F.3.7, the results of this evaluation indicate that the contaminant contribution via this pathway is insignificant and can be neglected in the surface water modeling. Because both Paddys Run and SSOD are losing streams (to the Great Miami Aquifer) in the vicinity of the FEMP, the effect of contaminated groundwater from the Great Miami Aquifer entering the surface water bodies is considered insignificant. Contaminants can move with the runoff in two phases; adsorbed to sediments eroded from the land surface or dissolved in the runoff itself. The area surrounding the FEMP is divided into several contaminant source areas. Within each, the concentration of contaminant is assumed to be areally uniform.

The following assumptions were made concerning contaminant transport in the surface water runoff:

- Contaminants adsorbed to soil in runoff remain adsorbed in the stream sediment.
- Contaminants dissolved in runoff water remain dissolved in the receiving stream.
- Contaminants in the runoff are uniformly and completely mixed with the water in the receiving stream or groundwater.

The assumptions made concerning contaminant transport in the surface water are reasonable and are consistent with assumptions made in the other operable unit RI, at the FEMP as well as the procedures presented in the Superfund Exposure Assessment Manual (EPA 1988b). The assumption that the contaminants do not change phase between adsorption to the sediment and being dissolved in the water is reasonable since the flow of the water is relatively ephemeral in and around the FEMP so that the contaminants would not have the time required to reach an equilibrium and change phases appreciably. The changing of phases would not have a significant effect on the concentrations in the surface water and sediment.

Modeling Framework and Approach

The overall Paddys Run drainage basin and the model area of the Operable Unit 5 surface water fate and transport modeling is illustrated in Figure 5-15. The modeling of the surface water for Operable Unit 5 at the FEMP, as shown in Figure 5-16, was completed in two stages. The results of the surface water, rainfall, runoff, and infiltration modeling are presented in the Surface Water Flow and Infiltration Model Summary Report (SWF&IM) (DOE 1994i). The results of the SWF&IM are

incorporated into this RI report and used to calculate the contaminant transport in the surface water pathway.

The surface water modeling task for Operable Unit 5 was completed as follows:

- The general/regional hydrology and hydraulic calculations were performed once with the results presented in the SWF&IM report
- The SWF&IM results were used for each waste source area
- For each waste area, each COPC was screened to determine if the COPC needed to be modeled further in the surface water pathway as a CPC
- If the COPC was not screened out, its concentrations in the surface water and sediment and its loading to the Great Miami Aquifer were calculated.

The SWF&IM consists of the following components. The rainfall and runoff were simulated with the HEC-1 modeling code (U.S. Army Corps of Engineers 1990). Rating curves for cross sections along Paddys Run and the SSOD were generated using Mannings equation (Henderson 1966). Mannings equation was applied along Paddys Run and the SSOD to determine the elevation of water in the stream (stage) at each cross-section location for a given flow rate (discharge). This relationship between stage and discharge at a cross section of a stream is called a rating curve.

Based on the drainage patterns and subbasin delineation in and around the FEMP, the SWF&IM provided the following information for the modeling of surface waters at the FEMP:

- Selection of the 1-year, 24-hour storm event as the representative storm that was used to estimate average dilution and infiltration factors in and through surface water bodies at the FEMP.
- Determination of the hydraulics of flow in Paddys Run and the SSOD to produce a stage versus discharge relationship (rating curve) at several cross-section locations along both Paddys Run and the SSOD.
- Definition of the extent of connection of the surface water bodies with the Great Miami Aquifer (see Section 5.3.2.1).
- Determination of the pattern of infiltration into the streambeds of Paddys Run and the SSOD.

- Quantification of the amount of infiltration that occurs from the surface water to the Great Miami Aquifer during a representative storm event.

In order to determine how well the runoff and flow portion of the surface water model simulated storm events, the model was set up to simulate two actual storm events. The modeled rise in water surface elevation was compared to the measured rise at two locations in Paddys Run. Section F.2.2.3 of Appendix F.2 describes this comparison in more detail. Based on this comparison, it was determined that the model can simulate actual rainfall and runoff events with acceptable accuracy.

The transport of contaminants, as presented in this report, centers on the use of the modified universal soil loss equation (MUSLE) and partitioning equations both of which are presented in the Superfund Exposure Assessment Manual (EPA 1988b). The MUSLE equation is used to calculate the amount of sediment generated from the representative storm event in each subbasin. The partitioning equations are then used to determine the amount of contaminant transported with the runoff and the amount transported with the sediment. As flows from different subbasins combine, the contaminant concentration in the combined flow is calculated based on a mass balance approach. For example, the maximum concentration in the Great Miami River at the confluence with Paddys Run is calculated by taking the maximum concentration in Paddys Run at that point multiplied by a dilution factor between Paddys Run and the Great Miami River. This dilution factor is the peak flow rate in Paddys Run at its confluence with the Great Miami River from the HEC-1 model divided by the average flow rate in the Great Miami River.

For baseline conditions, the runoff around the production area and the waste pit areas are collected in the storm water retention basin and discharged to the Great Miami River via the discharge outfall line. The concentration in the Great Miami River due to the flow from the discharge outfall line is needed for assessing the risk. Two concentrations are calculated; the first is the concentration due to the representative storm event and the other is a year-long average. The concentration in the Great Miami River is calculated by summing the amount of contaminant released (adsorbed and dissolved phase contaminants from the waste pit and production areas and from the contaminants in the flow from the South Groundwater Contamination Plume recovery wells) and dividing by the total volume of water available for the same time frame. The total flow of water is the sum of one-third of the average flow in the Great Miami River, the runoff volume from the production and waste pit areas, and the flow from the recovery wells.

The contaminant transport in the Great Miami Aquifer is modeled to determine groundwater exposure point concentrations. The amount of contaminant infiltrating through the streambeds of Paddys Run and the SSOD is input as loading terms to the groundwater solute transport model (see Section 5.3.3). Loading for two cases are calculated; one from the single representative storm event and another average rate to represent all of the storm events occurring during the year.

The contaminant loading to the Great Miami Aquifer is simulated for 1000 years in the groundwater solute transport model. Because of this long time frame, the depletion of the source soil at the FEMP is an important consideration. Two processes of source depletion are considered in this analysis, erosion of the contaminated surface soil and decay of the source contaminants. To account for the erosion of surface soil, the universal soil loss equation (USLE) (EPA 1988b) was used to estimate the yearly loss of soil due to erosion from each subbasin. Erosion calculations were conducted for each subbasin in the surface water model. The maximum depth of soil loss was less than 8 inches in 1000 years. These calculations indicated that the source soil would not completely erode away during the modeling time frame. Since the contaminated source soil would still be present during the time frame of the study, the depletion of the source soil by erosion was not significant and was not retained in the procedure. The effects of radioactive decay and biodegradation are taken into account in calculating the source concentrations at the beginning of the future conditions (70 years after the baseline conditions). The loadings from the surface water to the Great Miami Aquifer are only calculated at the beginning of baseline and future time points (i.e., time 0 and 70 years, respectively) and are assumed to be constant between these points.

The total annual contaminant loading to the Great Miami Aquifer was a combination of the loading patterns simulated with the representative storm event (i.e., a 1-year 24-hour storm event) and the total annual runoff. Contaminated runoff for rainfall events other than the representative storm event was conservatively assumed to completely enter the Great Miami Aquifer. However, only the portion of contaminated runoff caused by the representative storm event, that was simulated to enter the Great Miami Aquifer, was included in the total annual loading. The representative storm event only accounts for approximately six percent of the annual runoff so that the amount of contaminant which infiltrates from the representative storm only accounts for a small portion of the annual loading. Because of this, the actual volume of infiltration from Paddys Run and the SSOD caused by the representative storm event was not as important as the simulated pattern, or distribution, of the infiltration (see Figure 5-17) when estimating the total annual loading. The distribution of infiltration

was needed to accurately predict the local contaminant loading rates and groundwater concentrations along the discharge points so that one area's concentration was not underestimated and another area overestimated.

5.3.2.2 Source Term Determination

The sources of contamination in the surface water pathway used for modeling are assumed to be the surface soil in and around the FEMP. As was briefly discussed in Section 5.3.2.1, the surface water model assumes a uniform concentration within a source area. The drainage subbasins from the HEC-1 model are relatively large and contain a significant areal variation in the contaminant concentrations in the surface soil. To account for this variation, the drainage subbasins were then further subdivided based on contaminant concentrations. The assumption of uniform concentrations used in the surface water model is much more reasonable for the smaller areas delineated based on soil concentrations. Source areas which were defined and modeled in other operable unit studies were first broken out from the HEC-1 drainage areas and made separate source areas. Further delineation of source areas was based on the uranium concentrations in the surface soil as shown in Figure 5-10. The subbasins surrounding the FEMP are delineated into 34 source areas for surface water modeling (see Figure F.2.3-1 in Appendix F.2).

For the baseline and future conditions as defined in Section 5.1.2.1, it is assumed that contaminant releases from Operable Units 1, 2, and 4 have been terminated. To account for this, background concentrations are assigned to these operable units. The assumption is that these areas will be capped with the top layer being clean soil which would contain background levels of contamination.

For each of the remaining source areas, surface soil samples in the top 1.5 feet are statistically analyzed to determine a representative concentration for each contaminant in each source area. If a contaminant is detected above background in any source area, a concentration is required for each source area to be able to evaluate the cumulative effects of all of the source areas. If a contaminant is analyzed for in a source area but is not detected, the background concentration is assigned to that area. If a contaminant is not analyzed for in a source area but a concentration is required, a concentration is "borrowed" from an adjacent area or an area that was likely to contain similar levels of contamination. Two to four source areas in which contaminations are expected to be in similar levels are grouped together. The borrowing process can best be illustrated with a short example. For instance, three source areas (A, B, and C) are grouped together because they are suspected of having

similar levels of contamination; in addition a particular constituent was not analyzed for in area B. The representative concentration of either area A or C could be assigned to area B. If only one of the areas, A or C, is immediately adjacent to area B, then that area's concentration is borrowed. If both areas A and C are adjacent to area B, then the higher of the representative concentrations for the areas, A or C, is assigned to area B. In some instances, entire groups of source areas require borrowed concentrations. When this happens the concentrations are borrowed from another group of source areas or, depending on the area and the expected amount of contamination, background levels could be assigned. Table 5-16 summarizes source concentrations and contaminant inventories for each COPC in the surface water pathway.

The source concentrations used for future conditions are adjusted to account for radioactive decay and biodegradation of the contaminants in the 70 years from the beginning of the baseline conditions. Attachment F.2-I presents all of the source concentrations for the 34 source areas for baseline and future conditions.

5.3.2.3 CPC Screening in the Surface Water Pathway

As shown in Figure 5-16, a constituent screening procedure was performed to select CPCs in the surface water pathway. Figure 5-8 demonstrates the constituent screening process used. All of the contaminants detected above background levels in the surface soil undergo an initial screening to determine which chemicals need to be modeled in the surface water pathway. The CPCs which passed the initial screening process are then screened again midway through the modeling process to determine if the contaminant concentrations pose a significant risk that requires additional modeling in both the surface water and groundwater exposure routes. The dissolved contaminant concentrations in the surface water flow coming from each contaminated subbasin were screened to determine if concentrations in Paddys Run and the Great Miami River needed to be calculated. The dissolved contaminant concentrations in the Great Miami Aquifer that originate from infiltration through Paddys Run and the SSOD were screened to determine if these contaminants need to be modeled in the groundwater solute transport model. Water criteria based on 10^{-7} risk level or 0.1 HQ were used in the screening process.

The CPC screening for surface water used the predicted concentration in the flow coming from each subbasin. That concentration is compared to the 10^{-7} risk-based concentrations for carcinogens or 0.1 HQ concentrations for noncarcinogens. If the contaminant concentration in the flow from all of

the subbasins is below the screening concentrations, then the contaminant is screened out and the concentrations in Paddys Run and the Great Miami River need not be calculated.

The concentration of CPCs that enter the Great Miami Aquifer through the streambeds of Paddys Run and the SSOD due to a 1-year, 24-hour storm event were estimated for screening purposes. The estimated concentrations to the Great Miami Aquifer are compared to the 10^{-7} risk-based concentrations for carcinogens or the 0.1 HQ concentrations for noncarcinogens. If the contaminant concentration in the Great Miami Aquifer was below the screening concentrations for each subbasin, then the contaminant was screened out and the contaminant's migration was not simulated in the groundwater solute transport model. The combined effect of multiple subbasins would not produce a concentration higher than any of the individual subbasin's surface water concentrations; therefore, comparing the screening levels with each subbasin's surface water concentration is a more conservative approach.

Tables 5-17 and 5-18 summarize the CPCs not screened out in the surface water and the groundwater from the surface water pathway.

5.3.2.4 Required Modeling Results

The following fate and transport modeling results under both the baseline condition (i.e., the first 70 years with active environmental management activities such as the storm water retention basin and discharge outfall) and future condition (i.e., the remaining years in the modeling time frame without active environmental management activities) in the surface water pathway are required to support the Operable Unit 5 baseline risk assessment:

- List of pathway-specific CPCs.
- Maximum sediment contaminant concentrations and locations.
- Maximum Paddys Run contaminant concentrations at various points between the northern boundary of the FEMP and the Great Miami River.
- Maximum Paddys Run and the SSOD surface water contaminant concentrations.
- Maximum Great Miami River contaminant concentrations at the mouth of Paddys Run.
- Great Miami Aquifer contaminant concentrations along Paddys Run and the SSOD due to contaminated surface water infiltration.

In addition to the above-listed results, maximum Great Miami River contaminant concentrations at the discharge outfall line under the baseline conditions are also required.

5.3.3 Groundwater Pathway

Rainfall and surface water runoff can infiltrate through the surface sediment and percolate down to the groundwater aquifer. The Great Miami Aquifer is considered the primary pathway by which contaminants released from Operable Unit 5 sources could be transported to a human receptor. The migration of water and dissolved contaminants from the source to the receptor involves flow through both unsaturated (vadose zone) and saturated materials. Flow and contaminant transport in these materials is affected by the permeability of the media, the driving gradient, and the saturation conditions (Section 3.6). Another factor considered in fate and transport modeling is dispersion (mixing) in groundwater. Attenuation and retardation are also considered as factors and both factors may affect the transport of the solute through the system. The five controlling mechanisms for the groundwater migration pathway are:

- The leaching of contaminants from the soil matrix into the dissolved phase.
- The percolation of the contaminated leachate or perched water through the overburden to the underlying aquifer.
- Lateral migration of contaminants in the perched groundwater system.
- The infiltration of contaminated surface water from the SSOD and Paddys Run to the Great Miami Aquifer.
- The movement of water in the Great Miami Aquifer.

The contaminant concentrations in leachate reaching groundwater depend on the precipitation infiltration rate, the initial concentrations, contaminant mass, solubility of the contaminants, degradation rates, soil textures, soil hydraulic conductivities, depth to the groundwater, and a number of other chemical- and soil-specific factors as discussed in Sections 5.2.2 and 5.2.3.

Although not specifically quantified, the potential colloidal transport in the Great Miami Aquifer was considered in the transport modeling by using unfiltered groundwater concentrations (or, in some cases, the higher ones among the filtered and unfiltered samples) for the transport model calibration and determination of initial aquifer conditions. This approach provides additional conservativeness in estimates of groundwater concentrations at receptor locations.

5.3.3.1 Conceptual Model and Modeling Framework

General conditions of the hydrogeologic environment to be simulated in the groundwater pathway of Operable Unit 5 contaminant fate and transport modeling are described in Section 3.6 and Appendix F.3. Figure 5-18 shows the overall Operable Unit 5 groundwater fate and transport modeling area. This area was selected based on the hydrogeological conditions as well as the sources of groundwater contamination, the potential receptor locations, and the needs of future groundwater remedial design.

Two major hydrogeological units in the groundwater modeling domain include the glacial overburden and the Great Miami Aquifer (Section 3.6). The vadose zone beneath the FEMP extends from the ground surface to the water table of the Great Miami Aquifer, which consists of up to 60 feet of glacial overburden material overlying approximately 20 to 45 feet of unsaturated sand and gravel outwash of the Great Miami Aquifer. The hydraulic conductivity of the glacial overburden is much lower than that of the Great Miami Aquifer. The highest hydraulic conductivity calculated for the glacial overburden is 3 orders of magnitude lower than the hydraulic conductivity calculated for the sand and gravel of the Great Miami Aquifer. In general, the perched water lateral flow rate is relatively low in the glacial overburden with the predominant lateral flow direction generally to the west. The potential for flow in the Great Miami Aquifer is high with the predominant flow direction to the east and south.

Conceptual Model of the Glacial Overburden

Glacial overburden sediment lies between the FEMP facility and the underlying Great Miami Aquifer. The glacial overburden is very heterogeneous and contains clay, silt, sand, and gravel and is saturated beginning approximately 3 to 5 feet below ground surface. Gray clay deposits located at the base of the overburden serve to limit the downward movement of fluids and create a perched groundwater system within the overburden sediment. Perched water table maps made using an average of several years of elevation data indicate that the general potential for lateral fluid movement within the glacial overburden is to the west towards Paddys Run or southwest towards the SSOD (Section 3.6.1).

The low hydraulic conductivity of the clay contained within the glacial overburden makes direct vertical migration of water a very lengthy process (i.e., over 10 to 15 years). The possibility exists though, that fluids could "short circuit" the protective nature of the clay and find a route through or out of the glacial overburden that would require less travel time (e.g., interconnected coarse-grained

sediment or fractures). The density of fractures in the overburden is believed to decrease with depth. Most fractures appear to be near-surface features. Fractures do not appear to be a major problem at depth.

The possibility of a coarse-grained interconnection through the clay is greatest beneath the western portion of the FEMP. A basin deposit is present where much of the coarser grained material within the overburden is located. It is likely that there are channels leading into this basin from the north, the north being the most probable source of sediment for this area. Drilling just east of the waste pit area has revealed that channels as small as 20 feet wide exist. The possibility that similar small channels exist elsewhere cannot be overlooked.

Conceptual Model of the Great Miami Aquifer

The Great Miami Aquifer is a textbook example of a glaciofluvial buried valley aquifer. It is a sand and gravel water table system consisting of approximately 150 feet of glacial fluvial outwash deposits (Section 3.6.2). The outwash deposits are divided by a 15-foot clay interbed which serves as an aquitard and are capped by approximately 50 feet of glacial overburden sediment which consist predominately of glacial till and contain perched groundwater. No evidence of fracturing has been reported in the sand and gravel of the Great Miami Aquifer. Groundwater in the aquifer enters the FEMP area by way of buried channels on the west, north, and east and exits to the south and southeast.

In order for fluids to get from the FEMP into the Great Miami Aquifer they either have to travel across the overburden to a location where they can infiltrate into the aquifer or move vertically through the overburden sediment. If fluids move through the overburden they can either leak out through the bottom of the overburden or seep out onto the land surface. The pathway of least resistance is across the overburden sediment. Fluids that can reach eroded areas (i.e., where Paddys Run and the SSOD have exposed the underlying aquifer) have direct access to the Great Miami Aquifer. Historically, this pathway appears to be the one that allowed the most contaminants to enter the Great Miami Aquifer. Fluids in the Great Miami Aquifer are transported either to the east or south depending upon their point of entry.

Modeling Framework

Based on the conceptual model of groundwater flow which controls the potential contaminant migration in the groundwater pathway, Figure 5-19 presents the overall framework and procedures employed in the Operable Unit 5 groundwater fate and transport modeling. The capabilities and developments of all the models shown in Figure 5-19 are presented in Appendix F.3. Not all CPCs need to be modeled using the complex fate and transport model (i.e., ODAST/SWIFT model) due to differences in chemical persistence and extent of contamination. All the COPCs which failed the mobility and toxicity screening were modeled with ODATS/SWIFTLOAD to determine their mass loading rates through the overburden into the Great Miami Aquifer. Two Great Miami Aquifer models were then used to simulate the contaminant migration in the aquifer. Most of the common predominant COCs identified in Section 5.2.1.3 and additional Operable Unit 5 CPCs, which were more persistent or had larger extent of contamination, were simulated and evaluated by using the main groundwater transport model (i.e., SWIFT Great Miami Aquifer model). The constituents simulated by using SWIFT Great Miami Aquifer model are designated as the primary constituents for modeling in the groundwater pathway. A supplemental model (i.e., ECTran) was used to provide estimates of exposure point concentrations of all the CPCs not simulated by the main model (i.e., secondary constituents) vertically through the overburden, Paddys Run, and the SSOD. The ECTran model was also used to screen and simulate lateral migration of CPCs in the major perched groundwater zones in the glacial overburden.

As previously mentioned, the upper surface of the glacial overburden contains secondary porosity features (fractures and bioturbations). The density of these secondary porosity features decreases with depth and essentially controls the depth of active infiltration. The contaminant migration pathway, for the purpose of transport modeling, begins beneath the highly fractured surface layer. No credit was taken for contaminant attenuation by this fractured zone. This provides the simulated effect that contaminants which infiltrate the ground surface would instantaneously move through the near-surface fractured zone.

Five representative cross sections of the vadose zone and their distributions throughout the Operable Unit 5 area were created for infiltration modeling with the HELP model and initial constituent screening by considering contaminant travel time and decay. The first four cross sections are consistent with the zonation and cross sections presented in Section 3.4. A fifth zone was added for modeling purposes to account for soil degradation in the vicinity of Plant 6. The thickness and layer

structure of the vadose zone was then defined in more detail with a 125- by 125-foot grid in the SWIFT/ODAST model and the three-dimensional glacial overburden and upper Great Miami Aquifer system (GO/UGMAS) model for determining the contaminant loading through the vadose zone.

The saturated portion of the Great Miami Aquifer was represented by six model layers in the SWIFT model. Five of these model layers were designed to coincide with the depth of Type 2, Type 3, and Type 4 monitoring wells, the clay interbed, and the top of bedrock contours. One model layer was used to represent the zone between Type 2 and Type 3 wells for additional vertical resolutions. Higher surface recharge rates through surface water bodies (i.e., Paddys Run, SSOD, and the Great Miami River) were incorporated in the model. Unfiltered groundwater concentrations (or, in some cases, the higher ones among the filtered and unfiltered samples) are used for the transport model calibration and determination of initial aquifer conditions. This approach provides additional conservativism in estimates of groundwater concentrations at receptor locations considering the potential for colloidal transport.

5.3.3.2 Evaluation of Lateral Migration of Contaminants in Perched Groundwater

The ODAST overburden transport model used in the GO/UGMAS at the FEMP is restricted to the vertical dimension only. As such, it cannot answer important questions regarding the degree of horizontal (lateral) migration of contaminant plumes in the perched groundwater system. Although ODAST represents a simplified but conservative method of modeling fate and transport in the GO/UGMAS in the vertical direction, it was determined from the materials presented in Section 3.6.1 that lateral migration also needs to be evaluated, especially for perched water contamination in the area where significant and potentially far-reaching lenses of coarser materials with an underlying gray clay layer exist in the overburden.

A three-dimensional GO/UGMAS flow and transport model was developed to simulate the perched groundwater flow conditions in the glacial overburden. The initial purpose of this model was to quantify lateral contaminant transport in glacial overburden perched water zones due to loading at multiple, areally distributed sources of major COCs. Development and applications of the three-dimensional GO/UGMAS model are briefly described in Appendix F.3; further details can be found in the Glacial Overburden/Upper Great Miami Aquifer System Model Report (DOE 1994f). Results of the applications indicate that lateral plume migrations of the predominant COC at the FEMP (i.e., uranium) and other constituents with similar transport characteristics (i.e., retardation

factor in the overburden) are not significant in relation to vertical transport. For uranium, the plumes originating from the perched groundwater in the Plant 2/3 and Plant 6 areas did not reach the surface water exposure points (pilot plant drainage ditch and Paddys Run) or the FEMP property line in 1000 years even with very high lateral dispersivities in the modeling. On the other hand, the model demonstrates that significant amounts of uranium can reach the Great Miami Aquifer through vertical migration in the same time frame from these two sources. It was then determined that a one-dimensional vertical conceptual model of flow and transport through the overburden (i.e., ODAST) can be used as the main model for all the CPCs in the Operable Unit 5 RI for the fate and transport modeling.

As shown in Figure 5-19, however, the ECTran model was used to screen and simulate the lateral migration of more mobile CPCs, or CPCs from source areas closer to the surface water exposure points in the major perched groundwater zone, to the nearest surface water exposure point. This perched groundwater zone is between the southwest corner of the production area, a surface drainage ditch, the waste pit area, and Paddys Run. These significant perched groundwater plumes originated from the waste pit area, silo area, Plants 2/3 and 6, and the pilot plant and laboratory buildings.

5.3.3.3 Source Term Determination and Geochemical Conditions

Contamination in Soil

Twenty-seven Operable Unit 5 contaminant source areas (excluding six areas in Operable Units 1, 2, and 4 from the surface water pathway) were defined based on the contouring of total uranium surface soil sampling data (< 1.5 feet deep), as shown in Figure 5-10, and the boundaries of surface water drainage basins. Three additional deeper source areas of contamination in the production area (i.e., in the vicinity of Plants 2/3 and 6 and the laboratory building) were defined based upon three-dimensional solid block modeling of uranium in the glacial overburden.

Constituent mass in each source area was calculated from the representative concentration, usually the 95 percent UCL on the mean determined by statistical analysis (see Appendix A, Attachment A-II) and the mass of soil within the source area. Soil mass is derived from the volume of each source area and the bulk density of the soil within the area. Table 5-19 summarizes the range of representative source concentrations and contaminant inventories for each COPC in the vertical groundwater pathway. After the solid phase concentrations were obtained, constituent-specific source leachate concentrations were then determined for every source area, following the procedure shown in

Figure 5-11. The source leaching coefficients (K_l) used in this process are chemical- and preferably site-specific. The general geochemical conditions of the major COC (i.e., uranium) at the FEMP is described in Appendix F.3. As a summary, the zones of K_l and K_d values for uranium are shown in Figure 5-20.

Contamination in the Great Miami Aquifer

The current contaminant concentrations in the Great Miami Aquifer were also incorporated in the groundwater modeling as initial conditions. Table 5-20 summarizes the initial Great Miami Aquifer conditions. The general process used to develop the initial Great Miami Aquifer contaminant concentrations is described in Appendix F.3. For example, initial concentrations of uranium in the Great Miami Aquifer at the beginning of the modeled period were developed from the four sources listed below.

- Source 1: Field results of total uranium (filtered and unfiltered) in Type 2, 3, and 4 wells in the Great Miami Aquifer from the 1993 data set.
- Source 2: Uranium concentrations developed through geostatistical analysis of field data as presented in the SWIFT Great Miami Aquifer Model - Summary of Improvements Report (DOE 1994j).
- Source 3: Results of groundwater fate and transport modeling for the Operable Unit 2 Remedial Investigation Report (DOE 1994h).
- Source 4: Results of groundwater fate and transport modeling Operable Unit 1 Remedial Investigation Report (DOE 1994g).

The 1993 field data set for filtered and unfiltered groundwater samples from Type 2, Type 3 and Type 4 monitoring wells (Source 1) were combined into a single conservative depiction of the plume by taking the highest value at each location. Since Type 2 wells are screened at depths corresponding to layer 1 of the SWIFT Great Miami Aquifer model and Type 3 wells were screened at depths corresponding to layer 3 of the model, well monitoring data could be directly translated to their respective layers. There is no significant (> 10 parts per billion [ppb]) contamination detected in wells screened at depths corresponding to model layers 4, 5, or 6. Grid files (on the 120 by 112 SWIFT Great Miami Aquifer model grid) were available from Sources 2, 3, and 4 because both the geostatistical analysis and fate and transport modeling used this grid. Grid files from Sources 2, 3, and 4 were electronically combined such that the highest value for each cell was retained. "Combined" files for layers 1 and 3 were compared to contour maps from Source 1 for Type 2, 3

and 4 wells. "Final combined" contour maps for layers 1 and 3 were generated to conservatively present all the data from all four sources.

Contamination in Perched Groundwater

Contaminants in the perched groundwater system were also evaluated to define the source terms for additional vertical mass loading to the Great Miami Aquifer and potential lateral migration to select surface water exposure points. Perched water contaminant plumes were drawn to determine the source locations, dimensions, and volumes. Representative perched water concentrations for every plume were selected and used as the initial source leachate concentrations directly. Table 5-21 summarizes the range of representative source concentrations and Table F.3.6-2 in Appendix F summarizes contaminant inventories for each CPC in the lateral perched groundwater pathway.

5.3.3.4 Pathway-Specific CPC Screening

As shown in Figure 5-19, constituent screening procedures were performed to select CPCs for groundwater fate and transport modeling. The screening procedures focus on both the vertical and lateral migration potential of contaminants (see Figure 3-60) to select exposure points. Figure 5-9 demonstrates the constituent screening process used in the vertical transport pathway through the overburden. The screening process used for lateral migration through the perched water zones in the glacial overburden was similar to the process shown in Figure 5-9. The differences between the two screening processes include the original locations of the contaminant sources, hydraulic flow gradients, permeabilities of the media, flow paths, times of travel, and exposure points where the water criteria comparisons took place.

Table 5-22 summarizes the CPCs which passed the screening through the vertical migration pathway to the Great Miami Aquifer. Table 5-23 presents the CPCs which passed the screening in the lateral migration pathway in the perched water zone to a surface water drainage ditch west of the production area that is the first surface water exposure point in the perched groundwater migration pathway.

5.3.3.5 Required Modeling Results

The following fate and transport modeling results under the no-action scenario are required to support the Operable Unit 5 baseline risk assessment:

- List of pathway-specific CPCs.

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- Times of occurrences, locations, and values of the on-property, fence line, and off-property maximum groundwater concentrations in the Great Miami Aquifer for every CPC originating from Operable Unit 5 source areas in the groundwater pathway.

- Zone-specific average and maximum CPC concentrations for on-property risk assessment zones shown in Figure 5-5.

- Times of occurrence and values of the maximum concentrations for every CPC at the following specific locations (shown in Figure 5-4):

  - FEMP production well
  - Knollman wells (Wells 12/26, 13, and 14)
  - SOWC collection wells (Wells Coll-1 and -2)
  - Stricker's Grove well
  - Pottenger well (Well 34)
  - Monitoring Wells 2071, 2119, 2127, and 3127

- Concentrations of all the CPCs at the above-listed locations when the location-specific maximum U-238 concentrations occur.

- Concentration contours of major CPCs such as U-238 when the baseline condition ends, when the maximum fence line concentration occurs, and at the end of model simulation (i.e., 1000th year).

- Overall area where future uranium concentrations can potentially exceed 20 μg/L (proposed MCL) and 1 μg/L (in range of background), respectively.

- Times when all the simulated on-property uranium concentrations will be below 20 μg/L (proposed MCL) and 1 μg/L (in range of background), respectively.

- Times when all the simulated off-property uranium concentrations will be below 20 μg/L (proposed MCL) and 1 μg/L (in range of background), respectively.

5.4 SUMMARY OF MODELING RESULTS

Results of the pathway-specific fate and transport modeling are summarized in this section.

5.4.1 Air Quality

This section summarizes the results of the air transport modeling of Operable Unit 5 sources as determined from the conceptual model scenarios and surface soil contamination data. The parameters and assumptions used in the analysis are discussed in detail in Appendix F.1. Modeling results are discussed below in terms of predominant Operable Unit 5 air pathway contaminants and maximum on- and off-property and discrete receptor contaminant concentrations.

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5.4.1.1 Predominant Air Contaminants

The predominant contaminants associated with the Operable Unit 5 air transport analysis are the radiological analytes, as indicated by a review of site-wide surface soil contaminant characterization data. Of particular interest are Ra-226, Th-230 and U-238 that are associated with some of the highest surface soil activity levels within the Operable Unit 5 soil database.

Modeling results presented in this section are for all contaminants identified within the volatile, semivolatile, PCB, radionuclide, and inorganics surface soil database. Figures showing the spatial distribution of Ra-226, Th-230, U-238 and Ra-222 air concentrations across the local area are also presented.

5.4.1.2 Maximum On- and Off-Property Contaminant Concentrations

The air transport modeling results for on- and off-property contaminant air concentrations in the current and agricultural scenarios are summarized in Tables 5-24a, 5-24b, 5-25a and 5-25b. These tables both show the COPCs for each contaminant class, the location (x,y) of the maximum calculated concentration (in meters) grid, and the maximum on- or off-property annual average concentration for each COPC. The spatial distributions of air concentrations associated with Ra-226, Th-230, U-238 and Ra-222 are shown in Figures 5-21 through 5-24 for the current and agricultural scenarios.

The maximum annual average on-property concentrations calculated for the radionuclide contaminant group were associated Ra-226, U-234, U-238 and total uranium. On-property concentrations in the current scenario (Table 5-24a) ranged from 4.80×10^{-4} for Ra-226 to 1.70×10^{-3} pCi/m^3 for U-238. The maximum annual concentration for total uranium was 5.00×10^{-3} μg/m^3. The location of the maximum concentration for each contaminant was different; however, all were generally located in the south or southeastern portion of the production area or just east of the sewage treatment plant. In the agricultural scenario (Table 5-24b), on-property concentrations ranged from 1.30×10^{-2} for Ra-226 to 4.50×10^{-2} pCi/m^3 for U-238. The maximum annual average concentration for total uranium was 1.30×10^{-1} μg/m^3. The maximum annual on-property radon-222 concentration was calculated to be 352 pCi/m^3 in the eastern portion of the production area.

Maximum off-property radionuclide concentrations for the current scenario (Table 5-25a) ranged from 4.60×10^{-5} pCi/m^3 for Ra-226 to 4.50×10^{-4} pCi/m^3 for Th-230. The maximum concentrations for the agricultural scenario (Table 5-25b) ranged from 1.20×10^{-3} pCi/m^3 for Ra-226 to

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1.20×10^{-2} pCi/m^3 for Th-230. The maximum annual off-property Ra-222 concentration was calculated to be 8.21 pCi/m^3. Maximum off-property radionuclide concentrations were calculated to generally occur at the eastern boundary of the FEMP.

The maximum calculated on-property annual average concentrations for the inorganic contaminant class in the current scenario were associated with many of the more commonly occurring soil inorganics such as aluminum, calcium, iron, magnesium, and potassium. Maximum annual average concentrations of other inorganics included arsenic at 6.90×10^{-6} μg/m^3, cadmium at 2.00×10^{-6} μg/m^3, chromium at 9.00×10^{-6} μg/m^3, and lead at 3.80×10^{-4} μg/m^3. The general location of the maximum on-property concentrations for the inorganics group was in the center of the production area. In the agricultural scenario (Table 5-24b), on-property inorganic concentrations were generally two orders of magnitude higher than those calculated for the current scenario. Maximum annual average concentrations were 1.90×10^{-2} μg/m^3 for arsenic, 5.50×10^{-5} μg/m^3 for cadmium, 2.40×10^{-4} μg/m^3 for chromium and 1.00×10^{-2} μg/m^3 for lead.

Maximum off-property concentrations for arsenic, cadmium, iron, and lead (Tables 5-25a and 5-25b) were generally two to three times lower than the maximum on-property concentrations in both the current and agricultural scenarios.

The maximum annual average on-property concentrations for the volatiles, semivolatiles and PCB contaminant groups were also calculated to occur within the center of the production area in both the current and agricultural scenarios. The maximum annual average concentrations for the volatiles, semivolatiles and PCB groups were calculated to occur on-property in the agricultural scenario. The highest on-property concentrations were 0.52×10^{-1} μg/m^3 for trichloroethene, 6.40×10^{-6} μg/m^3 for benzo(a)pyrene and 6.30×10^{-6} μg/m^3 for benzo(k)fluoranthene. Maximum off-property annual average concentrations for this contaminant group were generally 1 to 2 orders of magnitude lower than the calculated on-property concentrations.

5.4.1.3 Maximum Contaminant Concentrations at Discrete Receptor Locations

Results of the air transport modeling for the 11 discrete receptors in the current and agricultural scenarios are shown in Figures 5-25a and 5-25b for radionuclides, inorganics, volatiles, semivolatiles, and PCBs. The discrete receptor group includes six schools, one farm, two points along the Great Miami River and two residential locations along Paddy's Run Road and the Village of Fernald.

The maximum annual average discrete receptor concentrations for the radionuclide contaminant class in the current and agricultural scenarios were generally calculated for Ra-226, U-238, U-234, Th-230 and Ra-222. The maximum annual discrete receptor radon concentration (Table 5-26a) was 1.4 pCi/m^3 and occurred at the east Great Miami River discrete receptor. The maximum annual average concentrations for Ra-226, U-234, U-238 and Th-230 occurred in the agricultural scenario and were in the range of 1.90 x 10^{-4} pCi/m^3 to 5.70 x 10^{-4} pCi/m^3 and all were calculated to occur at either the Knollman's farm or the east Great Miami River discrete receptor locations.

A comparison of Tables 5-26a and 5-26b shows that the maximum annual average concentrations for the inorganic contaminant class occurred in the agricultural scenario at the Knollman's farm receptor location. The highest annual air concentrations were calculated for all of the naturally occurring inorganics such as calcium, aluminum, iron, and magnesium. Maximum discrete receptor concentrations at the Knollman's farm receptor for the inorganics arsenic, lead, cadmium and chromium ranged from 8.00 x 10^{-4} μg/m^3 to 3.70 x 10^{-6} μg/m^3.

Maximum annual discrete receptor concentrations for the volatile, semivolatile and PCB contaminant classes were all calculated to occur in the agricultural scenario at either the Knollman's farm or the east Great Miami River discrete receptors. The highest concentrations for these three respective contaminant classes occurred with the constituents tetrachloroethene, trichloroethene, benzo(b)fluoranthene, and Aroclor-1254.

5.4.2 Surface Water and Sediment Quality

The following subsections describe the simulated results for the baseline and future conditions in the surface water contaminant migration pathway including the predicted concentrations in sediment, surface water, and in the Great Miami Aquifer due to infiltration from the surface water. These results are used in the risk assessment described in Section 6.0.

As described in Sections 5.1.2 and 5.3.2.2, both the baseline and future conditions assume that the other operable units have been remediated. In the baseline condition, the storm water controls around the waste pit area (including the silos) and the production area are still in operation and surface runoff from these areas is discharged to the Great Miami River. In the future condition, the storm water controls are no longer in operation. The storm water from the production and waste pit areas returns to the natural drainage paths (i.e., Paddys Run and the SSOD). These two different conditions have

significant impacts on the contaminant conditions in the surface water pathway. Therefore, their modeling results are summarized and presented separately. The modeling results for the northeast drainage on the northeast corner of the FEMP (see Figure 3-9), which is not within the Paddys Run drainage basin, is also summarized separately due to the much shorter list of CPCs and different hydrological conditions.

5.4.2.1 Paddys Run Drainage Basin Baseline Conditions

Tables 5-27 through 5-30 summarize the results of the surface water modeling for the baseline conditions as defined in Section 5.1.2.1 for the Paddys Run drainage basin. These tables provide results for contaminants not screened out in the CPC screening (Section 5.3.2.3).

Contaminant Concentrations in Sediment

Table 5-27 presents the maximum predicted sediment concentration for each contaminant not screened out in the surface water CPC screening. Table 5-27 also indicates the drainage course which would receive the maximum sediment concentration. The highest uranium concentration in sediment is predicted to occur in the pilot plant drainage ditch. The total uranium concentration in this ditch is predicted to be 552 mg/kg. Most of the other radionuclides are predicted to have the maximum concentration in a north side drainage area and in the east side drainage, respectively. The maximum concentration of sediment for inorganics is predicted to occur in the ditches north of the production area. The maximum concentration predicted is for magnesium (31500 mg/kg) in the ditch east of the production area. The highest concentration predicted for organic contaminants is for benzo(a)pyrene (2.14 mg/kg) in the ditch north of the production area. All of the sediment concentrations for each subbasin for each contaminant are presented in the surface water model summary output sheets in Attachment F.2-II.

Contaminant Concentrations in Surface Water

Table 5-28 presents a summary of the following surface water concentrations: the maximum concentration in Paddys Run, the year-long average concentration in the Great Miami River at the discharge outfall line, the maximum weekly concentration in the Great Miami River at the discharge outfall line, and the maximum concentration in the Great Miami River at the mouth of Paddys Run. The highest predicted concentration in each of these four surface water locations is for magnesium, then total uranium, manganese, cyanide, and 4-methylphenol. The predicted maximum concentration in Paddys Run for total uranium is 102 μg/L, the maximum concentration in the Great Miami River at the mouth of Paddys Run is predicted to be 8.5 μg/L, and the concentration in the Great Miami River during the maximum week is predicted to be 5.9 μg/L.

Contaminant Loading into the Great Miami Aquifer

Tables 5-29 and 5-30 provide summaries of the maximum concentration and yearly loading, respectively, to the Great Miami Aquifer from the surface water bodies. The concentration and loadings were calculated for three channel reaches in Paddys Run and the SSOD. The loadings and the concentrations were predicted to be highest under the SSOD for most of the CPCs. This is due to the higher contamination around the SSOD and the higher infiltration percentages in the SSOD. The highest loadings and concentrations are for magnesium, manganese, cyanide, and then total uranium. The predicted concentration of total uranium under the SSOD is 97 μg/L and the loading is 45.8 kg/year. Figure 5-25 shows the predicted uranium loading rates to the Great Miami Aquifer under the baseline condition. Attachment F.2-II presents the concentration for all of the contaminants modeled for baseline conditions.

5.4.2.2 Paddys Run Drainage Basin Future Conditions

As was discussed in Section 5.1.2.1 the future conditions assume that the other operable units have been remediated and that the storm water controls around the waste pit area (including the silos) and the production area are no longer in operation. The storm water from the production and waste pit areas then return to their natural drainage paths (i.e., the waste pit area to Paddys Run and the production area to the SSOD). This section describes the surface water modeling results for the future conditions in the Paddys Run drainage basin. Tables 5-31 through 5-34 summarize the results of the surface water modeling for the chemicals not screened out in the CPC screening. Attachment F.2-III presents the summary output tables from the surface water model for all of the chemicals modeled for the future conditions.

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Contaminant Concentrations in Sediment

Table 5-31 is similar to Table 5-27 and presents the same type of data for the future condition. For most of the CPCs, the maximum concentrations in the sediment are predicted to occur in the SSOD or the ditch east of the former production area. The total uranium concentration in the SSOD is predicted to be 3380 mg/kg. These high concentrations are due to the modeled conditions of removing the buildings in the former production area and exposing the contaminated soil. The maximum concentrations of inorganics are predicted to occur in several different drainage subbasins. The maximum concentration predicted is for magnesium (31500 mg/kg) in the ditch east of the former production area. This is the same as in the baseline condition because the inorganics are assumed to not decay and the subbasin contributing to this ditch lies outside of any of the storm water controls. The highest concentration predicted for organic contaminants is for 4-methylphenol in the lower SSOD. All of the sediment concentrations for each subbasin for each contaminant are presented in the surface water model summary output sheets in Attachment F.2-III.

Contaminant Concentrations in Surface Water

Table 5-32 presents a summary of the following surface water concentrations, the maximum concentration in Paddys Run, and the maximum concentration in the Great Miami River at the mouth of Paddys Run. Concentrations are not calculated at the discharge outfall line because under the future conditions it is assumed that this line and the rest of the storm water controls are not in operation. The highest predicted concentration in both of these surface water locations is for magnesium, then total uranium, manganese, and cyanide. The predicted maximum total uranium concentration in Paddys Run is 1980 μg/L and the maximum concentration in the Great Miami River at the mouth of Paddys Run is predicted to be 174 μg/L.

Contaminant Loadings into the Great Miami Aquifer

Tables 5-33 and 5-34 provide summaries of the maximum concentration and yearly loading, respectively, to the Great Miami Aquifer from the surface water bodies for future conditions. The concentration and loadings were calculated for three cross sections in Paddys Run and the SSOD. The loadings and the concentrations were predicted to be highest under the SSOD for most of the CPCs. This was due to the higher contamination around the SSOD and the higher infiltration percentages in the SSOD. The highest loading and concentration are for total uranium with a predicted concentration under the SSOD of 1760 μg/L and a loading of 1400 kg/year. Figure 5-26 shows the predicted uranium loading rates to the Great Miami Aquifer under the future condition.

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Attachment F.2-III presents the concentration for all of the contaminants modeled for future conditions.

5.4.2.3 Northeast Drainage Ditch

Table 5-35 summarizes the results of the constituents which were not screened out based on the predicted surface water concentration. Five constituents were not screened out: arsenic, beryllium, manganese, Sr-90, and total uranium. The concentration for sediment and surface water were calculated at two points. The first point is at the surface water sampling location located approximately 900 feet east of the FEMP property line and the second is at the FEMP property line. The predicted concentrations at the FEMP property line are higher than at the sampling point. The baseline and future concentrations are nearly identical because most of the constituents not screened out either do not decay or have very long half-lives. The highest predicted concentrations are for manganese (170 μg/L surface water and 876 mg/kg in sediment) at the sampling point. The predicted concentration of manganese was 225 μg/L in surface water and 1170 mg/kg in the sediment at the fenceline. The predicted concentrations at the property line of the FEMP for total uranium were 4 μg/L and 24.7 mg/kg in surface water and sediment, respectively. The predicted concentrations at the sampling point were 1.0 μg/L and 7.0 mg/kg in surface water and sediment respectively. Attachment F.2-IV presents the calculations concerning this drainage ditch northeast of the FEMP.

5.4.2.4 Model Performance Evaluation

To evaluate the performance of the surface water model the current site conditions were modeled and compared to sample data. The evaluation of the model was focused primarily on uranium since uranium is the most prevalent contaminant at the FEMP and the contaminant for which the most sample data is available for comparison. The predicted concentrations in the surface water, sediment, and in the Great Miami Aquifer near the Paddys Run and the SSOD were compared to the sampling data of the environmental media and estimates from other studies. Section F.2.5 in Appendix F.2 discusses surface water model performance evaluation in more detail and provides tables comparing sample results to modeled results.

Current Contaminant Source Terms

As in the baseline and future conditions, the source terms for the current conditions were based on surface soil sampling data. The source terms for the baseline and future conditions were based on the UCL on the mean or median depending on the number of sample data points in each source area.

This provided a conservative source concentration to be used in predicting concentrations for risk assessment purposes. To evaluate the model, it is felt that the average of the sample data provided a less conservative but more reasonable source concentration when comparing the model output to sampling data. The current source term concentrations were, therefore, based on the average of the surface soil sampling data.

To simulate the current conditions, two sets of source terms were developed to provide a range of values to compare to the sampling data. The first set of source terms includes all of the samples taken under the buildings in the former production area (as in the baseline and future conditions). The second set of source terms excludes the samples from under the buildings because rainfall cannot directly come in contact with this soil and become runoff while the buildings are still intact. Only source areas PAc, PAd, PAe, PAg, and PAh (see Figure 5-20) contained samples from under buildings; therefore, only those terms from these areas changed in the second source set. Both sets of source terms were run with and without the storm water controls in place so that data from years before the storm water controls were put into operation can also be compared. The current condition source concentrations are presented with the surface model output sheets contained in Attachment F.2-V.

Current Surface Water Concentrations

The current simulated surface water concentrations were compared to samples taken in the surface water in and around the FEMP. The modeled results were compared to the range of results for filtered samples taken between 1988 and 1993, except for the comparison with the northeast drainage ditch which was compared to samples taken in 1993 (the only year samples were taken). The range of modeled results for the production area were from model runs with and without samples from under the buildings. The modeled concentrations in the SSOD, Paddys Run, and the Great Miami River were for the case with storm water controls because the sampling was done after the storm water retention basin was put into operation.

In general, the sampling results match the modeled results fairly well with a few exceptions. The modeled concentrations in the pilot plant drainage ditch are significantly lower than the sampling range of results. This may be due to contamination coming from sources other than the surface soil which were not modeled in the surface water pathway (such as discharges from the pilot plant). The uranium concentration predicted in the northeast drainage ditch is lower than the measured results,

although the difference is approximately only 10 μg/L. This may be due to seepage of water directly out of the source soil to the water course which could generate a higher concentration but a smaller amount of contaminant released. During a storm event the runoff is diluted somewhat by the excess rainwater running off the ground surface. If the representative soil concentration (24.7 mg/kg) for uranium in this area is converted directly to a liquid concentration using K_d of 222 L/kg, the liquid concentration would be 111 μg/L.

5.4.2.4 Current Sediment Concentrations

The modeled current sediment concentrations are compared to sampling data taken in drainage channels in and around the FEMP. The modeled results are compared to the same years of data as the surface water comparison in the previous section. As with the surface water, in some cases the samples were not taken at the subbasin outlet. The results for these cases are presented in the same manner as in the surface water section. The range of modeled results for the production area are from model runs with and without samples from under the buildings. The modeled concentrations in the SSOD are for the case with storm water controls because the samples were taken after the storm water retention basin was put into operation.

Overall, the sampling results match the modeled results fairly well. The modeled result in the SSOD is higher than the sampling results which may be due to the deposition of the contaminated sediment before the surface water enters the SSOD. Under current conditions, the majority of the contaminated surface water entering the SSOD originates from subbasin 581 (see Figure 5-20). The sediment concentrations in this subbasin match fairly well with the sampling results, possibly indicating that the sediment is deposited there and does not reach the SSOD. Sampling results from the routine Environmental Monitoring program do show some results in the SSOD for total uranium closer to the modeled results. The modeled sediment concentration in the SSOD is 44.5 mg/kg; the sampling results from the routine Environmental Monitoring data in 1988 indicated a maximum concentration of 114 mg/kg although most of the maximum sampling results in that year are in the 20 to 30 mg/kg range. The maximum modeled sediment concentration in Paddys Run is predicted to be 157 mg/kg. This is higher than the measured range of sediment concentrations in Paddys Run (1.2 to 12.5 mg/kg). This may be due to the difficulty of taking samples that contain only sediment and not bed materials in the stream. The bed materials may be less contaminated which could then decrease the overall measured concentration of sediment.

Surface Water Contaminant Loadings to the Great Miami Aquifer

The modeled results for the current conditions were compared to two types of information to evaluate the model performance. The results were compared to sample data from monitoring wells in the Great Miami Aquifer. Also discussed in this section is a comparison of the estimated total amount of uranium released to Paddys Run to modeled results.

The modeled results were compared to sampling data from Type 2 monitoring wells (screened in the upper Great Miami Aquifer) along Paddys Run and the SSOD. Concentrations in the Great Miami Aquifer were calculated for three channel reaches in Paddys Run and in the SSOD. Monitoring wells are located near Paddys Run stream reaches C-C to D-D, E-E to F-F and in the SSOD). The predicted concentration in Paddys Run for reach C-C to D-D was for the case without storm water controls because most of the data used in the comparison was collected before the storm water controls around the waste pit area were put in place in 1992. The modeled results presented for the SSOD and reach E-E to F-F were for the cases with and without storm water controls. It should be noted that the concentrations predicted by the surface water model only predict concentrations from a single storm event and do not include contamination that may have been present in the aquifer from previous storm events or reached the aquifer via a different contaminant migration pathway, such as vertical migration through the soil to the aquifer. It would be expected that the predicted Great Miami Aquifer concentrations due solely to surface water loading would be less than the measured data. In general, the range of predicted modeled results fall within the range of sampling results for stream reaches between cross section E-E and F-F and the SSOD. The surface water model conservatively predicted the groundwater concentration to be higher than the sampling range for the stream reach between cross sections C-C and D-D.

The Fernald Dosimetry Reconstruction Project (RAC 1993) estimated the total amount of uranium released to Paddys Run and the SSOD from the FEMP during the years of operation between 1951-1988 to be 17,000 kg with a range of 14,000 to 20,000 kg. The total amount of uranium predicted to be released to Paddys Run and the SSOD by the surface water model was compared to the RAC estimates. The amount of uranium released was calculated with and without samples from under buildings in the production area to provide a range of modeled results. The mass of contaminant released was calculated by estimating the yearly amount released in both the adsorbed and dissolved phases for all of the subbasins (see the storm water model output in Attachments F.2-V) and then multiplying by the number of years of operation of the FEMP. For the years from 1951

through 1985 (35 years) the released amount was calculated with the modeled case in which no storm water controls were in operation. In 1986, the storm water retention basin was put into operation, so the released amount calculated for years 1986 through 1988 (3 years) was based on the modeled case in which the storm water controls were in operation. The modeled range of total uranium released to Paddys Run and the SSOD was estimated to be 16,400 to 19,800 kg.

Based on sampling results, the estimated mass of uranium within the plume of significant concentration in the Great Miami Aquifer was estimated to be 5100 kg (Table 5-20). The amount of uranium in the Great Miami Aquifer which could be attributed solely to surface water loading (i.e., South Plume south of the SSOD) was estimated to be about 1900 kg. The total amount of uranium predicted to be released to the Great Miami Aquifer by the surface water model was estimated to be between 10,300 and 13,200 kg. This amount of total uranium was based on the dissolved phase uranium in the runoff that can reach the aquifer. The modeled estimate was based on loadings from the surface water through Paddys Run and the SSOD to the Great Miami Aquifer for 43 years (1951 to 1993). The lower value of the modeled loading results from the source terms which do not include samples from under the buildings; the upper estimate was from the source terms which included samples from under the buildings. These results demonstrate some of the conservativeness in the assumptions used in estimating the amount of contaminant that reached the Great Miami Aquifer from surface water such as the assumption that all of the dissolved contaminant in the annual runoff for storms other than the representative storm event reach the aquifer. Figure 5-27 shows the percent of the total annual runoff that is assumed to reach the Great Miami Aquifer.

5.4.2.5 Sensitivity Analysis

In order to determine the model's uncertainty, sensitivity analyses were performed on several of the input parameters. The analyses focused on the sensitivity of the predicted infiltration amount and on the sensitivity of the predicted concentrations in the surface water and in sediment.

The sensitivity analyses on the infiltration amount were presented in the SWF&IM Report (DOE 1994i). Four sets of simulations were performed to examine the sensitivity of input parameters on the amount of infiltration in Paddys Run and the SSOD. The four simulations varied the Soil Conservation Service (SCS) curve number, the saturated hydraulic conductivity, the groundwater table elevation, and the fitting parameters in the Van Genuchten relative hydraulic conductivity equation.

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Each of these parameters and their sensitivity are discussed in detail in the SWF&IM Report and are summarized below.

The sensitivity analysis of the SCS curve number (which is used to simulate the rainfall losses and affects the amount of runoff produced from a storm event) indicated that changing the curve numbers so that the runoff volume doubles resulted in less than a six percent increase in infiltration amount. The sensitivity analysis also indicated that the predicted runoff volume is very sensitive to the SCS curve number. In the next sensitivity analysis, the saturated hydraulic conductivity was increased and decreased by 50 percent. The increase in saturated hydraulic conductivity produced an increase of 18 percent in the infiltration volume and the decreased conductivity produced a 24 percent decrease in infiltration volume. The relative hydraulic conductivity fitting parameters were used to simulate the movement of water through unsaturated soil beneath the streambed and are based on the soil type. This sensitivity analysis varied the soil type used in the infiltration model. The fitting parameters for sand were used in the infiltration model. The model was rerun using the fitting parameters for fine sand. This change produced a decrease in infiltration amount of 29 percent. The final sensitivity analysis concerning infiltration amount was on the initial groundwater elevation used in the infiltration model. The infiltration model assumed a springtime initial water table elevation; in the sensitivity analysis the water table was lowered to the average groundwater elevation, producing a 27 percent increase in the infiltration amount.

To complete the sensitivity analysis, source concentrations determined by using preliminary Operable Unit 5 database were input in to the surface water model to be used as a basis for comparison in the sensitivity analyses. The source concentrations were a preliminary set of source terms for uranium which are very close to the final source terms used in the RI fate and transport modeling. Three parameters were varied to determine the sensitivity of the surface water and sediment concentrations. The SCS curve number, precipitation amount, and soil/water partitioning coefficient were all varied to determine their effect on the surface water and sediment concentrations. The sensitivity analysis of each of these parameters is discussed below. Section F.2.6 in Appendix F.2 describes the sensitivity analysis in greater detail and provides tables of results.

SCS Curve Number

Three modifications to the original SCS curve numbers were run to determine the effect on the predicted surface water and sediment concentration: (1) the decrease of the curve numbers by

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10 percent; (2) the increase of the curve numbers by 10 percent; and (3) the modification of the curve numbers to reflect Antecedent Moisture Conditions III (wetter than average initial soil moisture conditions). All other input parameters were held constant. The infiltration volumes were not adjusted because they will not affect the sediment and surface water concentrations. The predicted infiltration volumes can affect the predicted Great Miami Aquifer loadings; however, the infiltration volume is fairly insensitive to the SCS curve number.

The concentration of contaminants in the runoff and in the sediment coming from an individual subbasin does not change appreciably with changes in the SCS curve number; however, as the flow from each individual subbasin combines with others and mixes with uncontaminated flow from upstream, the concentrations of contaminants in the sediment and the surface water decrease as the runoff volume (and curve number) increases in Paddys Run and in the SSOD. This is due to the general result that the peak runoff from uncontaminated upstream areas occurs closer in time to the peak discharges coming from the site as the runoff volume increases. Because of the timing of the peak discharges, there is generally more water available in the Paddys Run and the SSOD as the runoff volume increases to dilute the contaminated runoff from the site when the peak discharge from the site occurs.

Precipitation

To test the sensitivity of the surface water and sediment concentration to the precipitation amount, the precipitation amount was varied in the HEC-1 model and the other parameters held constant. The precipitation was increased by 20 percent and decreased by 20 percent and input into the HEC-1 model. The 20 percent decrease in precipitation resulted in approximately a 50 percent decrease in runoff volume. The 20 percent increase in precipitation resulted in approximately a 70 percent increase in runoff volume. As with the SCS curve number the changes in the runoff volume had a comparatively small effect on the concentration of contaminants and the contaminant loading to the Great Miami Aquifer.

Partitioning Coefficient (K_d)

The sensitivity of the surface water and sediment concentrations to the solid/liquid partitioning coefficient was tested by increasing the K_d value by 10 percent and then decreasing the K_d value by 10 percent. The surface water concentrations varied almost proportionally with the variations in the K_d values so that a 10 percent increase in K_d produced approximately a 10 percent decrease in surface

water concentration. The sediment concentrations show almost no change in concentration with the variation in the K_d values. This may be attributed to the fairly high K_d values used for uranium for most of the site in the baseline sensitivity conditions (K_d=222). In order to determine if a lower K_d would cause the concentration results to be react differently to a variation in K_d, the K_d value was divided by 1000 and then increased and decreased by 10 percent. Dividing the uranium K_d value by 1000 yields K_d values around 0.2. The K_d range between 0.2 to 222 encompasses the K_d values for the majority of the constituents found at the FEMP. After dividing the K_d values by 1000, a 10 percent increase in K_d then produced approximately a five percent increase in the sediment concentration and a four percent decrease in surface water concentration.

Summary of Sensitivity Analyses

Of the parameters which were evaluated for the sensitivity of the surface water and sediment concentrations, K_d was the most sensitive. The other parameters tested, SCS curve number and precipitation amount, did not have a large effect on the surface water and sediment concentrations.

The loading of contaminants to the Great Miami Aquifer from surface water is primarily controlled by the amount of infiltration and the surface water concentration. The infiltration amount is relatively insensitive to the runoff volume (governed by the SCS curve number and the precipitation amount) and the surface water concentration is also relatively insensitive to the runoff volume, so that the loading to the Great Miami Aquifer is also insensitive to the runoff volume.

The sensitivity analyses for the SCS curve number, the saturated hydraulic conductivity, and the relative hydraulic conductivity all produce a change in the total infiltration of 30 percent or less. Under the possible range of values, 30 percent uncertainty is acceptable for the intended use of the model results. The runoff volume from the representative storm event only accounts for approximately six percent of the estimated annual runoff and therefore only accounts for six percent of the annual amount of dissolved contaminant released in the surface water from surface soil. All of the other 94 percent of the annual amount of dissolved contaminant is conservatively assumed to reach the Great Miami Aquifer (see Table 5-27). The infiltration volume calculated from the representative storm event only accounts for a small amount of the total contaminant loading to the Great Miami Aquifer so that a 30 percent uncertainty is acceptable for the estimate of the infiltration volume from the representative storm event.

5.4.3 Groundwater Quality

As discussed in previous sections, CPCs have been categorized as primary or secondary and different modeling approaches have been followed for these different categories. Future contamination conditions in the Great Miami Aquifer are predicted using both ECTran and SWIFT models, as shown in Figure 5-19. Important modeling results are presented in this section. These results are used in the baseline risk assessment (Section 6.0 and Appendix A) and will be considered in selecting remedial actions for the Great Miami Aquifer. Additional modeling results are included in Appendix F.3.

Because of the termination of contaminant sources in other operable units, the current perched groundwater contaminants in Operable Unit 5 source areas are at their maximum levels and will start to decrease. The contaminated perched groundwater is treated as one of the source terms in the groundwater fate and transport modeling. Therefore, for risk assessment purposes, the maximum on-property perched groundwater concentrations are available before the modeling. Nevertheless, the perched groundwater conditions at certain surface water exposure locations may increase due to future lateral contaminant migration. The results of the ECTran modeling for the lateral migration are also presented in this section.

5.4.3.1 Predominant Groundwater Contaminants

Table 5-36 summarizes the CPCs (identified through the groundwater pathway CPC screening processes and listed in Tables 5-22 and 5-23) and the models used to predict their future concentrations in the Great Miami Aquifer. The ODAST/SWIFTLOAD model was used to determine all the vertical mass loading through overburden from contaminated soil and perched groundwater sources. In general, the SWIFT model was then used to simulate the transport of primary CPCs in the Great Miami Aquifer. For the secondary CPCs, the ECTran model was used for simulating transport in the Great Miami Aquifer in a source- and receptor-specific approach. The ECTran model was also used for screening and simulation of all the CPCs in the lateral perched groundwater migration.

5.4.3.2 Future Spatial Extent of Groundwater Contamination

Because uranium is the predominant groundwater COC, the predicted uranium conditions are discussed here to demonstrate the general future Great Miami Aquifer groundwater contamination. Figure 5-28 shows the current uranium plumes in the top of the Great Miami Aquifer (i.e., model

layer corresponding to the Type 2 wells) used as initial conditions of transport modeling. These plumes are combinations of field measured data and supplemental modeling characterizations for source areas in other operable units.

At the end of the baseline condition (i.e., 70 years) during which the South Groundwater Contamination Plume recovery well system and storm water runoff controls are in operation, the predicted uranium plumes in the Great Miami Aquifer are shown in Figure 5-29. Uranium plumes under the other operable unit areas will be flushed out because it was assumed that there will be no additional loading to the Great Miami Aquifer from these areas as a result of remedial actions. Contaminants in the current South Plume along Paddys Run will be significantly reduced in both size and concentration. However, even with the storm water retention basin, the surface water loading of uranium from areas around the former production area through the upper section of the SSOD still can create a significant plume in that vicinity. The general area that will be impacted by this plume is located to the east of the current South Plume.

The uranium plumes when the FEMP fenceline (i.e., southern fenceline) concentration reaches its maximum (the 260th year) are shown in Figure 5-30. The predicted impacts of the mass loadings from the SSOD can be clearly seen.

The uranium plumes at the end of model simulation (i.e., 1000 years) are presented in Figure 5-31. Based on the 1 μg/L and 20 μg/L contours of these plumes, the maximum areal extent of the Great Miami Aquifer that potentially may be impacted by uranium contamination with concentrations higher than background or drinking water standard is shown in Figure 5-32. The extent of the 1000-year plumes is larger than the uranium plumes at 890 years (see Figure 5-30), indicating that plume size is still increasing. The maximum concentration at both times are nearly the same, 9052 μg/L compared to 9063 μg/L, with the 1000-year concentration being slightly larger.

Based on the modeled uranium conditions, it is clear that the time required to wash out the groundwater contaminations at the FEMP by natural processes is beyond the time frame of the simulation (i.e., 1000 years). The groundwater conditions in the Great Miami Aquifer will continue to deteriorate for a very long period of time under the no-action scenario.

5.4.3.3 Maximum Future Groundwater Contaminant Concentrations

CPC-specific times, locations, and mass loading rates to the Great Miami Aquifer when the maximum loading concentrations occur are presented in Table 5-37 for the primary CPCs. This information is useful when setting priorities and timing of cleanup actions in different source areas. These maximum loadings are based upon the results from the ODAST/SWIFTLOAD modeling. Time and location of maximum loadings vary for each constituent based upon source mass, initial concentration, constituent attenuation, vadose zone layer thicknesses, and vadose zone layer hydraulic properties. As expected, the SSOD has the highest loadings for most of the CPCs because the contaminated surface runoff can directly recharge the Great Miami Aquifer through the sand and gravel streambed.

In the vertical migration pathway through the glacial overburden, for several constituents, the Plants 6 and 9 areas produced maximums, because these areas typically have higher soil concentrations of constituents and because of the simulated increased hydraulic conductivity in this area (see discussion in Section F.3.4). Uranium had the highest loading of 5.48×10^{-2} lbs/day/(125- by 125-foot area) in the Plant 6 area, almost 2 orders of magnitude greater than the next highest CPC. The vertical loading to the Great Miami Aquifer is negligible until around 350 years at which time it increases sharply to its maximum of 5.48×10^{-2} pounds/day at 650 years. The mass loading then decreases gradually to 3.74×10^{-2} lbs/day/(125- by 125-foot area) at 1000 years.

CPC-specific times of occurrence and the maximum concentrations in the overall Great Miami Aquifer, the aquifer under the FEMP fenceline, and the aquifer under the FEMP property are summarized in Table 5-38. Both the ODAST/SWIFT and ECTran models were used to predict these concentrations. These concentrations are used in determining the overall maximum, maximum on-property, and maximum off-property risks due to groundwater exposures. The time of maximum concentration is largely dependent on receptor location, source loading from the vadose zone, and constituent attenuation in the Great Miami Aquifer.

The overall maximum concentration represents the highest concentration in any model grid block considering the entire model area; the fenceline maximum considers only model grid blocks located on the fence line; and the on-site maximum considers only those grid blocks within the property boundary. Grid maximums typically correspond to on-property maximums indicating a contaminant source located on property. Fence line maximums are less than on-property maximums due to adsorption and decay of the constituents during travel to the fenceline from the source. The time of

maximum concentration at the fenceline differs from the on-property maximum by the travel time from the source to the fenceline. There are exceptions to the above discussion due to the presence of initial concentrations in the Great Miami Aquifer and due to surface water loading to the aquifer occurring south of the FEMP boundary. Beryllium, which has significant loadings from surface water only (no on-property vadose zone loading within 1000 years), has a greater off- than on-property maximum.

As shown in Table 5-38, the FEMP total uranium maximum of 9063 μg/L occurs beneath the SSOD at 1000 years (i.e., the uranium concentration was increasing around the SSOD throughout the modeled time frame). Within the former production area, the maximum total uranium concentration is 2749 μg/L under the Plant 6 at 790 years. At the eastern fenceline, a uranium maximum of 1263 μg/L occurs at 890 years. The overall maximum fenceline uranium concentration of 1760 μg/L occurs at 260 years along the southern fenceline due to loading from the SSOD. The uranium concentrations for the other receptors are less than these values, although some have values greater than 1000 μg/L. The time of the maximum uranium concentration for each receptor is reported for the other CPCs at the same locations to provide an estimate of total risk. It has been assumed that total risk is dictated by uranium concentrations due to their higher concentrations and typically higher risk factors than the other CPCs.

5.4.3.4 Future Contaminant Concentrations at Specific Receptor Locations

Maximum concentrations of different CPCs at a location usually do not occur at the same time due to the different chemical-specific migration rates in the aquifer. In order to determinate the overall maximum receptor-specific risks, CPC concentrations at receptor locations when the predominant contaminant (i.e., uranium) reaches its location-specific maximum are determined and summarized in Table 5-39. Both ODAST/SWIFT and ECTran models were used to predict these concentrations. The maximum uranium concentrations and times of occurrence at these receptor locations are also shown in Figure 5-33. Two examples of the receptor- and CPC-specific future concentrations are shown in Figures 5-34 and 5-35.

ECTran modeling was completed to investigate the potential for perched water, which is contaminated with highly mobile CPCs, to migrate to the pilot plant drainage ditch and Paddys Run and subsequently contaminate the surface water in either surface water body. Six potential source areas were selected for the modeling and they are shown in Figure 5-36. The areas include the Plant 2/3,

pilot plant and laboratory areas, Operable Unit 4, and two Operable Unit 1 areas. They were selected because the perched water in these areas typically has the maximum CPC concentrations and the flow patterns are such that perched water from these areas has the potential to flow to and discharge into the pilot plant drainage ditch or Paddys Run (Figure 5-36). A summary of the ECTran modeled maximum CPC concentrations and mass loading rates that would be discharged into the pilot plant drainage ditch or Paddys Run due to perched water contamination is presented in Table 5-40.

5.4.3.5 Uranium Breakthrough Time

The breakthrough time, which is defined as the time it takes for a significant contaminant concentration (e.g., a concentration higher than 1 percent of the original source leachate) to vertically migrate through the overburden from its current location and reach the Great Miami Aquifer is information required by the Operable Unit 5 FS to prioritize the cleanup efforts. The breakthrough time is generally controlled by the area-specific infiltration rate, gray clay thickness and chemical-specific retardation factors.

As previously described, vertical migration of contaminants through overburden in every 125- by 125-foot area was determined by using the ODAST/SWIFTLOAD model to screen CPCs and determine mass loading terms into the Great Miami Aquifer models. By comparing all the area-specific loading terms, locations of the contaminant-specific maximum loading and corresponding loading curves (i.e., leachate concentrations vs. time) within each of the six baseline risk assessment zones (see Figure 5-6) can be identified. These results are representative of the area-specific contaminant breakthrough times that need to be considered in the FS.

As an example, Figures 5-37 and 5-38 show the zone-specific locations of the maximum loading and corresponding loading curves for total uranium, respectively. As mentioned in Section 5.4.3.3, the uranium breakthrough time in the Plant 6 area is about 350 years. The breakthrough times in the following specific source areas were also evaluated in the modeling:

- Plant 2/3 - about 950 years
- Sewage treatment plant - greater than 1000 years
- Plant 9 - about 1000 years
- Fire training area - greater than 1000 years.

5.4.3.6 Sensitivity and Uncertainty Analysis

Sensitivity and uncertainty analyses of the major fate and transport models and model parameters used in the groundwater pathway for the Operable Unit 5 RI were conducted. In general, fate and transport modeling only presents one set of the future conditions (e.g., concentrations at receptor locations and occurring times of maximum concentrations) using the best estimated value for each model parameter. These predicted future conditions are then used in the risk assessment. The purpose of sensitivity/uncertainty analysis is to provide information regarding the potential ranges of future conditions. Therefore, the level of conservativeness of the risk assessment can be understood.

Great Miami Aquifer Model

Uncertainty/sensitivity analysis of the Great Miami Aquifer model used in the Operable Unit 5 RI was conducted as part of the model improvement program (DOE 1994j). The objective of this uncertainty analysis is to quantify the uncertainty of the output from the improved Great Miami Aquifer groundwater flow and transport model. For this evaluation, model uncertainty analysis was focused upon the definition of the statistical distribution of specific performance measures used in risk assessments. These performance measures included the maximum concentration anywhere in the aquifer and the maximum concentration and travel time to a receptor (e.g., the property line).

The ECTran and SWIFT Great Miami Aquifer models were used in a complementary fashion to perform this uncertainty analysis. ECTran was used to perform Monte Carlo analysis using defined ranges of input values of several model parameters. However, because certain simplifications were necessary when using the analytical ECTran model, SWIFT simulations were performed to confirm the ECTran results with the more sophisticated, three-dimensional, numeric model that was actually used in the risk assessment for primary COCs.

Both the ECTran and SWIFT simulation results show that, while the model will produce a reasonably wide range of output based on ranges of input parameters, nevertheless, the baseline model output is within an order of magnitude of the maximum cases based upon both the ECTran Monte Carlo and SWIFT sensitivity results. The ECTran results showed possible higher concentration values (by four to six times) than the baseline case. SWIFT results indicate a tighter range of concentrations; typically less than a factor of 2.5 for the maximum grid concentration and 2 for the fence line maximum. Since other portions of risk assessments typically contain several orders of magnitude of uncertainty, the uncertainty attributable to the Great Miami Aquifer model is relatively minor. Based

on a comparison with the original model, the revised SWIFT Great Miami Aquifer model presents a more conservative depiction of on-property and property line predicted concentrations than the original model. The improved model predicted a moderately conservative, but realistic depiction of plume transport based on the estimated ranges of model input. Additional information of this sensitivity/uncertainty analysis is presented in Appendix F.3 and the Summary of Improvements Report (DOE 1994j).

Uranium K_l and K_d Values

Uncertainty/sensitivity analysis for the Great Miami Aquifer model described in the previous subsection did not consider uncertainties associated with contaminant source loading terms (i.e., source leachate concentration and mobility of uranium in the overburden). During the uncertainty/sensitivity analysis, contaminant source loading terms or initial plumes in the Great Miami Aquifer were fixed in order to focus the analysis on the Great Miami Aquifer model parameters only. However, the source loading term is expected to be the most important factor for determining future impacts to the Great Miami Aquifer. Therefore, an uncertainty analysis was conducted for the uranium source loading term. As discussed in the Attachment I of Appendix F.3, based on available geochemical information, the baseline geochemical conditions shown in Figure 5-20 was suggested as a reasonable representation of the conditions existing in the FEMP. Nevertheless, because of the limited geochemical data available in the depleted source areas (i.e., areas outside the former production area), uncertainties of the assumed conditions need to be evaluated. The objective of this uncertainty analysis is to define the upper bound of potential impacts to the Great Miami Aquifer. Unlike the sensitivity analysis, therefore, if a parameter had already been assigned a very conservative value in the baseline case, it was not adjusted in this analysis.

The source loading term to the Great Miami Aquifer from soil contamination is most sensitive to current source concentration, leaching and partitioning coefficients (i.e., K_l and K_d) among all the relevant model parameters. Since the source concentration was determined through a very rigorous statistical analysis protocol, it is usually very conservative. Similarly for the areas shown in Figure 5-20 where uranium contamination was determined to be soluble and a lower representative value (i.e. 15 L/Kg) was assigned to both the K_l for source leachate determination and the K_d for underlying gray clay, the source loading terms are very conservative. Therefore, all the solid phase source concentrations and areas with soluble uranium remained the same as in the baseline conditions for this uncertainty analysis. K_l and K_d were adjusted and evaluated only in areas where these two

parameters originally had the same value of 222 L/Kg in the baseline case. Soluble uranium in these areas were assumed to be depleted and therefore a higher K_d value was assigned in the baseline condition. The higher K_d value represents the desorption-dominated condition as discussed in the Attachment I of Appendix F.3.

For this uncertainty analysis, ODAST/SWIFTLOAD and SWIFT Great Miami Aquifer models were used to simulate the uranium loading from areas where the K_l and K_d were adjusted (i.e., areas with depleted sources). In general, these areas are located to the north, east, and south of the former production area as shown in Figure 5-20. The following two sets of adjustments were first made in the initial analysis:

Case 1: Use 25% of the original source concentrations with both K_l and K_d equal to 15 L/Kg.

Case 2: Use 100% of the original source concentrations with K_l of 222 L/Kg and K_d of 15 L/Kg.

The Case 1 was designed to bound the impact due to uncertainty of the baseline assumption that all uranium contamination currently in these areas is less soluble (i.e., depleted sources). It was assumed that 25% of the current uranium contamination is soluble and mobile (i.e., with a lower value of K_l/K_d). The Case 2 studied the uncertainty regarding the mobility of uranium leachate in the overburden from these areas. This case assumed that all the uranium in soil leachate is mobile (i.e., with K_d of 15 L/Kg) even when the source is depleted and less soluble (i.e., with K_l of 222 L/Kg). These same areas were also simulated separated from all the other source areas, with the baseline conditions (i.e., 100% of source concentrations with both K_l and K_d equal to 222 L/Kg), for comparison with the results of the Cases 1 and 2. This simulation indicated that no additional uranium will reach the Great Miami Aquifer in 1000 years from the depleted source areas through vertical migration with a K_d value of 222 L/Kg.

Simulated uranium concentrations at receptor locations from the Cases 1 and 2 are summarized in Table 5-41. Because the baseline case did not have loading to the Great Miami Aquifer from the areas evaluated in the uncertainty analysis, results of the Case 1 and 2 simulations can be directly superimposed to the overall results of the baseline conditions for defining upper bounds of potential impacts to the Great Miami Aquifer during the Baseline Risk Assessment. However, a simulation

which used the baseline source conditions (i.e., source concentrations and values of K_l as shown in Figure 5-20) for the whole model area but with an uniform K_d value of 15 L/Kg in the gray clay was conducted. This complete simulation was designated as the Case 3 in this uncertainty analysis. The Case 3 simulation provided the same effects as combining the Case 2 and baseline results. The resulting receptor concentrations of this case are summarized in Table 5-42.

The three cases studied in this uncertainty analysis provide information regarding the potential ranges of uranium concentrations at receptor locations. Operable Unit 5 Baseline Risk Assessment evaluated the results of this uncertainty analysis when determining potential future impacts due to migration of uranium contamination. It is also expected that additional geochemical data from the depleted source areas will be available for the Operable Unit 5 FS to evaluate and select remedial alternatives.

5.5 SYNOPSIS OF FATE AND TRANSPORT MODELING

The fate and transport of the constituents contained in the Operable Unit 5 contaminant sources were evaluated to provide a basis for estimating future risks under the no-action scenario. Contaminant concentrations were estimated for both on- and off-property areas to provide a range of potential exposure scenarios. The fate and transport evaluation included modeling of surface water, groundwater, and air releases (Figure 5-7). Conservative assumptions were built into the modeling process in order to provide a reasonable worst-case estimate regarding the migration of constituents from the sources and to account for uncertainties associated with the database and models. Screening of CPCs was performed at various stages during the fate and transport assessment process in order to effectively focus the evaluation on those compounds that could potentially pose some measure of risk through the various media.

All the fate and transport models used in this study are mathematical tools which simplify the actual situation. Uncertainties in the output from these models are introduced from three primary sources:

- Input variable uncertainty: the accuracy of the model prediction is highly dependent on the accuracy of the input variables. Model parameters used to quantify physical and chemical processes are only approximations of the real world conditions. Sensitivity analyses for key input parameters are discussed.

- Modeling uncertainty: Any mathematical model representing physical and/or chemical processes tends to be simplified by making approximations and assumptions. The uncertainties in model predictions will increase with increased simplification of the conceptual models used as the bases of the model developments.

- Scenario uncertainty: The production area represents the most significant contaminant source in Operable Unit 5. As an example of the scenario uncertainty, the fate and transport analyses assumed that buildings in the production area will be removed but without any additional remedial actions taken for the highly contaminated soil and perched water under the buildings. Because the leading alternatives for remediation of this contaminated soil include active remediation options such as excavation, soil washing, and disposal or capping, the approach taken regarding the amount of contaminants in the production area is likely to result in an overestimation of future contaminant migration from Operable Unit 5. One other example of the scenario uncertainty is the length of the baseline condition period in which the active environmental management activities will be maintained.

The uncertainties associated with model-predicted future conditions were taken into account during the baseline risk assessment. The following discussions summarize the results of the evaluation of constituent migration from Operable Unit 5 through air, surface water, and groundwater.

5.5.1 Air Pathway

The air transport analysis assessed the impact of Operable Unit 5 air pathway sources to receptor locations within and outside of the FEMP boundary for two conceptual model scenarios. The conceptual models included a current and agricultural scenario. The primary mechanism for air emissions was the wind erosion of contaminated surface soil. The release of radon gas was also evaluated for areas having elevated concentrations of Ra-226.

Most of the contamination within Operable Unit 5 surface soil is associated with radionuclides (see Section 4.0). Other contaminants such as inorganic metals, volatiles, semivolatiles and PCBs were also evaluated in the analysis. Most of the maximum contaminant concentrations occurred within the FEMP boundary. Maximum annual off-property concentrations for U-238 were calculated to occur just beyond the FEMP's eastern boundary.

The maximum annual average air concentrations of radionuclides were highest for the contaminants U-238, U-234, Ra-226 and Th-230, as well as total uranium and total thorium. Maximum concentrations for volatiles, semivolatiles and PCBs were associated with trichloroethene, benzo(b)fluoranthene, and Aroclor-1254, respectively. Other than the more common inorganic metals associated with surface soil, air concentrations of arsenic, cadmium, chromium, and lead did not exceed 0.36×10^{-3} $\mu g/m^3$.

The Ra-222 concentrations calculated for receptor locations along the FEMP boundary in the current scenario were compared to radon concentrations collected at the boundary air monitoring stations in 1992. The comparison indicated that the 1992 monitoring station concentrations were generally 2 to 3 orders of magnitude higher then the results calculated by the ISCLT2 model for the Operable Unit 5 sources. This difference can be attributed to the fact that other more significant sources of radon gas currently exist at the FEMP, such as Operable Unit 4. Also, some contribution is likely from the decay of elements other than Ra-226. These additional sources were not included in the Operable Unit 5 air transport modeling.

5.5.2 Surface Water Modeling

The fate and transport evaluation for surface water assessed the potential impacts on the SSOD and Paddys Run from contaminants transported to the streams by way of surface water runoff from the Operable Unit 5 contaminant source areas. Concentrations of various constituents were estimated in Paddys Run for both surface water and sediment. In addition, the impacts of discharges of contaminated water from the SSOD and Paddys Run to both the Great Miami River and Great Miami Aquifer were evaluated. Impacts of contaminant loadings through the effluent outfall line to the Great Miami River were also estimated.

Because of the infiltration that occurs from Paddys Run to the Great Miami Aquifer, dissolved contaminants in Paddys Run can infiltrate in locations where the streambed lies in direct contact with the aquifer and the aquifer water table is lower than the streambed. Modeling of Paddys Run infiltration to the Great Miami Aquifer indicates that uranium is the dominant constituent that reaches the aquifer. The results of these simulations were also used as inputs to the groundwater fate and transport modeling.

5.5.3 Groundwater Modeling

Groundwater transport of contaminants from Operable Unit 5 source areas is considered to be the most significant pathway for contaminant migration in the future. The Great Miami Aquifer underlies the FEMP and is separated from surface contaminants by little or no glacial overburden in certain areas. In areas where the glacial overburden is thin or absent, there is a much greater probability that contaminated surface water or perched groundwater will reach the permeable sand of the aquifer than in those areas where there is thick, low-permeability glacial overburden.

The fate and transport evaluation for groundwater consisted of long-term modeling of glacial overburden and vadose zone contaminant transport laterally to a drainage ditch, vertically downward to the Great Miami Aquifer, and the transport of contaminants through groundwater. In addition, the infiltration of contaminated surface water from the SSOD and Paddys Run to the aquifer was included as another source of future groundwater contamination.

Quantitative modeling results for the baseline risk assessment are presented in Section 5.4.3. The future spread of uranium contamination in the Great Miami Aquifer predicted by the modeling indicates the following qualitative observations can be made:

- Surface water loading: The maximum future uranium concentration in the Great Miami Aquifer (i.e., 9.06 mg/L) was predicted to be caused by the mass loading from the SSOD. The current South Groundwater Contamination Plume area, primarily along the lower sections of the SSOD and Paddys Run, remains to be impacted by surface water loading. However, contaminant loading from the upper section of the SSOD may create additional significant impacts on the Great Miami Aquifer. The portion of the South Plume originating from the upper section of the SSOD has a more southeastern migration path but will still flow through the Paddys Run outlet. This portion of the plume is outside of the capture zone of the current South Plume recovery well system.

- Production area loading: Although the current groundwater contamination in the Great Miami Aquifer under the production area is still relatively minor (i.e., < 50 μg/L of uranium), significant future impact (i.e., 2.75 mg/L of uranium at 790 years) will be due to vertical loading through overburden from the former production area, more specifically the Plant 6 area.

- Extent of the current and future impacted area: Currently the South Groundwater Contamination Plume is the most extensively impacted off-property area. Additional areas that will be impacted by uranium contamination are much more extensive if no preventive action is taken. The production area will become the major source of groundwater contamination to the area east of the FEMP. The SOWC wells may also be impacted in the future. SSOD and Paddys Run will continue to impact the area to the south of the FEMP.

- Uranium breakthrough time: The time it takes for significant uranium mass to vertically migrate through the overburden from its current location and reach the Great Miami Aquifer in select source areas is information required by the Operable Unit 5 FS to prioritize the cleanup efforts. Zone-specific maximum uranium mass loading curves through the overburden are presented to show the breakthrough times and mass loading (i.e., Figures 5-37 and 5-38) which vary with the thickness of the low-permeability clay under each area.

TABLE 5-1

SUMMARY OF OPERABLE UNIT 5 BASELINE AND FUTURE CONDITIONS

Area or Activity	Baseline Condition (first 70 years)	Future Condition (after 70 years)
Operable Unit 1	All major contaminant source loadings in the air, surface water, and groundwater pathways to the environmental media have been terminated. Only minor uncapped residual contaminated soil remains in place around the capped areas. Contaminant plumes in the Great Miami Aquifer due to past loadings will be included as part of the initial Great Miami Aquifer conditions in the OU5 RI fate and transport modeling.	Same as the baseline.
Operable Unit 2	All major contaminant source loadings in the air, surface water, and groundwater pathways to the environmental media have been terminated. Only minor uncapped residual contaminated soil remains in place around the capped areas. Contaminant plumes in the Great Miami Aquifer due to past loadings will be included as part of the initial Great Miami Aquifer conditions in the OU5 RI fate and transport modeling.	Same as the baseline.
Operable Unit 3	All the above-and below-grade structures in the Production Area not related to wastewater treatment have been removed. All the contaminated soil currently under these buildings will be exposed. OU5 baseline contaminant sources will include contaminated soil and contaminated plumes in perched water underlying the Production Area. Contaminant plumes in the Great Miami Aquifer due to past loadings from OU3 will also be included as parts of the initial Great Miami Aquifer conditions in the OU5 RI fate and transport modeling.	All the buildings and structures will be removed.

TABLE 5-1 (Continued)

Area or Activity	Baseline Condition (first 70 years)	Future Condition (after 70 years)
Operable Unit 4	All major contaminant source loadings in the air, surface water, and groundwater pathways to the environmental media have been terminated. Only minor uncapped residual contaminated soil remains in place around the capped areas. Contaminant plumes in the Great Miami Aquifer due to past loadings will be included as parts of the initial Great Miami Aquifer conditions in the OU5 RI fate and transport modeling.	Same as the baseline.
Stormwater Retention Basin and the Waste Pit Area Stormwater Runoff Control	Stormwater will be collected in the existing retention basins and treated and discharged under the NPDES permit.	The surface runoff will return to its natural discharge pattern (e.g., to the SSOD and Paddys Run) without treatment.
South Plume Recovery Well System	In operation at a constant rate.	Operation terminated.
SOWC production wells	In operation at a total pumping rate for Collectors 1 and 2 of 25 MGD (projected future pumping rate).	Same as the baseline.
FEMP production well	In operation at a pumping rate of 0.346 MGD (current pumping rate).	Same as the baseline.
Future On-property disposal areas	No significant loading.	Same as the baseline.

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TABLE 5-2

MAJOR COMPONENTS OF THE AIR EMISSION AND DISPERSION MODELING

Model	Description and Use
RAECOM	RAECOM is a computer model developed by the U.S. Nuclear Regulatory Commission (NRC 1984) to simulate the emission of Radon-222 gas from soil and material containing Radium-226. RAECOM is used in this modeling effort to estimate the Radon-222 emission rate from FEMP surface soils and through cover soils placed over on-property consolidation areas. The output from RAECOM is used as input to ISCLT2.
Particulate Matter Emission Equations	The Particulate Matter Emission Equations are also presented in *Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites* (EPA 1985). These equations are used in this modeling effort to estimate particulate matter emissions from surface soil caused by wind erosion. The results from these equations are used as input to ISCLT2.
ISCLT2	ISCLT2 is a computer model developed by the United States Environmental Protection Agency (EPA 1992) to simulate the dispersion of gas-phase and particulate-phase contaminants emitted to the atmosphere. ISCLT2 is used in this modeling effort to predict the airborne concentrations and deposition rates of contaminants emitted from the FEMP surface soils. The output from RAECOM and particulate matter emission models are used as input to ISCLT2.

EPA, 1985, "Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites." EPA/600/8-85/002. Office of Health and Environmental Assessment, EPA: Washington, D.C.

EPA, September 1992. "User's Guide for the Industrial Source Complex (ISC2) Dispersion Model," Volumes I-III, including Addendum A. EPA-540/4-92-008a,b,c. Office of Air Quality Planning and Standards, Research Triangle Park, N.C.

U.S. NRC, 1984. "Radon Attenuation Handbook for Uranium Mill Tailing Cover Design." NUREG/CR-3533. Office of Nuclear Regulatory Research, U.S. NRC, Washington, D.C.

TABLE 5-3

MAJOR COMPONENTS OF THE SURFACE WATER FLOW AND INFILTRATION MODEL

Model	Description and Use
HEC-1	HEC-1 is a computer model developed by the U.S. Army Corps of Engineers (USCOE 1990) to simulate rainfall and runoff. HEC-1 is used in this modeling effort to estimate the hydrologic parameters of the Paddys Run drainage basin which encompasses the FEMP. The output for HEC-1 is used as input for VS2DT, MUSLE, and the Partitioning Equations.
VS2DT	VS2DT is a computer model developed by the U.S. Geological Survey (USGS 1990) to simulate variably saturated groundwater flow in two dimensions. VS2DT is used in this modeling effort to estimate the amount and pattern of infiltration of surface water through the streambeds of Paddys Run and the SSOD.
MUSLE	The Modified Universal Soil Loss Equation presented in the Superfund Exposure Assessment Manual (EPA 1988) is used to estimate the amount of sediment which is generated by a single storm event. This equation is used in this modeling effort to estimate the amount of sediment generated by the representative storm event.
USLE	The Universal Soil Loss Equation presented in the Superfund Exposure Assessment Manual is used to estimate the annual amount of sediment produced in the subbasins of the Paddys Run drainage basin.
Partitioning Equations	The Partitioning Equations also are presented in the Superfund Exposure Assessment Manual. The partitioning equations consist of a series of equations used to determine the amount and concentration of contaminant released from the source surface soils in the dissolved phase (surface water) and the adsorbed phase (in sediments) from a single storm event.
SWF&IM	The Surface Water Flow and Infiltration Model is the term applied to collectively identify the above models used to simulate the rainfall, runoff, and Contaminant Transport. This is also sometimes referred to generically as the surface water model.

TABLE 5-4

MAJOR COMPONENTS OF THE GROUNDWATER FATE AND TRANSPORT MODELING

Model	Description and Use
HELP	The HELP model is used in the OU5 analysis to define infiltration rates (seepage velocities) for use in travel time screening and in vadose zone modeling with ODAST. The HELP model (EPA 1984) is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of a waste area. The systems that can be modeled by HELP include various combinations of vegetation, cover soils, waste cells, special drainage layers, and relatively impermeable barrier soils.
ODAST	The ODAST model is used in the OU5 analysis to define vertical contaminant transport from contaminated soil or perched water to the GMA. The ODAST computer code is based on the solution originally developed by Ogata and Banks (1961) and calculates the normalized concentrations of a given constituent in a uniform flow field from a source having a constant or varying concentration in the initial layer. ODAST evaluates the basic one-dimensional analytical solute transport equation as a function of seepage velocity, dispersion coefficient, source decay, retardation factor, depletion time, and source rate.
ECTran	The ECTran model is a screening level groundwater contaminant fate and transport model implemented in Excel 4.0 which was developed to support the RI/FS processes at the FEMP. The Crystal Ball 3.0 add on module for Excel can be used with the ECTran model to perform Monte Carlo simulations. The ECTran model can be utilized to supplement other more complex fate and transport models during parameter estimation, risk assessment, cleanup goal development, and stochastical sensitivity analysis. The model is based on straight-forward mass-balances and advection/dispersion analytical equations, but can be used to simulate a variety of complex conditions.
SWIFT	The SWIFT Great Miami Aquifer is used for simulating the three dimensional contaminant transport in the Great Miami Aquifer. The SWIFT code is fully coupled, transient, 3-dimensional finite difference model for groundwater flow through both porous and fractured media. The mass transport equations solved include terms for convection, dispersion, retardation by sorption, and decay or degradation of the contaminant. The SWIFT code, originally developed by Sandia National Laboratory in the late 1970s for the High Level Waste Program, has been revised several times to increase its capability and to change computer platforms. The SWIFT GMA model was originally calibrated in 1989. Recently the model has been redesigned and recalibrated based on recent data.

TABLE 5-5

PREDOMINANT COCs OVER OPERABLE UNITS 1, 2, AND 4 FOR FATE AND TRANSPORT MODELING AIR PATHWAYS

Carcinogens		Noncarcinogens	
COC	% Contribution to Total Risk	COC	% Contribution to Total HI
Arsenic	47.3	Arsenic	71.6
Uranium-238+2D	24.6	Barium	6.67
Thorium-230	16.4	Manganese	5.87
Uranium-234	3.46	Cobalt	5.70
Thorium-232+10D	2.05	Thallium	3.49
Radon-222+4D	1.40	Total Uranium	1.91
Indeno(1,2,3-cd)pyrene	1.01		
Uranium-235/236 (U-235+1D)	0.886		
PCBs	0.636		

TABLE 5-6

PREDOMINANT COCs OVER OPERABLE UNITS 1, 2, AND 4 FOR FATE AND TRANSPORT MODELING SURFACE WATER PATHWAYS

Carcinogens		Noncarcinogens	
COC	% Contribution to Total Risk	COC	% Contribution to Total HI
Cesium-137+1D	29.3	Total Uranium	52.2
Technetium-99	27.4	Silver	29.0
Uranium-238+2D	26.3		
Uranium-234	6.30		
Strontium-90+1D	5.56		
Arsenic	2.30		
Thorium-228+7D	0.630		
Radium-226+8D	0.170		
Benzo(a)pyrene	0.060		

TABLE 5-7

PREDOMINANT COCs OVER OPERABLE UNITS 1, 2, AND 4 FOR FATE AND TRANSPORT MODELING GROUNDWATER PATHWAYS

Carcinogens		Noncarcinogens	
COC	% Contribution to Total Risk	COC	% Contribution to Total HI
Arsenic	62.8	Uranium-Total	76.8
Uranium-238+2D	33.0	Arsenic	14.2
Uranium-234	4.43	Antimony	4.15
Uranium-235/236 (U-235+1D)	0.87	Manganese	0.154
Radium-226+8D	0.150	Barium	0.111
Technetium-99	0.004	Mercury	0.051
Plutonium-238	0.003		
Thorium-230	0.001		
Neptunium-237+1D	0.001		

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TABLE 5-8

DETECTED CONSTITUENTS AND POTENTIAL CONSTITUENTS
OF CONCERN IN OPERABLE UNIT 5

Constituents of Potential Concern	Soil	Perched Water	Groundwater
Radionuclides			
Actinium-227	X		
Cesium-137	X	X	X
Lead-210	X		
Neptunium-237	X	X	X
Plutonium-238	X	X	X
Plutonium-239/240	X	X	X
Polonium-210	X		
Protactinium-231	X		
Radium-224	X		
Radium-226	X	X	X
Radium-228	X	X	X
Ruthenium-106	X		
Strontium-90	X	X	X
Technetium-99	X	X	X
Thorium-228	X	X	X
Thorium-230	X	X	X
Thorium-232	X	X	X
Uranium, Total	X	X	X
Uranium-234	X	X	X
Uranium-235/236	X	X	X
Uranium-238	X	X	X
Organics			
1,1,1-Trichloroethane	X	X	X
1,1,2,2-Tetrachloroethane	X	X	X
1,1,2-Trichloroethane	X	X	
1,1-Dichloroethane	X	X	
1,1-Dichloroethene	X	X	X
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin		X	
1,2,3,7,8-Pentachlorodibenzofuran		X	
1,2,4-Trichlorobenzene		X	
1,2-Dichlorobenzene		X	
1,2-Dichloroethane	X	X	
1,2-Dichloroethene (total)	X	X	X
1,4-Dioxane		X	

TABLE 5-8 (Continued)

Constituents of Potential Concern	Soil	Perched Water	Groundwater
2,3,4,7,8-Pentachlorodibenzofuran		X	
2,3,7,8-Tetrachlorodibenzo-p-dioxin			X
2,3,7,8-Tetrachlorodibenzofuran		X	X
2,4-Dichlorophenol	X	X	
2,4-Dimethylphenol	X	X	
2,4-Dinitrophenol		X	
2,4-Dinitrotoluene	X		
2,6-Dinitrotoluene	X	X	
2-Butanone	X	X	X
2-Chlorophenol	X	X	
2-Hexanone	X	X	X
2-Methylnaphthalene	X	X	
2-Methylphenol	X	X	
2-Nitrophenol		X	
2-Picoline		X	
3,3'-Dichlorobenzidine	X		
3-Chloropropene		X	
3-Methylphenol		X	
4,4'-DDE	X		
4,4'-DDT	X	X	
4,6-Dinitro-2-Methylphenol		X	
4-Chloro-3-Methylphenol	X	X	
4-Methyl-2-Pentanone	X	X	X
4-Methylphenol	X	X	
4-Nitroaniline	X		
4-Nitrophenol		X	X
Acenaphthene	X	X	
Acenaphthylene	X		
Acetone	X	X	X
Acetonitrile		X	
Acetophenone		X	
Acrolein		X	
Acrylonitrile		X	
Aldrin	X		X
Alpha-Chlordane	X		
Ammonia		X	X
Anthracene	X	X	
Aroclor-1248		X	

TABLE 5-8 (Continued)

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Constituents of Potential Concern	Soil	Perched Water	Groundwater
Aroclor-1254	X		
Aroclor-1260	X		
Benzene	X	X	X
Benzo(a)anthracene	X	X	
Benzo(a)pyrene	X		
Benzo(b)fluoranthene	X		
Benzo(g,h,i)perylene	X		
Benzo(k)fluoranthene	X		
Benzoic Acid	X	X	
Benzyl Alcohol	X	X	
Beta-BHC	X		
Bicarbonate		X	X
Bis(2-Chloroisopropyl)Ether	X		
Bis(2-Ethylhexyl)phthalate	X	X	X
Bromodichloromethane	X	X	
Bromoform		X	X
Bromomethane	X		
Butyl benzyl phthalate	X	X	X
Carbazole	X	X	
Carbon disulfide	X	X	X
Carbon tetrachloride		X	
Chloride		X	X
Chlorobenzene	X	X	X
Chlorobenzilate		X	
Chloroethane		X	
Chloroform	X	X	X
Chloromethane		X	X
Chrysene	X	X	
cis-1,3-Dichloropropene		X	
Di-n-butyl phthalate	X	X	X
Di-n-octyl phthalate	X		
Dibenzo(a,h)anthracene	X		
Dibenzofuran	X	X	
Dibromochloromethane		X	
Dieldrin	X		X
Diethyl phthalate	X	X	X
Endosulfan - I			X
Endosulfan - II	X		X

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TABLE 5-8 (Continued)

Constituents of Potential Concern	Soil	Perched Water	Groundwater
Endosulfan sulfate	X		X
Endrin	X		
Endrin aldehyde	X		
Endrin ketone			X
Ethyl cyanide		X	
Ethylbenzene	X	X	X
Fecal coliform			X
Fluoranthene	X	X	
Fluorene	X	X	
Fluoride		X	X
Heptachlor			X
Heptachlor epoxide	X	X	
Heptachlorodibenzo-p-dioxins		X	
Heptachlorodibenzofurans	X	X	X
Hexachlorobutadiene	X		
Hexachlorodibenzofurans		X	X
Hexachloroethane		X	
Indeno(1,2,3-cd)pyrene	X		
Isobutyl alcohol		X	
Isophorone	X		X
Methoxychlor	X		
Methyl methacrylate		X	
Methylene chloride	X	X	X
Meyhacrylonitrile		X	
N-nitroso-di-n-propylamine	X		
N-nitrosodiethylamine		X	
N-nitrosodiphenylamine	X	X	X
Naphthalene	X	X	
Nitrate		X	X
Nitrate/nitrite		X	X
Nitrobenzene		X	
Octachlorodibenzo-p-dioxin	X	X	X
Octachlorodibenzofuran		X	
Pentachlorodibenzofurans		X	X
Pentachlorophenol		X	
Phenanthrene	X	X	
Phenol	X	X	X
Phenols		X	X

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TABLE 5-8 (Continued)

Constituents of Potential Concern	Soil	Perched Water	Groundwater
Phosphate		X	X
Phosphorous		X	X
Pyrene	X	X	
Styrene	X	X	
Sulfate		X	X
Sulfide		X	X
Tetrachlorodibenzo-p-dioxins			X
Tetrachlorodibenzofurans		X	X
Tetrachloroethene	X	X	X
Toluene	X	X	X
Total xylenes	X	X	X
trans-1,2-Dichloroethene		X	
trans-1,4-Dichloro-2-butene		X	
Tributyl phosphate	X	X	
Trichloroethene	X	X	X
Trichloroflouromethane		X	X
Vinyl acetate		X	
Vinyl chloride		X	
Inorganics			
Aluminum	X	X	X
Antimony	X	X	X
Arsenic	X	X	X
Barium	X	X	X
Beryllium	X	X	X
Boron	X	X	
Cadmium	X	X	X
Calcium	X	X	X
Chromium	X	X	X
Cobalt	X	X	X
Copper	X	X	X
Cyanide	X	X	X
Iron	X	X	X
Lead	X	X	X
Magnesium	X	X	X
Manganese	X	X	X
Mercury	X	X	X
Molybdenum	X	X	X

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TABLE 5-8 (Continued)

Constituents of Potential Concern	Soil	Perched Water	Groundwater
Nickel	X	X	X
Potassium	X	X	X
Selenium	X	X	X
Silicon	X	X	X
Silver	X	X	X
Sodium	X	X	X
Thallium	X	X	X
Vanadium	X	X	X
Zinc	X	X	X

TABLE 5-9

GENERAL PHYSICAL AND CHEMICAL CONDITION OF CONCEPTUAL OPERABLE UNIT 5 CONTAMINANT SOURCE AREAS

Area[a]	Size (ft^2)	Contaminated Depth (ft)	Dry Bulk Density (g/cm^3)	Level of Contamination	Type of Contamination[b]	Fraction of Organic Content (%)	Ground Coverage Type
Areas surrounding the FEMP to the north, east, and south	3.03×10^7	1.5	1.44	Low	R,O	1	Grass
Area between production area and Paddys Run	5.91×10^6	1.5	1.37	Low	R,I,O	1	Grass
Area of higher contamination near pilot plant drainage ditch	8.08×10^5	1.5	1.34	Medium	R	1	Grass
Area in the immediate vicinity of the production area	5.77×10^6	1.5	1.46	Medium	R,I,O	1	Pavement/Building
Plant 1 drum storage area	6.41×10^5	1.5	1.41	High	R,I,O	1	Bare ground/Grass
Solid waste landfill	5.57×10^4	1.5	1.45	High	R,I,O	1	Grass
South Field/Inactive flyash pile	5.58×10^5	1.5	1.36	High	R,I,O	1	Grass
Sewage treatment plant	1.39×10^5	1.5	1.48	High	R,I,O	1	Building
Downstream of active flyash pile	1.39×10^5	1.5	1.41	Medium	R,I	1	Woods
Active flyash pile	8.36×10^4	1.5	1.41	High	R,I	1	Bare ground
Scrap metal pile, graphite furnace, and oil burner	1.25×10^6	1.5	1.40	High	R,I,O	1	Building
Plant 2/3 area	3.90×10^5	20.0	1.40	High	R,O	1	Building
Plant 4 area	2.23×10^5	11.0	1.40	High	R,I,O	1	Building
Plant 6 and Plant 9 areas	6.13×10^5	16.0	1.40	High	R,I,O	1	Building

TABLE 5-9 (Continued)

Area[a]	Size (ft^2)	Contaminated Depth (ft)	Dry Bulk Density (g/cm^3)	Level of Contamination	Type of Contamination[b]	Fraction of Organic Content (%)	Ground Coverage Type
Clearwell pipeline area in production area	4.46×10^5	1.5	1.40	High	R,O	1	Building
Laboratory area	2.51×10^5	1.5	1.40	High	R,I,O	1	Building
Lime sludge ponds	8.36×10^4	1.5	1.40	High	R,I,O	1	Grass
Remaining production area	2.20×10^6	1.5	1.40	High	R,I,O	1	Pavement/Building
Waste pit area	1.03×10^6	1.5	1.45	High	R,I,O	1	Grass
Silo area	1.67×10^5	1.5	1.45	High	R,I,O	1	Grass
K-65/Clearwell pipeline area	5.02×10^5	1.5	1.33	Medium	R,I	1	Grass
Portion of FEMP draining directly to east	1.37×10^6	1.5	1.45	Low	R,I	1	Woods/Grass

[a] See Figure 5-10
[b] R-Radionuclide

I-Inorganic
O-Organic

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TABLE 5-10

FATE AND TRANSPORT PARAMETERS OF RADIONUCLIDE CONSTITUENTS

Constituent of Potential Concern	Contaminant Source Material/ Glacial Overburden K_l/K_d (mL/g)	Great Miami Aquifer K_d (mL/g)	λ^a (1/day)	K_e (%)	Screening Level[b] (pCi/L)	Specific Activity (pCi/μg)
Actinium-227	$2.40 \times 10^{+03}$	$4.50 \times 10^{+02}$	8.72×10^{-05}	NA	1.70×10^{-02}	$7.24 \times 10^{+07}$
Cesium-137	$1.81 \times 10^{+03}$	$1.37 \times 10^{+03}$	6.29×10^{-05}	NA	1.70×10^{-01}	$8.65 \times 10^{+07}$
Lead-210	$3.00 \times 10^{+03}$	$3.80 \times 10^{+01}$	8.53×10^{-05}	NA	9.30×10^{-03}	$7.64 \times 10^{+07}$
Neptunium-237	$5.50 \times 10^{+01}$	$5.00 \times 10^{+00}$	8.87×10^{-10}	NA	2.20×10^{-02}	$7.05 \times 10^{+02}$
Plutonium-238	$1.70 \times 10^{+03}$	$1.00 \times 10^{+02}$	2.16×10^{-05}	NA	2.20×10^{-02}	$1.71 \times 10^{+07}$
Plutonium-239/240	$1.70 \times 10^{+03}$	$1.00 \times 10^{+02}$	7.87×10^{-08}	NA	2.10×10^{-02}	$6.21 \times 10^{+04}$
Polonium-210	$3.00 \times 10^{+03}$	$1.50 \times 10^{+02}$	5.01×10^{-03}	NA	3.20×10^{-02}	$3.88 \times 10^{+18}$
Protactinium-231	$2.70 \times 10^{+03}$	$5.50 \times 10^{+02}$	5.81×10^{-08}	NA	5.20×10^{-02}	$4.72 \times 10^{+04}$
Radium-224	$6.96 \times 10^{+02}$	$1.06 \times 10^{+02}$	1.92×10^{-01}	NA	1.30×10^{-01}	$1.59 \times 10^{+11}$
Radium-226	$6.96 \times 10^{+02}$	$1.06 \times 10^{+02}$	1.19×10^{-06}	NA	4.00×10^{-02}	$9.89 \times 10^{+05}$
Radium-228	$6.96 \times 10^{+02}$	$1.06 \times 10^{+02}$	3.30×10^{-04}	NA	4.80×10^{-02}	$2.72 \times 10^{+08}$
Ruthenium-106	$8.00 \times 10^{+02}$	$5.50 \times 10^{+01}$	$1.89 \times 10^{+03}$	NA	5.00×10^{-01}	$3.36 \times 10^{+09}$
Strontium-90	$1.00 \times 10^{+01}$	$2.50 \times 10^{+00}$	6.64×10^{-05}	NA	1.40×10^{-01}	$1.37 \times 10^{+08}$
Technetium-99	1.18×10^{-01}	7.00×10^{-02}	8.92×10^{-09}	NA	$3.70 \times 10^{+00}$	$1.70 \times 10^{+04}$
Thorium-228	$5.80 \times 10^{+03}$	$3.20 \times 10^{+03}$	9.93×10^{-04}	NA	4.30×10^{-01}	$8.20 \times 10^{+08}$
Thorium-230	$5.80 \times 10^{+03}$	$3.20 \times 10^{+03}$	2.47×10^{-08}	NA	3.70×10^{-01}	$2.06 \times 10^{+04}$
Thorium-232	$5.80 \times 10^{+03}$	$3.20 \times 10^{+03}$	1.36×10^{-13}	NA	4.00×10^{-01}	1.10×10^{-01}
Uranium-Total	$1.50 \times 10^{+01}$	$1.78 \times 10^{+00}$	4.25×10^{-13}	30-50[c]	3.00×10^{-01}	NA

[a] λ - Radioactive decay rate
[b] Based on 10^{-7} risk or 0.1 hazard quotient level
[c] Not used in RI
NA Not Available or Not Applicable

TABLE 5-11

FATE AND TRANSPORT PARAMETERS OF INORGANIC CONSTITUENTS

Constituents of Potential Concern	Contaminant Source Material/Glacial Overburden K_l/K_d (L/kg)	Great Miami Aquifer K_d (L/kg)	Screening Level[a] (mg/L)
Aluminum	$1.50 \times 10^{+03}$	$1.50 \times 10^{+03}$	$1.1 \times 10^{+1}$
Antimony	$2.50 \times 10^{+02}$	$4.50 \times 10^{+01}$	1.500×10^{-03}
Arsenic	$2.00 \times 10^{+02}$	$2.00 \times 10^{+02}$	4.900×10^{-06}
Barium	$1.14 \times 10^{+03}$	$2.00 \times 10^{+01}$	2.600×10^{-01}
Beryllium	$1.30 \times 10^{+03}$	$2.50 \times 10^{+02}$	2.000×10^{-06}
Boron	$3.00 \times 10^{+00}$	$3.00 \times 10^{+00}$	3.300×10^{-01}
Cadmium	$5.00 \times 10^{+02}$	$1.20 \times 10^{+01}$	1.800×10^{-03}
Calcium	$5.00 \times 10^{+01}$	$5.00 \times 10^{+00}$	NA
Chromium	$1.50 \times 10^{+03}$	$7.00 \times 10^{+01}$	1.800×10^{-02}
Cobalt	$5.50 \times 10^{+02}$	$6.00 \times 10^{+01}$	2.200×10^{-01}
Copper	$1.25 \times 10^{+02}$	$3.50 \times 10^{+01}$	1.40×10^{-1}
Cyanide	4.29×10^{-02}	1.85×10^{-02}	7.300×10^{-02}
Iron	$1.65 \times 10^{+02}$	$2.20 \times 10^{+02}$	NA
Lead	$3.00 \times 10^{+03}$	$3.80 \times 10^{+01}$	1.5×10^{-3}
Magnesium	$4.50 \times 10^{+00}$	$4.50 \times 10^{+00}$	$3.500 \times 10^{+01}$
Manganese	$1.80 \times 10^{+02}$	$5.00 \times 10^{+01}$	1.800×10^{-02}
Mercury	$1.00 \times 10^{+01}$	$1.00 \times 10^{+01}$	1.100×10^{-03}
Molybdenum	$9.00 \times 10^{+01}$	$1.00 \times 10^{+01}$	1.800×10^{-02}
Nickel	$6.50 \times 10^{+02}$	$4.00 \times 10^{+02}$	7.300×10^{-02}
Potassium	$7.50 \times 10^{+01}$	$1.50 \times 10^{+01}$	NA
Selenium	$7.40 \times 10^{+02}$	$1.50 \times 10^{+02}$	1.800×10^{-02}
Silicon	$3.50 \times 10^{+01}$	$1.80 \times 10^{+02}$	NA
Silver	$1.80 \times 10^{+02}$	$9.00 \times 10^{+01}$	1.800×10^{-02}
Sodium	$1.00 \times 10^{+02}$	$1.00 \times 10^{+02}$	NA
Thallium	$1.50 \times 10^{+03}$	$1.50 \times 10^{+03}$	2.600×10^{-04}
Vanadium	$1.00 \times 10^{+03}$	$2.00 \times 10^{+02}$	2.600×10^{-02}
Zinc	$2.40 \times 10^{+03}$	$2.00 \times 10^{+02}$	$1.100 \times 10^{+00}$

[a] Based on 10^{-7} risk or 0.1 hazard quotient level
NA Not Available

TABLE 5-12

FATE AND TRANSPORT PARAMETERS OF ORGANIC CONSTITUENTS

Constituents of Potential Concern	KOW[a]	λ[b] (1/day)	Screening Level[c] (mg/L)
1,1-Dichloroethane	$3.887 \times 10^{+01}$	1.13×10^{-03}	9.700×10^{-02}
1,1-Dichloroethene	$1.903 \times 10^{+01}$	3.85×10^{-03}	6.700×10^{-06}
1,1,1-Trichloroethane	$1.859 \times 10^{+02}$	6.30×10^{-04}	1.510×10^{-01}
1,1,2-Trichloroethane	$1.859 \times 10^{+02}$	4.70×10^{-04}	3.200×10^{-05}
1,1,2,2-Tetrachloroethane	$1.550 \times 10^{+02}$	3.79×10^{-03}	9.000×10^{-06}
1,2-Dichloroethane	$1.777 \times 10^{+01}$	9.50×10^{-04}	2.000×10^{-05}
1,2-Dichloroethene (total)	$1.903 \times 10^{+01}$	9.50×10^{-04}	3.700×10^{-02}
2-Butanone	$1.140 \times 10^{+00}$	2.48×10^{-02}	$2.190 \times 10^{+00}$
2-Chlorophenol	$8.883 \times 10^{+01}$	0.00	1.800×10^{-02}
2-Hexanone	$1.512 \times 10^{+01}$	0.00	1.460×10^{-01}
2-Methylnaphthalene	$4.561 \times 10^{+03}$	0.00	1.46×10^{-1}
2-Methylphenol	$5.613 \times 10^{+01}$	0.00	1.830×10^{-01}
2,4-Dichlorophenol	$3.541 \times 10^{+02}$	9.90×10^{-03}	1.100×10^{-02}
2,4-Dimethylphenol	$1.657 \times 10^{+02}$	2.48×10^{-02}	7.300×10^{-02}
2,4-Dinitrotoluene	$5.985 \times 10^{+01}$	1.90×10^{-03}	1.300×10^{-05}
2,6-Dinitrotoluene	$1.197 \times 10^{+02}$	1.90×10^{-03}	1.300×10^{-05}
3,3'-Dichlorobenzidine	$2.041 \times 10^{+03}$	1.90×10^{-03}	1.900×10^{-05}
4-Chloro-3-methylphenol	$7.938 \times 10^{+02}$	0.00	1.83×10^{-1}
4-Methyl-2-pentanone	$7.749 \times 10^{+00}$	2.48×10^{-02}	1.830×10^{-01}
4-Methylphenol	$5.002 \times 10^{+01}$	0.00	1.830×10^{-01}
4-Nitroaniline	$1.544 \times 10^{+01}$	0.00	1.100×10^{-02}
4-Nitrophenol	$5.122 \times 10^{+01}$	7.07×10^{-02}	2.260×10^{-01}
4,4'-DDE	$5.733 \times 10^{+06}$	1.20×10^{-04}	2.500×10^{-05}
4,4'-DDT	$9.765 \times 10^{+05}$	0.00	2.500×10^{-05}
Acenaphthene	$5.242 \times 10^{+03}$	1.70×10^{-03}	2.190×10^{-01}
Acenaphthylene	$7.371 \times 10^{+03}$	1.70×10^{-03}	1.46×10^{-1}
Acetone	3.591×10^{-01}	2.48×10^{-02}	3.650×10^{-01}
Aldrin	$8.127 \times 10^{+04}$	5.93×10^{-04}	5.000×10^{-07}
Alpha-chlordane	$3.799 \times 10^{+02}$	0.00	6.600×10^{-06}
Anthracene	$1.764 \times 10^{+04}$	3.80×10^{-04}	$1.095 \times 10^{+00}$

TABLE 5-12
(Continued)

Constituents of Potential Concern	KOW[a]	λ^b (1/day)	Screening Level[c] (mg/L)
Arochlor-1254	$6.741 \times 10^{+05}$	0.00	1.100×10^{-06}
Arochlor-1260	$8.127 \times 10^{+05}$	0.00	1.100×10^{-06}
Benzene	$8.505 \times 10^{+01}$	9.50×10^{-04}	6.200×10^{-05}
Benzoic acid	$4.670 \times 10^{+01}$	9.90×10^{-02}	$1.460 \times 10^{+01}$
Benzo(a)anthracene	$2.520 \times 10^{+05}$	2.50×10^{-04}	7.700×10^{-06}
Benzo(a)pyrene	$6.017 \times 10^{+05}$	2.50×10^{-04}	1.200×10^{-06}
Benzo(b)fluoranthene	$2.344 \times 10^{+06}$	2.80×10^{-04}	9.500×10^{-06}
Benzo(g,h,i)perylene	$1.071 \times 10^{+07}$	2.70×10^{-04}	1.46×10^{-1}
Benzo(k)fluoranthene	$4.360 \times 10^{+06}$	8.00×10^{-05}	2.200×10^{-05}
Benzyl alcohol	$7.938 \times 10^{+00}$	0.00	$1.095 \times 10^{+00}$
Beta-BHC	$3.975 \times 10^{+03}$	2.80×10^{-03}	4.700×10^{-06}
Bis(2-chloroisopropyl)ether	$7.938 \times 10^{+01}$	0.00	4.200×10^{-05}
Bis(2-ethylhexyl)phthalate	$1.260 \times 10^{+05}$	1.78×10^{-03}	6.100×10^{-04}
Bromodichloromethane	$4.782 \times 10^{+01}$	0.00	1.400×10^{-04}
Bromomethane	$7.938 \times 10^{+00}$	1.82×10^{-02}	1.080×10^{-03}
Butylbenzylphthalate	$3.799 \times 10^{+03}$	3.85×10^{-03}	7.300×10^{-01}
Carbazole	$1.229 \times 10^{+03}$	0.00	4.300×10^{-04}
Carbon disulfide	$9.135 \times 10^{+01}$	6.20×10^{-03}	2.800×10^{-03}
Chlorobenzene	$4.360 \times 10^{+02}$	1.16×10^{-03}	5.200×10^{-03}
Chloroform	$5.878 \times 10^{+01}$	3.79×10^{-03}	2.800×10^{-05}
Chrysene	$2.520 \times 10^{+05}$	1.70×10^{-04}	2.700×10^{-04}
Dibenzofuran	$8.316 \times 10^{+03}$	6.19×10^{-03}	1.5×10^{-2}
Dibenzo(a,h)anthracene	$5.878 \times 10^{+05}$	1.80×10^{-04}	1.100×10^{-06}
Dieldrin	$7.749 \times 10^{+03}$	2.71×10^{-04}	5.300×10^{-07}
Diethylphthalate	$4.668 \times 10^{+01}$	3.09×10^{-03}	$2.920 \times 10^{+00}$
Di-n-butyl phthalate	$9.954 \times 10^{+04}$	3.01×10^{-02}	3.650×10^{-01}
Di-n-octylphthalate	$9.954 \times 10^{+08}$	1.90×10^{-03}	7.300×10^{-02}
Endosulfan II	$2.627 \times 10^{+03}$	0.00	7.40×10^{-2}
Endosulfan sulfate	$2.879 \times 10^{+03}$	0.00	7.40×10^{-2}
Endrin	$2.507 \times 10^{+05}$	0.00	1.100×10^{-03}
Endrin aldehyde	$8.820 \times 10^{+02}$	0.00	1.1×10^{-3}

TABLE 5-12
(Continued)

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Constituents of Potential Concern	KOW[a]	λ[b] (1/day)	Screening Level[c] (mg/L)
Ethylbenzene	$8.820 \times 10^{+02}$	3.04×10^{-03}	1.580×10^{-01}
Fluoranthene	$1.348 \times 10^{+05}$	3.90×10^{-04}	1.460×10^{-01}
Fluorene	$9.450 \times 10^{+03}$	5.77×10^{-03}	1.460×10^{-01}
Heptachlor epoxide	$2.835 \times 10^{+02}$	6.28×10^{-04}	2.000×10^{-07}
Heptachlorodibenzofurans	$4.164 \times 10^{+05}$	6.19×10^{-03}	5.70×10^{-9}
Hexachlorobutadiene	$3.799 \times 10^{+04}$	1.90×10^{-03}	2.300×10^{-05}
Indeno(1,2,3-cd)pyrene	$2.879 \times 10^{+07}$	2.40×10^{-04}	4.300×10^{-06}
Isophorone	$3.156 \times 10^{+01}$	1.24×10^{-02}	9.000×10^{-03}
Methoxychlor	$3.018 \times 10^{+04}$	1.90×10^{-03}	1.800×10^{-02}
Methylene chloride	$1.121 \times 10^{+01}$	2.48×10^{-02}	6.300×10^{-04}
Napthalene	$1.449 \times 10^{+03}$	2.69×10^{-03}	1.460×10^{-01}
N-nitroso-di-n-propylamine	$1.953 \times 10^{+01}$	1.90×10^{-03}	1.200×10^{-06}
N-nitrosodiphenylamine	$8.505 \times 10^{+02}$	1.02×10^{-02}	1.700×10^{-03}
Octachlorodibenzofuran	$5.878 \times 10^{+07}$	6.19×10^{-03}	5.70×10^{-8}
Octachlorodibenzo-p-dioxin	$6.615 \times 10^{+06}$	0.00	5.70×10^{-8}
Phenanthrene	$1.827 \times 10^{+04}$	8.70×10^{-04}	1.46×10^{-1}
Phenol	$1.814 \times 10^{+01}$	2.48×10^{-02}	$2.190 \times 10^{+00}$
Pyrene	$9.513 \times 10^{+04}$	9.00×10^{-05}	1.100×10^{-01}
Styrene	$5.613 \times 10^{+02}$	3.30×10^{-03}	2.800×10^{-04}
Tetrachloroethene	$2.136 \times 10^{+02}$	4.20×10^{-04}	3.700×10^{-02}
Toluene	$3.087 \times 10^{+02}$	3.30×10^{-03}	9.300×10^{-02}
Tributylphosphate	$6.300 \times 10^{+03}$	0.00	1.800×10^{-02}
Trichloroethene	$2.136 \times 10^{+02}$	4.20×10^{-04}	2.500×10^{-04}

[a] KOW - Octanol/water partition coefficient
[b] λ-Degradation rate; if lambda value was not available from literature, 0 was conservatively assumed
[c] Based on 10^{-7} risk or 0.1 hazard quotient level

TABLE 5-13

RADIOLOGICAL SOURCE GROUP CONCENTRATIONS FOR OPERABLE UNIT 5 AIR TRANSPORT MODELING

Parameter	Units	Source Group 1	Source Group 2	Source Group 3	Source Group 4	Source Group 5	Source Group 6	Source Group 7
Cesium-137	pCi/g	2.9	0.73	0.48	1.6	1.02		0.7
Neptunium-237	pCi/g		0.72	2.63	0.21			
Plutonium-238	pCi/g	151	6.1	0.72	4.1			1.05
Plutonium-239/240	pCi/g	12.9	1.65	0.93	0.6	0.61		
Radium-226	pCi/g	2.3	7.69	16.6	1.9	1		1.1
Radium-228	pCi/g	546	26.05	1.81	1			27.9
Ruthenium-106	pCi/g					10.55		
Strontium-90	pCi/g	3.7	0.92	6.9		2.45	1.48	1.17
Technetium-99	pCi/g	5.7	4.8	1.8	16	1.75	210	1.9
Thorium-total	mg/kg		46.7	27.7	0.46		92.1	766
Thorium-total	pCi/g	8.91	1.5		56.54	20.98		
Thorium-228	pCi/g	176	8.68	2.77	35	1.27	22.1	2.07
Thorium-230	pCi/g	206	44.8	102	12.72	9.4		24.75
Thorium-232	pCi/g	193	6.6	1.99	38	5.2		84.9
Uranium, total	mg/kg	43118.6	338.36	3880	1752.64	157.23		229.74
Uranium-234	pCi/g	13262	100.91	852.93	108.12	29.79	18093	61.95
Uranium-235/236	pCi/g	950	10.61	310	24.6	1.72	1021	5.42
Uranium-238	pCi/g	14321	105.84	982.48	583	41.15	19067	85.29
Radon-222	pCi/m^2-sec	5.8	1.3	1.1	2.8	452.6	490.9	1.7

TABLE 5-13 (Continued)

Parameter	Units	Source Group 8	Source Group 9	Source Group 10	Source Group 11	Source Group 12	Source Group 13	Source Group 14
Cesium-137	pCi/g	0.59	0.68		0.5		0.98	1
Neptunium-237	pCi/g							
Plutonium-238	pCi/g	1.5			0.7			2.2
Plutonium-239/240	pCi/g	1.5			0.8			2.9
Radium-226	pCi/g	2.97	1.28	2720	3.4		2950	2.23
Radium-228	pCi/g	16.9	558	56.2	53.3	1.2	5.42	30.5
Ruthenium-106	pCi/g							
Strontium-90	pCi/g	6.1	3.6	3.1	1.3	0.7	2.7	2.5
Technetium-99	pCi/g	228	2.6		9.6		18.5	27.3
Thorium-total	mg/kg	14.5						
Thorium-total	pCi/g		2.01		10.03		57.6	18.24
Thorium-228	pCi/g	24.8	39.2	6.4	31.2	6.6	3.29	18.39
Thorium-230	pCi/g	806	7901	2729	31.8	225	17	14.28
Thorium-232	pCi/g	61.9	104.6	31.4	26.7	194	3.02	6.3
Uranium, total	mg/kg	5533.31	98.78	12336.9	2524.37	21423.9	276.15	821.24
Uranium-234	pCi/g	2899	31.4	3857	748	7075	68.22	261.29
Uranium-235/236	pCi/g	143	2.18	204	51.9	69.9	6.91	17.9
Uranium-238	pCi/g	1849	32.68	4108	839	7178	82.46	265.85
Radon-222	pCi/m^2-sec	4.6	0.8					

TABLE 5-14

INORGANIC SOURCE GROUP CONCENTRATIONS FOR OPERABLE UNIT 5 AIR TRANSPORT MODELING

Parameter	Units	Source Group 1	Source Group 2	Source Group 3	Source Group 4	Source Group 5	Source Group 6	Source Group 7	Source Group 8	Source Group 9
Aluminum	mg/kg	9278.9	9616.81	12525.1	9644.39	8794.57	9649.51	8200	9200.96	10239
Antimony	mg/kg	2.8	21.2	41.7	32.3	3.2	10.6	28.4		21.5
Arsenic	mg/kg	8.6	8.4	7.26	26	4.42	8.63	5.8	6.02	14.1
Barium	mg/kg	130.27	336	93.11	70.82	89.78	94.82	56.6	81.77	123.79
Beryllium	mg/kg	1.5	1.41	0.65	0.81	0.86	0.83	1.7	1.7	1.7
Cadmium	mg/kg	4.2	2.69	5.8	6.7	5.9	3.4	5.8	1.3	7.2
Calcium	mg/kg	140000	125275	157000	64381.7	122000	114000	138000	191000	178000
Chromium	mg/kg	22.86	20.91	25.3	17.11	14.34	15.97	19.8	11.8	32.15
Cobalt	mg/kg	10	11.29	10.59	10.34	10.96	8.83	11.8	9.55	11.79
Copper	mg/kg	76.32	21.9	45.5	19	18.44	65.1	19.9	13.4	25.9
Cyanide	mg/kg	0.49	0.52	0.5	0.24	0.46	0.91		0.44	0.88
Iron	mg/kg	20151.2	19696.9	23228.5	18505.9	16440.2	19071.4	21300	17242.4	22519.7
Lead	mg/kg	220	240	56	21.58	99.3	2020	11.1	23.1	118.91
Magnesium	mg/kg	20538	25215.9	20886.3	16874.5	34400	30700	65300	24357.7	65300
Manganese	mg/kg	894.29	995	630.92	1440	833.09	779.85	676	948.5	1780
Mercury	mg/kg	0.28	1.3	0.2			0.17			0.65

TABLE 5-14 (Continued)

Parameter	Units	Source Group 1	Source Group 2	Source Group 3	Source Group 4	Source Group 5	Source Group 6	Source Group 7	Source Group 8	Source Group 9
Molybdenum	mg/kg	11.3	12.8	5	4.02	10.8	8.1	4.7		8.5
Nickel	mg/kg	26.71	23.85	25.78	24.62	20.2	16.34	41.3	13.66	35.55
Potassium	mg/kg	1236.23	1345.18	1609.58	1075.52	1143.46	1134.36	1340	1020.43	1330.59
Selenium	mg/kg	0.57	2.3	1.4	0.65	0.77	0.42		0.8	
Silicon	mg/kg	672.46	1235.55	6510	1362.93	986.75	489.75	714	865.29	3271.41
Silver	mg/kg	7.1	10.8	9.7	10.1	7.6	7.9	10.4	0.48	4.4
Sodium	mg/kg	461.68	1340	151.23	105.31	99.36	112.52	181	157	310.88
Thallium	mg/kg	0.42	0.29	0.33	0.51	0.67	0.23			0.38
Vanadium	mg/kg	26.37	25.35	27.7	23.83	21.71	23.12	23.8	21.17	28.86
Zinc	mg/kg	378	123	86.1	59.93	707	82.96	49.6	52.78	201.56

TABLE 5-15

VOLATILES, SEMIVOLATILES, AND PCBs SOURCE GROUP CONCENTRATIONS FOR OPERABLE UNIT 5 AIR TRANSPORT MODELING

Parameter	Units	Source Group 1	Source Group 2	Source Group 3	Source Group 4	Source Group 5	Source Group 6
4,4'-DDE	µg/kg			38			
4,4'-DDT	µg/kg			15			
Alpha-chlordane	µg/kg			2.8			
Aroclor-1254	µg/kg			14000	430	460	120
Aroclor-1260	µg/kg						
Benzene	µg/kg						
Benzo(a)anthracene	µg/kg		57	400	6300	2000	330
Benzo(a)pyrene	µg/kg		60	340	6000	2300	230
Benzo(b)fluoranthene	µg/kg		55	540	6100	2300	520
Benzo(k)fluoranthene	µg/kg		61	390	2900	2600	360
Bis(2-ethylhexyl)phthalate	µg/kg	62	700	200	71	780	100
Carbazole	µg/kg		7	74		570	170
Chloroform	µg/kg					14	
Chrysene	µg/kg		75	480	7800	2200	430
Dibenzo(a,h)anthracene	µg/kg			74	1500	610	100
Dieldrin	µg/kg			8.9			
Indeno(1,2,3-cd)pyrene	µg/kg		40	260	4800	1700	380
Methylene chloride	µg/kg			36			6
N-nitroso-di-n-propylamine	µg/kg						
N-nitrosodiphenylamine	µg/kg						
Octachlorodibenzo-p-dioxin	ng/kg						
Octachlorodibenzofuran	ng/kg						
Tetrachloroethene	µg/kg	3	52	2			1
Trichloroethene	µg/kg	2	34		5		

TABLE 5-15 (Continued)

Parameter	Units	Source Group 7	Source Group 8	Source Group 9	Source Group 10	Source Group 11	Source Group 12
4,4'-DDE	µg/kg						
4,4'-DDT	µg/kg		19			3	
Alpha-chlordane	µg/kg					5.1	
Aroclor-1254	µg/kg	6200	1300			240	
Aroclor-1260	µg/kg		240				
Benzene	µg/kg		2				
Benzo(a)anthracene	µg/kg	240	2400	61000	19000	630	27
Benzo(a)pyrene	µg/kg	440	3300	69000	24000	600	
Benzo(b)fluoranthene	µg/kg	480	4500		39000	670	56
Benzo(k)fluoranthene	µg/kg	510	3800	69000		660	52
Bis(2-ethylhexyl)phthalate	µg/kg	470	880		650	45	96
Carbazole	µg/kg		65	10000		46	
Chloroform	µg/kg		9				
Chrysene	µg/kg	410	3600		18000	720	46
Dibenzo(a,h)anthracene	µg/kg	170	1200	23000	6900	59	
Dieldrin	µg/kg					2.4	
Indeno(1,2,3-cd)pyrene	µg/kg	450	3000		13000	470	
Methylene chloride	µg/kg	11	7	49000		23	
N-nitroso-di-n-propylamine	µg/kg		39				
N-nitrosodiphenylamine	µg/kg		120	680		1300	
Octachlorodibenzo-p-dioxin	ng/kg		270			900	
Octachlorodibenzofuran	ng/kg		500				
Tetrachloroethene	µg/kg		12			3	2
Trichloroethene	µg/kg		1		18	6	4

TABLE 5-16

SOURCE CONCENTRATION AND INVENTORIES IN THE SURFACE WATER PATHWAY

Constituents of Potential Concern	Total Contaminated Area (ft^2)	Range of Source Concentration (mg/kg)		Mass of Contaminated Soil (kg)	Mass of Constituents in Soil (kg)
		Minimum	Maximum		
Radionuclides					
Actinium-227	$3.35 \times 10^{+06}$	1.66×10^{-08}	5.46×10^{-08}	$2.09 \times 10^{+08}$	4.81×10^{-06}
Cesium-137	$4.97 \times 10^{+07}$	5.78×10^{-09}	3.35×10^{-08}	$3.01 \times 10^{+09}$	2.94×10^{-05}
Neptunium-237	$1.32 \times 10^{+07}$	2.94×10^{-04}	3.73×10^{-03}	$7.93 \times 10^{+08}$	8.89×10^{-01}
Plutonium-238	$5.58 \times 10^{+06}$	1.50×10^{-08}	8.83×10^{-06}	$3.34 \times 10^{+08}$	3.31×10^{-04}
Plutonium-239/240	$2.68 \times 10^{+07}$	3.43×10^{-0}	2.08×10^{-04}	$1.63 \times 10^{+09}$	2.86×10^{-02}
Protactinium-231	$5.85 \times 10^{+05}$	1.07×10^{-04}	1.07×10^{-04}	$3.53 \times 10^{+07}$	3.77×10^{-03}
Radium-226[a]	$2.31 \times 10^{+07}$	1.27×10^{-06}	2.98×10^{-03}	$1.42 \times 10^{+09}$	1.13×10^{-01}
Ruthenium-106	$2.70 \times 10^{+06}$	2.90×10^{-09}	3.14×10^{-09}	$1.59 \times 10^{+08}$	4.69×10^{-07}
Strontium-90	$4.60 \times 10^{+07}$	5.11×10^{-09}	4.74×10^{-08}	$2.80 \times 10^{+09}$	3.63×10^{-05}
Technetium-99	$2.93 \times 10^{+07}$	6.47×10^{-05}	1.34×10^{-02}	$1.80 \times 10^{+09}$	9.57×10^{-01}
Thorium-230	$5.00 \times 10^{+07}$	7.28×10^{-05}	1.33×10^{-01}	$3.03 \times 10^{+09}$	$7.72 \times 10^{+00}$
Thorium-232[b]	$3.01 \times 10^{+07}$	$1.04 \times 10^{+01}$	$2.57 \times 10^{+03}$	$1.81 \times 10^{+09}$	$1.15 \times 10^{+05}$
Uranium (Total)	$5.10 \times 10^{+07}$	$1.15 \times 10^{+01}$	$4.31 \times 10^{+04}$	$3.09 \times 10^{+09}$	$1.74 \times 10^{+06}$
Uranium-234	$5.10 \times 10^{+07}$	1.67×10^{-04}	$2.13 \times 10^{+00}$	$3.09 \times 10^{+09}$	$9.19 \times 10^{+01}$
Uranium-235/236	$5.10 \times 10^{+07}$	4.20×10^{-02}	$4.40 \times 10^{+02}$	$3.09 \times 10^{+09}$	$1.85 \times 10^{+04}$
Uranium-238[c]	$5.10 \times 10^{+07}$	$5.36 \times 10^{+00}$	$4.26 \times 10^{+04}$	$3.09 \times 10^{+09}$	$2.23 \times 10^{+06}$
Inorganics					
Aluminum	$4.00 \times 10^{+07}$	$9.09 \times 10^{+03}$	$1.98 \times 10^{+04}$	$2.41 \times 10^{+09}$	$2.65 \times 10^{+07}$
Antimony	$2.33 \times 10^{+07}$	$2.90 \times 10^{+00}$	$3.81 \times 10^{+01}$	$1.44 \times 10^{+09}$	$1.50 \times 10^{+04}$
Arsenic	$4.99 \times 10^{+07}$	$5.66 \times 10^{+00}$	$3.25 \times 10^{+01}$	$3.03 \times 10^{+09}$	$3.09 \times 10^{+04}$
Barium	$5.02 \times 10^{+07}$	$7.01 \times 10^{+01}$	$5.12 \times 10^{+02}$	$3.04 \times 10^{+09}$	$3.29 \times 10^{+05}$
Beryllium	$4.83 \times 10^{+07}$	6.22×10^{-01}	$3.50 \times 10^{+00}$	$2.93 \times 10^{+09}$	$4.15 \times 10^{+03}$
Boron	$2.94 \times 10^{+07}$	$1.43 \times 10^{+01}$	$1.43 \times 10^{+01}$	$1.80 \times 10^{+09}$	$2.57 \times 10^{+04}$
Cadmium	$2.25 \times 10^{+07}$	$1.10 \times 10^{+00}$	$7.60 \times 10^{+00}$	$1.36 \times 10^{+09}$	$4.98 \times 10^{+03}$
Chromium	$4.83 \times 10^{+07}$	$1.34 \times 10^{+01}$	$4.69 \times 10^{+01}$	$2.93 \times 10^{+09}$	$5.26 \times 10^{+04}$
Copper	$5.02 \times 10^{+07}$	$1.17 \times 10^{+01}$	$2.07 \times 10^{+02}$	$3.04 \times 10^{+09}$	$1.22 \times 10^{+05}$
Cyanide	$4.56 \times 10^{+07}$	3.00×10^{-01}	$1.50 \times 10^{+00}$	$2.77 \times 10^{+09}$	$1.68 \times 10^{+03}$
Lead	$5.01 \times 10^{+07}$	$1.92 \times 10^{+01}$	$2.16 \times 10^{+03}$	$3.03 \times 10^{+09}$	$1.42 \times 10^{+06}$
Magnesium	$5.00 \times 10^{+07}$	$2.05 \times 10^{+03}$	$4.86 \times 10^{+04}$	$3.03 \times 10^{+09}$	$7.92 \times 10^{+07}$
Manganese	$3.07 \times 10^{+07}$	$8.30 \times 10^{+02}$	$3.42 \times 10^{+03}$	$1.89 \times 10^{+09}$	$3.42 \times 10^{+06}$

TABLE 5-16
(Continued)

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Constituents of Potential Concern	Total Contaminated Area (ft^2)	Range of Source Concentration (mg/kg)		Mass of Contaminated Soil (kg)	Mass of Constituents in Soil (kg)
		Minimum	Maximum		
Inorganics (Continued)					
Mercury	$1.38 \times 10^{+07}$	3.20×10^{-01}	$2.10 \times 10^{+00}$	$8.53 \times 10^{+08}$	$5.10 \times 10^{+02}$
Molybdenum	$3.61 \times 10^{+07}$	$3.55 \times 10^{+00}$	$1.31 \times 10^{+01}$	$2.18 \times 10^{+09}$	$1.76 \times 10^{+04}$
Nickel	$4.93 \times 10^{+07}$	$1.31 \times 10^{+01}$	$7.22 \times 10^{+01}$	$2.99 \times 10^{+09}$	$6.71 \times 10^{+04}$
Silver	$3.28 \times 10^{+07}$	4.70×10^{-01}	$1.72 \times 10^{+01}$	$2.00 \times 10^{+09}$	$1.22 \times 10^{+04}$
Thallium	$1.61 \times 10^{+07}$	6.70×10^{-01}	7.70×10^{-01}	$1.01 \times 10^{+09}$	$7.20 \times 10^{+02}$
Vanadium	$5.09 \times 10^{+07}$	$2.25 \times 10^{+01}$	$3.88 \times 10^{+01}$	$3.08 \times 10^{+09}$	$7.94 \times 10^{+04}$
Organics					
1,1,2,2-Tetrachloroethane	$1.76 \times 10^{+06}$	2.00×10^{-03}	1.90×10^{-01}	$1.04 \times 10^{+08}$	$1.30 \times 10^{+01}$
1,1,2-Trichloroethane	$2.23 \times 10^{+05}$	1.40×10^{-02}	1.40×10^{-02}	$1.33 \times 10^{+07}$	1.86×10^{-01}
1,1-Dichloroethene	$1.04 \times 10^{+07}$	4.00×10^{-03}	3.90×10^{-02}	$6.49 \times 10^{+08}$	$6.11 \times 10^{+00}$
1,2-Dichloroehtane	$1.14 \times 10^{+06}$	2.00×10^{-03}	2.00×10^{-03}	$6.80 \times 10^{+07}$	1.36×10^{-01}
1,2-Dichloroethene (Total)	$2.23 \times 10^{+06}$	4.00×10^{-03}	3.40×10^{-01}	$1.33 \times 10^{+08}$	$5.79 \times 10^{+00}$
2,4-Dichlorophenol	$1.14 \times 10^{+06}$	1.00×10^{-01}	1.00×10^{-01}	$6.80 \times 10^{+07}$	$6.80 \times 10^{+00}$
2,4-Dinitrotoluene	$1.14 \times 10^{+06}$	5.30×10^{-02}	5.30×10^{-02}	$6.80 \times 10^{+07}$	$3.60 \times 10^{+00}$
2,6-Dinitrotoluene	$2.23 \times 10^{+05}$	1.10×10^{-02}	1.10×10^{-02}	$1.33 \times 10^{+07}$	1.46×10^{-01}
2-Butanone	$2.63 \times 10^{+07}$	1.00×10^{-03}	7.40×10^{-02}	$1.60 \times 10^{+09}$	$7.44 \times 10^{+00}$
2-Chlorophenol	$1.56 \times 10^{+06}$	4.80×10^{-02}	4.80×10^{-02}	$9.62 \times 10^{+07}$	$4.62 \times 10^{+00}$
3,3'-Dichlorobenzidine	$1.56 \times 10^{+06}$	1.90×10^{-01}	1.90×10^{-01}	$9.62 \times 10^{+07}$	$1.83 \times 10^{+01}$
4-Methyl-2-Pentanone	$1.36 \times 10^{+07}$	1.00×10^{-03}	1.60×10^{-01}	$8.26 \times 10^{+08}$	$1.66 \times 10^{+01}$
4-Methylphenol	$1.72 \times 10^{+07}$	5.00×10^{-02}	$1.70 \times 10^{+00}$	$1.02 \times 10^{+09}$	$1.39 \times 10^{+03}$
4-Nitroaniline	$1.56 \times 10^{+06}$	3.30×10^{-01}	3.30×10^{-01}	$9.62 \times 10^{+07}$	$3.17 \times 10^{+01}$
Acetone	$2.73 \times 10^{+07}$	3.00×10^{-03}	1.50×10^{-01}	$1.68 \times 10^{+09}$	$3.68 \times 10^{+01}$
Aldrin	$5.30 \times 10^{+05}$	1.60×10^{-03}	1.60×10^{-03}	$3.15 \times 10^{+07}$	5.04×10^{-02}
Alpha-Chlordane	$1.45 \times 10^{+06}$	2.80×10^{-03}	5.10×10^{-03}	$8.62 \times 10^{+07}$	3.14×10^{-01}
Aroclor-1254	$2.12 \times 10^{+07}$	4.50×10^{-02}	$1.40 \times 10^{+01}$	$1.30 \times 10^{+09}$	$1.20 \times 10^{+03}$
Aroclor-1260	$4.32 \times 10^{+06}$	1.40×10^{-01}	$2.10 \times 10^{+00}$	$2.57 \times 10^{+08}$	$3.42 \times 10^{+02}$
Benzene	$8.39 \times 10^{+06}$	2.00×10^{-03}	5.00×10^{-03}	$5.14 \times 10^{+08}$	$1.50 \times 10^{+00}$
Benzo(a)Anthracene	$2.34 \times 10^{+07}$	4.80×10^{-02}	$9.20 \times 10^{+00}$	$1.41 \times 10^{+09}$	$1.59 \times 10^{+03}$
Benzo(a)Pyrene	$1.64 \times 10^{+07}$	5.40×10^{-02}	$1.20 \times 10^{+01}$	$9.78 \times 10^{+08}$	$1.97 \times 10^{+03}$
Benzo(b)Fluoranthene	$2.39 \times 10^{+07}$	4.70×10^{-02}	$1.50 \times 10^{+01}$	$1.44 \times 10^{+09}$	$2.31 \times 10^{+03}$
Benzo(k)Fluoranthene	$2.31 \times 10^{+07}$	3.30×10^{-02}	$1.20 \times 10^{+01}$	$1.39 \times 10^{+09}$	$2.05 \times 10^{+03}$

TABLE 5-16
(Continued)

Constituents of Potential Concern	Total Contaminated Area (ft^2)	Range of Source Concentration (mg/kg)		Mass of Contaminated Soil (kg)	Mass of Constituents in Soil (kg)
		Minimum	Maximum		
Organics (Continued)					
Benzyl Alcohol	$2.70 \times 10^{+06}$	6.90×10^{-02}	2.90×10^{-01}	$1.64 \times 10^{+08}$	$2.63 \times 10^{+01}$
Beta-BHC	$1.39 \times 10^{+06}$	7.80×10^{-02}	2.20×10^{-01}	$8.29 \times 10^{+07}$	$8.58 \times 10^{+00}$
Bis(2)-chloroisopropyl ether	$2.76 \times 10^{+06}$	4.40×10^{-02}	4.80×10^{-02}	$1.59 \times 10^{+08}$	$7.28 \times 10^{+00}$
Bis(2)-ethylhexyl)phthalate	$4.63 \times 10^{+07}$	4.50×10^{-02}	$1.10 \times 10^{+01}$	$2.81 \times 10^{+09}$	$3.55 \times 10^{+03}$
Bromodichloromethane	$2.56 \times 10^{+06}$	6.00×10^{-03}	6.00×10^{-03}	$1.48 \times 10^{+08}$	8.89×10^{-01}
Bromomethane	$5.30 \times 10^{+05}$	7.20×10^{-01}	7.20×10^{-01}	$3.15 \times 10^{+07}$	$2.27 \times 10^{+01}$
Carbazole	$1.01 \times 10^{+07}$	7.00×10^{-03}	5.70×10^{-01}	$5.92 \times 10^{+08}$	$5.93 \times 10^{+01}$
Carbon disulfide	$4.29 \times 10^{+06}$	4.00×10^{-03}	1.40×10^{-02}	$2.56 \times 10^{+08}$	$2.10 \times 10^{+00}$
Chloroform	$6.75 \times 10^{+06}$	1.00×10^{-03}	3.20×10^{-02}	$3.97 \times 10^{+08}$	$6.40 \times 10^{+00}$
Chrysene	$2.34 \times 10^{+07}$	7.70×10^{-02}	$1.20 \times 10^{+01}$	$1.41 \times 10^{+09}$	$1.83 \times 10^{+03}$
Dibenzo(a,h)anthracene	$1.01 \times 10^{+07}$	5.90×10^{-02}	$3.50 \times 10^{+00}$	$6.13 \times 10^{+08}$	$5.89 \times 10^{+02}$
Dibenzofuran	$7.03 \times 10^{+06}$	1.40×10^{-01}	$2.50 \times 10^{+00}$	$4.23 \times 10^{+08}$	$2.40 \times 10^{+02}$
Dieldrin	$9.26 \times 10^{+06}$	2.40×10^{-03}	2.00×10^{-02}	$5.67 \times 10^{+08}$	$1.01 \times 10^{+01}$
Endrin aldehyde	$1.56 \times 10^{+06}$	1.50×10^{-02}	1.50×10^{-02}	$9.62 \times 10^{+07}$	$1.44 \times 10^{+00}$
Heptachlor epoxide	$1.45 \times 10^{+06}$	1.00×10^{-03}	2.80×10^{-03}	$8.62 \times 10^{+07}$	1.85×10^{-01}
Heptachlorodibenzofurans	$1.20 \times 10^{+06}$	3.20×10^{-04}	3.20×10^{-04}	$7.48 \times 10^{+07}$	2.39×10^{-02}
Hexachlorobutadiene	$1.14 \times 10^{+06}$	4.30×10^{-01}	4.30×10^{-01}	$6.80 \times 10^{+07}$	$2.92 \times 10^{+01}$
Indeno(1,2,3-cd)pyrene	$1.46 \times 10^{+07}$	5.00×10^{-02}	$8.70 \times 10^{+00}$	$8.74 \times 10^{+08}$	$1.60 \times 10^{+03}$
Isophorone	$2.51 \times 10^{+05}$	8.30×10^{-01}	8.30×10^{-01}	$1.49 \times 10^{+07}$	$1.24 \times 10^{+01}$
Methylene chloride	$2.29 \times 10^{+07}$	5.00×10^{-03}	$1.87 \times 10^{+00}$	$1.40 \times 10^{+09}$	$1.99 \times 10^{+02}$
N-Nitroso-di-n-propylamine	$1.56 \times 10^{+06}$	3.90×10^{-02}	3.90×10^{-02}	$9.62 \times 10^{+07}$	$3.75 \times 10^{+00}$
N-Nitrosodiphenylamine	$1.67 \times 10^{+06}$	1.20×10^{-01}	$1.30 \times 10^{+00}$	$9.95 \times 10^{+07}$	$4.91 \times 10^{+01}$
Styrene	$1.67 \times 10^{+06}$	1.00×10^{-03}	2.80×10^{-02}	$9.95 \times 10^{+07}$	$1.93 \times 10^{+00}$
Tetrachloroethene	$3.28 \times 10^{+07}$	1.00×10^{-03}	$3.30 \times 10^{+00}$	$2.00 \times 10^{+09}$	$5.99 \times 10^{+01}$
Tributyl phosphate	$1.12 \times 10^{+07}$	4.60×10^{-02}	$1.20 \times 10^{+00}$	$6.81 \times 10^{+08}$	$1.52 \times 10^{+02}$
Trichloroethene	$2.56 \times 10^{+07}$	2.00×10^{-03}	$8.90 \times 10^{+01}$	$1.54 \times 10^{+09}$	$1.19 \times 10^{+03}$

[a] Radium-226 is used to model daughter products Lead-210 and PO-210
[b] Thorium-232 is used to model daughter products Ra-228, Th-228, and Ra-224
[c] U-238 is used to model daughter product Th-234

TABLE 5-17

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CONSTITUENTS OF POTENTIAL CONCERN SCREENING RESULTS IN THE SURFACE WATER PATHWAY - BASELINE CONDITION

Constituents of Concern	Surface Water Impact	Groundwater Impact	Major Source Areas
Radionuclides			
Neptunium-237	X	X	North of the production area, around Pilot Plant drainage ditch
Plutonium-238	X		East of production area, around Pilot Plant drainage ditch
Radium-226	X	X	North of the production area, around Pilot Plant drainage ditch
Strontium-90	X	X	North of the production area, east of production area
Technetium-99	X	X	Area Around South Field, around Pilot Plant drainage ditch
Uranium-Total	X	X	East of production area, around Pilot Plant drainage ditch
Organics			
1,1-Dichloroethene	X	X	East of production area
3,3'-Dichlorobenzidine	X		North of the production area
4-Methylphenol	X	X	Around active flyash pile, area around South Field
4-Nitroaniline	X		North of the production area
Aroclor-1254	X		North of the production area, east of production area
Benzene	X		North of the production area
Benzo(a)anthracene	X		North of the production area, around Pilot Plant drainage ditch
Benzo(a)pyrene	X		North of the production area, east of production area
Bis(2-chloroisopropyl)ether	X	X	Around Pilot Plant drainage ditch
Bromodichloromethane	X		Area Around South Field
Chloroform	X	X	Area Around South Field
Dibenzo(a,h)anthracene	X		North of the production area, east of production area
Dieldrin	X	X	North of the production area
Methylene chloride	X	X	North of the production area, around Pilot Plant drainage ditch
N-nitroso-di-n-propylamine	X	X	North of the production area

TABLE 5-17 (Continued)

Constituents of Concern	Surface Water Impact	Groundwater Impact	Major Source Areas
Inorganics			
Arsenic	X	X	Around Pilot Plant drainage ditch, north of the production area
Beryllium	X	X	Around Pilot Plant drainage ditch, east of production area
Cyanide	X	X	East of production area, north of the production area
Lead	X	X	East of production area, north of the production area
Magnesium	X	X	East of production area, north of the production area
Manganese	X	X	East of production area, area around South Field
Mercury	X	X	East of production area, around active flyash pile

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TABLE 5-18

CONSTITUENTS OF POTENTIAL CONCERN SCREENING RESULTS IN THE SURFACE WATER PATHWAY
FUTURE CONDITION

Constituents of Concern	Surface Water Impact	Groundwater Impact	Major Source Areas
Radionuclides			
Neptunium-237	X	X	North of the production area, Production area
Plutonium-238	X	X	Production area, east of production area
Plutonium-239/240	X		Production area, east of production area
Radium-226	X	X	Production area, north of the production area
Strontium-90	X	X	Production area, north of the production area
Technetium-99	X	X	Area around South Field, Production area
Thorium-230	X	X	Production area, around Pilot Plant drainage ditch
Thorium-232	X	X	Production area, around Pilot Plant drainage ditch
Uranium-Total	X	X	Production area, east of production area
Organics			
4-Methylphenol	X	X	Around active flyash pile, area around South Field
4-Nitroaniline	X		North of the production area
Alpha-Chlordane	X		Production area
Aroclor-1254	X	X	Production area, north of the production area
Aroclor-1260	X	X	Production area, north of the production area
Bis(2-chloroisopropyl)ether	X	X	Around Pilot Plant drainage ditch, Production area
Bromodichloromethane	X		Area Around South Field
Bromomethane	X	X	Production area

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TABLE 5-18 (Continued)

Constituents of Concern	Surface Water Impact	Groundwater Impact	Major Source Areas
Inorganics			
Antimony	X		Waste pit area, around Pilot Plant drainage ditch
Arsenic	X	X	Around Pilot Plant drainage ditch, north of the production area
Beryllium	X	X	Production area, around active flyash pile
Cyanide	X	X	East of production area, Production area
Lead	X	X	East of production area, Production area
Magnesium	X	X	East of production area, north of the production area
Manganese	X	X	East of production area, area around South Field
Mercury	X	X	Production area, east of production area

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TABLE 5-19

SOURCE CONCENTRATIONS AND INVENTORIES IN THE GROUNDWATER PATHWAY VERTICAL MIGRATION

Constituent of Potential Concern	Total Contaminated Area (ft^2)	Range of Source Concentration (mg/kg)		Mass of Contaminated Soil (kg)	Mass of Constituents in Soil (kg)
		Minimum	Maximum		
Radionuclides					
Neptunium-237	$1.29 \times 10^{+07}$	2.94×10^{-04}	3.73×10^{-03}	$2.21 \times 10^{+09}$	$3.64 \times 10^{+00}$
Radium-226	$3.72 \times 10^{+07}$	3.03×10^{-07}	2.98×10^{-03}	$4.60 \times 10^{+09}$	1.79×10^{-01}
Strontium-90	$3.72 \times 10^{+07}$	3.10×10^{-09}	4.74×10^{-08}	$4.60 \times 10^{+09}$	8.25×10^{-05}
Technetium-99	$2.81 \times 10^{+07}$	6.47×10^{-05}	1.34×10^{-02}	$3.76 \times 10^{+09}$	$2.01 \times 10^{+00}$
Uranium-Total	$3.72 \times 10^{+07}$	$1.15 \times 10^{+01}$	$4.31 \times 10^{+04}$	$4.60 \times 10^{+09}$	$2.80 \times 10^{+06}$
Inorganics					
Antimony	$3.72 \times 10^{+07}$	7.60×10^{-01}	$3.81 \times 10^{+01}$	$4.60 \times 10^{+09}$	$4.20 \times 10^{+04}$
Arsenic	$3.72 \times 10^{+07}$	$3.30 \times 10^{+00}$	$3.25 \times 10^{+01}$	$4.60 \times 10^{+09}$	$4.27 \times 10^{+04}$
Barium	$3.72 \times 10^{+07}$	$6.38 \times 10^{+01}$	$5.12 \times 10^{+02}$	$4.60 \times 10^{+09}$	$5.94 \times 10^{+05}$
Boron	$3.72 \times 10^{+07}$	$1.37 \times 10^{+01}$	$1.43 \times 10^{+01}$	$4.60 \times 10^{+09}$	$6.40 \times 10^{+04}$
Chromium (hex)	$3.72 \times 10^{+07}$	9.80×10^{-01}	$4.69 \times 10^{+00}$	$4.60 \times 10^{+09}$	$2.31 \times 10^{+03}$
Cyanide	$3.72 \times 10^{+07}$	1.10×10^{-01}	$8.60 \times 10^{+00}$	$4.60 \times 10^{+09}$	$4.23 \times 10^{+03}$
Magnesium	$3.72 \times 10^{+07}$	$1.20 \times 10^{+03}$	$4.86 \times 10^{+04}$	$4.60 \times 10^{+09}$	$1.27 \times 10^{+08}$
Manganese	$3.72 \times 10^{+07}$	$4.43 \times 10^{+02}$	$3.42 \times 10^{+03}$	$4.60 \times 10^{+09}$	$5.92 \times 10^{+06}$
Mercury	$3.72 \times 10^{+07}$	2.00×10^{-02}	$1.30 \times 10^{+00}$	$4.60 \times 10^{+09}$	$1.91 \times 10^{+03}$
Molybdenum	$3.72 \times 10^{+07}$	8.30×10^{-01}	$1.28 \times 10^{+01}$	$4.60 \times 10^{+09}$	$2.74 \times 10^{+04}$
Thallium	$3.72 \times 10^{+07}$	2.20×10^{-01}	7.70×10^{-01}	$4.60 \times 10^{+09}$	$2.30 \times 10^{+03}$
Organics					
1,1-Dichloroethene	$1.03 \times 10^{+07}$	2.00×10^{-03}	3.90×10^{-02}	$2.10 \times 10^{+09}$	$1.45 \times 10^{+01}$
1,1,1-Trichloroethane	$1.38 \times 10^{+07}$	1.00×10^{-03}	1.20×10^{-01}	$2.42 \times 10^{+09}$	$7.31 \times 10^{+01}$
1,1,2-Trichloroethane	$8.44 \times 10^{+05}$	2.00×10^{-03}	1.40×10^{-02}	$7.66 \times 10^{+08}$	$3.43 \times 10^{+00}$
1,1-Dichloroethane	$1.16 \times 10^{+07}$	1.00×10^{-03}	3.70×10^{-02}	$2.22 \times 10^{+09}$	$2.01 \times 10^{+01}$
1,2-Dichloroethane	$2.18 \times 10^{+06}$	2.00×10^{-03}	6.00×10^{-03}	$8.90 \times 10^{+08}$	$4.21 \times 10^{+00}$
1,2-Dichloroethene (Total)	$2.43 \times 10^{+06}$	4.00×10^{-03}	3.40×10^{-01}	$9.14 \times 10^{+08}$	$6.69 \times 10^{+01}$
2-Chlorophenol	$1.93 \times 10^{+06}$	4.80×10^{-02}	4.80×10^{-02}	$1.79 \times 10^{+08}$	$8.61 \times 10^{+00}$
2-Hexanone	$9.88 \times 10^{+06}$	1.00×10^{-03}	2.00×10^{-03}	$1.61 \times 10^{+09}$	$2.45 \times 10^{+00}$
2-Methylnaphthalene	$1.01 \times 10^{+07}$	2.50×10^{-02}	$1.30 \times 10^{+00}$	$1.63 \times 10^{+09}$	$4.81 \times 10^{+02}$
2-Methylphenol	$1.33 \times 10^{+06}$	4.50×10^{-02}	4.50×10^{-02}	$1.24 \times 10^{+08}$	2.91×10^{-11}

TABLE 5-19 (Continued)

Constituent of Potential Concern	Total Contaminated Area (ft^2)	Range of Source Concentration (mg/kg)		Mass of Contaminated Soil (kg)	Mass of Constituents in Soil (kg)
		Minimum	Maximum		
Organics (Continued)					
2,4-Dinitrotoluene	$1.33 \times 10^{+06}$	5.30×10^{-02}	5.30×10^{-02}	$1.24 \times 10^{+08}$	3.43×10^{-11}
2,6-Dinitrotoluene	$2.32 \times 10^{+05}$	1.10×10^{-02}	1.10×10^{-02}	$1.58 \times 10^{+08}$	8.79×10^{-13}
4-Chloro-3-Methylphenol	$2.54 \times 10^{+06}$	4.60×10^{-02}	8.80×10^{-02}	$7.87 \times 10^{+08}$	$8.26 \times 10^{+00}$
4-Methylphenol	$4.87 \times 10^{+06}$	5.00×10^{-02}	$1.70 \times 10^{+00}$	$4.53 \times 10^{+08}$	8.26×10^{-01}
4-Nitroaniline	$1.93 \times 10^{+06}$	3.30×10^{-01}	3.30×10^{-01}	$1.79 \times 10^{+08}$	$5.92 \times 10^{+01}$
Alpha-Chlordane	$1.46 \times 10^{+06}$	2.80×10^{-03}	5.10×10^{-03}	$1.36 \times 10^{+08}$	4.93×10^{-01}
Benzene	$1.01 \times 10^{+07}$	1.00×10^{-03}	6.67×10^{-02}	$1.63 \times 10^{+09}$	$4.32 \times 10^{+01}$
Benzyl Alcohol	$3.26 \times 10^{+06}$	6.90×10^{-02}	2.90×10^{-01}	$3.03 \times 10^{+08}$	$1.24 \times 10^{+01}$
Bis(2-Chloroisopropyl) Ether	$2.05 \times 10^{+06}$	4.40×10^{-02}	4.80×10^{-02}	$1.91 \times 10^{+08}$	$2.94 \times 10^{+00}$
Bromodichloromethane	$2.19 \times 10^{+06}$	6.00×10^{-03}	7.00×10^{-03}	$7.54 \times 10^{+08}$	8.79×10^{-01}
Carbazole	$1.04 \times 10^{+07}$	7.00×10^{-03}	2.50×10^{-01}	$1.98 \times 10^{+09}$	$1.28 \times 10^{+02}$
Diethylphthalate	$3.43 \times 10^{+06}$	1.00×10^{-03}	5.20×10^{-02}	$4.56 \times 10^{+08}$	$1.01 \times 10^{+01}$
Endosulfan II	$5.27 \times 10^{+05}$	2.00×10^{-03}	2.00×10^{-03}	$4.90 \times 10^{+07}$	5.17×10^{-13}
Endosulfan Sulfate	$5.27 \times 10^{+05}$	7.30×10^{-04}	7.30×10^{-04}	$4.90 \times 10^{+07}$	1.89×10^{-13}
Endrin Aldehyde	$1.93 \times 10^{+06}$	1.50×10^{-02}	1.50×10^{-02}	$1.79 \times 10^{+08}$	$2.69 \times 10^{+00}$
Heptachlor Epoxide	$1.46 \times 10^{+06}$	1.00×10^{-03}	2.80×10^{-03}	$1.36 \times 10^{+08}$	2.92×10^{-01}
N-nitroso-di-n-propylamine	$1.93 \times 10^{+06}$	3.90×10^{-02}	3.90×10^{-02}	$1.79 \times 10^{+08}$	$7.00 \times 10^{+00}$
Tetrachloroethene	$2.06 \times 10^{+07}$	1.00×10^{-03}	$1.60 \times 10^{+00}$	$3.06 \times 10^{+09}$	$2.80 \times 10^{+02}$
Trichloroethene	$1.49 \times 10^{+07}$	2.00×10^{-03}	$8.90 \times 10^{+01}$	$2.07 \times 10^{+09}$	$1.43 \times 10^{+04}$

TABLE 5-20

SOURCE CONCENTRATIONS AND INVENTORIES IN THE GROUNDWATER PATHWAY INITIAL GREAT MIAMI AQUIFER CONDITIONS

	Neptunium-237	Radium-226	Technetium-99	Uranium-Total	Arsenic	Manganese	Antimony
Mass (mg)							
Mass in Layer 1	4.06×10^{5}	1.22×10^{3}	3.34×10^{3}	1.50×10^{9}	1.01×10^{10}	2.45×10^{11}	1.66×10^{11}
Mass in Layer 2	2.03×10^{2}	2.14×10^{3}	6.78×10^{3}	3.29×10^{9}	2.36×10^{10}	7.19×10^{11}	0
Mass in Layer 3	1.40×10^{1}	7.75×10^{2}	1.79×10^{3}	2.63×10^{8}	6.21×10^{9}	1.90×10^{11}	2.66×10^{10}
Mass in Layer 4	1.10×10^{0}	2.44×10^{2}	8.18×10^{2}	8.26×10^{6}	4.01×10^{9}	5.77×10^{10}	0
Mass in Layer 5	1.32×10^{0}	1.77×10^{3}	2.30×10^{3}	3.99×10^{7}	7.77×10^{9}	3.53×10^{11}	0
Mass in Layer 6	6.58×10^{-2}	0.00×10^{0}	4.09×10^{2}	7.88×10^{4}	0.00×10^{0}	8.84×10^{10}	0
Total Mass in Layers 1-6	4.06×10^{5}	6.14×10^{3}	1.54×10^{4}	5.10×10^{9}	5.17×10^{10}	1.65×10^{12}	1.93×10^{11}
Maximum Concentration[a] (mg/L)							
Layer 1	1.60×10^{-6}	1.24×10^{-8}	1.28×10^{-5}	1.095×10^{0}	1.68×10^{-1}	1.75×10^{1}	8.18×10^{-2}
Layer 2	8.12×10^{-8}	6.22×10^{-9}	6.00×10^{-6}	5.47×10^{-1}	1.40×10^{-1}	8.88×10^{1}	0
Layer 3	1.99×10^{-8}	6.22×10^{-9}	6.00×10^{-6}	1.07×10^{-1}	1.62×10^{-1}	2.44×10^{0}	7.2×10^{-2}
Layer 4	1.56×10^{-8}	6.22×10^{-9}	6.00×10^{-6}	4.41×10^{-2}	8.10×10^{-2}	1.49×10^{0}	0
Layer 5	2.46×10^{-9}	6.22×10^{-9}	6.00×10^{-6}	4.41×10^{-2}	8.10×10^{-2}	1.49×10^{0}	0
Layer 6	2.75×10^{-10}	0.00×10^{0}	1.46×10^{-7}	1.23×10^{-4}	0.00×10^{0}	1.11×10^{0}	0
Maximum Concentration in Layers 1-6	1.60×10^{-6}	1.24×10^{-8}	1.28×10^{-5}	1.095×10^{0}	1.68×10^{-1}	8.88×10^{1}	8.18×10^{-2}

[a]Maximum concentrations are from measured groundwater data or the Supplemental Modeling Characterization.

TABLE 5-21

SOURCE CONCENTRATIONS
PERCHED WATER AS A LATERAL SOURCE AT THE FEMP

Source Area[a]	Contaminant of Potential Concern	Perched Water Concentrations[b]
OU1 "A" Area	Strontium-90	5.30×10^{0} pCi/L
	Technetium-99	1.07×10^{3} pCi/L
	Cyanide	1.50×10^{-2} mg/L
	Magnesium	1.62×10^{2} mg/L
	Vinyl Chloride	2.00×10^{0} μg/L
	Carbazole	7.04×10^{0} μg/L
OU1 "B" Area	Strontium-90	1.32×10^{0} pCi/L
	Uranium-234	6.93×10^{0} pCi/L
	Uranium-235/236	4.45×10^{0} pCi/L
	Uranium-238	1.03×10^{2} pCi/L
	Cadmium	4.92×10^{-1} mg/L
	Cyanide	7.94×10^{-2} mg/L
	Magnesium	5.76×10^{1} mg/L
	Mercury	2.00×10^{-3} mg/L
	Molybdenum	3.94×10^{1} mg/L
	Carbazole	7.04×10^{0} μg/L
OU4 Area	Technetium-99	2.01×10^{1} pCi/L
	Uranium-234	7.10×10^{0} pCi/L
	Uranium 235-236	6.10×10^{-1} pCi/L
	Uranium-238	8.20×10^{0} pCi/L
	Antimony	1.29×10^{2} mg/L
	Cadmium	1.18×10^{1} mg/L
	Cyanide	1.20×10^{-2} mg/L
	Magnesium	5.88×10^{1} mg/L
	Manganese	5.10×10^{-1} mg/L
	Mercury	2.00×10^{-3} mg/L
	Molybdenum	3.30×10^{-2} mg/L
	1,1,2,2-Tetrachloroethane	5.00×10^{0} μg/L
	1,1,2-Trichloroethane	2.00×10^{0} μg/L
	Bromoform	2.00×10^{0} μg/L
	Carbazole	7.04×10^{0} μg/L
	Trichloroethene	3.19×10^{0} μg/L

TABLE 5-21 (Continued)

Source Area[a]	Contaminant of Potential Concern	Perched Water Concentrations[b]
Pilot Plant Area	Technetium-99	9.97×10^{0} pCi/L
	Uranium-234	4.57×10^{1} pCi/L
	Uranium-235/236	4.40×10^{0} pCi/L
	Uranium-238	4.43×10^{1} pCi/L
	1,2-Dichloroethene	6.80×10^{1} μg/L
	1,1-Dichloroethane	1.00×10^{2} μg/L
	1,1-Dichloroethene	4.00×10^{0} μg/L
	Carbazole	6.85×10^{0} μg/L
	Tetrachloroethene	4.90×10^{1} μg/L
	Trichloroethene	5.30×10^{1} μg/L
Plant 2/3 Area	Technetium-99	2.07×10^{3} pCi/L
	Uranium-234	2.31×10^{4} pCi/L
	Uranium-235/236	1.85×10^{3} pCi/L
	Uranium-238	1.83×10^{4} pCi/L
	Cyanide	4.00×10^{-3} mg/L
Laboratory Area	Technetium-99	9.97×10^{0} pCi/L
	Uranium-234	2.53×10^{2} pCi/L
	Uranium-235/236	1.71×10^{1} pCi/L
	Uranium-238	1.72×10^{2} pCi/L
	Cyanide	2.87×10^{1} mg/L
	Magnesium	7.60×10^{1} mg/L
	1,1-Dichloroethene	2.40×10^{1} μg/L
	Carbazole	6.85×10^{0} μg/L

[a] See Figure 5-36 for location of Source Areas
[b] Maximum perched water detection in area

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TABLE 5-22

CONSTITUENTS OF POTENTIAL CONCERN SCREENING RESULTS IN THE GROUNDWATER PATHWAY VERTICAL MIGRATION

Potential COC	Existing GMA Plume	Additional Groundwater Loading	Surface Water Loading
Radionuclides			
Neptunium-237	X	X	X
Plutonium-238			X
Plutonium-239/240			X
Radium-226	X		X
Strontium-90		X	X
Technetium-99	X	X	X
Thorium-230			X
Thorium-232			X
Uranium-Total	X	X	X
Organics			
1,1-Dichloroethene			X
1,2-Dichloroethane		X	
3,3'-Dichlorobenzidine			X
4-Methylphenol			X
4-Nitroaniline		X	X
Alpha-chlordane		X	X
Arochlor-1254			X
Arochlor-1260			X
Benzene			X
Benzo(a)anthracene			X
Benzo(a)pyrene			X
Bis(2-chloroisopropyl)ether		X	X
Bromodichloromethane		X	X
Bromomethane			X

TABLE 5-22 (Continued)

Potential COC	Existing GMA Plume	Additional Groundwater Loading	Surface Water Loading
Organics (Continued)			
Carbazole		X	
Chloroform			X
Dibenzo(a,h)anthracene			X
Dieldrin			X
Methylene chloride			X
N-nitroso-di-n-propylamine			X
Inorganics			
Antimony	X		X
Arsenic	X		X
Beryllium			X
Boron		X	
Chromium (Hex)		X	
Cyanide			X
Lead			X
Magnesium		X	X
Manganese	X		X
Mercury		X	X

0 0 0 0

TABLE 5-23

CONSTITUENTS OF POTENTIAL CONCERN PERCHED WATER AS A LATERAL SOURCE AT THE FEMP

Constituents of Potential Concern	Source Area[a]					
	Plant 2/3	Pilot Plant Area	Laboratory Area	OU1 "A" Area	OU1 "B" Area	OU4 Area
Radionuclides						
Strontium-90				X	X	
Technetium-99	X	X	X	X		X
Uranium-234	X	X	X		X	X
Uranium-235/236	X	X	X		X	X
Uranium-238	X	X	X		X	X
Inorganics						
Antimony						X
Cadmium					X	X
Cyanide	X		X	X	X	X
Magnesium			X	X	X	X
Manganese						X
Mercury					X	X
Molybdenum					X	X
Organics						
1,1,2,2,-Tetrachloroethane						X
1,1,2-Trichloroethane						X
1,2-Dichloroethene		X				
1,1-Dichloroethane		X				
1,1-Dichloroethene		X	X			
Bromoform						X
Carbazole		X	X	X	X	X
Tetrachloroethene		X				
Trichloroethene		X				X
Vinyl Chloride				X		

[a] See Figure 5-36 for location of Source Areas

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TABLE 5-24a

MAXIMUM ANNUAL AVERAGE CONCENTRATIONS AT ON PROPERTY RECEPTORS (CURRENT SCENARIO)

Contaminant	Location* (X,Y)		Concentration
Radiological (pCi/m³)			
Cesium-137	1150	-850	5.10E-07
Neptunium-237	1200	-550	3.20E-07
Plutonium-238	1150	-850	1.80E-05
Plutonium-239/24	1150	-850	1.80E-06
Radium-226	1600	-250	4.80E-04
Radium-228	1700	-500	7.20E-05
Ruthenium-106	1000	-500	1.10E-06
Strontium-90	1200	-550	9.80E-07
Technetium-99	2000	-750	2.60E-05
Thorium-Total (ug/m3)	1550	-850	1.30E-04
Thorium-228	1150	-850	2.20E-05
Thorium-230	1700	-500	9.90E-04
Thorium-232	1150	-850	2.50E-05
Uranium, Total (ug/m3)	1150	-850	5.00E-03
Uranium-234	1150	-850	1.50E-03
Uranium-235/236	1150	-850	1.20E-04
Uranium-238	1150	-850	1.70E-03
Radon	1500	-200	3.52E+02
Inorganics (ug/m3)			
Aluminum	1000	-450	4.40E-03
Antimony	1000	-450	1.20E-05
Arsenic	700	-700	6.90E-06
Barium	1150	-750	1.20E-04
Beryllium	1150	-750	5.70E-07
Cadmium	700	-600	2.00E-06

TABLE 5-24a (Continued)

Contaminant	Location* (X,Y)		Concentration
Calcium	1000	-450	5.40E-02
Chromium	1000	-500	9.00E-06
Cobalt	1150	-750	4.70E-06
Copper	1350	-250	1.90E-05
Cyanide	1550	-800	2.20E-07
Iron	1000	-500	8.50E-03
Lead	1550	-800	3.80E-04
Magnesium	1400	-450	1.20E-02
Manganese	1150	-750	4.40E-04
Mercury	1150	-750	4.50E-07
Molybdenum	1150	-750	4.80E-06
Nickel	1150	-750	1.00E-05
Potassium	1000	-500	5.70E-04
Selenium	1150	-750	8.20E-07
Silicon	1050	-300	1.60E-03
Silver	1150	-750	4.30E-06
Sodium	1150	-750	4.60E-04
Thallium	700	-600	1.50E-07
Vanadium	1150	-750	1.10E-05
Zinc	1300	0	1.10E-04
Volatiles/Semi-Volatiles/PCBs (ug/m3)			
4,4'-DDE	1200	-650	4.10E-10
4,4'-DDT	1300	-100	3.10E-10
Alpha-chlordane	1050	-400	5.80E-11
Aroclor-1254	1200	-650	1.60E-07
Aroclor-1260	1300	-100	3.80E-09
Benzene	1300	-100	3.10E-11
Benzo(a)anthracene	1450	-350	2.10E-07
Benzo(a)pyrene	1450	-350	2.40E-07

TABLE 5-24a (Continued)

Contaminant	Location* (X,Y)		Concentration
Benzo(b)fluoranthane	1350	-500	2.20E-07
Benzo(k)fluoranthane	1450	-350	2.30E-07
Bis(2-ethylhexyl)phthalate	1300	-100	1.50E-08
Carbazole	1450	-350	3.00E-08
Chloroform	1300	-100	1.40E-10
Chrysene	1350	-500	1.20E-07
Dibenzo(a,h)anthracene	1450	-350	7.90E-08
Dieldrin	1200	-650	1.00E-10
Indeno(1,2,3-cd)pyrene	1350	-500	8.70E-08
Methylene chloride	1450	-350	1.40E-07
N-nitroso-di-n-propylamine	1300	-100	6.10E-10
N-nitrosodiphenylamine	1050	-350	1.50E-08
Octachlorodibenzo-p-dioxin	1050	-350	1.00E-11
Octachlorodibenzofuran	1300	-100	7.80E-12
Tetrachloroethene	950	200	1.90E-02
Trichloroethene	950	200	3.90E-02

* Distance in meters from origin located at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).

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TABLE 5-24b

MAXIMUM ANNUAL AVERAGE CONCENTRATIONS AT ON PROPERTY RECEPTORS (AGRICULTURAL SCENARIO)

Contaminant	Location* (X,Y)		Concentration
Radiological (pCi/m3)			
Cesium-137	1150	-850	1.40E-05
Neptunium-237	1200	-550	8.70E-06
Plutonium-238	1150	-850	4.80E-04
Plutonium-239/24	1150	-850	4.80E-05
Radium-226	1600	-250	1.30E-02
Radium-228	1700	-500	1.90E-03
Ruthenium-106	1000	-500	3.10E-05
Strontium-90	1200	-550	2.70E-05
Technetium-99	2000	-750	7.00E-04
Thorium-Total (ug/m3)	1550	-850	3.60E-03
Thorium-228	1150	-850	5.90E-04
Thorium-230	1700	-500	2.70E-02
Thorium-232	1150	-850	6.80E-04
Uranium, Total (ug/m3)	1150	-850	1.30E-01
Uranium-234	1150	-850	4.20E-02
Uranium-235/236	1150	-850	3.10E-03
Uranium-238	1150	-850	4.50E-02
Radon	1500	-200	3.52E+02
Inorganics (ug/m3)			
Aluminum	1000	-450	1.20E-01
Antimony	1000	-450	3.30E-04
Arsenic	700	-700	1.90E-04
Barium	1150	-750	3.20E-03
Beryllium	1150	-750	1.50E-05
Cadmium	700	-600	5.50E-05

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TABLE 5-24b (Continued)

Contaminant	Location* (X,Y)		Concentration
Calcium	1000	-450	1.50E+00
Chromium	1000	-500	2.40E-04
Cobalt	1150	-750	1.30E-04
Copper	1350	-250	5.10E-04
Cyanide	1550	-800	6.00E-06
Iron	1000	-500	2.30E-01
Lead	1550	-800	1.00E-02
Magnesium	1400	-450	3.10E-01
Manganese	1150	-750	1.20E-02
Mercury	1150	-750	1.20E-05
Molybdenum	1150	-750	1.30E-04
Nickel	1150	-750	2.80E-04
Potassium	1000	-500	1.50E-02
Selenium	1150	-750	2.20E-05
Silicon	1050	-300	4.40E-02
Silver	1150	-750	1.20E-04
Sodium	1150	-750	1.20E-02
Thallium	700	-600	4.10E-06
Vanadium	1150	-750	2.90E-04
Zinc	1300	0	3.00E-03
Volatiles/Semi-Volatiles/PCBs (ug/m3)			
4,4'-DDE	1200	-650	1.10E-08
4,4'-DDT	1300	-100	8.40E-09
Alpha-chlordane	1050	-400	1.60E-09
Aroclor-1254	1200	-650	4.20E-06
Aroclor-1260	1300	-100	1.00E-07
Benzene	1300	-100	8.40E-10
Benzo(a)anthracene	1450	-350	5.50E-06
Benzo(a)pyrene	1450	-350	6.40E-06

TABLE 5-24b (Continued)

Contaminant	Location* (X,Y)		Concentration
Benzo(b)fluoranthane	1350	-500	5.90E-06
Benzo(k)fluoranthane	1450	-350	6.30E-06
Bis(2-ethylhexyl)phthalate	1300	-100	4.00E-07
Carbazole	1450	-350	8.00E-07
Chloroform	1300	-100	3.80E-09
Chrysene	1350	-500	3.10E-06
Dibenzo(a,h)anthracene	1450	-350	2.10E-06
Dieldrin	1200	-650	2.70E-09
Indeno(1,2,3-cd)pyrene	1350	-500	2.30E-06
Methylene chloride	1450	-350	3.80E-06
N-nitroso-di-n-propylamine	1300	-100	1.60E-08
N-nitrosodiphenylamine	1050	-350	3.90E-07
Octachlorodibenzo-p-dioxin	1050	-350	2.80E-10
Octachlorodibenzofuran	1300	-100	2.10E-10
Tetrachloroethene	950	200	5.20E-01
Trichloroethene	950	200	1.00E+00

* Distance in meters from origin located at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).

TABLE 5-25a

MAXIMUM ANNUAL AVERAGE CONCENTRATIONS
AT OFF PROPERTY RECEPTORS
(CURRENT SCENARIO)

Contaminant	Location* (X,Y)		Concentration
Radiological (pCi/m³)			
Cesium-137	2050	-750	9.50E-08
Neptunium-237	2050	-650	1.50E-08
Plutonium-238	2050	-900	5.10E-07
Plutonium-239/24	2050	-800	1.70E-07
Radium-226	2050	-300	4.60E-05
Radium-228	2050	-550	3.30E-05
Ruthenium-106	1250	400	3.50E-08
Strontium-90	2050	-750	6.40E-07
Technetium-99	2050	-800	1.90E-05
Thorium-Total (ug/m3)	2050	-850	1.20E-05
Thorium-228	2050	-750	3.40E-06
Thorium-230	2050	-550	4.50E-04
Thorium-232	2050	-550	8.80E-06
Uranium, Total (ug/m3)	2050	-800	5.60E-04
Uranium-234	2050	-800	2.80E-04
Uranium-235/236	2050	-800	1.50E-05
Uranium-238	2050	-800	2.00E-04
Radon	2050	-200	8.21E+00
Inorganics (ug/m3)			
Aluminum	2050	-800	1.80E-03
Antimony	2050	-800	3.50E-06
Arsenic	2050	-800	2.20E-06
Barium	2050	-800	2.40E-05
Beryllium	2050	-800	2.50E-07
Cadmium	2050	-800	1.00E-06

TABLE 5-25a (Continued)

Contaminant	Location* (X,Y)		Concentration
Calcium	2050	-800	2.80E-02
Chromium	2050	-800	4.70E-06
Cobalt	2050	-800	2.00E-06
Copper	2050	-800	6.40E-06
Cyanide	2050	-800	1.40E-07
Iron	2050	-800	3.80E-03
Lead	2050	-1350	1.50E-04
Magnesium	2050	-800	8.80E-03
Manganese	2050	-800	2.50E-04
Mercury	2050	-800	9.60E-08
Molybdenum	2050	-800	1.50E-06
Nickel	2050	-800	5.30E-06
Potassium	2050	-800	2.30E-04
Selenium	1450	400	8.40E-08
Silicon	2050	-800	4.40E-04
Silver	2050	-800	1.10E-06
Sodium	2050	-800	6.10E-05
Thallium	2050	-800	6.20E-08
Vanadium	2050	-800	4.90E-06
Zinc	2050	-800	3.10E-05
Volatiles/Semi-Volatiles/PCBs (ug/m3)			
4,4'-DDE	1600	400	1.30E-11
4,4'-DDT	1450	400	3.80E-11
Alpha-chlordane	1250	400	3.80E-12
Aroclor-1254	1600	400	1.20E-08
Aroclor-1260	1450	400	4.00E-10
Benzene	1450	400	3.40E-12
Benzo(a)anthracene	1600	400	8.10E-09
Benzo(a)pyrene	1600	400	1.00E-08

TABLE 5-25a (Continued)

Contaminant	Location* (X,Y)		Concentration
Benzo(b)fluoranthane	2050	-750	1.00E-08
Benzo(k)fluoranthane	1600	400	1.00E-08
Bis(2-ethylhexyl)phthalate	1600	400	2.10E-09
Carbazole	2050	-750	2.10E-09
Chloroform	1450	400	1.60E-11
Chrysene	2050	-750	8.10E-09
Dibenzo(a,h)anthracene	1600	400	3.40E-09
Dieldrin	1550	400	4.10E-12
Indeno(1,2,3-cd)pyrene	2050	-750	6.70E-09
Methylene chloride	1750	450	2.40E-09
N-nitroso-di-n-propylamine	1450	400	6.60E-11
N-nitrosodiphenylamine	1250	400	9.20E-10
Octachlorodibenzo-p-dioxin	1450	400	9.10E-13
Octachlorodibenzofuran	1450	400	8.40E-13
Tetrachloroethene	950	400	7.20E-03
Trichloroethene	950	400	1.40E-02

* Distance in meters from origin located at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).

TABLE 5-25b

MAXIMUM ANNUAL AVERAGE CONCENTRATIONS
AT OFF PROPERTY RECEPTORS
(AGRICULTURAL SCENARIO)

Contaminant	Location* (X,Y)		Concentrations
Radiological (pCi/m3)			
Cesium-137	2050	-750	2.60E-06
Neptunium-237	2050	-650	4.10E-07
Plutonium-238	2050	-900	1.40E-05
Plutonium-239/24	2050	-800	4.60E-06
Radium-226	2050	-300	1.20E-03
Radium-228	2050	-550	8.80E-04
Ruthenium-106	1250	400	9.40E-07
Strontium-90	2050	-750	1.70E-05
Technetium-99	2050	-800	5.00E-04
Thorium-Total (ug/m3)	2050	-850	3.20E-04
Thorium-228	2050	-750	9.20E-05
Thorium-230	2050	-550	1.20E-02
Thorium-232	2050	-550	2.40E-04
Uranium, Total (ug/m3)	2050	-800	1.50E-02
Uranium-234	2050	-800	7.50E-03
Uranium-235/236	2050	-800	4.20E-04
Uranium-238	2050	-800	5.40E-03
Radon	2050	-200	8.21E+00
Inorganics (ug/m3)			
Aluminum	2050	-800	4.90E-02
Antimony	2050	-800	9.40E-05
Arsenic	2050	-800	6.00E-05
Barium	2050	-800	6.40E-04
Beryllium	2050	-800	6.80E-06
Cadmium	2050	-800	2.80E-05

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TABLE 5-25b (Continued)

Contaminant	Location* (X,Y)		Concentrations
Calcium	2050	-800	7.50E-01
Chromium	2050	-800	1.30E-04
Cobalt	2050	-800	5.30E-05
Copper	2050	-800	1.70E-04
Cyanide	2050	-800	3.80E-06
Iron	2050	-800	1.00E-01
Lead	2050	-1350	4.10E-03
Magnesium	2050	-800	2.40E-01
Manganese	2050	-800	6.80E-03
Mercury	2050	-800	2.60E-06
Molybdenum	2050	-800	4.10E-05
Nickel	2050	-800	1.40E-04
Potassium	2050	-800	6.20E-03
Selenium	1450	400	2.30E-06
Silicon	2050	-800	1.20E-02
Silver	2050	-800	3.00E-05
Sodium	2050	-800	1.70E-03
Thallium	2050	-800	1.70E-06
Vanadium	2050	-800	1.30E-04
Zinc	2050	-800	8.40E-04
Volatiles/Semi-Volatiles/PCBs (ug/m3)			
4,4'-DDE	1600	400	3.50E-10
4,4'-DDT	1450	400	1.00E-09
Alpha-chlordane	1250	400	1.00E-10
Aroclor-1254	1600	400	3.20E-07
Aroclor-1260	1450	400	1.10E-08
Benzene	1450	400	9.10E-11
Benzo(a)anthracene	1600	400	2.20E-07
Benzo(a)pyrene	1600	400	2.70E-07

TABLE 5-25b (Continued)

Contaminant	Location* (X,Y)		Concentrations
Benzo(b)fluoranthane	2050	-750	2.70E-07
Benzo(k)fluoranthane	1600	400	2.70E-07
Bis(2-ethylhexyl)phthalate	1600	400	5.60E-08
Carbazole	2050	-750	5.70E-08
Chloroform	1450	400	4.20E-10
Chrysene	2050	-750	2.20E-07
Dibenzo(a,h)anthracene	1600	400	9.20E-08
Dieldrin	1550	400	1.10E-10
Indeno(1,2,3-cd)pyrene	2050	-750	1.80E-07
Methylene chloride	1750	450	6.60E-08
N-nitroso-di-n-propylamine	1450	400	1.80E-09
N-nitrosodiphenylamine	1250	400	2.50E-08
Octachlorodibenzo-p-dioxin	1450	400	2.50E-11
Octachlorodibenzofuran	1450	400	2.30E-11
Tetrachloroethene	950	400	1.90E-01
Trichloroethene	950	400	3.90E-01

* Distance in meters from origin located at State Planer coordinates 482,752.690 feet (North) and 1,376,778.760 feet (East).

TABLE 5-26a

MAXIMUM ANNUAL AVERAGE CONCENTRATIONS
AT DISCRETE RECEPTORS
(CURRENT SCENARIO)

	Crosby Elementary	Morgan Elementary	Elda Elementary	St. Johns Elementary	Ross Middle High School	Ross County Day Nursery	Knolmanns Dairy Farm	East (near the Great Miami River)	South (near the Great Miami River)	Paddys Run Road	Town of Fernald
Radiological (pCi/m3)											
Cesium-137	4.80E-09	2.50E-09	6.00E-09	4.50E-09	5.20E-09	5.70E-09	1.30E-08	1.40E-08	3.10E-09	8.70E-09	4.20E-09
Neptunium-237	1.30E-09	3.40E-10	1.40E-09	8.80E-10	1.20E-09	1.30E-09	4.50E-09	4.20E-09	1.10E-09	3.20E-09	1.50E-09
Plutonium-238	3.80E-08	7.10E-09	3.70E-08	2.20E-08	3.00E-08	3.40E-08	1.70E-07	1.20E-07	3.40E-08	1.10E-07	4.70E-08
Plutonium-239/24	5.50E-09	1.00E-09	5.60E-09	3.30E-09	4.60E-09	5.30E-09	2.30E-08	1.90E-08	4.90E-09	1.50E-08	6.70E-09
Radium-226	1.10E-06	4.40E-08	1.60E-06	6.00E-07	1.20E-06	1.50E-06	4.80E-06	7.20E-06	1.30E-06	3.10E-06	1.80E-06
Radium-228	3.20E-07	1.10E-08	3.80E-07	1.60E-07	2.80E-07	3.50E-07	1.80E-06	1.90E-06	3.50E-07	1.10E-06	5.00E-07
Ruthenium-106	2.50E-09	8.50E-11	2.10E-09	1.00E-09	1.70E-09	2.00E-09	8.60E-09	7.90E-09	2.30E-09	6.20E-09	3.00E-09
Strontium-90	7.60E-09	2.60E-10	8.90E-09	3.80E-09	6.70E-09	8.30E-09	3.90E-08	4.40E-08	8.40E-09	2.30E-08	1.20E-08
Technetium-99	8.20E-08	2.60E-08	1.10E-07	6.40E-08	9.10E-08	1.10E-07	4.10E-07	5.30E-07	7.10E-08	1.80E-07	1.00E-07
Thorium-Total (ug/m3)	4.00E-07	1.40E-08	4.50E-07	2.00E-07	3.40E-07	4.20E-07	2.10E-06	2.10E-06	4.50E-07	1.30E-06	6.60E-07
Thorium-228	1.10E-07	5.40E-08	1.40E-07	1.00E-07	1.20E-07	1.30E-07	3.60E-07	3.40E-07	7.50E-08	2.30E-07	1.00E-07
Thorium-230	2.80E-06	1.10E-07	3.90E-06	1.50E-06	2.80E-06	3.60E-06	1.70E-05	2.10E-05	3.30E-06	9.30E-06	4.60E-06
Thorium-232	1.90E-07	6.10E-08	2.30E-07	1.40E-07	1.90E-07	2.10E-07	7.60E-07	7.70E-07	1.50E-07	4.50E-07	2.20E-07
Uranium, Total (ug/m3)	1.30E-05	3.00E-06	1.40E-05	8.50E-06	1.10E-05	1.30E-05	5.90E-05	4.80E-05	1.20E-05	3.70E-05	1.70E-05
Uranium-234	3.90E-06	2.90E-07	4.10E-06	2.00E-06	3.10E-06	3.80E-06	2.10E-05	1.80E-05	4.10E-06	1.20E-05	5.70E-06
Uranium-235/236	3.40E-07	4.60E-08	3.50E-07	1.90E-07	2.80E-07	3.30E-07	1.60E-06	1.30E-06	3.30E-07	1.00E-06	4.50E-07
Uranium-238	4.70E-06	1.00E-06	5.00E-06	3.00E-06	4.10E-06	4.70E-06	2.10E-05	1.80E-05	4.20E-06	1.30E-05	5.90E-06
Radon	1.66E-01	7.89E-01	4.30E-01	1.65E-01	2.80E-01	3.78E-01	1.03E+00	1.44E+00	1.43E-01	3.42E-01	2.01E-01

TABLE 5-26a (Continued)

	Crosby Elementary	Morgan Elementary	Elda Elementary	St. Johns Elementary	Ross Middle High School	Ross County Day Nursery	Knolmanns Dairy Farm	East (near the Great Miami River)	South (near the Great Miami River)	Paddys Run Road	Town of Fernald
Inorganics (ug/m3)											
Aluminum	6.00E-05	2.20E-06	5.80E-05	2.60E-05	4.50E-05	5.40E-05	3.30E-04	2.50E-04	5.90E-05	1.70E-04	8.20E-05
Antimony	1.30E-07	4.70E-09	1.10E-07	5.30E-08	8.70E-08	1.00E-07	5.50E-07	4.70E-07	1.20E-07	3.10E-07	1.60E-07
Arsenic	7.30E-08	2.70E-09	6.40E-08	3.00E-08	5.00E-08	6.00E-08	3.50E-07	2.80E-07	6.70E-08	1.80E-07	9.20E-08
Barium	8.70E-07	3.00E-08	8.40E-07	3.90E-07	6.50E-07	7.90E-07	4.50E-06	3.60E-06	8.70E-07	2.50E-06	1.20E-06
Beryllium	6.90E-09	2.40E-10	6.70E-09	3.10E-09	5.20E-09	6.30E-09	3.70E-08	3.00E-08	6.80E-09	2.00E-08	9.50E-09
Cadmium	2.90E-08	1.10E-09	2.70E-08	1.20E-08	2.10E-08	2.60E-08	1.40E-07	1.20E-07	2.70E-08	7.20E-08	3.70E-08
Calcium	7.60E-04	2.70E-05	7.50E-04	3.40E-04	5.80E-04	7.00E-04	4.20E-03	3.30E-03	7.60E-04	2.20E-03	1.10E-03
Chromium	1.20E-07	4.40E-09	1.20E-07	5.50E-08	9.30E-08	1.10E-07	6.40E-07	5.40E-07	1.20E-07	3.30E-07	1.70E-07
Cobalt	6.40E-08	2.30E-09	6.10E-08	2.80E-08	4.70E-08	5.70E-08	3.30E-07	2.60E-07	6.20E-08	1.70E-07	8.60E-08
Copper	2.10E-07	7.30E-09	2.30E-07	1.00E-07	1.70E-07	2.10E-07	1.40E-06	1.00E-06	2.20E-07	6.00E-07	3.10E-07
Cyanide	3.20E-09	1.10E-10	3.40E-09	1.50E-09	2.60E-09	3.20E-09	2.20E-08	1.60E-08	3.40E-09	9.60E-09	4.80E-09
Iron	1.20E-04	4.30E-06	1.20E-04	5.30E-05	9.00E-05	1.10E-04	6.50E-04	5.10E-04	1.20E-04	3.30E-04	1.60E-04
Lead	2.70E-06	7.70E-08	3.00E-06	1.30E-06	2.20E-06	2.70E-06	3.00E-05	1.50E-05	3.00E-06	8.60E-06	4.50E-06
Magnesium	1.80E-04	6.10E-06	1.80E-04	8.00E-05	1.40E-04	1.70E-04	1.00E-03	8.20E-04	1.80E-04	4.90E-04	2.50E-04
Manganese	6.40E-06	2.30E-07	6.10E-06	2.80E-06	4.70E-06	5.70E-06	3.30E-05	2.70E-05	6.20E-06	1.70E-05	8.50E-06
Mercury	2.40E-09	8.20E-11	2.50E-09	1.10E-09	1.90E-09	2.30E-09	1.30E-08	1.10E-08	2.50E-09	7.20E-09	3.50E-09
Molybdenum	4.70E-08	1.70E-09	4.90E-08	2.20E-08	3.80E-08	4.60E-08	2.70E-07	2.20E-07	4.80E-08	1.30E-07	6.70E-08
Nickel	1.50E-07	5.30E-09	1.40E-07	6.40E-08	1.10E-07	1.30E-07	7.20E-07	6.20E-07	1.40E-07	3.90E-07	2.00E-07
Potassium	7.60E-06	2.70E-07	7.30E-06	3.40E-06	5.70E-06	6.90E-06	4.00E-05	3.20E-05	7.50E-06	2.10E-05	1.00E-05
Selenium	5.90E-09	2.10E-10	5.30E-09	2.60E-09	4.20E-09	5.00E-09	2.70E-08	2.10E-08	5.80E-09	1.70E-08	7.90E-09

TABLE 5-26a (Continued)

	Crosby Elementary	Morgan Elementary	Elda Elementary	St. Johns Elementary	Ross Middle High School	Ross County Day Nursery	Knolmanns Dairy Farm	East (near the Great Miami River)	South (near the Great Miami River)	Paddys Run Road	Town of Fernald
Silicon	1.10E-05	4.10E-07	1.10E-05	4.90E-06	8.40E-06	1.00E-05	4.70E-05	4.60E-05	1.10E-05	2.90E-05	1.50E-05
Silver	5.10E-08	1.90E-09	4.80E-08	2.20E-08	3.70E-08	4.50E-08	2.60E-07	2.00E-07	4.90E-08	1.30E-07	6.80E-08
Sodium	2.50E-06	8.80E-08	2.50E-06	1.10E-06	1.90E-06	2.30E-06	1.20E-05	1.00E-05	2.60E-06	7.50E-06	3.50E-06
Thallium	2.10E-09	7.80E-11	2.00E-09	9.20E-10	1.60E-09	1.90E-09	9.80E-09	8.70E-09	2.00E-09	5.30E-09	2.70E-09
Vanadium	1.50E-07	5.40E-09	1.50E-07	6.70E-08	1.10E-07	1.40E-07	8.10E-07	6.40E-07	1.50E-07	4.20E-07	2.10E-07
Zinc	9.20E-07	3.40E-08	1.00E-06	4.30E-07	8.00E-07	9.60E-07	4.30E-06	4.50E-06	9.40E-07	2.40E-06	1.30E-06
Volatiles/Semi-Volatiles/PCBs (ug/m3)											
4,4'-DDE	4.90E-13	<1.00E-14	8.40E-13	4.20E-13	5.30E-13	7.20E-13	4.60E-12	2.90E-12	8.00E-13	2.50E-12	1.20E-12
4,4'-DDT	6.50E-13	<1.00E-14	1.30E-12	5.40E-13	8.50E-13	1.20E-12	4.80E-12	4.90E-12	9.70E-13	2.70E-12	1.40E-12
Alpha-chlordane	1.30E-13	<1.00E-14	1.90E-13	9.20E-14	1.30E-13	1.70E-13	7.90E-13	6.30E-13	1.70E-13	4.90E-13	2.50E-13
Aroclor-1254	2.70E-10	<1.00E-14	5.70E-10	2.50E-10	3.70E-10	5.00E-10	2.40E-09	2.20E-09	4.50E-10	1.30E-09	6.50E-10
Aroclor-1260	5.00E-12	<1.00E-14	1.20E-11	4.30E-12	7.40E-12	1.00E-11	3.40E-11	4.50E-11	7.40E-12	1.90E-11	1.10E-11
Benzene	4.20E-14	<1.00E-14	9.60E-14	3.60E-14	6.20E-14	8.40E-14	2.90E-13	3.70E-13	6.20E-14	1.60E-13	8.80E-14
Benzo(a)anthracene	1.80E-10	<1.00E-14	3.70E-10	1.70E-10	2.20E-10	2.70E-10	1.30E-09	1.40E-09	2.40E-10	6.80E-10	3.30E-10
Benzo(a)pyrene	2.10E-10	<1.00E-14	4.40E-10	2.00E-10	2.60E-10	3.10E-10	1.50E-09	1.60E-09	2.80E-10	7.80E-10	3.80E-10
Benzo(b)fluoranthene	2.00E-10	<1.00E-14	4.10E-10	1.70E-10	2.60E-10	3.30E-10	1.50E-09	1.60E-09	2.80E-10	7.60E-10	4.30E-10
Benzo(k)fluoranthene	2.00E-10	<1.00E-14	4.10E-10	1.80E-10	2.50E-10	3.10E-10	1.40E-09	1.60E-09	2.60E-10	7.20E-10	3.50E-10
Bis(2-ethylhexyl)phthalate	4.50E-11	<1.00E-14	8.70E-11	3.70E-11	5.70E-11	7.60E-11	3.60E-10	3.40E-10	6.70E-11	1.90E-10	9.70E-11
Carbazole	1.90E-11	<1.00E-14	3.80E-11	1.70E-11	2.10E-11	2.50E-11	1.50E-10	1.60E-10	2.40E-11	6.70E-11	3.00E-11
Chloroform	2.20E-13	<1.00E-14	5.00E-13	1.90E-13	3.20E-13	4.30E-13	1.60E-12	1.90E-12	3.30E-13	8.70E-13	4.80E-13
Chrysene	1.60E-10	<1.00E-14	3.30E-10	1.40E-10	2.10E-10	2.80E-10	1.20E-09	1.30E-09	2.40E-10	6.50E-10	3.50E-10

TABLE 5-26a (Continued)

	Crosby Elementary	Morgan Elementary	Elda Elementary	St. Johns Elementary	Ross Middle High School	Ross County Day Nursery	Knolmanns Dairy Farm	East (near the Great Miami River)	South (near the Great Miami River)	Paddys Run Road	Town of Fernald
Dibenzo(a,h)anthracene	6.70E-11	<1.00E-14	1.40E-10	6.30E-11	8.40E-11	1.00E-10	4.80E-10	5.30E-10	8.80E-11	2.40E-10	1.20E-10
Dieldrin	1.60E-13	<1.00E-14	2.60E-13	1.30E-13	1.70E-13	2.20E-13	1.30E-12	8.70E-13	2.40E-13	7.30E-13	3.50E-13
Indeno(1,2,3-cd)pyrene	1.20E-10	<1.00E-14	2.50E-10	1.10E-10	1.60E-10	2.10E-10	9.40E-10	9.90E-10	1.80E-10	4.90E-10	2.70E-10
Methylene chloride	5.00E-11	<1.00E-14	1.00E-10	5.00E-11	5.10E-11	5.10E-11	3.00E-10	3.50E-10	5.10E-11	1.50E-10	5.20E-11
N-nitroso-di-n-propylamine	8.20E-13	<1.00E-14	1.90E-12	7.00E-13	1.20E-12	1.60E-12	5.60E-12	7.30E-12	1.20E-12	3.00E-12	1.70E-12
N-nitrosodiphenylamine	2.70E-11	<1.00E-14	4.10E-11	1.80E-11	2.80E-11	3.60E-11	1.40E-10	1.30E-10	3.30E-11	8.90E-11	4.80E-11
Octachlorodibenzo-p-dioxin	2.20E-14	<1.00E-14	3.60E-14	1.60E-14	2.50E-14	3.20E-14	1.20E-13	1.20E-13	2.80E-14	7.50E-14	4.10E-14
Octachlorodibenzofuran	1.00E-14	<1.00E-14	2.40E-14	9.00E-15	1.50E-14	2.10E-14	7.10E-14	9.30E-14	1.50E-14	3.90E-14	2.20E-14
Tetrachloroethene	5.00E-05	<1.00E-14	6.20E-05	2.40E-05	4.40E-05	5.80E-05	1.40E-04	1.90E-04	4.40E-05	1.00E-04	6.00E-05
Trichloroethene	1.00E-04	<1.00E-14	1.20E-04	4.80E-05	8.80E-05	1.20E-04	2.80E-04	3.80E-04	8.80E-05	2.00E-04	1.20E-04

TABLE 5-26b

MAXIMUM ANNUAL AVERAGE CONCENTRATIONS
AT DISCRETE RECEPTORS
(AGRICULTURAL SCENARIO)

	Crosby Elementary	Morgan Elementary	Elda Elementary	St. Johns Elementary	Ross Middle High School	Ross County Day Nursery	Knolmanns Dairy Farm	East (near the Great Miami River)	South (near the Great Miami River)	Paddys Run Road	Town of Fernald
Radiological (pCi/m3)											
Cesium-137	7.70E-08	2.60E-09	8.10E-08	3.60E-08	6.30E-08	7.60E-08	3.50E-07	3.60E-07	8.00E-08	2.30E-07	1.10E-07
Neptunium-237	2.80E-08	9.60E-10	2.70E-08	1.30E-08	2.10E-08	2.60E-08	1.20E-07	1.10E-07	3.00E-08	8.50E-08	4.00E-08
Plutonium-238	8.90E-07	2.70E-08	7.90E-07	3.90E-07	6.00E-07	7.30E-07	4.50E-06	3.10E-06	9.10E-07	3.00E-06	1.30E-06
Plutonium-239/24	1.30E-07	4.20E-09	1.20E-07	5.70E-08	9.40E-08	1.10E-07	6.10E-07	5.10E-07	1.30E-07	4.00E-07	1.80E-07
Radium-226	3.00E-05	1.20E-06	4.20E-05	1.60E-05	3.30E-05	4.00E-05	1.30E-04	1.90E-04	3.40E-05	8.30E-05	4.70E-05
Radium-228	8.60E-06	2.80E-07	1.00E-05	4.20E-06	7.60E-06	9.40E-06	4.80E-05	5.10E-05	9.50E-06	2.90E-05	1.30E-05
Ruthenium-106	6.70E-08	2.40E-09	5.50E-08	2.80E-08	4.50E-08	5.30E-08	2.30E-07	2.10E-07	6.10E-08	1.70E-07	8.20E-08
Strontium-90	2.00E-07	7.00E-09	2.40E-07	1.00E-07	1.80E-07	2.20E-07	1.00E-06	1.20E-06	2.30E-07	6.10E-07	3.10E-07
Technetium-99	1.70E-06	5.40E-08	2.30E-06	8.90E-07	1.70E-06	2.10E-06	1.10E-05	1.40E-05	1.90E-06	4.70E-06	2.70E-06
Thorium-Total (ug/m3)	1.10E-05	3.40E-07	1.20E-05	5.30E-06	9.00E-06	1.10E-05	5.80E-05	5.50E-05	1.20E-05	3.40E-05	1.80E-05
Thorium-228	1.90E-06	6.20E-08	2.00E-06	8.70E-07	1.50E-06	1.80E-06	9.50E-06	9.00E-06	2.00E-06	6.00E-06	2.80E-06
Thorium-230	7.60E-05	2.50E-06	1.00E-04	4.00E-05	7.60E-05	9.50E-05	4.50E-04	5.70E-04	8.80E-05	2.50E-04	1.20E-04
Thorium-232	3.70E-06	1.20E-07	4.30E-06	1.80E-06	3.20E-06	3.90E-06	2.00E-05	2.10E-05	4.10E-06	1.20E-05	5.80E-06
Uranium, Total (ug/m3)	3.10E-04	9.70E-06	2.90E-04	1.40E-04	2.20E-04	2.70E-04	1.60E-03	1.30E-03	3.20E-04	1.00E-03	4.40E-04
Uranium-234	1.00E-04	3.20E-06	1.00E-04	4.80E-05	7.90E-05	9.70E-05	5.60E-04	4.90E-04	1.10E-04	3.40E-04	1.50E-04
Uranium-235/236	8.30E-06	2.70E-07	8.20E-06	3.80E-06	6.20E-06	7.60E-06	4.20E-05	3.60E-05	8.80E-06	2.70E-05	1.20E-05
Uranium-238	1.10E-04	3.40E-06	1.10E-04	4.90E-05	8.10E-05	9.90E-05	5.60E-04	4.70E-04	1.10E-04	3.50E-04	1.60E-04
Radon	1.66E-01	7.89E-02	4.30E-01	1.65E-01	2.80E-01	3.78E-01	1.03E+00	1.44E+00	1.43E-01	3.42E-01	2.01E-01

TABLE 5-26b (Continued)

	Crosby Elementary	Morgan Elementary	Elda Elementary	St. Johns Elementary	Ross Middle High School	Ross County Day Nursery	Knolmanns Dairy Farm	East (near the Great Miami River)	South (near the Great Miami River)	Paddys Run Road	Town of Fernald
Inorganics (ug/m3)											
Aluminum	1.60E-03	5.80E-05	1.60E-03	7.20E-04	1.20E-03	1.50E-03	8.80E-03	6.80E-03	1.60E-03	4.50E-03	2.20E-03
Antimony	3.40E-06	1.30E-07	3.00E-06	1.40E-06	2.30E-06	2.80E-06	1.50E-05	1.30E-05	3.10E-06	8.50E-06	4.30E-06
Arsenic	2.00E-06	7.40E-08	1.70E-06	8.20E-07	1.30E-06	1.60E-06	9.50E-06	7.40E-06	1.80E-06	5.00E-06	2.50E-06
Barium	2.30E-05	8.10E-07	2.30E-05	1.00E-05	1.80E-05	2.10E-05	1.20E-04	9.70E-05	2.40E-05	6.80E-05	3.30E-05
Beryllium	1.90E-07	6.60E-09	1.80E-07	8.30E-08	1.40E-07	1.70E-07	9.90E-07	8.00E-07	1.80E-07	5.30E-07	2.60E-07
Cadmium	7.70E-07	2.90E-08	7.40E-07	3.40E-07	5.70E-07	6.90E-07	3.70E-06	3.20E-06	7.30E-07	2.00E-06	1.00E-06
Calcium	2.00E-02	7.20E-04	2.00E-02	9.20E-03	1.60E-02	1.90E-02	1.10E-01	9.00E-02	2.10E-02	5.90E-02	2.90E-02
Chromium	3.30E-06	1.20E-07	3.30E-06	1.50E-06	2.50E-06	3.10E-06	1.70E-05	1.50E-05	3.30E-06	9.00E-06	4.50E-06
Cobalt	1.70E-06	6.20E-08	1.60E-06	7.60E-07	1.30E-06	1.50E-06	9.00E-06	7.10E-06	1.70E-06	4.70E-06	2.30E-06
Copper	5.70E-06	2.00E-07	6.10E-06	2.70E-06	4.70E-06	5.70E-06	3.90E-05	2.80E-05	6.00E-06	1.60E-05	8.40E-06
Cyanide	8.70E-08	2.90E-09	9.20E-08	4.10E-08	6.90E-08	8.50E-08	6.00E-07	4.20E-07	9.20E-08	2.60E-07	1.30E-07
Iron	3.20E-03	1.20E-04	3.10E-03	1.40E-03	2.40E-03	2.90E-03	1.80E-02	1.40E-02	3.20E-03	9.00E-03	4.40E-03
Lead	7.20E-05	2.10E-06	8.10E-05	3.60E-05	5.90E-05	7.40E-05	8.00E-04	3.90E-04	8.20E-05	2.30E-04	1.20E-04
Magnesium	4.70E-03	1.70E-04	4.80E-03	2.20E-03	3.70E-03	4.50E-03	2.80E-02	2.20E-02	4.80E-03	1.30E-02	6.70E-03
Manganese	1.70E-04	6.20E-06	1.60E-04	7.50E-05	1.30E-04	1.50E-04	8.90E-04	7.20E-04	1.70E-04	4.70E-04	2.30E-04
Mercury	6.50E-08	2.20E-09	6.60E-08	3.00E-08	5.10E-08	6.20E-08	3.40E-07	2.90E-07	6.80E-08	2.00E-07	9.40E-08
Molybdenum	1.30E-06	4.40E-08	1.30E-06	5.90E-07	1.00E-06	1.20E-06	7.20E-06	5.80E-06	1.30E-06	3.50E-06	1.80E-06
Nickel	3.90E-06	1.40E-07	3.80E-06	1.70E-06	3.00E-06	3.60E-06	2.00E-05	1.70E-05	3.80E-06	1.00E-05	5.30E-06
Potassium	2.10E-04	7.30E-06	2.00E-04	9.10E-05	1.50E-04	1.90E-04	1.10E-03	8.60E-04	2.00E-04	5.60E-04	2.80E-04
Selenium	1.60E-07	5.70E-09	1.40E-07	6.90E-08	1.10E-07	1.40E-07	7.40E-07	5.80E-07	1.60E-07	4.60E-07	2.10E-07

TABLE 5-26b (Continued)

	Crosby Elementary	Morgan Elementary	Elda Elementary	St. Johns Elementary	Ross Middle High School	Ross County Day Nursery	Knolmanns Dairy Farm	East (near the Great Miami River)	South (near the Great Miami River)	Paddys Run Road	Town of Fernald
Silicon	3.00E-04	1.10E-05	2.90E-04	1.30E-04	2.30E-04	2.70E-04	1.30E-03	1.30E-03	2.90E-04	7.80E-04	3.90E-04
Silver	1.40E-06	5.00E-08	1.30E-06	6.00E-07	1.00E-06	1.20E-06	7.10E-06	5.50E-06	1.30E-06	3.60E-06	1.80E-06
Sodium	6.80E-05	2.40E-06	6.60E-05	3.10E-05	5.10E-05	6.20E-05	3.30E-04	2.80E-04	6.90E-05	2.00E-04	9.50E-05
Thallium	5.60E-08	2.10E-09	5.50E-08	2.50E-08	4.30E-08	5.10E-08	2.70E-07	2.30E-07	5.40E-08	1.40E-07	7.40E-08
Vanadium	4.10E-06	1.50E-07	4.00E-06	1.80E-06	3.10E-06	3.70E-06	2.20E-05	1.70E-05	4.00E-06	1.10E-05	5.60E-06
Zinc	2.50E-05	9.20E-07	2.80E-05	1.20E-05	2.20E-05	2.60E-05	1.20E-04	1.20E-04	2.50E-05	6.60E-05	3.50E-05
Volatiles/Semi-Volatiles/PCBs (ug/m3)											
4,4'-DDE	1.30E-11	<1.00E-14	2.30E-11	1.10E-11	1.50E-11	2.00E-11	1.20E-10	7.70E-11	2.10E-11	6.80E-11	3.20E-11
4,4'-DDT	1.70E-11	<1.00E-14	3.60E-11	1.50E-11	2.30E-11	3.10E-11	1.30E-10	1.30E-10	2.60E-11	7.20E-11	3.80E-11
Alpha-chlordane	3.50E-12	<1.00E-14	5.30E-12	2.50E-12	3.50E-12	4.70E-12	2.10E-11	1.70E-11	4.60E-12	1.30E-11	6.70E-12
Aroclor-1254	7.40E-09	<1.00E-14	1.50E-08	6.60E-09	1.00E-08	1.40E-08	6.60E-08	5.90E-08	1.20E-08	3.60E-08	1.70E-08
Aroclor-1260	1.30E-10	<1.00E-14	3.10E-10	1.20E-10	2.00E-10	2.70E-10	9.30E-10	1.20E-09	2.00E-10	5.10E-10	2.80E-10
Benzene	1.10E-12	<1.00E-14	2.60E-12	9.70E-13	1.70E-12	2.30E-12	7.70E-12	1.00E-11	1.70E-12	4.20E-12	2.40E-12
Benzo(a)anthracene	4.10E-09	7.40E-13	9.20E-09	3.80E-09	6.00E-09	8.10E-09	3.50E-08	3.70E-08	6.80E-09	1.90E-08	9.60E-09
Benzo(a)pyrene	4.80E-09	7.80E-13	1.10E-08	4.40E-09	7.10E-09	9.60E-09	4.00E-08	4.40E-08	7.80E-09	2.10E-08	1.10E-08
Benzo(b)fluoranthene	4.90E-09	7.10E-13	1.10E-08	4.40E-09	6.90E-09	9.30E-09	4.00E-08	4.20E-08	7.80E-09	2.10E-08	1.10E-08
Benzo(k)fluoranthene	4.60E-09	7.90E-13	1.00E-08	4.10E-09	6.80E-09	9.20E-09	3.70E-08	4.30E-08	7.30E-09	1.90E-08	1.00E-08
Bis(2-ethylhexyl) phthalate	1.20E-09	9.30E-12	2.30E-09	9.80E-10	1.50E-09	2.10E-09	9.60E-09	9.30E-09	1.80E-09	5.20E-09	2.60E-09
Carbazole	4.10E-10	9.10E-14	9.20E-10	3.70E-10	5.90E-10	8.10E-10	3.90E-09	4.30E-09	6.70E-10	1.80E-09	9.30E-10
Chloroform	5.90E-12	<1.00E-14	1.30E-11	5.20E-12	8.70E-12	1.20E-11	4.40E-11	5.20E-11	9.00E-12	2.40E-11	1.30E-11
Chrysene	4.20E-09	9.80E-13	8.60E-09	3.60E-09	5.60E-09	7.60E-09	3.40E-08	3.40E-08	6.50E-09	1.80E-08	9.30E-09

TABLE 5-26b (Continued)

	Crosby Elementary	Morgan Elementary	Elda Elementary	St. Johns Elementary	Ross Middle High School	Ross County Day Nursery	Knolmanns Dairy Farm	East (near the Great Miami River)	South (near the Great Miami River)	Paddys Run Road	Town of Fernald
Dibenzo(a,h)anthracene	1.50E-09	<1.00E-14	3.50E-09	1.40E-09	2.30E-09	3.10E-09	1.30E-08	1.50E-08	2.50E-09	6.60E-09	3.50E-09
Dieldrin	4.30E-12	<1.00E-14	7.00E-12	3.40E-12	4.60E-12	6.20E-12	3.50E-11	2.30E-11	6.50E-12	2.00E-11	9.50E-12
Indeno(1,2,3-cd)pyrene	3.20E-09	5.20E-13	6.70E-09	2.80E-09	4.40E-09	5.90E-09	2.50E-08	2.70E-08	4.90E-09	1.30E-08	7.10E-09
Methylene chloride	8.20E-10	<1.00E-14	2.30E-09	8.60E-10	1.50E-09	2.00E-09	7.80E-09	9.90E-09	1.50E-09	4.00E-09	2.00E-09
N-nitroso-di-n-propylamine	2.20E-11	<1.00E-14	5.00E-11	1.90E-11	3.30E-11	4.40E-11	1.50E-10	2.00E-10	3.30E-11	8.30E-11	4.60E-11
N-nitrosodiphenylamine	7.20E-10	<1.00E-14	1.10E-09	4.90E-10	7.40E-10	9.80E-10	3.70E-09	3.60E-09	9.00E-10	2.40E-09	1.30E-09
Octachlorodibenzo-p-dioxin	6.00E-13	<1.00E-14	9.80E-13	4.20E-13	6.50E-13	8.70E-13	3.20E-12	3.40E-12	7.70E-13	2.00E-12	1.10E-12
Octachlorodibenzofuran	2.80E-13	<1.00E-14	6.50E-13	2.40E-13	4.20E-13	5.70E-13	1.90E-12	2.50E-12	4.20E-13	1.10E-12	5.90E-13
Tetrachloroethene	1.40E-03	6.90E-13	1.70E-03	6.70E-04	1.20E-03	1.60E-03	3.80E-03	5.20E-03	1.20E-03	2.70E-03	1.60E-03
Trichloroethene	2.70E-03	4.50E-13	3.40E-03	1.30E-03	2.40E-03	3.10E-03	7.50E-03	1.00E-02	2.40E-03	5.50E-03	3.30E-03

5696

TABLE 5-27

SUMMARY OF PREDICTED CONCENTRATIONS OF CONSTITUENTS OF POTENTIAL CONCERN IN SEDIMENT BASELINE CONDITION

Constituents of Potential Concern	Maximum Concentration (mg/kg)	Major Impacted Area
Radionuclides		
Neptunium-237	9.07×10^{-04}	North side drainage ditch
Plutonium-238	1.02×10^{-07}	East side drainage ditch
Radium-226	3.87×10^{-05}	North side drainage ditch
Strontium-90	1.45×10^{-08}	North side drainage ditch
Technetium-99	6.03×10^{-04}	Paddys Run near South Field
Uranium-Total	$5.52 \times 10^{+02}$	Pilot Plant drainage ditch
Organics		
1,1-Dichloroethene	2.20×10^{-03}	East side drainage ditch
3,3'-Dichlorobenzidine	3.33×10^{-02}	North side drainage ditch
4-Methylphenol	$1.23 \times 10^{+00}$	Lower SSOD
4-Nitroaniline	2.77×10^{-02}	North side drainage ditch
Aroclor-1254	3.72×10^{-01}	North side drainage ditch
Benzene	1.98×10^{-03}	North side drainage ditch
Benzo(a)anthracene	$1.70 \times 10^{+00}$	North side drainage ditch
Benzo(a)pyrene	$2.14 \times 10^{+00}$	North side drainage ditch
Bis(2-chloroisopropyl)ether	1.76×10^{-02}	Pilot Plant drainage ditch
Bromodichloromethane	3.39×10^{-03}	Paddys Run near South Field
Chloroform	1.90×10^{-02}	Paddys Run near South Field
Dibenzo(a,h)anthracene	6.19×10^{-01}	North side drainage ditch
Dieldrin	1.58×10^{-02}	North side drainage ditch
Methylene chloride	1.32×10^{-01}	North side drainage ditch
N-Nitroso-di-n-propylamine	3.68×10^{-03}	North side drainage ditch

TABLE 5-27
(Continued)

Constituents of Potential Concern	Maximum Concentration (mg/kg)	Major Impacted Area
Inorganics		
Arsenic	$2.40 \times 10^{+01}$	Pilot Plant drainage ditch
Beryllium	$1.58 \times 10^{+00}$	Pilot Plant drainage ditch
Cyanide	9.21×10^{-02}	Lower SSOD
Lead	$1.65 \times 10^{+03}$	East side drainage ditch
Magnesium	$3.15 \times 10^{+04}$	East side drainage ditch
Manganese	$2.88 \times 10^{+03}$	East side drainage ditch
Mercury	4.45×10^{-01}	East side drainage ditch

TABLE 5-28

SUMMARY OF PREDICTED CONCENTRATIONS OF CONSTITUENTS OF POTENTIAL CONCERN IN SURFACE WATER BASELINE CONDITION

Constituents of Potential Concern	Maximum Paddys Run Concentration (mg/L)	Great Miami River Concentration at Discharge Outfall Yearly Average (mg\L)	Great Miami River Concentration at Discharge Outfall Maximum Week (mg\L)	Maximum Great Miami River Concentration at Paddys Run (mg\L)
Radionuclides				
Neptunium-237	2.61×10^{-07}	1.72×10^{-10}	7.94×10^{-10}	2.17×10^{-08}
Plutonium-238	9.38×10^{-13}	1.95×10^{-14}	2.54×10^{-13}	7.78×10^{-14}
Radium-226	3.84×10^{-10}	9.53×10^{-12}	1.01×10^{-10}	3.18×10^{-11}
Strontium-90	3.36×10^{-11}	2.08×10^{-14}	7.15×10^{-14}	2.79×10^{-12}
Technetium-99	6.03×10^{-05}	5.40×10^{-08}	1.70×10^{-07}	5.00×10^{-06}
Uranium-Total	1.02×10^{-01}	7.47×10^{-04}	5.87×10^{-03}	8.46×10^{-03}
Organics				
1,1-Dichloroethene	1.47×10^{-04}	2.32×10^{-07}	7.32×10^{-07}	1.22×10^{-05}
3,3'-Dichlorobenzidine	1.27×10^{-05}	0.00	0.00	1.05×10^{-06}
4-Methylphenol	2.67×10^{-02}	1.58×10^{-07}	5.00×10^{-07}	2.21×10^{-03}
4-Nitroaniline	1.39×10^{-03}	0.00	0.00	1.16×10^{-04}
Aroclor-1254	4.98×10^{-07}	5.84×10^{-08}	8.60×10^{-07}	4.13×10^{-08}
Benzene	1.79×10^{-05}	6.48×10^{-09}	2.05×10^{-08}	1.48×10^{-06}
Benzo(a)anthracene	5.23×10^{-06}	4.01×10^{-08}	5.41×10^{-07}	4.34×10^{-07}
Benzo(a)pyrene	2.77×10^{-06}	4.22×10^{-08}	6.16×10^{-07}	2.29×10^{-07}
Bis(2-Chloroisopropyl)ether	7.64×10^{-04}	1.06×10^{-07}	3.36×10^{-07}	6.33×10^{-05}
Bromodichloromethane	6.96×10^{-05}	0.00	0.00	5.77×10^{-06}
Chloroform	3.18×10^{-04}	6.85×10^{-08}	2.17×10^{-07}	2.63×10^{-05}
Dibenzo(a,h)anthracene	8.19×10^{-07}	1.23×10^{-08}	1.82×10^{-07}	6.79×10^{-08}
Dieldrin	1.56×10^{-06}	6.93×10^{-10}	3.46×10^{-09}	1.30×10^{-07}

TABLE 5-28
(Continued)

Constituents of Potential Concern	Maximum Paddys Run Concentration (mg/L)	Great Miami River Concentration at Discharge Outfall Yearly Average (mg\L)	Great Miami River Concentration at Discharge Outfall Maximum Week (mg\L)	Maximum Great Miami River Concentration at Paddys Run (mg\L)
Organics (Continued)				
Methylene Chloride	9.15×10^{-03}	9.33×10^{-07}	2.94×10^{-06}	7.59×10^{-04}
N-Nitroso-di-n-propylamine	1.46×10^{-04}	0.00	0.00	1.21×10^{-05}
Inorganics				
Arsenic	3.80×10^{-03}	1.07×10^{-06}	7.28×10^{-06}	3.15×10^{-04}
Beryllium	3.80×10^{-05}	7.10×10^{-08}	7.69×10^{-07}	3.15×10^{-06}
Cyanide	1.16×10^{-01}	4.79×10^{-05}	1.51×10^{-04}	9.61×10^{-03}
Lead	6.36×10^{-03}	3.29×10^{-06}	4.16×10^{-05}	5.27×10^{-04}
Magnesium	$1.69 \times 10^{+02}$	7.74×10^{-02}	2.54×10^{-01}	$1.40 \times 10^{+01}$
Manganese	2.64×10^{-01}	1.21×10^{-04}	7.92×10^{-04}	2.19×10^{-02}
Mercury	1.13×10^{-03}	6.55×10^{-07}	2.25×10^{-06}	9.37×10^{-05}

TABLE 5-29

SUMMARY OF PREDICTED CONCENTRATIONS OF CONSTITUENTS OF POTENTIAL CONCERN IN THE GREAT MIAMI AQUIFER ALONG PADDYS RUN BASELINE CONDITION

Constituents of Potential Concern	Section C-D[a] (μg/L)	Section D-E[a] (μg/L)	Section E-F[a] (μg/L)	Storm Sewer Outfall Ditch (μg/L)
Radionuclides				
Neptunium-237	7.69×10^{-05}	3.61×10^{-05}	4.88×10^{-06}	0.00
Plutonium-238	7.74×10^{-11}	4.03×10^{-11}	5.44×10^{-11}	9.45×10^{-10}
Radium-226	1.73×10^{-07}	7.83×10^{-08}	1.30×10^{-08}	7.80×10^{-08}
Strontium-90	7.23×10^{-09}	4.01×10^{-09}	2.09×10^{-09}	3.11×10^{-08}
Technetium-99	7.88×10^{-03}	1.21×10^{-02}	2.37×10^{-03}	1.94×10^{-02}
Uranium-Total	$1.29 \times 10^{+01}$	$6.59 \times 10^{+00}$	$5.89 \times 10^{+00}$	$9.69 \times 10^{+01}$
Organics				
1,1-Dichloroethene	0.00	0.00	1.04×10^{-02}	2.07×10^{-01}
3,3'-Dichlorobenzidine	5.13×10^{-03}	2.22×10^{-03}	2.42×10^{-04}	0.00
4-Methylphenol	3.57×10^{-03}	3.83×10^{-01}	$1.87 \times 10^{+00}$	$3.63 \times 10^{+01}$
4-Nitroaniline	5.63×10^{-01}	2.44×10^{-01}	2.65×10^{-02}	0.00
Aroclor-1254	2.13×10^{-04}	9.59×10^{-05}	3.40×10^{-05}	4.44×10^{-04}
Benzene	7.23×10^{-03}	3.13×10^{-03}	3.40×10^{-04}	0.00
Benzo(a)anthracene	2.41×10^{-03}	1.10×10^{-03}	1.74×10^{-04}	9.13×10^{-04}
Benzo(a)pyrene	1.22×10^{-03}	5.50×10^{-04}	9.32×10^{-05}	6.08×10^{-04}
Bis(2-chloroisopropyl)ether	9.14×10^{-02}	4.79×10^{-02}	8.04×10^{-03}	0.00
Bromodichloromethane	0.00	1.25×10^{-02}	1.15×10^{-03}	0.00
Chloroform	0.00	5.69×10^{-02}	5.24×10^{-03}	0.00
Dibenzo(a,h)anthracene	3.39×10^{-04}	1.48×10^{-04}	2.96×10^{-05}	2.63×10^{-04}
Dieldrin	6.32×10^{-04}	2.74×10^{-04}	2.98×10^{-05}	0.00
Methylene chloride	$3.94 \times 10^{+00}$	$1.73 \times 10^{+00}$	2.18×10^{-01}	4.41×10^{-01}
N-Nitroso-di-n-propylamine	5.91×10^{-02}	2.56×10^{-02}	2.78×10^{-03}	0.00

TABLE 5-29
(Continued)

Constituents of Potential Concern	Section C-D[a] (μg/L)	Section D-E[a] (μg/L)	Section E-F[a] (μg/L)	Storm Sewer Outfall Ditch (μg/L)
Inorganics				
Arsenic	6.11×10^{-01}	3.60×10^{-01}	1.16×10^{-01}	$1.27 \times 10^{+00}$
Beryllium	7.66×10^{-03}	5.49×10^{-03}	2.21×10^{-03}	2.97×10^{-02}
Cyanide	$1.79 \times 10^{+01}$	$1.20 \times 10^{+01}$	$7.34 \times 10^{+00}$	$1.15 \times 10^{+02}$
Lead	8.52×10^{-02}	5.13×10^{-02}	4.49×10^{-01}	$8.78 \times 10^{+00}$
Magnesium	$3.41 \times 10^{+04}$	$2.41 \times 10^{+04}$	$1.10 \times 10^{+04}$	$1.60 \times 10^{+05}$
Manganese	$2.79 \times 10^{+01}$	$2.44 \times 10^{+01}$	$1.79 \times 10^{+01}$	$2.98 \times 10^{+02}$
Mercury	1.77×10^{-01}	1.32×10^{-01}	7.26×10^{-02}	$1.11 \times 10^{+00}$

[a] See Figure 5-25

TABLE 5-30

SUMMARY OF PREDICTED LOADING OF CONCENTRATIONS OF POTENTIAL CONCERN THROUGH PADDYS RUN AND THE STORM SEWER OUTFALL DITCH INTO THE GREAT MIAMI AQUIFER BASELINE CONDITION

Constituents of Potential Concern	Section C-D[a] (kg/yr)	Section D-E[a] (kg/yr)	Section E-F[a] (kg/yr)	Storm Sewer Outfall Ditch (kg/yr)
Radionuclides				
Neptunium-237	9.96×10^{-05}	3.75×10^{-05}	4.00×10^{-06}	0.00
Plutonium-238	4.39×10^{-11}	1.90×10^{-11}	1.48×10^{-11}	4.44×10^{-10}
Radium-226	2.91×10^{-07}	1.09×10^{-07}	1.15×10^{-08}	4.20×10^{-08}
Strontium-90	8.98×10^{-09}	4.04×10^{-09}	8.84×10^{-10}	1.75×10^{-08}
Technetium-99	5.42×10^{-03}	1.11×10^{-02}	1.26×10^{-03}	9.10×10^{-03}
Uranium-Total	$1.14 \times 10^{+01}$	$4.69 \times 10^{+00}$	$1.80 \times 10^{+00}$	$4.58 \times 10^{+01}$
Organics				
1,1-Dichloroethene	0.00	0.00	2.57×10^{-03}	9.71×10^{-02}
3,3'-Dichlorobenzidine	9.30×10^{-03}	3.39×10^{-03}	3.16×10^{-04}	0.00
4-Methylphenol	6.47×10^{-03}	4.19×10^{-01}	7.42×10^{-01}	$2.67 \times 10^{+01}$
4-Nitroaniline	$1.02 \times 10^{+00}$	3.72×10^{-01}	3.47×10^{-02}	0.00
Aroclor-1254	3.35×10^{-04}	1.23×10^{-04}	1.77×10^{-05}	2.09×10^{-04}
Benzene	1.31×10^{-02}	4.77×10^{-03}	4.45×10^{-04}	0.00
Benzo(a)anthracene	3.99×10^{-03}	1.50×10^{-03}	1.56×10^{-04}	4.31×10^{-04}
Benzo(a)pyrene	2.08×10^{-03}	7.76×10^{-04}	8.14×10^{-05}	2.87×10^{-04}
Bis(2-chloroisopropyl)ether	4.77×10^{-02}	2.10×10^{-02}	3.44×10^{-03}	0.00
Bromodichloromethane	0.00	1.36×10^{-02}	1.08×10^{-03}	0.00
Chloroform	0.00	6.20×10^{-02}	4.91×10^{-03}	0.00
Dibenzo(a,h)anthracene	6.04×10^{-04}	2.20×10^{-04}	2.40×10^{-05}	1.24×10^{-04}
Dieldrin	1.15×10^{-03}	4.17×10^{-04}	3.90×10^{-05}	0.00
Methylene Chloride	$6.84 \times 10^{+00}$	$2.50 \times 10^{+00}$	2.43×10^{-01}	2.07×10^{-01}
N-Nitroso-di-n-propylamine	1.07×10^{-01}	3.90×10^{-02}	3.64×10^{-03}	0.00

TABLE 5-30
(Continued)

Constituents of Potential Concern	Section C-D[a] (kg/yr)	Section D-E[a] (kg/yr)	Section E-F[a] (kg/yr)	Storm Sewer Outfall Ditch (kg/yr)
Inorganics				
Arsenic	5.23×10^{-01}	2.67×10^{-01}	5.12×10^{-02}	7.45×10^{-01}
Beryllium	8.06×10^{-03}	5.03×10^{-03}	9.82×10^{-04}	1.76×10^{-02}
Cyanide	$2.02 \times 10^{+01}$	$1.14 \times 10^{+01}$	$2.83 \times 10^{+00}$	$6.26 \times 10^{+01}$
Lead	1.14×10^{-01}	5.53×10^{-02}	1.16×10^{-01}	$4.15 \times 10^{+00}$
Magnesium	$4.20 \times 10^{+04}$	$2.46 \times 10^{+04}$	$4.75 \times 10^{+03}$	$8.80 \times 10^{+04}$
Manganese	$3.16 \times 10^{+01}$	$2.41 \times 10^{+01}$	$6.33 \times 10^{+00}$	$1.51 \times 10^{+02}$
Mercury	1.99×10^{-01}	1.27×10^{-01}	2.92×10^{-02}	6.22×10^{-01}

[a] See Figure 5-25.

TABLE 5-31

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SUMMARY OF PREDICTED CONCENTRATIONS OF CONSTITUENTS OF POTENTIAL CONCERN IN SEDIMENT FUTURE CONDITION

Constituents of Potential Concern	Maximum Concentration (mg/kg)	Major Impacted Area
Radionuclides		
Neptunium-237	9.07×10^{-04}	North side drainage ditch
Plutonium-238	3.42×10^{-07}	SSOD
Plutonium-239/240	2.80×10^{-05}	SSOD
Radium-226	2.10×10^{-04}	SSOD
Strontium-90	3.15×10^{-09}	SSOD
Technetium-99	6.03×10^{-04}	Paddys Run near South Field
Thorium-230	1.47×10^{-02}	SSOD
Thorium-232	$1.92 \times 10^{+02}$	SSOD
Uranium-Total	$3.38 \times 10^{+03}$	SSOD
Organics		
4-Methylphenol	$1.23 \times 10^{+00}$	Lower SSOD
4-Nitroaniline	2.77×10^{-02}	North side drainage ditch
Alpha-Chlordane	7.41×10^{-04}	SSOD
Aroclor-1254	$2.09 \times 10^{+00}$	SSOD
Aroclor-1260	8.24×10^{-01}	SSOD
Bis(2-chloroisopropyl)ether	1.76×10^{-02}	Pilot Plant drainage ditch
Bromodichloromethane	3.39×10^{-03}	Paddys Run near South Field
Bromomethane	1.72×10^{-02}	SSOD

TABLE 5-31
(Continued)

Constituents of Potential Concern	Maximum Concentration (mg/kg)	Major Impacted Area
Inorganics		
Antimony	$1.35 \times 10^{+01}$	Paddys Run near waste pit area
Arsenic	$2.43 \times 10^{+01}$	Pilot Plant drainage ditch
Beryllium	$1.58 \times 10^{+00}$	Pilot Plant drainage ditch
Cyanide	6.36×10^{-02}	East side drainage ditch
Lead	$1.65 \times 10^{+03}$	East side drainage ditch
Magnesium	$3.15 \times 10^{+04}$	East side drainage ditch
Manganese	$2.88 \times 10^{+03}$	East side drainage ditch
Mercury	5.34×10^{-01}	SSOD

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TABLE 5-32

SUMMARY OF PREDICTED CONCENTRATIONS OF CONSTITUENTS OF POTENTIAL CONCERN IN SURFACE WATER
FUTURE CONDITION

Constituents of Potential Concern	Maximum Paddys Run Concentration (mg/L)	Maximum Great Miami River Concentration (mg/L)
Radionuclides		
Neptunium-237	2.81×10^{-07}	2.46×10^{-08}
Plutonium-238	3.49×10^{-12}	3.06×10^{-13}
Plutonium-239/240	3.68×10^{-10}	3.23×10^{-11}
Radium-226	4.75×10^{-09}	4.17×10^{-10}
Strontium-90	8.73×10^{-12}	7.66×10^{-13}
Technetium-99	8.70×10^{-05}	7.63×10^{-06}
Thorium-230	4.12×10^{-08}	3.61×10^{-09}
Thorium-232	5.80×10^{-04}	5.08×10^{-05}
Uranium-Total	$1.98 \times 10^{+00}$	1.74×10^{-01}
Organics		
4-Methylphenol	2.42×10^{-02}	2.12×10^{-03}
4-Nitroaniline	1.39×10^{-03}	1.22×10^{-04}
Alpha-Chlordane	3.45×10^{-06}	3.02×10^{-07}
Aroclor-1254	5.79×10^{-06}	5.08×10^{-07}
Aroclor-1260	1.79×10^{-06}	1.57×10^{-07}
Bis(2-chloroisopropyl)ether	4.92×10^{-04}	4.32×10^{-05}
Bromodichloromethane	5.59×10^{-05}	4.90×10^{-06}
Bromomethane	3.84×10^{-03}	3.37×10^{-04}

TABLE 5-32
(Continued)

Constituents of Potential Concern	Maximum Paddys Run Concentration (mg/L)	Maximum Great Miami River Concentration (mg/L)
Inorganics		
Antimony	1.50×10^{-03}	1.31×10^{-04}
Arsenic	2.85×10^{-03}	2.50×10^{-04}
Beryllium	3.77×10^{-05}	3.30×10^{-06}
Cyanide	1.38×10^{-01}	1.21×10^{-02}
Lead	6.27×10^{-03}	5.50×10^{-04}
Magnesium	$2.07 \times 10^{+02}$	$1.82 \times 10^{+01}$
Manganese	2.84×10^{-01}	2.49×10^{-02}
Mercury	1.58×10^{-03}	1.38×10^{-04}

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TABLE 5-33

SUMMARY OF PREDICTED CONCENTRATIONS OF CONSTITUENTS OF POTENTIAL CONCERN IN THE GREAT MIAMI AQUIFER ALONG PADDYS RUN FUTURE CONDITION

Constituents of Potential Concern	Section C-D[a] (μg/L)	Section D-E[a] (μg/L)	Section E-F[a] (μg/L)	Storm Sewer Outfall Ditch (μg/L)
Radionuclides				
Neptunium-237	9.17×10^{-05}	4.60×10^{-05}	1.53×10^{-05}	1.55×10^{-04}
Plutonium-238	5.44×10^{-11}	2.98×10^{-11}	1.96×10^{-10}	3.10×10^{-09}
Plutonium-239/240	8.91×10^{-09}	4.81×10^{-09}	2.09×10^{-08}	3.27×10^{-07}
Radium-226	2.10×10^{-07}	1.02×10^{-07}	2.73×10^{-07}	4.23×10^{-06}
Strontium-90	1.44×10^{-09}	8.22×10^{-10}	5.76×10^{-10}	7.72×10^{-09}
Technetium-99	8.45×10^{-03}	1.23×10^{-02}	6.06×10^{-03}	7.67×10^{-02}
Thorium-230	1.87×10^{-06}	1.13×10^{-06}	2.41×10^{-06}	3.65×10^{-05}
Thorium-232	3.88×10^{-02}	2.28×10^{-02}	3.48×10^{-02}	5.13×10^{-01}
Uranium-Total	$1.36 \times 10^{+01}$	$7.30 \times 10^{+00}$	$1.10 \times 10^{+02}$	$1.76 \times 10^{+03}$
Organics				
4-Methylphenol	3.34×10^{-03}	3.69×10^{-01}	$1.36 \times 10^{+00}$	$2.16 \times 10^{+01}$
4-Nitroaniline	5.27×10^{-01}	2.35×10^{-01}	2.24×10^{-02}	0.00
Alpha-Chlordane	0.00	0.00	1.90×10^{-04}	3.07×10^{-03}
Aroclor-1254	2.18×10^{-04}	1.03×10^{-04}	3.30×10^{-04}	5.15×10^{-03}
Aroclor-1260	5.85×10^{-06}	2.61×10^{-06}	9.88×10^{-05}	1.60×10^{-03}
Bis(2-chloroisopropyl)ether	8.54×10^{-02}	4.70×10^{-02}	1.50×10^{-02}	1.31×10^{-01}
Bromodichloromethane	0.00	1.20×10^{-02}	1.03×10^{-03}	0.00
Bromomethane	0.00	0.00	2.12×10^{-01}	$3.42 \times 10^{+00}$
Inorganics				
Antimony	3.35×10^{-01}	1.81×10^{-01}	6.02×10^{-02}	5.76×10^{-01}
Arsenic	6.41×10^{-01}	3.89×10^{-01}	1.40×10^{-01}	$1.44 \times 10^{+00}$
Beryllium	8.32×10^{-03}	5.97×10^{-03}	2.75×10^{-03}	3.31×10^{-02}
Cyanide	$2.12 \times 10^{+01}$	$1.41 \times 10^{+01}$	$9.23 \times 10^{+00}$	$1.22 \times 10^{+02}$
Lead	9.64×10^{-02}	5.89×10^{-02}	3.52×10^{-01}	$5.58 \times 10^{+00}$
Magnesium	$3.70 \times 10^{+04}$	$2.61 \times 10^{+04}$	$1.43 \times 10^{+04}$	$1.83 \times 10^{+05}$
Manganese	$3.66 \times 10^{+01}$	$2.94 \times 10^{+01}$	$1.89 \times 10^{+01}$	$2.51 \times 10^{+02}$
Mercury	2.08×10^{-01}	1.52×10^{-01}	1.04×10^{-01}	$1.39 \times 10^{+00}$

[a] See Figure 5-26.

TABLE 5-34

SUMMARY OF PREDICTED LOADING OF CONCENTRATIONS OF POTENTIAL CONCERN THROUGH PADDYS RUN AND THE STORM SEWER OUTFALL DITCH INTO THE GREAT MIAMI AQUIFER
FUTURE CONDITION

Constituents of Potential Concern	Section C-D[a] (kg/yr)	Section D-E[a] (kg/yr)	Section E-F[a] (kg/yr)	Storm Sewer Outfall Ditch (kg/yr)
Radionuclides				
Neptunium-237	1.11×10^{-04}	4.27×10^{-05}	6.90×10^{-06}	1.23×10^{-04}
Plutonium-238	3.24×10^{-11}	1.43×10^{-11}	5.72×10^{-11}	2.47×10^{-09}
Plutonium-239/240	6.23×10^{-09}	2.64×10^{-09}	6.58×10^{-09}	2.80×10^{-07}
Radium-226	3.12×10^{-07}	1.19×10^{-07}	8.59×10^{-08}	3.37×10^{-06}
Strontium-90	1.76×10^{-09}	7.95×10^{-10}	2.23×10^{-10}	6.68×10^{-09}
Technetium-99	6.03×10^{-03}	1.14×10^{-02}	2.32×10^{-03}	6.11×10^{-02}
Thorium-230	1.55×10^{-06}	7.98×10^{-07}	7.37×10^{-07}	2.92×10^{-05}
Thorium-232	2.92×10^{-02}	1.45×10^{-02}	1.09×10^{-02}	4.15×10^{-01}
Uranium-Total	$1.23 \times 10^{+01}$	$5.13 \times 10^{+00}$	$3.20 \times 10^{+01}$	$1.40 \times 10^{+03}$
Organics				
4-Methylphenol	6.49×10^{-03}	4.21×10^{-01}	6.32×10^{-01}	$2.69 \times 10^{+01}$
4-Nitroaniline	$1.03 \times 10^{+00}$	3.73×10^{-01}	2.99×10^{-02}	0.00
Alpha-Chlordane	0.00	0.00	5.46×10^{-05}	2.44×10^{-03}
Aroclor-1254	3.46×10^{-04}	1.29×10^{-04}	1.03×10^{-04}	4.10×10^{-03}
Aroclor-1260	1.14×10^{-05}	4.15×10^{-06}	2.87×10^{-05}	1.27×10^{-03}
Bis(2-chloroisopropyl)ether	4.77×10^{-02}	2.14×10^{-02}	5.33×10^{-03}	1.04×10^{-01}
Bromodichloromethane	0.00	1.37×10^{-02}	9.84×10^{-04}	0.00
Bromomethane	0.00	0.00	6.09×10^{-02}	$2.72 \times 10^{+00}$
Inorganics				
Antimony	2.91×10^{-01}	1.23×10^{-01}	2.43×10^{-02}	4.69×10^{-01}
Arsenic	5.63×10^{-01}	2.87×10^{-01}	5.91×10^{-02}	$1.30 \times 10^{+00}$
Beryllium	8.72×10^{-03}	5.36×10^{-03}	1.17×10^{-03}	3.00×10^{-02}
Cyanide	$2.27 \times 10^{+01}$	$1.26 \times 10^{+01}$	$3.55 \times 10^{+00}$	$1.06 \times 10^{+02}$
Lead	1.24×10^{-01}	5.98×10^{-02}	1.06×10^{-01}	$4.48 \times 10^{+00}$
Magnesium	$4.50 \times 10^{+04}$	$2.60 \times 10^{+04}$	$5.85 \times 10^{+03}$	$1.59 \times 10^{+05}$
Manganese	$3.75 \times 10^{+01}$	$2.69 \times 10^{+01}$	$7.16 \times 10^{+00}$	$2.12 \times 10^{+02}$
Mercury	2.23×10^{-01}	1.39×10^{-01}	3.97×10^{-02}	$1.21 \times 10^{+00}$

[a] See Figure 5-26.

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TABLE 5-35

SURFACE WATER MODELING RESULTS FOR THE NORTHEAST DRAINAGE DITCH

Chemical	Baseline Surface Water Concentration (mg/L)	Baseline Sediment Concentration (mg/kg)	Future Surface Water Concentration (mg/L)	Future Sediment Concentration (mg/kg)
Concentration at the Surface Water Sampling Location (SWS-13)				
Arsenic	9.85×10^{-04}	$5.65 \times 10^{+00}$	9.85×10^{-04}	$5.65 \times 10^{+00}$
Beryllium	1.70×10^{-05}	6.35×10^{-01}	1.70×10^{-05}	6.35×10^{-01}
Manganese	1.70×10^{-01}	$8.76 \times 10^{+02}$	1.70×10^{-01}	$8.76 \times 10^{+02}$
Strontium-90	2.95×10^{-12}	4.62×10^{-09}	2.92×10^{-12}	8.36×10^{-10}
Uranium - Total	1.10×10^{-03}	$7.02 \times 10^{+00}$	1.10×10^{-03}	$7.02 \times 10^{+00}$
Concentration at the FEMP Fenceline				
Arsenic	1.06×10^{-03}	$6.10 \times 10^{+00}$	1.06×10^{-03}	1.06×10^{-03}
Beryllium	2.13×10^{-05}	8.00×10^{-01}	2.13×10^{-05}	8.00×10^{-01}
Manganese	2.25×10^{-01}	$1.17 \times 10^{+03}$	2.25×10^{-01}	$1.17 \times 10^{+03}$
Strontium-90	1.66×10^{-11}	2.62×10^{-08}	1.64×10^{-11}	4.75×10^{-09}
Uranium - Total	3.86×10^{-03}	$2.47 \times 10^{+01}$	3.86×10^{-03}	$2.47 \times 10^{+01}$

TABLE 5-36

CONSTITUENTS OF POTENTIAL CONCERN IN THE GROUNDWATER PATHWAY AND MODELING APPROACHES

Potential COC	Level of Concern	ODAST/ SWIFTLOAD	ECTran	SWIFT
Radionuclides				
Neptunium-237	Primary	X		X
Plutonium-238	Secondary		X	
Plutonium-239/240	Secondary		X	
Radium-226	Primary			X
Strontium-90	Primary	X		X
Technetium-99	Primary	X		X
Thorium-230	Secondary		X	
Thorium-232	Secondary		X	
Uranium-Total	Primary	X		X
Organics				
1,1-Dichloroethene	Secondary		X	
1,2-Dichloroethane	Secondary	X	X	
3,3'-Dichlorobenzidine	Secondary		X	
4-Methylphenol	Secondary		X	
4-Nitroaniline	Secondary	X	X	
Alpha-chlordane	Secondary	X	X	
Arochlor-1254	Secondary		X	
Arochlor-1260	Secondary		X	
Benzo(a)anthracene	Secondary		X	
Benzo(a)pyrene	Secondary		X	
Bis(2-chloroisopropyl)ether	Secondary	X	X	
Bromodichloromethane	Secondary	X	X	
Bromomethane	Secondary		X	
Carbazole	Secondary	X	X	
Chloroform	Secondary		X	
Dibenzo(a,h)anthracene	Secondary		X	

TABLE 5-36 (Continued)

Potential COC	Level of Concern	ODAST/ SWIFTLOAD	ECTran	SWIFT
Organics (Continued)				
Dieldrin	Secondary		X	
Methylene chloride	Secondary		X	
N-nitroso-di-n-propylamine	Secondary		X	
Inorganics				
Antimony	Primary			X
Arsenic	Primary			X
Beryllium	Primary			X
Boron	Secondary	X	X	
Chromium (Hex)	Primary	X		X
Cyanide	Secondary		X	
Lead	Secondary		X	
Magnesium	Primary	X		X
Manganese	Primary			X
Mercury	Secondary	X	X	

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TABLE 5-37

SUMMARY OF TIMES, LOCATIONS, AND MAXIMUM MASS LOADING FOR CONSTITUENTS OF POTENTIAL CONCERN TO THE GREAT MIAMI AQUIFER

Constituent of Potential Concern	Mass Loading at Maximum Concentration (lbs/day)	Time of Maximum Concentration (Years)	Grid Block Location x,y
Radionuclides			
Neptunium-237	1.979×10^{-08}	360	36,95
Radium-226	0.000	NA	NA
Strontium-90	1.426×10^{-14}	150	36,95
Technetium-99	1.566×10^{-05}	30	47,79
Uranium-Total	5.481×10^{-02}	650	57,70
Organics			
1,1-Dichloroethane	2.098×10^{-09}	10	36,95
1,1-Dichloroethene	3.218×10^{-14}	10	49,61
1,1,1-Trichloroethane	7.900×10^{-10}	20	36,95
1,1,2-Trichloroethane	6.171×10^{-12}	70	53,73
1,2-Dichloroethane	4.296×10^{-08}	20	55,72
1,2-Dichloroethene (tot)	2.013×10^{-06}	20	53,73
2-Chlorophenol	1.100×10^{-05}	120	46,94
2-Hexanone	8.137×10^{-06}	20	57,73
2-Methylnaphthalene	1.578×10^{-05}	490	36,95
2-Methylphenol	1.827×10^{-05}	60	60,73
2,4-Dinitrotoluene	9.687×10^{-16}	30	59,71
2,6-Dinitrotoluene	1.471×10^{-20}	40	53,73
4-Chloro-3-methylphenol	1.758×10^{-05}	340	57,70
4-Methylphenol	2.131×10^{-04}	40	30,52
4-Nitroaniline	4.134×10^{-05}	50	46,94
Alpha-chlordane	3.970×10^{-07}	390	55,84
Benzene	9.904×10^{-11}	40	57,72
Benzyl alcohol	3.634×10^{-05}	40	55,80

TABLE 5-37 (Continued)

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Constituent of Potential Concern	Mass Loading at Maximum Concentration (lbs/day)	Time of Maximum Concentration (Years)	Grid Block Location x,y
Bis(2-chloroisopropyl)ether	1.582×10^{-05}	70	60,73
Bromodichloromethane	2.212×10^{-05}	30	57,70
Carbazole	1.083×10^{-05}	530	51,69
Diethylphthalate	7.147×10^{-21}	20	30,71
Endosulfan II	1.880×10^{-28}	1000	55,84
Endosulfan Sulfate	1.275×10^{-33}	1000	55,84
Endrin Aldehyde	3.212×10^{-07}	1000	46,94
Heptachlor Epoxide	3.800×10^{-15}	70	48,65
N-nitroso-di-n-propylamine	2.939×10^{-17}	30	46,94
Tetrachloroethene	5.574×10^{-10}	80	53,73
Trichloroethene	2.524×10^{-08}	30	36,95
Inorganics			
Antimony	7.388×10^{-20}	1000	36,95
Arsenic	0.000	NA	NA
Barium	8.012×10^{-06}	1000	36,95
Boron	4.829×10^{-03}	390	49,74
Chromium (Hex)	3.493×10^{-05}	260	36,95
Cyanide	4.179×10^{-05}	10	53,73
Magnesium	$9.112 \times 10^{+00}$	470	53,73
Manganese	3.456×10^{-22}	1000	36,95
Mercury	5.765×10^{-05}	1000	46,76
Molybdenum	3.597×10^{-05}	690	36,95
Thallium	0.000	NA	NA

NA=Not Applicable

TABLE 5-38

SUMMARY OF TIME, LOCATION, AND MAXIMUM CONCENTRATIONS OF PRIMARY CONSTITUENTS OF CONCERN IN THE GMA - ON SITE AND OFF SITE

Constituent of Potential Concern	On-Property Maximum		On-Property Fenceline Maximum[a]	
	Concentration (ppb)	Time (Yr)	Concentration (ppb)	Time (Yr)
Radionuclides				
Neptunium-237	8.66×10^{-04}	910	2.48×10^{-04}	850
Plutonium-238	3.68×10^{-08}	600	8.06×10^{-15}	860
Plutonium-239/240	1.27×10^{-05}	960	2.77×10^{-11}	1000
Radium-226	1.62×10^{-05}	1000	1.78×10^{-06}	1000
Strontium-90	9.89×10^{-08}	70	1.45×10^{-08}	70
Technetium-99	4.01×10^{-01}	90	8.67×10^{-02}	100
Thorium-230	1.57×10^{-04}	1000	2.44×10^{-53}	1000
Thorium-232	$2.23 \times 10^{+00}$	1000	3.52×10^{-49}	1000
Uranium-Total	$9.06 \times 10^{+03}$	1000	$1.76 \times 10^{+03}$	260
Inorganics				
Antimony	$4.65 \times 10^{+01}$	10	$1.56 \times 10^{+00}$	110
Arsenic	$1.36 \times 10^{+02}$	10	$1.36 \times 10^{+02}$	10
Beryllium	1.19×10^{-01}	1000	$2.40 \times 10^{+02}$	1000
Chromium (hex)	$1.07 \times 10^{+01}$	1000	$3.10 \times 10^{+00}$	1000
Cyanide	$6.36 \times 10^{+03}$	20	$9.74 \times 10^{+02}$	40
Lead	$2.44 \times 10^{+02}$	1000	1.23×10^{-01}	780
Magnesium	$1.35 \times 10^{+06}$	520	$4.75 \times 10^{+05}$	880
Manganese	$2.38 \times 10^{+03}$	10	$4.43 \times 10^{+02}$	10
Mercury	$9.55 \times 10^{+00}$	1000	6.15×10^{-03}	720
Organics				
Alpha-chlordane	1.47×10^{-01}	60	1.95×10^{-02}	60
Aroclor-1254	5.66×10^{-02}	1000	3.14×10^{-25}	1000
Aroclor-1260	1.48×10^{-02}	1000	8.18×10^{-29}	1000
Benzene	1.33×10^{-01}	20	1.16×10^{-04}	60
Benzo(a)anthracene	7.31×10^{-04}	60	2.82×10^{-46}	580
Benzo(a)pyrene	3.64×10^{-06}	100	2.47×10^{-52}	680
Bis(2-chloroisopropyl)ether	$6.25 \times 10^{+00}$	40	$1.07 \times 10^{+00}$	100
Bromodichloromethane	$1.95 \times 10^{+00}$	40	9.91×10^{-01}	60
Bromomethane	$3.80 \times 10^{+01}$	20	3.95×10^{-03}	40
Carbazole	$2.38 \times 10^{+00}$	520	1.60×10^{-01}	600
Chloroform	7.87×10^{-01}	20	9.05×10^{-03}	40
Dibenzo(a,h)anthracene	1.48×10^{-05}	100	1.57×10^{-45}	740
3,3-Dichlorobenzidine	2.53×10^{-02}	20	8.32×10^{-17}	60
1,1-Dichloroethene	$2.92 \times 10^{+00}$	20	4.90×10^{-02}	40
Dieldrin	4.86×10^{-03}	60	5.94×10^{-14}	200
Methylene Chloride	$2.87 \times 10^{+01}$	20	7.15×10^{-08}	40
4-Methylphenol	$1.62 \times 10^{+03}$	20	$3.43 \times 10^{+02}$	40
4-Nitroaniline	$1.22 \times 10^{+01}$	20	4.50×10^{-01}	80
N-nitroso-di-n-propylamine	$1.06 \times 10^{+00}$	20	4.17×10^{-04}	40

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TABLE 5-38 (Continued)

Constituent of Potential Concern	FEMP Production Well (43,75,1)[b]		FEMP Production Well (43,75,5)[b]	
	Concentration (ppb)	Time (Yr)	Concentration (ppb)	Time (Yr)
Radionuclides				
Neptunium-237	3.57×10^{-05}	550	2.17×10^{-05}	630
Plutonium-238	NA	NA	NA	NA
Plutonium-239/240	NA	NA	NA	NA
Radium-226	1.58×10^{-08}	1000	1.52×10^{-08}	1000
Strontium-90	4.65×10^{-10}	90	1.25×10^{-10}	100
Technetium-99	8.84×10^{-03}	40	1.57×10^{-03}	90
Thorium-230	NA	NA	NA	NA
Thorium-232	NA	NA	NA	NA
Uranium-Total	$1.16 \times 10^{+01}$	30	$3.29 \times 10^{+00}$	270
Inorganics				
Antimony	1.49×10^{-05}	160	3.08×10^{-08}	1000
Arsenic	1.68×10^{-01}	1000	8.03×10^{-02}	1000
Beryllium	$5.47 \times 10^{+01}$	1000	$2.20 \times 10^{+02}$	1000
Chromium (hex)	1.11×10^{-01}	410	7.02×10^{-02}	530
Cyanide	NA	NA	NA	NA
Lead	NA	NA	NA	NA
Magnesium	$4.12 \times 10^{+04}$	700	$1.31 \times 10^{+05}$	750
Manganese	7.45×10^{-01}	1000	1.85×10^{-01}	10
Mercury	NA	NA	NA	NA
Organics				
Alpha-chlordane	NA	NA	NA	NA
Aroclor-1254	NA	NA	NA	NA
Aroclor-1260	NA	NA	NA	NA
Benzene	NA	NA	NA	NA
Benzo(a)anthracene	NA	NA	NA	NA
Benzo(a)pyrene	NA	NA	NA	NA
Bis(2-chloroisopropyl)ether	NA	NA	NA	NA
Bromodichloromethane	NA	NA	NA	NA
Bromomethane	NA	NA	NA	NA
Carbazole	1.78×10^{-02}	220	NA	NA
Chloroform	NA	NA	NA	NA
Dibenzo(a,h)anthracene	NA	NA	NA	NA
3,3-Dichlorobenzidine	NA	NA	NA	NA
1,1-Dichloroethene	NA	NA	NA	NA
Dieldrin	NA	NA	NA	NA
Methylene Chloride	NA	NA	NA	NA
4-Methylphenol	NA	NA	NA	NA
4-Nitroaniline	NA	NA	NA	NA
n-Nitroso-di-n-propylamine	NA	NA	NA	NA

TABLE 5-38 (Continued)

Constituent of Potential Concern	Well 12 (28,46,1)[b] Concentration (ppb)	Well 12 (28,46,1)[b] Time (Yr)	Well 26 (28,46,2)[b] Concentration (ppb)	Well 26 (28,46,2)[b] Time (Yr)	Well 13 (39,44,1)[b] Concentration (ppb)	Well 13 (39,44,1)[b] Time (Yr)
Radionuclides						
Neptunium-237	1.99×10^{-04}	690	1.54×10^{-04}	490	2.48×10^{-04}	850
Plutonium-238	8.06×10^{-15}	860	NA	NA	3.38×10^{-18}	1000
Plutonium-239/240	2.77×10^{-11}	1000	NA	NA	3.72×10^{-14}	1000
Radium-226	1.78×10^{-06}	1000	6.18×10^{-07}	1000	3.60×10^{-07}	1000
Strontium-90	1.45×10^{-08}	70	6.68×10^{-09}	70	7.32×10^{-09}	70
Technetium-99	7.71×10^{-02}	100	5.06×10^{-02}	100	8.67×10^{-02}	100
Thorium-230	2.44×10^{-53}	1000	NA	NA	0.00	0
Thorium-232	3.53×10^{-49}	1000	NA	NA	0.00	0
Uranium-Total	$1.40 \times 10^{+03}$	180	$7.45 \times 10^{+02}$	270	$1.76 \times 10^{+03}$	260
Inorganics						
Antimony	3.31×10^{-01}	1000	5.23×10^{-02}	1000	1.29×10^{-03}	1000
Arsenic	$3.88 \times 10^{+00}$	1000	$2.40 \times 10^{+00}$	1000	$4.32 \times 10^{+00}$	1000
Beryllium	$2.40 \times 10^{+02}$	1000	$1.46 \times 10^{+02}$	1000	$2.17 \times 10^{+02}$	1000
Chromium (hex)	$2.01 \times 10^{+00}$	990	$1.28 \times 10^{+00}$	1000	$3.10 \times 10^{+00}$	1000
Cyanide	$9.74 \times 10^{+02}$	40	NA	NA	$6.68 \times 10^{+02}$	40
Lead	1.23×10^{-01}	780	NA	NA	2.92×10^{-03}	1000
Magnesium	$2.03 \times 10^{+05}$	410	$1.33 \times 10^{+05}$	450	$3.51 \times 10^{+05}$	470
Manganese	$4.85 \times 10^{+00}$	1000	$1.58 \times 10^{+00}$	1000	$2.74 \times 10^{+00}$	1000
Mercury	NA	NA	NA	NA	NA	NA
Organics						
Alpha-chlordane	1.95×10^{-02}	60	NA	NA	1.18×10^{-02}	80
Aroclor-1254	3.14×10^{-25}	1000	NA	NA	2.03×10^{-38}	1000
Aroclor-1260	8.18×10^{-29}	1000	NA	NA	2.42×10^{-44}	1000
Benzene	NA	NA	NA	NA	1.16×10^{-04}	60
Benzo(a)anthracene	NA	NA	NA	NA	2.82×10^{-46}	580
Benzo(a)pyrene	2.47×10^{-52}	680	NA	NA	6.62×10^{-71}	880
Bis(2-chloroisopropyl)ether	9.29×10^{-01}	40	NA	NA	6.22×10^{-01}	60
Bromodichloromethane	5.51×10^{-02}	40	NA	NA	1.42×10^{-02}	60
Bromomethane	3.95×10^{-03}	40	NA	NA	2.05×10^{-05}	40
Carbazole	NA	NA	NA	NA	NA	NA
Chloroform	9.05×10^{-03}	40	NA	NA	4.34×10^{-05}	40
Dibenzo(a,h)anthracene	1.57×10^{-45}	740	NA	NA	9.35×10^{-52}	980
3,3-Dichlorobenzidine	NA	NA	NA	NA	8.32×10^{-17}	60
1,1-Dichloroethene	4.90×10^{-02}	40	NA	NA	3.92×10^{-03}	40
Dieldrin	NA	NA	NA	NA	5.94×10^{-14}	200
Methylene Chloride	NA	NA	NA	NA	7.15×10^{-08}	40
4-Methylphenol	$2.43 \times 10^{+02}$	40	NA	NA	$1.65 \times 10^{+02}$	40
4-Nitroaniline	NA	NA	NA	NA	4.50×10^{-01}	80
n-Nitroso-di-n-propylamine	NA	NA	NA	NA	4.17×10^{-04}	40

TABLE 5-38 (Continued)

Constituent of Potential Concern	Well 14 (59,38,1)[b] Concentration (ppb)	Well 14 (59,38,1)[b] Time (Yr)	Well 34 (5,11,1)[b] Concentration (ppb)	Well 34 (5,11,1)[b] Time (Yr)	Well 2071 (85,66,1)[b] Concentration (ppb)	Well 2071 (85,66,1)[b] Time (Yr)
Radionuclides						
Neptunium-237	1.11×10^{-04}	990	9.47×10^{-05}	10	2.10×10^{-06}	1000
Plutonium-238	9.09×10^{-26}	1000	NA	NA	NA	NA
Plutonium-239/240	5.28×10^{-21}	1000	NA	NA	NA	NA
Radium-226	1.23×10^{-08}	390	3.78×10^{-09}	500	3.08×10^{-15}	1000
Strontium-90	1.32×10^{-10}	160	2.80×10^{-13}	170	3.61×10^{-14}	240
Technetium-99	4.07×10^{-02}	110	6.51×10^{-05}	140	4.43×10^{-03}	80
Thorium-230	0.00	0	NA	NA	NA	NA
Thorium-232	0.00	0	NA	NA	NA	NA
Uranium-Total	$8.73 \times 10^{+02}$	990	9.92×10^{-01}	940	$6.21 \times 10^{+01}$	200
Inorganics						
Antimony	1.29×10^{-13}	1000	4.46×10^{-01}	140	8.75×10^{-13}	1000
Arsenic	4.06×10^{-01}	1000	8.05×10^{-04}	870	1.43×10^{-06}	1000
Beryllium	$2.74 \times 10^{+00}$	1000	$1.49 \times 10^{+00}$	1000	$4.87 \times 10^{+00}$	80
Chromium (hex)	$1.13 \times 10^{+00}$	1000	1.63×10^{-03}	1000	5.53×10^{-03}	820
Cyanide	$2.73 \times 10^{+02}$	60	NA	NA	NA	NA
Lead	2.37×10^{-07}	1000	NA	NA	NA	NA
Magnesium	$2.33 \times 10^{+05}$	810	$1.70 \times 10^{+02}$	1000	$1.42 \times 10^{+04}$	1000
Manganese	9.27×10^{-01}	500	1.21×10^{-02}	1000	3.87×10^{-02}	1000
Mercury	2.20×10^{-03}	760	NA	NA	NA	NA
Organics						
Alpha-chlordane	3.14×10^{-03}	160	NA	NA	3.05×10^{-03}	480
Aroclor-1254	0.00	0	NA	NA	NA	NA
Aroclor-1260	0.00	0	NA	NA	NA	NA
Benzene	4.68×10^{-06}	60	NA	NA	NA	NA
Benzo(a)anthracene	1.06×10^{-74}	940	NA	NA	NA	NA
Benzo(a)pyrene	4.25×10^{-116}	1000	NA	NA	NA	NA
Bis(2-chloroisopropyl)ether	2.33×10^{-01}	80	NA	NA	1.27×10^{-01}	140
Bromodichloromethane	NA	NA	NA	NA	NA	NA
Bromomethane	2.53×10^{-10}	40	NA	NA	NA	NA
Carbazole	NA	NA	NA	NA	NA	NA
Chloroform	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)anthracene	1.96×10^{-103}	1000	NA	NA	NA	NA
3,3-Dichlorobenzidine	2.29×10^{-23}	80	NA	NA	NA	NA
1,1-Dichloroethene	1.51×10^{-05}	40	NA	NA	NA	NA
Dieldrin	1.96×10^{-19}	240	NA	NA	NA	NA
Methylene Chloride	1.26×10^{-13}	40	NA	NA	NA	NA
4-Methylphenol	$6.42 \times 10^{+01}$	80	NA	NA	NA	NA
4-Nitroaniline	2.29×10^{-01}	100	NA	NA	NA	NA
n-Nitroso-di-n-propylamine	1.09×10^{-05}	40	NA	NA	NA	NA

TABLE 5-38 (Continued)

Constituent of Potential Concern	Well 2119 (73,52,1)[b] Concentration (ppb)	Well 2119 (73,52,1)[b] Time (Yr)	Well 2127 (5,6,1)[b] Concentration (ppb)	Well 2127 (5,6,1)[b] Time (Yr)	SOWC COLL1 (101,38,1)[b] Concentration (ppb)	SOWC COLL1 (101,38,1)[b] Time (Yr)
Radionuclides						
Neptunium-237	2.09×10^{-05}	1000	2.47×10^{-05}	10	3.84×10^{-07}	1000
Plutonium-238	NA	NA	NA	NA	NA	NA
Plutonium-239/240	NA	NA	NA	NA	NA	NA
Radium-226	9.94×10^{-07}	10	3.67×10^{-08}	450	7.74×10^{-18}	1000
Strontium-90	4.61×10^{-12}	210	2.75×10^{-12}	170	2.18×10^{-15}	360
Technetium-99	1.14×10^{-02}	60	6.86×10^{-04}	150	2.68×10^{-04}	130
Thorium-230	NA	NA	NA	NA	NA	NA
Thorium-232	NA	NA	NA	NA	NA	NA
Uranium-Total	$2.04 \times 10^{+02}$	940	$1.06 \times 10^{+01}$	850	$5.97 \times 10^{+00}$	1000
Inorganics						
Antimony	1.94×10^{-14}	1000	$3.70 \times 10^{+00}$	70	1.48×10^{-21}	1000
Arsenic	1.12×10^{-02}	1000	7.55×10^{-03}	800	2.51×10^{-09}	160
Beryllium	$1.06 \times 10^{+00}$	1000	$1.42 \times 10^{+01}$	1000	9.16×10^{-01}	180
Chromium (hex)	1.39×10^{-01}	1000	1.73×10^{-02}	1000	6.08×10^{-03}	1000
Cyanide	NA	NA	NA	NA	NA	NA
Lead	NA	NA	NA	NA	NA	NA
Magnesium	$5.03 \times 10^{+04}$	1000	$1.80 \times 10^{+03}$	1000	$4.96 \times 10^{+02}$	1000
Manganese	1.26×10^{-01}	1000	1.84×10^{-01}	1000	9.81×10^{-04}	220
Mercury	1.86×10^{-06}	1000	NA	NA	9.44×10^{-11}	1000
Organics						
Alpha-chlordane	3.07×10^{-03}	480	NA	NA	2.65×10^{-03}	500
Aroclor-1254	NA	NA	NA	NA	NA	NA
Aroclor-1260	NA	NA	NA	NA	NA	NA
Benzene	NA	NA	NA	NA	NA	NA
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA
Bis(2-chloroisopropyl)ether	3.94×10^{-01}	100	NA	NA	1.73×10^{-01}	120
Bromodichloromethane	4.29×10^{-01}	60	NA	NA	1.86×10^{-01}	80
Bromomethane	NA	NA	NA	NA	NA	NA
Carbazole	9.94×10^{-03}	720	NA	NA	3.87×10^{-03}	740
Chloroform	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA
3,3-Dichlorobenzidine	NA	NA	NA	NA	NA	NA
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA
Dieldrin	NA	NA	NA	NA	NA	NA
Methylene Chloride	NA	NA	NA	NA	NA	NA
4-Methylphenol	NA	NA	NA	NA	NA	NA
4-Nitroaniline	NA	NA	NA	NA	NA	NA
n-Nitroso-di-n-propylamine	NA	NA	NA	NA	NA	NA

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TABLE 5-38 (Continued)

Constituent of Potential Concern	SOWC COLL1 (101,38,5)[b] Concentration (ppb)	SOWC COLL1 (101,38,5)[b] Time (Yr)	SOWC COLL2 (108,52,1)[b] Concentration (ppb)	SOWC COLL2 (108,52,1)[b] Time (Yr)	SOWC COLL2 (108,52,5)[b] Concentration (ppb)	SOWC COLL2 (108,52,5)[b] Time (Yr)
Radionuclides						
Neptunium-237	5.61×10^{-07}	1000	2.00×10^{-06}	1000	2.79×10^{-06}	1000
Plutonium-238	NA	NA	NA	NA	NA	NA
Plutonium-239/240	NA	NA	NA	NA	NA	NA
Radium-226	1.03×10^{-17}	1000	4.29×10^{-16}	1000	6.02×10^{-16}	1000
Strontium-90	3.12×10^{-15}	370	1.53×10^{-14}	320	2.11×10^{-14}	320
Technetium-99	4.01×10^{-04}	130	2.29×10^{-03}	80	3.12×10^{-03}	80
Thorium-230	NA	NA	NA	NA	NA	NA
Thorium-232	NA	NA	NA	NA	NA	NA
Uranium-Total	$1.00 \times 10^{+03}$	1000	$4.66 \times 10^{+01}$	1000	$6.44 \times 10^{+01}$	1000
Inorganics						
Antimony	2.29×10^{-21}	1000	1.36×10^{-21}	1000	1.94×10^{-21}	1000
Arsenic	3.47×10^{-09}	170	8.54×10^{-08}	180	1.08×10^{-07}	200
Beryllium	$1.28 \times 10^{+00}$	190	$5.27 \times 10^{+00}$	200	$7.81 \times 10^{+00}$	210
Chromium (hex)	9.06×10^{-03}	1000	1.57×10^{-02}	1000	2.23×10^{-02}	1000
Cyanide	NA	NA	NA	NA	NA	NA
Lead	NA	NA	NA	NA	NA	NA
Magnesium	$7.22 \times 10^{+02}$	1000	$6.46 \times 10^{+03}$	1000	$8.81 \times 10^{+03}$	1000
Manganese	1.17×10^{-03}	220	6.33×10^{-03}	280	8.00×10^{-03}	270
Mercury	NA	NA	3.93×10^{-08}	1000	NA	NA
Organics						
Alpha-chlordane	NA	NA	1.43×10^{-03}	480	NA	NA
Aroclor-1254	NA	NA	NA	NA	NA	NA
Aroclor-1260	NA	NA	NA	NA	NA	NA
Benzene	NA	NA	NA	NA	NA	NA
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA
Bis(2-chloroisopropyl)ether	NA	NA	1.88×10^{-01}	120	NA	NA
Bromodichloromethane	NA	NA	1.52×10^{-01}	80	NA	NA
Bromomethane	NA	NA	NA	NA	NA	NA
Carbazole	NA	NA	3.45×10^{-03}	720	NA	NA
Chloroform	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA
3,3-Dichlorobenzidine	NA	NA	NA	NA	NA	NA
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA
Dieldrin	NA	NA	NA	NA	NA	NA
Methylene Chloride	NA	NA	NA	NA	NA	NA
4-Methylphenol	NA	NA	NA	NA	NA	NA
4-Nitroaniline	NA	NA	NA	NA	NA	NA
n-Nitroso-di-n-propylamine	NA	NA	NA	NA	NA	NA

TABLE 5-38 (Continued)

Constituent of Potential Concern	STRICKERS GROVE WELL		N.E. Receptor (90,91,1)[b]	
	Concentration	Time	Concentration	Time
Radionuclides				
Neptunium-237	9.69×10^{-06}	1000	2.74×10^{-08}	1000
Plutonium-238	NA	NA	NA	NA
Plutonium-239/240	NA	NA	NA	NA
Radium-226	2.72×10^{-15}	1000	6.06×10^{-21}	1000
Strontium-90	8.69×10^{-14}	350	4.19×10^{-18}	380
Technetium-99	5.58×10^{-03}	120	0.00	0
Thorium-230	NA	NA	NA	NA
Thorium-232	NA	NA	NA	NA
Uranium-Total	$1.24 \times 10^{+02}$	1000	4.90×10^{-02}	240
Inorganics				
Antimony	9.97×10^{-22}	1000	0.00	1000
Arsenic	6.76×10^{-07}	80	9.69×10^{-15}	0
Beryllium	3.34×10^{-02}	80	2.67×10^{-05}	80
Chromium (hex)	1.34×10^{-01}	1000	7.29×10^{-05}	900
Cyanide	NA	NA	NA	NA
Lead	NA	NA	NA	NA
Magnesium	$1.30 \times 10^{+04}$	1000	$5.37 \times 10^{+02}$	1000
Manganese	4.40×10^{-03}	510	5.55×10^{-04}	1000
Mercury	4.30×10^{-10}	1000	NA	NA
Organics				
Alpha-chlordane	3.09×10^{-03}	500	NA	NA
Aroclor-1254	NA	NA	NA	NA
Aroclor-1260	NA	NA	NA	NA
Benzene	NA	NA	NA	NA
Benzo(a)anthracene	NA	NA	NA	NA
Benzo(a)pyrene	NA	NA	NA	NA
Bis(2-chloroisopropyl)ether	1.62×10^{-01}	120	NA	NA
Bromodichloromethane	2.17×10^{-01}	80	NA	NA
Bromomethane	NA	NA	NA	NA
Carbazole	4.85×10^{-03}	720	NA	NA
Chloroform	NA	NA	NA	NA
Dibenzo(a,h)anthracene	NA	NA	NA	NA
3,3-Dichlorobenzidine	NA	NA	NA	NA
1,1-Dichloroethene	NA	NA	NA	NA
Dieldrin	NA	NA	NA	NA
Methylene Chloride	NA	NA	NA	NA
4-Methylphenol	NA	NA	NA	NA
4-Nitroaniline	NA	NA	NA	NA
n-Nitroso-di-n-propylamine	NA	NA	NA	NA

TABLE 5-38 (Continued)

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Constituent of Potential Concern	Zone 1 Max Conc. (ppb)	Zone 1 Time (Yr)	Zone 2 Max Conc. (ppb)	Zone 2 Time (Yr)	Zone 3 Max. Conc. (ppb)	Zone 3 Time (Yr)
Radionuclides						
Neptunium-237	3.57×10^{-04}	230	6.74×10^{-04}	750	8.25×10^{-05}	540
Plutonium-238	N/A	N/A	N/A	N/A	N/A	N/A
Plutonium-239/240	N/A	N/A	N/A	N/A	N/A	N/A
Radium-226	1.21×10^{-05}	10	1.38×10^{-05}	920	3.27×10^{-06}	10
Strontium-90	2.44×10^{-08}	50	6.58×10^{-08}	70	2.40×10^{-09}	70
Technetium-99	1.94×10^{-02}	90	2.85×10^{-01}	90	1.94×10^{-01}	40
Thorium-230	N/A	N/A	N/A	N/A	N/A	N/A
Thorium-232	N/A	N/A	N/A	N/A	N/A	N/A
Uranium-Total	$1.70 \times 10^{+02}$	190	$6.28 \times 10^{+03}$	210	$2.75 \times 10^{+03}$	790
Inorganics						
Antimony	$4.65 \times 10^{+01}$	10	$1.22 \times 10^{+01}$	10	$3.69 \times 10^{+01}$	10
Arsenic	$1.70 \times 10^{+00}$	1000	$5.13 \times 10^{+00}$	1000	$9.66 \times 10^{+00}$	10
Beryllium	2.57×10^{-02}	1000	1.12×10^{-01}	1000	4.27×10^{-05}	1000
Chromium (hex)	$1.22 \times 10^{+00}$	1000	$8.34 \times 10^{+00}$	1000	3.01×10^{-01}	1000
Cyanide	N/A	N/A	N/A	N/A	N/A	N/A
Lead	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium	$1.66 \times 10^{+5}$	530	$8.60 \times 10^{+5}$	920	$9.09 \times 10^{+5}$	500
Manganese	$9.82 \times 10^{+02}$	10	$1.18 \times 10^{+03}$	10	$2.38 \times 10^{+03}$	10
Mercury	N/A	N/A	N/A	N/A	N/A	N/A
Organics						
Alpha-chlordane	N/A	N/A	N/A	N/A	N/A	N/A
Aroclor-1254	N/A	N/A	N/A	N/A	N/A	N/A
Aroclor-1260	N/A	N/A	N/A	N/A	N/A	N/A
Benzene	N/A	N/A	N/A	N/A	N/A	N/A
N/ABenzo(a)anthracene	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(a)pyrene	N/A	N/A	N/A	N/A	N/A	N/A
Bis(2-chloroisopropyl)ether	N/A	N/A	N/A	N/A	N/A	N/A
Bromodichloromethane	N/A	N/A	N/A	N/A	N/A	N/A
Bromomethane	N/A	N/A	N/A	N/A	N/A	N/A
Carbazole	N/A	N/A	N/A	N/A	N/A	N/A
Chloroform	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(a,h)anthracene	N/A	N/A	N/A	N/A	N/A	N/A
3,3-Dichlorobenzidine	N/A	N/A	N/A	N/A	N/A	N/A
1,1-Dichloroethene	N/A	N/A	N/A	N/A	N/A	N/A
Dieldrin	N/A	N/A	N/A	N/A	N/A	N/A
Methylene Chloride	N/A	N/A	N/A	N/A	N/A	N/A
4-methylphenol	N/A	N/A	N/A	N/A	N/A	N/A
4-Nitroaniline	N/A	N/A	N/A	N/A	N/A	N/A
n-Nitroso-di-n-propylamine	N/A	N/A	N/A	N/A	N/A	N/A

TABLE 5-38 (Continued)

Constituent of Potential Concern	Zone 4 Max Conc. (ppb)	Zone 4 Time	Zone 5 Max Conc. (ppb)	Zone 5 Time	Zone 6 Max. conc. (ppb)	Zone 6 Time
Radionuclides						
Neptunium-237	2.81×10^{-05}	810	8.66×10^{-04}	910	3.35×10^{-06}	440
Plutonium-238	N/A	N/A	N/A	N/A	N/A	N/A
Plutonium-239/240	N/A	N/A	N/A	N/A	N/A	N/A
Radium-226	3.37×10^{-06}	10	1.62×10^{-05}	1000	3.30×10^{-06}	10
Strontium-90	5.92×10^{-11}	130	9.89×10^{-08}	70	1.00×10^{-12}	170
Technetium-99	6.25×10^{-02}	60	4.01×10^{-01}	90	7.23×10^{-03}	80
Thorium-230	N/A	N/A	N/A	N/A	N/A	N/A
Thorium-232	N/A	N/A	N/A	N/A	N/A	N/A
Uranium-Total	$1.46 \times 10^{+03}$	780	$9.06 \times 10^{+03}$	1000	$6.37 \times 10^{+00}$	10
Inorganics						
Antimony	$4.04 \times 10^{+01}$	10	$2.91 \times 10^{+00}$	1000	2.17×10^{-01}	20
Arsenic	$4.64 \times 10^{+00}$	1000	$5.69 \times 10^{+00}$	1000	$1.36 \times 10^{+02}$	10
Beryllium	1.63×10^{-09}	1000	1.19×10^{-01}	1000	3.90×10^{-16}	1000
Chromium (hex)	1.29×10^{-01}	1000	$1.07 \times 10^{+01}$	1000	5.89×10^{-03}	320
Cyanide	N/A	N/A	N/A	N/A	N/A	N/A
Lead	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium	$2.53 \times 10^{+5}$	950	$1.35 \times 10^{+6}$	520	$2.03 \times 10^{+5}$	990
Manganese	$8.12 \times 10^{+02}$	60	$1.35 \times 10^{+03}$	1000	$4.27 \times 10^{+02}$	10
Mercury	N/A	N/A	N/A	N/A	N/A	N/A
Organics						
Alpha-chlordane	N/A	N/A	N/A	N/A	N/A	N/A
Aroclor-1254	N/A	N/A	N/A	N/A	N/A	N/A
Aroclor-1260	N/A	N/A	N/A	N/A	N/A	N/A
Benzene	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(a)anthracene	N/A	N/A	N/A	N/A	N/A	N/A
Benzo(a)pyrene	N/A	N/A	N/A	N/A	N/A	N/A
Bis(2-chloroisopropyl)ether	N/A	N/A	N/A	N/A	N/A	N/A
Bromodichloromethane	N/A	N/A	N/A	N/A	N/A	N/A
Bromomethane	N/A	N/A	N/A	N/A	N/A	N/A
Carbazole	N/A	N/A	N/A	N/A	N/A	N/A
Chloroform	N/A	N/A	N/A	N/A	N/A	N/A
Dibenzo(a,h)anthracene	N/A	N/A	N/A	N/A	N/A	N/A
3,3-Dichlorobenzidine	N/A	N/A	N/A	N/A	N/A	N/A
1,1-Dichloroethene	N/A	N/A	N/A	N/A	N/A	N/A
Dieldrin	N/A	N/A	N/A	N/A	N/A	N/A
Methylene Chloride	N/A	N/A	N/A	N/A	N/A	N/A
4-methylphenol	N/A	N/A	N/A	N/A	N/A	N/A
4-Nitroaniline	N/A	N/A	N/A	N/A	N/A	N/A
n-Nitroso-di-n-propylamine	N/A	N/A	N/A	N/A	N/A	N/A

TABLE 5-38 (Continued)

Constituent of Potential Concern	E. BOUND Concentration (ppb)	E. BOUND Time (Yr)	W. BOUND Concentration (ppb)	W. BOUND Time (Yr)	N. BOUND Concentration (ppb)	N. BOUND Time (Yr)
Radionuclides						
Neptunium-237	1.555×10^{-04}	1000	9.83×10^{-05}	350	3.117×10^{-08}	660
Plutonium-238	NA	NA	NA	NA	NA	NA
Plutonium-239/240	NA	NA	NA	NA	NA	NA
Radium-226	1.318×10^{-06}	110	1.186×10^{-06}	10	1.083×10^{-06}	10
Strontium-90	8.247×10^{-10}	120	5.867×10^{-09}	70	8.31×10^{-16}	220
Technetium-99	6.248×10^{-02}	60	5.363×10^{-03}	90	2.623×10^{-03}	90
Thorium-230	NA	NA	NA	NA	NA	NA
Thorium-232	NA	NA	NA	NA	NA	NA
Uranium-Total	$1.263 \times 10^{+03}$	890	$1.108 \times 10^{+01}$	140	3.735×10^{-02}	50
Inorganics						
Antimony	$1.563 \times 10^{+00}$	110	2.554×10^{-01}	1000	7.731×10^{-05}	1000
Arsenic	1.677×10^{-01}	1000	3.856×10^{-01}	1000	$1.359 \times 10^{+02}$	10
Beryllium	1.419×10^{-08}	1000	5.367×10^{-03}	1000	0	
Chromium (hex)	$1.622 \times 10^{+00}$	1000	3.372×10^{-01}	1000	5.462×10^{-05}	480
Cyanide	NA	NA	NA	NA	NA	NA
Lead	NA	NA	NA	NA	NA	NA
Magnesium	$5.283 \times 10^{+05}$	720	$4.051 \times 10^{+04}$	470	$1.633 \times 10^{+05}$	730
Manganese	$4.426 \times 10^{+02}$	10	$2.855 \times 10^{+02}$	10	8.144×10^{-01}	1000
Mercury	NA	NA	NA	NA	NA	NA
Organics						
Alpha-chlordane	NA	NA	NA	NA	NA	NA
Aroclor-1254	NA	NA	NA	NA	NA	NA
Aroclor-1260	NA	NA	NA	NA	NA	NA
Benzene	NA	NA	NA	NA	NA	NA
Benzo(a)anthracene	NA	NA	NA	NA	NA	NA
Benzo(a)pyrene	NA	NA	NA	NA	NA	NA
Bis(2-chloroisopropyl)ether	NA	NA	NA	NA	NA	NA
Bromodichloromethane	NA	NA	NA	NA	NA	NA
Bromomethane	NA	NA	NA	NA	NA	NA
Carbazole	NA	NA	NA	NA	NA	NA
Chloroform	NA	NA	NA	NA	NA	NA
Dibenzo(a,h)anthracene	NA	NA	NA	NA	NA	NA
3,3-Dichlorobenzidine	NA	NA	NA	NA	NA	NA
1,1-Dichloroethene	NA	NA	NA	NA	NA	NA
Dieldrin	NA	NA	NA	NA	NA	NA
Methylene Chloride	NA	NA	NA	NA	NA	NA
4-methylphenol	NA	NA	NA	NA	NA	NA
4-Nitroaniline	NA	NA	NA	NA	NA	NA
n-Nitroso-di-n-propylamine	NA	NA	NA	NA	NA	NA

[a] Fenceline maximum determined as the maximum from model cells representing the north, east, west, and south fencelines.

[b] See Model Grid in Appendix F for locations.

NA Not Applicable

TABLE 5-39

OU5 RECEPTOR CONCENTRATIONS AT TIME OF URANIUM-TOTAL MAXIMUM CONCENTRATION

Receptor Location	Well 12	Well 13	Well 14	Well 34	Well 2071	Well 2119	Well 2127	FEMP Production Well	SOWC Coll 1	SOWC Coll 2	Strickers Grove Well	N.E. Recept.
	28,46,1	39,44,1	59,38,1	5,11,1	85,66,1	73,52,1	5,6,1	43,75,5	101,38,5	108,52,5	87,44,1	90,91,1
Time (Years)	180	320	990	940	200	940	850	270	1,000	1,000	1,000	240
Constituents of Potential Concern												
Radionuclides (μg/L)												
Neptunium-237	$1.77 \times 10^{+04}$	$2.19 \times 10^{+04}$	$1.11 \times 10^{+04}$	$1.93 \times 10^{+07}$	6.58×10^{-10}	$2.00 \times 10^{+05}$	1.98×10^{-06}	1.44×10^{-05}	5.61×10^{-07}	2.79×10^{-06}	9.69×10^{-06}	4.32×10^{-14}
Plutonium-238	9.55×10^{-18}	3.13×10^{-21}	9.09×10^{-26}	NA	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-239/240	3.68×10^{-15}	2.21×10^{-18}	5.06×10^{-21}	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226	2.04×10^{-07}	8.16×10^{-05}	7.16×10^{-09}	1.70×10^{-09}	8.89×10^{-22}	5.24×10^{-08}	1.87×10^{-08}	1.87×10^{-09}	1.03×10^{-17}	6.02×10^{-16}	2.72×10^{-15}	8.95×10^{-22}
Strontium-90	4.34×10^{-09}	2.47×10^{-09}	1.02×10^{-10}	2.00×10^{-13}	2.37×10^{-14}	3.95×10^{-12}	1.92×10^{-12}	3.01×10^{-11}	2.95×10^{-15}	1.73×10^{-14}	8.20×10^{-14}	6.91×10^{-19}
Technetium-99	7.71×10^{-02}	8.67×10^{-02}	4.04×10^{-02}	6.51×10^{-05}	1.10×10^{-04}	4.23×10^{-03}	6.86×10^{-04}	1.10×10^{-03}	3.73×10^{-04}	7.09×10^{-04}	5.17×10^{-03}	3.47×10^{-07}
Thorium-230	0[a]	0[a]	0[a]	NA	NA	NA	NA	NA	NA	NA	NA	NA
Thorium-232	0[a]	0[a]	0[a]	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-Total	$1.40 \times 10^{+03}$	$1.76 \times 10^{+03}$	$8.73 \times 10^{+02}$	9.92×10^{-01}	$1.28 \times 10^{+00}$	$2.04 \times 10^{+02}$	$1.06 \times 10^{+01}$	$3.29 \times 10^{+00}$	$8.92 \times 10^{+00}$	$6.44 \times 10^{+01}$	$1.24 \times 10^{+02}$	4.90×10^{-02}
Radionuclides (pCi/L)												
Neptunium-237	1.25×10^{-01}	1.55×10^{-01}	7.80×10^{-02}	1.36×10^{-04}	4.64×10^{-07}	1.41×10^{-02}	1.40×10^{-03}	1.02×10^{-02}	3.96×10^{-04}	1.97×10^{-03}	6.83×10^{-03}	3.04×10^{-11}
Plutonium-238	1.63×10^{-10}	5.35×10^{-14}	1.56×10^{-18}	NA	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-239/240	2.28×10^{-10}	1.37×10^{-13}	3.14×10^{-16}	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226	2.02×10^{-01}	8.07×10^{-03}	7.08×10^{-03}	1.68×10^{-03}	8.79×10^{-16}	5.19×10^{-02}	1.85×10^{-02}	1.85×10^{-03}	1.01×10^{-11}	5.95×10^{-10}	2.69×10^{-09}	8.85×10^{-16}
Strontium-90	5.94×10^{-01}	3.38×10^{-01}	1.39×10^{-02}	2.75×10^{-05}	3.24×10^{-06}	5.41×10^{-04}	2.62×10^{-04}	4.12×10^{-03}	4.04×10^{-07}	2.37×10^{-06}	1.12×10^{-05}	9.47×10^{-11}
Technetium-99	$1.31 \times 10^{+03}$	$1.47 \times 10^{+03}$	$6.86 \times 10^{+02}$	$1.11 \times 10^{+00}$	$1.87 \times 10^{+00}$	$7.18 \times 10^{+01}$	$1.17 \times 10^{+01}$	$1.86 \times 10^{+01}$	$6.33 \times 10^{+00}$	$1.21 \times 10^{+01}$	$8.79 \times 10^{+01}$	5.91×10^{-03}
Thorium-230	0[a]	0[a]	0[a]	NA	NA	NA	NA	NA	NA	NA	NA	NA
Thorium-232	0[a]	0[a]	0[a]	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-Total	$9.43 \times 10^{+02}$	$1.19 \times 10^{+03}$	$5.90 \times 10^{+02}$	6.70×10^{-01}	8.62×10^{-01}	$1.38 \times 10^{+02}$	$7.16 \times 10^{+00}$	$2.23 \times 10^{+00}$	$6.03 \times 10^{+00}$	$4.35 \times 10^{+01}$	$8.37 \times 10^{+01}$	3.31×10^{-02}

TABLE 5-39 (Continued)

Receptor Location	Well 12	Well 13	Well 14	Well 34	Well 2071	Well 2119	Well 2127	FEMP Production Well	SOWC Coll 1	SOWC Coll 2	Strickers Grove Well	N.E. Recept.
	28,46,1	39,44,1	59,38,1	5,11,1	85,66,1	73,52,1	5,6,1	43,75,5	101,38,5	108,52,5	87,44,1	90,91,1
Time (Years)	180	320	990	940	200	940	850	270	1,000	1,000	1,000	240
Constituents of Potential Concern												
Organics (µg/L)												
Alpha-Chlordane	1.95×10^{-02}	1.18×10^{-02}	3.14×10^{-03}	NA	1.48×10^{-19}	9.42×10^{-10}	NA	NA	4.12×10^{-09}	1.62×10^{-10}	4.34×10^{-09}	NA
Aroclor-1254	0[a]	0[a]	0[a]	NA	NA	NA	NA	NA	NA	NA	NA	NA
Aroclor-1260	0[a]	0[a]	0[a]	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzene	NA	1.16×10^{-04}	4.68×10^{-06}	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)Anthracene	NA	0[a]	0[a]	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzo(a)Pyrene	0[a]	0[a]	0[a]	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bis(2-Chloroisopropyl)Ether	9.29×10^{-01}	6.22×10^{-01}	2.33×10^{-01}	NA	2.51×10^{-02}	0[a]	NA	NA	0[a]	0[a]	0[a]	NA
BromoDiChloroMethane	5.51×10^{-02}	1.42×10^{-02}	NA	NA	NA	0[a]	NA	NA	0[a]	0[a]	0[a]	NA
BromoMethane	3.45×10^{-03}	2.05×10^{-05}	2.53×10^{-10}	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbazole	NA	NA	NA	NA	NA	2.12×10^{-03}	NA	0[a]	4.31×10^{-04}	2.75×10^{-04}	4.87×10^{-05}	NA
Chloroform	9.05×10^{-03}	4.34×10^{-05}	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
DiBenzo(a,h)Anthracene	0[a]	0[a]	0[a]	NA	NA	NA	NA	NA	NA	NA	NA	NA
3,3'-DiChloroBenzidine	NA	8.32×10^{-17}	0[a]	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1-DiChloroEthene	4.90×10^{-02}	3.92×10^{-03}	1.51×10^{-05}	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dieldrin	NA	5.94×10^{-14}	1.96×10^{-19}	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylene Chloride	NA	7.15×10^{-08}	1.26×10^{-13}	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-MethylPhenol	$2.43 \times 10^{+02}$	$1.65 \times 10^{+02}$	$6.42 \times 10^{+01}$	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-NitroAniline	NA	4.50×10^{-01}	2.29×10^{-01}	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Nitroso-di-n-Propylamine	NA	4.17×10^{-04}	1.09×10^{-05}	NA	NA	NA	NA	NA	NA	NA	NA	NA

TABLE 5-39 (Continued)

Receptor Location	Well 12	Well 13	Well 14	Well 34	Well 2071	Well 2119	Well 2127	FEMP Production Well	SOWC Coll 1	SOWC Coll 2	Strickers Grove Well	N.E. Recept.
	28,46,1	39,44,1	59,38,1	5,11,1	85,66,1	73,52,1	5,6,1	43,75,5	101,38,5	108,52,5	87,44,1	90,91,1
Time (Years)	180	320	990	940	200	940	850	270	1,000	1,000	1,000	240
Constituents of Potential Concern												
Inorganics (mg/L)												
Antimony	6.41×10^{-05}	5.66×10^{-06}	4.51×10^{-07}	5.83×10^{-07}	1.34×10^{-13}	3.22×10^{-07}	3.90×10^{-06}	3.16×10^{-06}	3.53×10^{-15}	5.07×10^{-11}	1.26×10^{-16}	0[a]
Arsenic	3.64×10^{-07}	1.53×10^{-11}	1.04×10^{-16}	4.45×10^{-04}	9.67×10^{-25}	5.06×10^{-18}	3.70×10^{-03}	1.21×10^{-19}	0[a]	0[a]	0[a]	0[a]
Beryllium	2.26×10^{-09}	2.54×10^{-14}	1.88×10^{-20}	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]
Chromium (hex)	1.84×10^{-03}	2.30×10^{-03}	1.13×10^{-03}	1.62×10^{-06}	5.66×10^{-10}	1.37×10^{-04}	1.69×10^{-05}	5.26×10^{-05}	9.06×10^{-06}	2.23×10^{-05}	1.34×10^{-04}	2.38×10^{-15}
Cyanide	4.74×10^{-01}	6.68×10^{-01}	2.73×10^{-01}	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lead	8.70×10^{-06}	1.25×10^{-07}	2.34×10^{-10}	NA	NA	NA	NA	NA	NA	NA	NA	NA
Magnesium	$1.88 \times 10^{+02}$	$2.27 \times 10^{+02}$	$1.56 \times 10^{+02}$	$1.69 \times 10^{+01}$	1.15×10^{-06}	$4.46 \times 10^{+01}$	$1.77 \times 10^{+00}$	$1.74 \times 10^{+02}$	4.96×10^{-01}	$6.46 \times 10^{+00}$	$1.30 \times 10^{+01}$	6.15×10^{-13}
Manganese	4.43×10^{-02}	1.74×10^{-02}	2.49×10^{-03}	1.31×10^{-03}	4.39×10^{-08}	7.97×10^{-04}	1.03×10^{-02}	6.67×10^{-02}	2.77×10^{-05}	4.79×10^{-04}	1.76×10^{-05}	3.78×10^{-19}
Mercury	NA	NA	5.82×10^{-10}	NA	NA	1.35×10^{-10}	NA	NA	9.44×10^{-14}	3.93×10^{-11}	4.30×10^{-13}	NA

NA - not applicable
[a]- "0" indicates concentration less than SWIFT calculation limit of 1×10^{-22}.

TABLE 5-40

CPC MAXIMUM CONCENTRATIONS AT PILOT PLANT DITCH/PADDYS RUN PERCHED WATER AS A LATERAL SOURCE

Source Area	OU1 "A" Area			OU1 "B" Area		
Constituent of Potential Concern	Max. Conc. (μg/L)	Time of Max (yrs)	Loading Rate to Surface Water (kg/yr)	Max. Conc. (μg/L)	Time of Max (yrs)	Loading Rate to Surface Water (kg/yr)
Radionuclide						
Strontium-90	6.51×10^{-17}	100	6.53×10^{-20}	1.06×10^{-12}	60	9.36×10^{-16}
Technetium-99	3.90×10^{-4}	40	3.64×10^{-7}	NM	NA	NA
Uranium-234	NM	NA	NA	3.20×10^{-13}	180	2.27×10^{-16}
Uranium-235/6	NM	NA	NA	5.92×10^{-10}	180	4.19×10^{-13}
Uranium-238	NM	NA	NA	2.76×10^{-7}	200	7.81×10^{-10}
Inorganic						
Antimony	NM	NA	NA	NM	NA	NA
Cadmium	NM	NA	NA	2.31×10^{-6}	160	2.04×10^{-9}
Cyanide	3.51×10^{-1}	40	9.38×10^{-4}	3.59×10^{1}	20	1.02×10^{-1}
Magnesium	3.73×10^{-6}	160	2.49×10^{-9}	9.97×10^{-1}	100	1.06×10^{-3}
Manganese	NM	NA	NA	NM	NA	NA
Mercury	NM	NA	NA	1.52×10^{-7}	160	4.30×10^{-10}
Molybdenum	NM	NA	NA	2.99×10^{-3}	160	8.46×10^{-6}

TABLE 5-40 (Continued)

Source Area	OU1 "A" Area			OU1 "B" Area		
Constituent of Potential Concern	Max. Conc. (μg/L)	Time of Max (yrs)	Loading Rate to Surface Water (kg/yr)	Max. Conc. (μg/L)	Time of Max (yrs)	Loading Rate to Surface Water (kg/yr)
Organic						
1,1,2,2-Tetrachloroethane	NM	NA	NA	NM	NA	NA
1,1,2-Trichloroethane	NM	NA	NA	NM	NA	NA
1,1,1-Trichloroethane	NM	NA	NA	NM	NA	NA
1,2-Dichloroethene	NM	NA	NA	NM	NA	NA
1,1-Dichloroethane	NM	NA	NA	NM	NA	NA
1,1-Dichloroethene	NM	NA	NA	NM	NA	NA
2-Methylnaphthalene	NM	NA	NA	NM	NA	NA
Bromoform	NM	NA	NA	NM	NA	NA
Carbazole	5.41×10^{-7}	100	4.52×10^{-10}	1.49×10^{-2}	60	4.215×10^{-5}
Tetrachloroethene	NM	NA	NA	NM	NA	NA
Trichloroethene	NM	NA	NA	NM	NA	NA
Vinyl Chloride	4.63×10^{-3}	20	3.09×10^{-6}	NM	NA	NA

NM - Indicates COPC was not modeled using ECTran because COPC screened out due to decay or no positive hits were detected in perched water.
NA - Not applicable.

TABLE 5-40 (Continued)

Source Area	OU4 Area			Pilot Plant Area		
Constituent of Potential Concern	Max. Conc. (μg/L)	Time of Max (yrs)	Loading Rate to Surface Water (kg/yr)	Max. Conc. (μg/L)	Time of Max (yrs)	Loading Rate to Surface Water (kg/yr)
Radionuclide						
Strontium-90	NM	NA	NA	NM	NA	NA
Technetium-99	4.86×10^{-4}	20	1.10×10^{-6}	3.46×10^{-6}	40	9.81×10^{-10}
Uranium-234	3.47×10^{-8}	100	1.26×10^{-10}	1.14×10^{-25}	340	6.45×10^{-29}
Uranium-235/6	1.00×10^{-5}	100	3.62×10^{-8}	4.27×10^{-23}	340	3.87×10^{-26}
Uranium-238	1.10×10^{-3}	100	5.98×10^{-6}	2.76×10^{-21}	340	2.50×10^{-24}
Inorganic						
Antimony	2.96×10^{-4}	180	1.07×10^{-6}	NM	NA	NA
Cadmium	1.40×10^{0}	80	5.07×10^{-3}	NM	NA	NA
Cyanide	8.86×10^{0}	20	4.82×10^{-2}	NM	NA	NA
Magnesium	5.42×10^{2}	40	2.95×10^{0}	NM	NA	NA
Manganese	3.79×10^{-7}	180	1.79×10^{-9}	NM	NA	NA
Mercury	9.07×10^{-4}	80	4.93×10^{-6}	NM	NA	NA
Molybdenum	1.50×10^{-2}	80	8.16×10^{-5}	NM	NA	NA

TABLE 5-40 (Continued)

Source Area	OU4 Area			Pilot Plant Area		
Constituent of Potential Concern	Max. Conc. (μg/L)	Time of Max (yrs)	Loading Rate to Surface Water (kg/yr)	Max. Conc. (μg/L)	Time of Max (yrs)	Loading Rate to Surface Water (kg/yr)
Organic						
1,1,2,2-Tetrachloroethane	2.02×10^{-2}	20	1.10×10^{-4}	NM	NA	NA
1,1,2-Trichloroethane	4.23×10^{-1}	20	2.30×10^{-3}	NM	NA	NA
1,2-Dichloroethene	NM	NA	NA	3.43×10^{-3}	20	1.17×10^{-6}
1,1-Dichloroethane	NM	NA	NA	1.56×10^{-3}	20	1.41×10^{-6}
1,1-Dichloroethene	NM	NA	NA	4.08×10^{-4}	20	3.69×10^{-7}
2-Methylnaphthalene	NM	NA	NA	NM	NA	NA
Bromoform	8.56×10^{-2}	20	4.66×10^{-4}	NM	NA	NA
Carbazole	4.83×10^{-1}	40	2.627×10^{-3}	1.63×10^{-7}	140	1.475×10^{-10}
Tetrachloroethene	NM	NA	NA	1.21×10^{-4}	40	4.12×10^{-8}
Trichloroethene	1.58×10^{0}	20	8.59×10^{-3}	1.31×10^{-4}	40	4.46×10^{-8}
Vinyl Chloride	NM	NA	NA	NM	NA	NA

NM - Indicates COPC was not modeled using ECTran because COPC screened out due to decay or no positive hits were detected in perched water.
NA - Not applicable.

TABLE 5-40 (Continued)

Source Area	Plant 2/3 Area			Laboratory Area		
Constituent of Potential Concern	Max. Conc. (μg/L)	Time of Max (yrs)	Loading Rate to Surface Water (kg/yr)	Max. Conc. (μg/L)	Time of Max (yrs)	Loading Rate to Surface Water (kg/yr)
Radionuclide						
Strontium-90	NM	NA	NA	NA	NA	NA
Technetium-99	3.15×10^{-5}	60	3.30×10^{-8}	3.02×10^{-6}	40	1.01×10^{-9}
Uranium-234	4.88×10^{-36}	480	5.11×10^{-39}	8.11×10^{-25}	320	6.48×10^{-28}
Uranium-235/6	1.12×10^{-33}	460	1.17×10^{-36}	5.77×10^{-23}	320	1.54×10^{-26}
Uranium-238	7.17×10^{-32}	480	7.51×10^{-35}	1.26×10^{-20}	320	1.34×10^{-23}
Inorganic						
Antimony	NM	NA	NA	NM	NA	NA
Cadmium	NM	NA	NA	NM	NA	NA
Cyanide	2.82×10^{-3}	40	2.95×10^{-6}	3.26×10^{2}	40	3.48×10^{-1}
Magnesium	NM	NA	NA	1.21×10^{-7}	180	1.35×10^{-10}
Manganese	NM	NA	NA	NM	NA	NA
Mercury	NM	NA	NA	NM	NA	NA
Molybdenum	NM	NA	NA	NM	NA	NA

TABLE 5-40 (Continued)

Source Area	Plant 2/3 Area			Laboratory Area		
Constituent of Potential Concern	Max. Conc. (μg/L)	Time of Max (yrs)	Loading Rate to Surface Water (kg/yr)	Max. Conc. (μg/L)	Time of Max (yrs)	Loading Rate to Surface Water (kg/yr)
Organic						
1,1,2,2-Tetrachloroethane	NM	NA	NA	NM	NA	NA
1,1,2-Trichloroethane	NM	NA	NA	NM	NA	NA
1,1,1-Trichloroethane	NM	NA	NA	NM	NA	NA
1,2-Dichloroethene	NM	NA	NA	NM	NA	NA
1,1-Dichloroethane	NM	NA	NA	NM	NA	NA
1,1-Dichloroethene	NM	NA	NA	2.34×10^{-3}	20	2.49×10^{-6}
2-Methylnaphthalene	NM	NA	NA	NM	NA	NA
Bromoform	NM	NA	NA	NM	NA	NA
Carbazole	NM	NA	NA	1.61×10^{-7}	140	1.716×10^{-10}
Tetrachloroethene	NM	NA	NA	NM	NA	NA
Trichloroethene	NM	NA	NA	NM	NA	NA
Vinyl Chloride	NM	NA	NA	NM	NA	NA

NM - Indicates COPC was not modeled using ECTran because COPC screened out due to decay or no positive hits were detected in perched water.
NA - Not applicable.

TABLE 5-41

UNCERTAINTY ANALYSIS OF Kd FOR URANIUM-TOTAL CASES 1 AND 2

Receptor Location	Well 12	Well 13	Well 14	Well 34	Well 2071	Well 2119	Well 2127	FEMP Production Well	SOWC Coll 1	SOWC Coll 2	Strickers Grove Well	N.E. Recept.
	28,46,1	39,44,1	59,38,1	5,11,1	85,66,1	73,52,1	5,6,1	43,75,5	101,38,5	108,52,5	87,44,1	90,91,1
Constituents of Potential Concern												
Radionuclides (μg/L)												
U-Total Uncertainty Analysis Case 1												
Time	900	890	1000	1000	990	1000	1000	840	1000	1000	1000	1000
Concentration	2.00×10^{-02}	1.99×10^{01}	3.53×10^{02}	4.75×10^{-03}	5.25×10^{01}	4.90×10^{02}	5.72×10^{-02}	5.97×10^{01}	5.07×10^{00}	8.04×10^{01}	8.66×10^{01}	5.25×10^{-03}
U-Total Uncertainty Analysis Case 2												
Time	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Concentration	1.66×10^{-02}	1.04×10^{01}	2.56×10^{02}	2.50×10^{-03}	3.84×10^{01}	3.55×10^{02}	3.01×10^{-02}	5.13×10^{01}	2.62×10^{00}	4.68×10^{01}	4.61×10^{01}	2.90×10^{-03}

TABLE 5-41 (Continued)

Receptor Location	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	E. Bound	W. Bound	N. Bound
Constituents of Potential Concern									
Radionuclides (μg/L)									
U-Total Uncertainty Analysis Case 1									
Time	800	810	800(a)	860	830	870	910	870	920
Concentration	6.99×10^{00}	6.17×10^{03}	1.22×10^{04}	1.52×10^{03}	3.20×10^{03}	4.70×10^{-02}	9.96×10^{02}	9.65×10^{-05}	6.39×10^{-05}
U-Total Uncertainty Analysis Case 2									
Time	980	980	980	1000	1000	1000	1000	1000	1000
Concentration	5.79×10^{00}	5.05×10^{03}	9.94×10^{03}	1.28×10^{03}	2.64×10^{03}	3.93×10^{-02}	8.33×10^{0}	8.10×10^{-05}	5.21×10^{-05}

TABLE 5-42

UNCERTAINTY ANALYSIS OF Kd FOR URANIUM-TOTAL BASELINE CASE AND CASE 3

Receptor Location	Well 12	Well 13	Well 14	Well 34	Well 2071	Well 2119	Well 2127	FEMP Production Well	SOWC Coll 1	SOWC Coll 2	Strickers Grove Well	N.E. Recept.
	28,46,1	39,44,1	59,38,1	5,11,1	85,66,1	73,52,1	5,6,1	43,75,5	101,38,5	108,52,5	87,44,1	90,91,1
Constituents of Potential Concern												
Radionuclides (μg/L)												
U-Total Baseline												
Time (years)	180	320	990	940	200	940	850	270	1000	1000	1000	240
Concentration	1.39×10^{03}	1.78×10^{03}	8.73×10^{02}	9.92×10^{-01}	1.27×10^{00}	2.04×10^{02}	1.06×10^{01}	3.29×10^{00}	8.92×10^{00}	6.44×10^{01}	1.24×10^{02}	4.90×10^{-02}
U-Total Uncertainty Case 3												
Time (years)	480	730	1000	1000	950	1000	900	1000	1000	1000	1000	240
Concentration	1.40×10^{03}	1.77×10^{03}	9.07×10^{02}	9.44×10^{-01}	6.52×10^{01}	2.44×10^{02}	1.06×10^{01}	7.07×10^{00}	9.36×10^{00}	7.04×10^{01}	1.34×10^{02}	4.90×10^{-02}

TABLE 5-42 (Continued)

Receptor Location	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	E. Bound	W. Bound	N. Bound
Constituents of Potential Concern									
Radionuclides (μg/L)									
U-Total Baseline									
Time (years)	190	210(a)	790	780	1000	10	890(a)	140(a)	50
Concentration	1.70×10^{02}	6.28×10^{03}	2.75×10^{03}	1.46×10^{03}	9.06×10^{03}	6.37×10^{00}	1.26×10^{03}	1.11×10^{01}	3.73×10^{-02}
U-Total Uncertainty Case 3									
Time (years)	1000	1000	800	790	1000	1000	1000	990	1000
Concentration	9.12×10^{01}	6.29×10^{03}	2.80×10^{03}	1.49×10^{03}	9.12×10^{03}	2.08×10^{01}	1.30×10^{03}	1.11×10^{01}	1.92×10^{00}

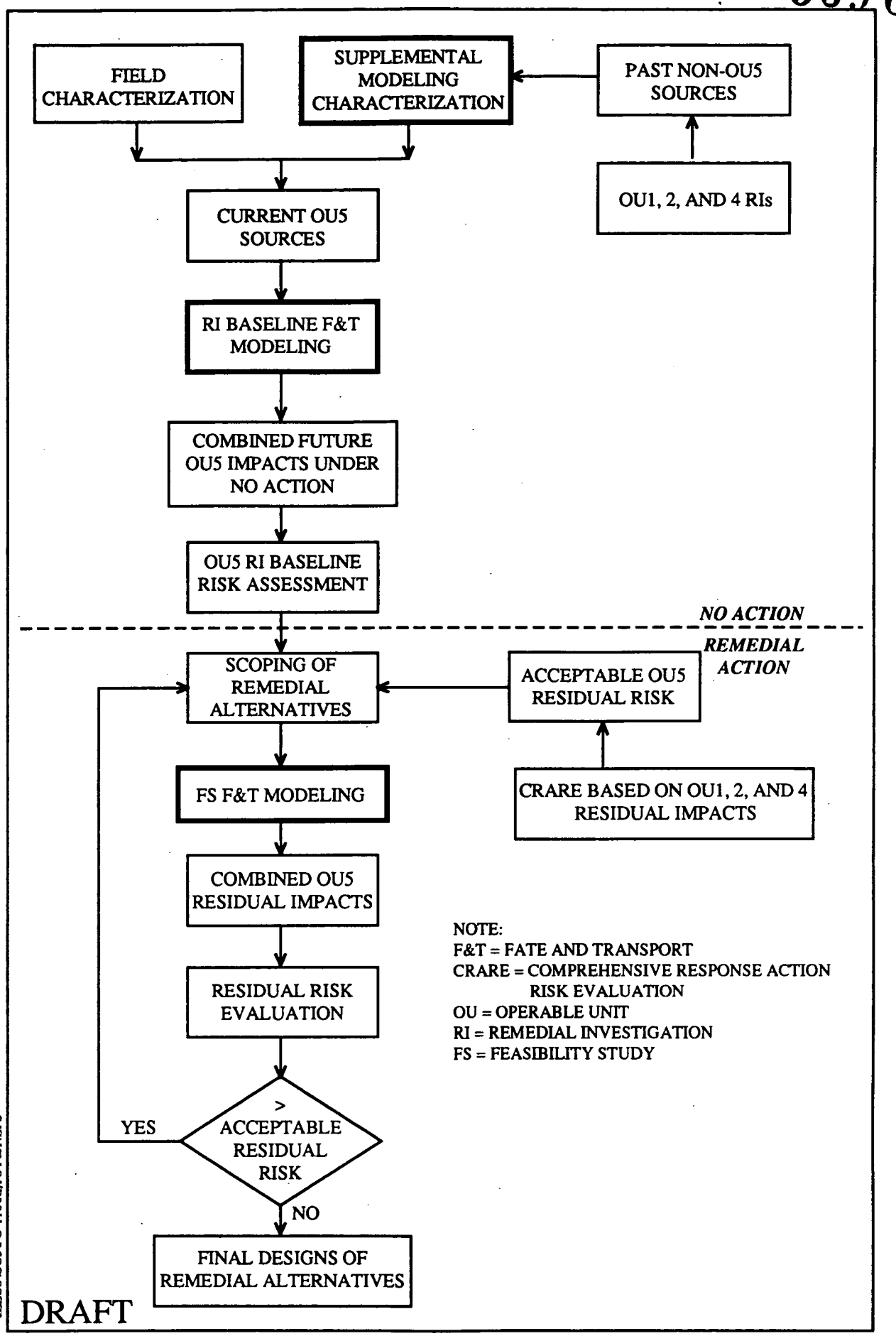

FIGURE 5-1. OVERALL OPERABLE UNIT 5 RI/FS FATE AND TRANSPORT MODELING PROCESS

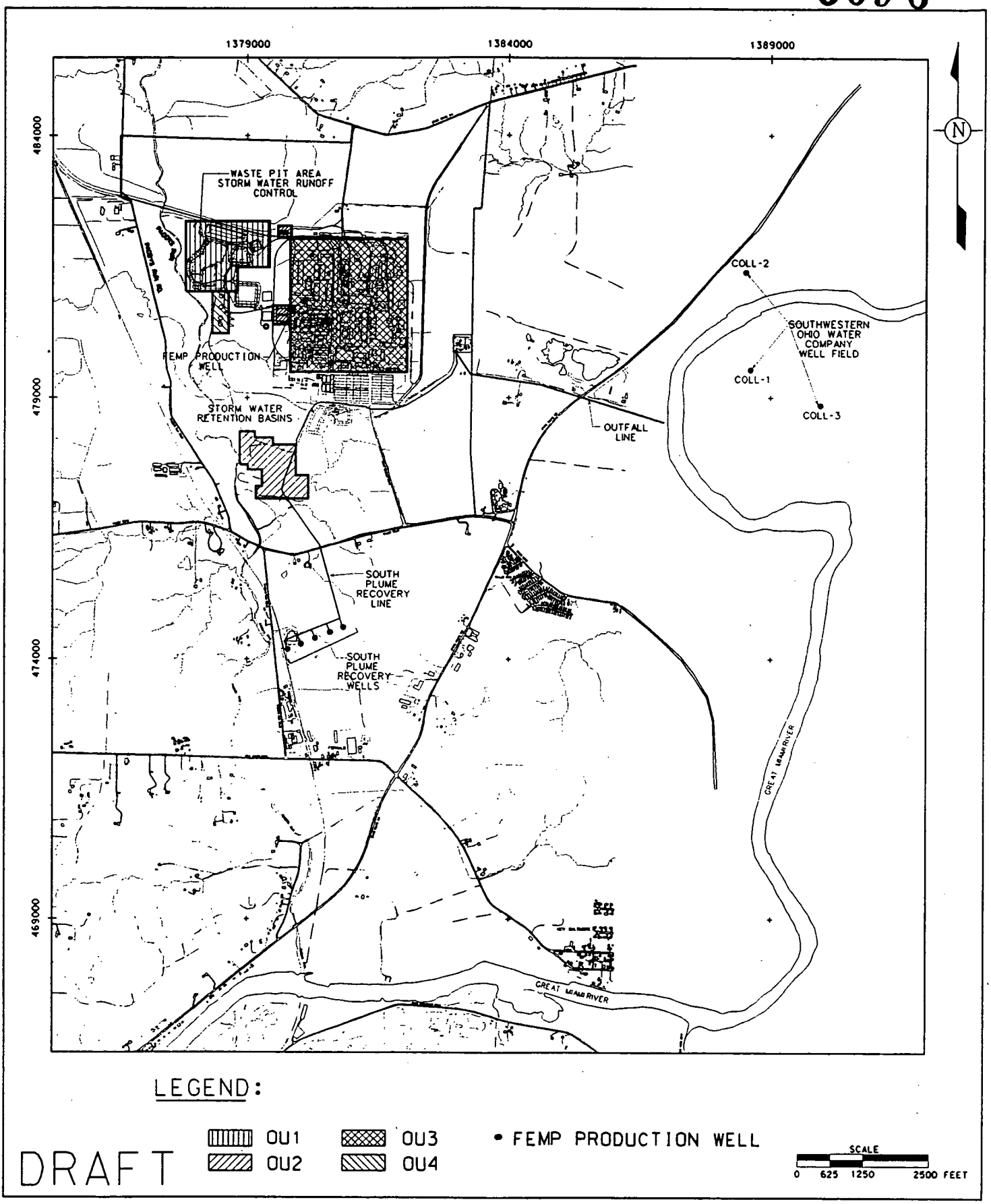

FIGURE 5-2. FUTURE CONDITIONS CONSIDERED IN THE OPERABLE UNIT 5 NO-ACTION SCENARIO

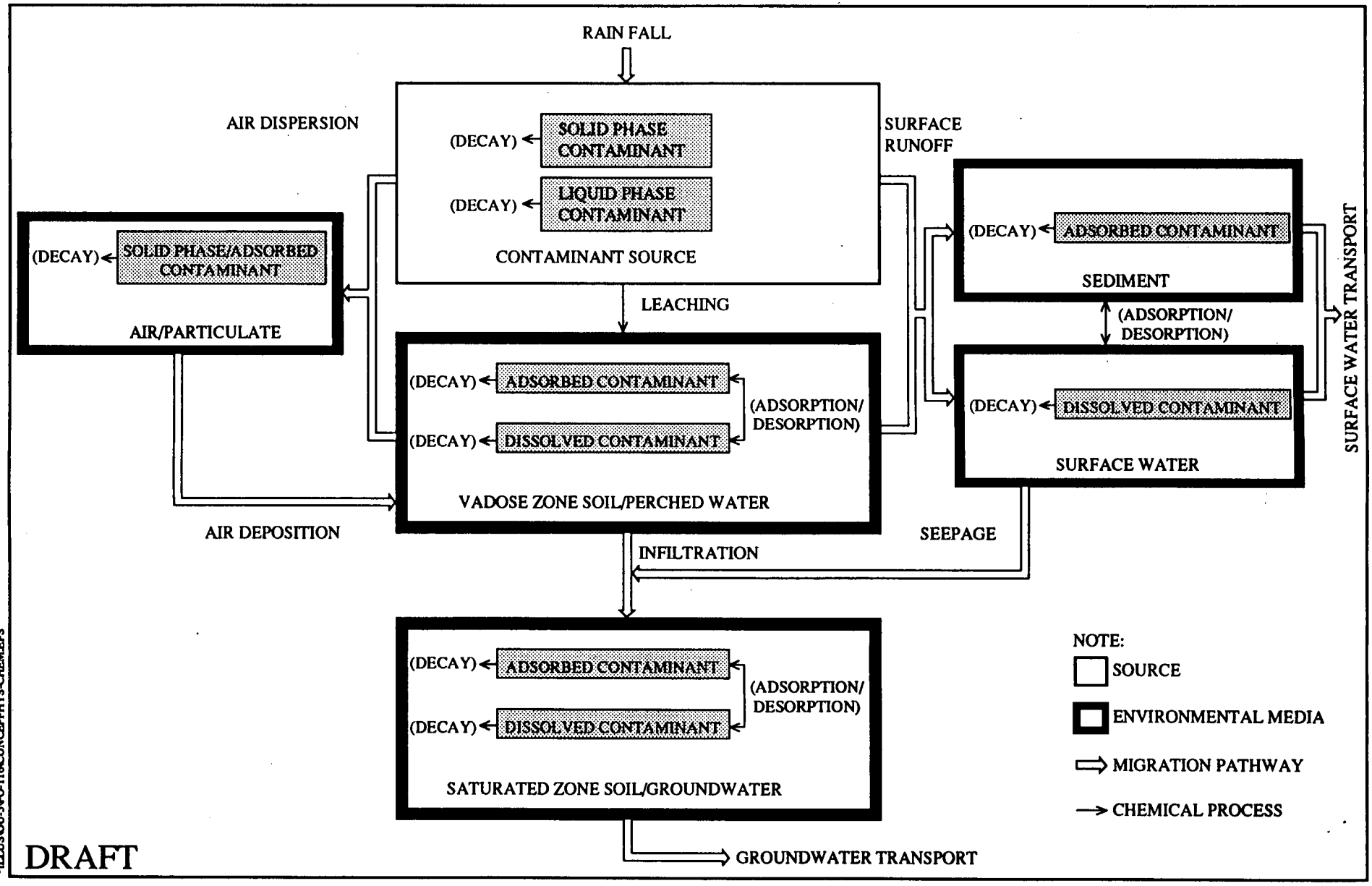

FIGURE 5-3. CONCEPTUAL PHYSICAL AND CHEMICAL PROCESSES OF CONTAMINANT FATE AND TRANSPORT

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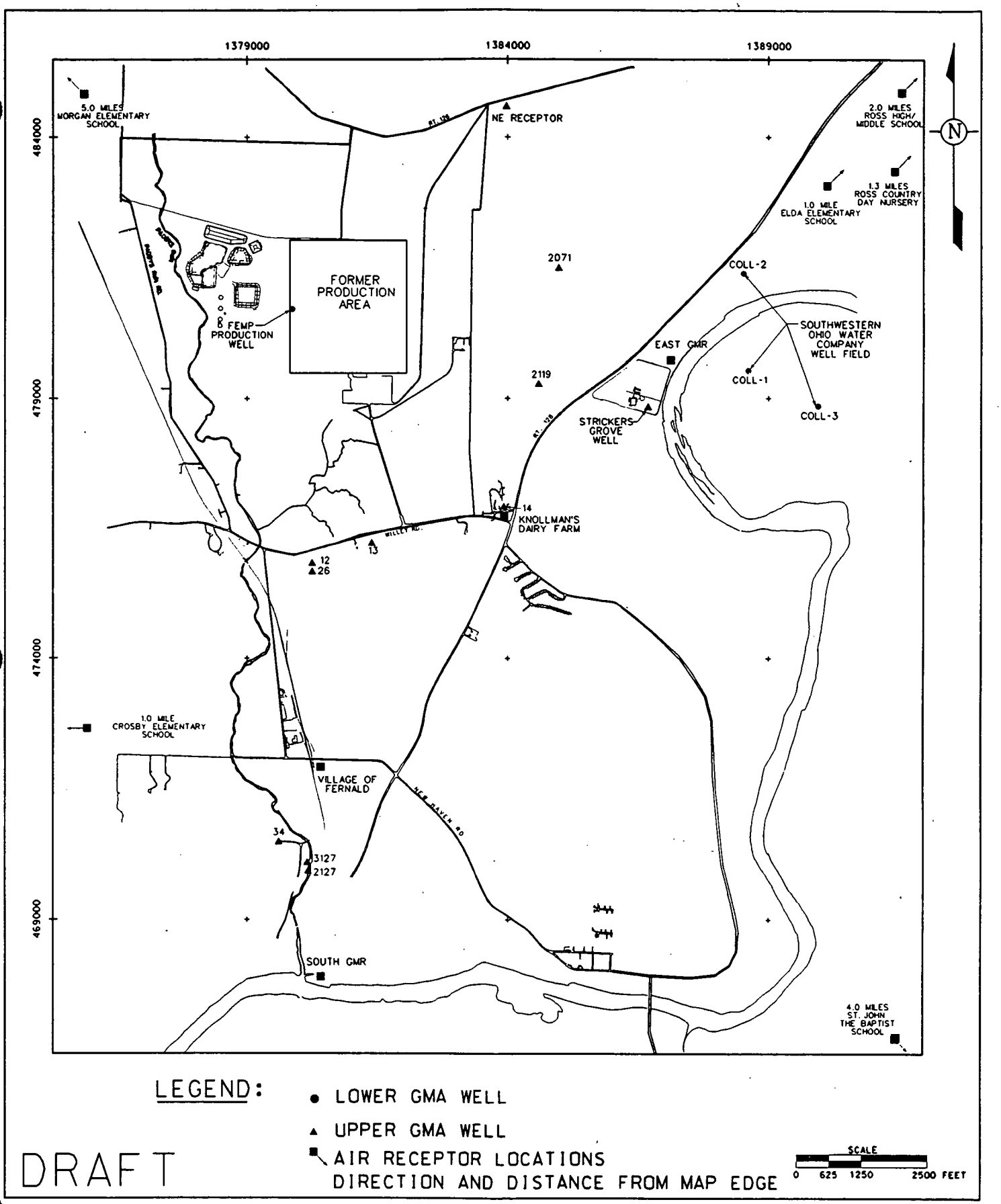


FIGURE 5-4. RECEPTOR LOCATIONS FOR OPERABLE UNIT 5 FATE & TRANSPORT MODELING

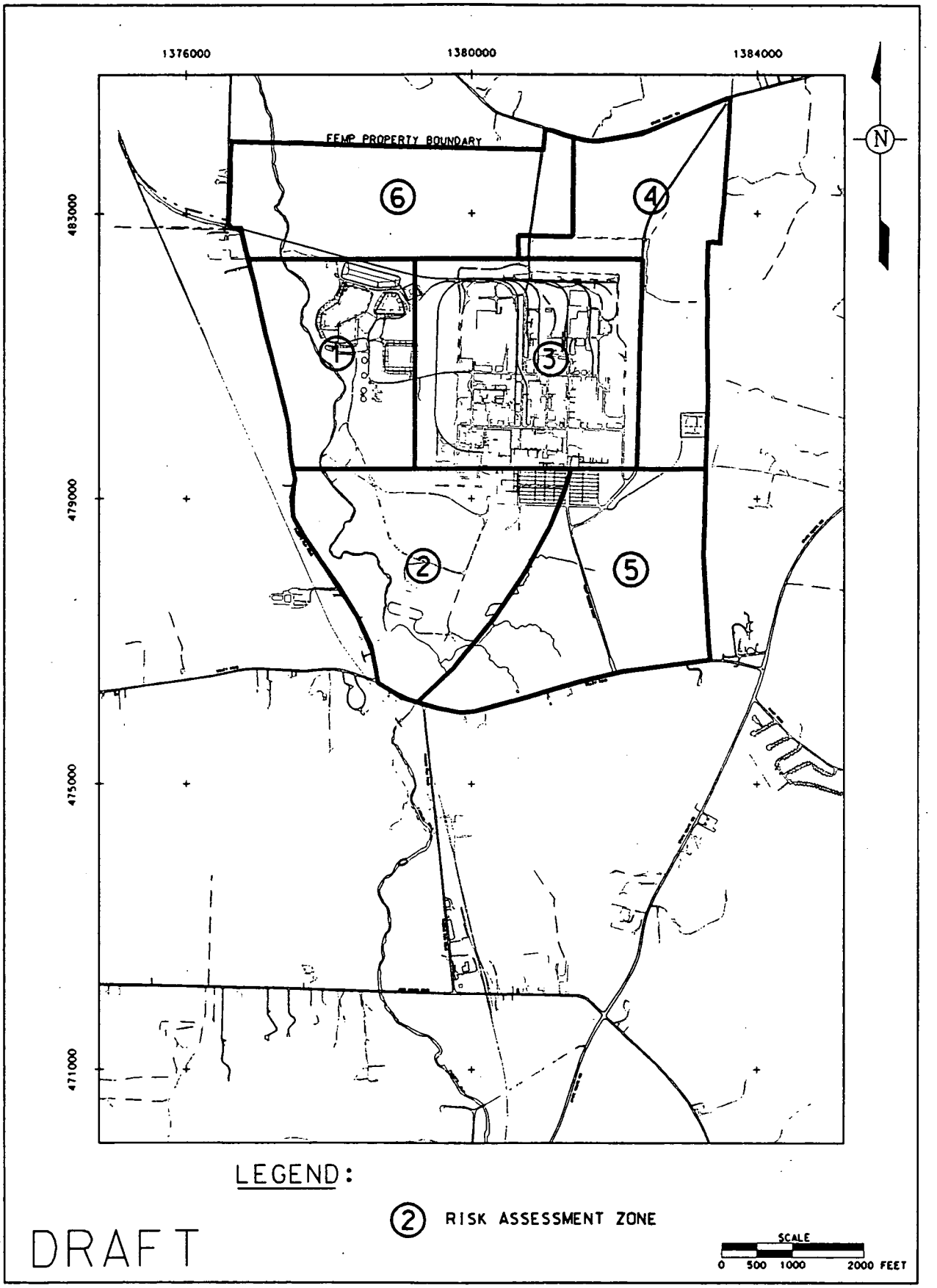
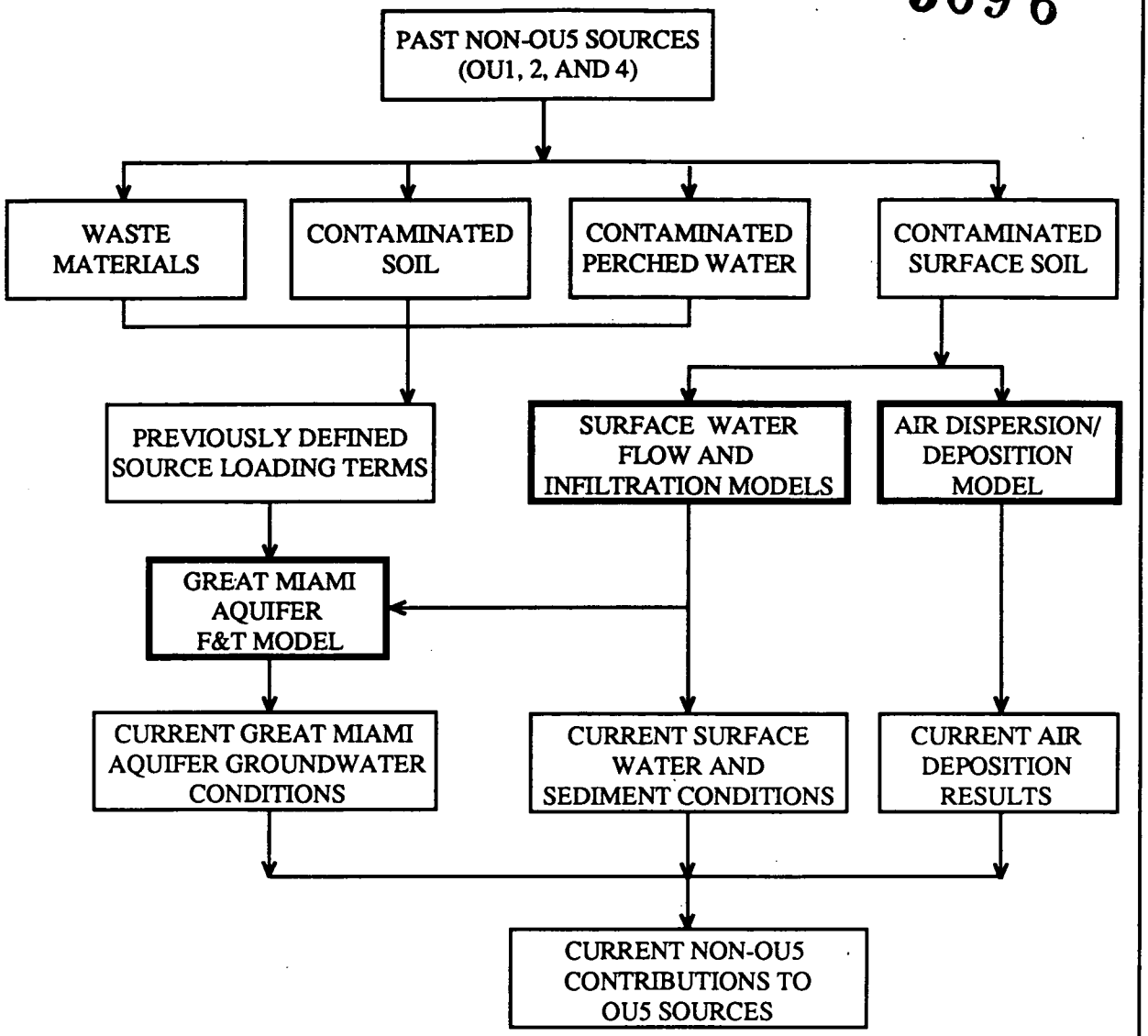


FIGURE 5-5. OPERABLE UNIT 5 RISK ASSESSMENT ZONES



NOTE:
F&T = FATE AND TRANSPORT
OU = OPERABLE UNIT

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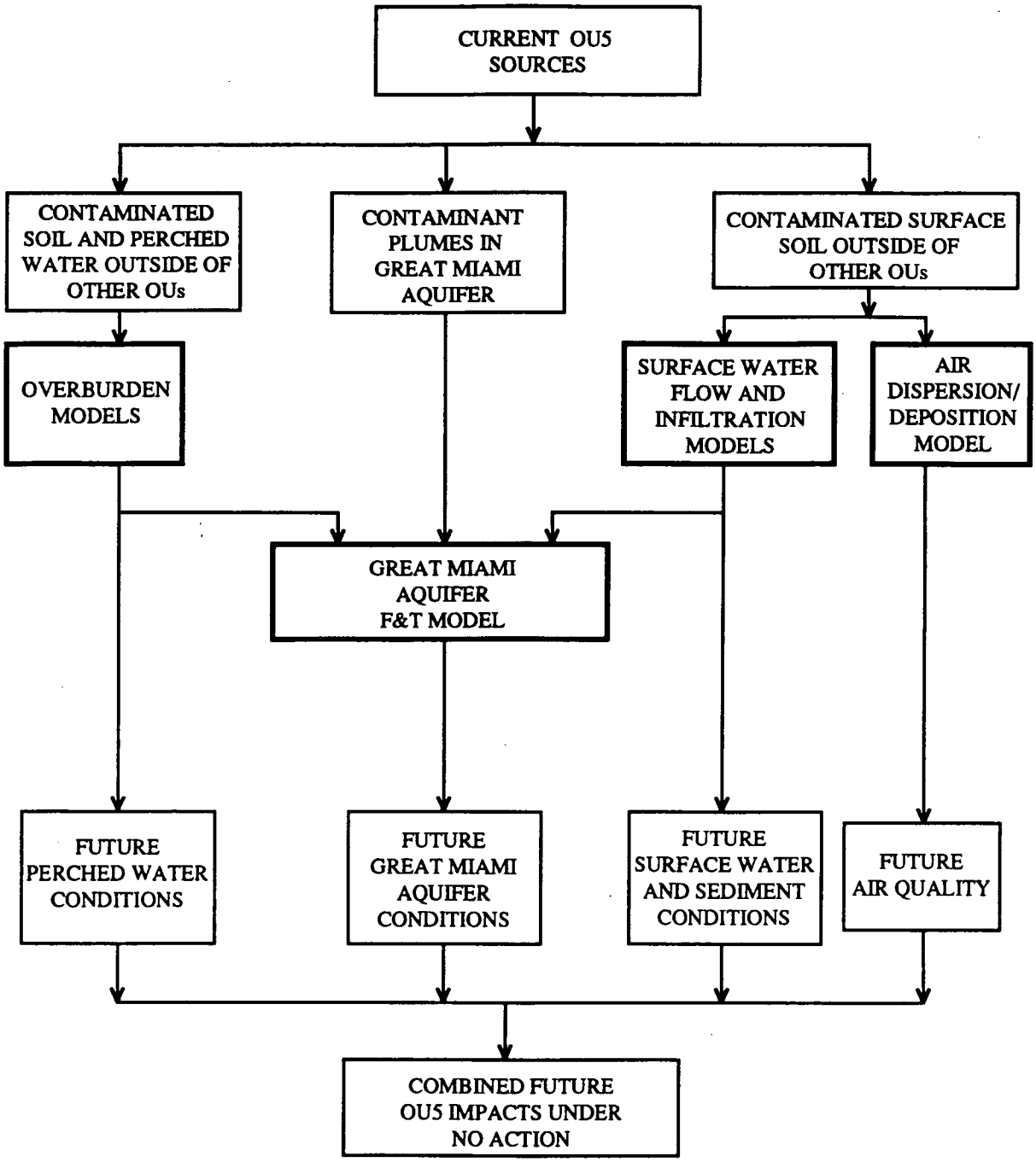
*ILLUS\OU-5\PO-116\SUPPMOD CHAR.EPS

FIGURE 5-6. SUPPLEMENTAL MODELING CHARACTERIZATION OF OPERABLE UNITS 1, 2, AND 4



*ILLUS\OU-5\PO-116\BASELINE CONTAM.EPS

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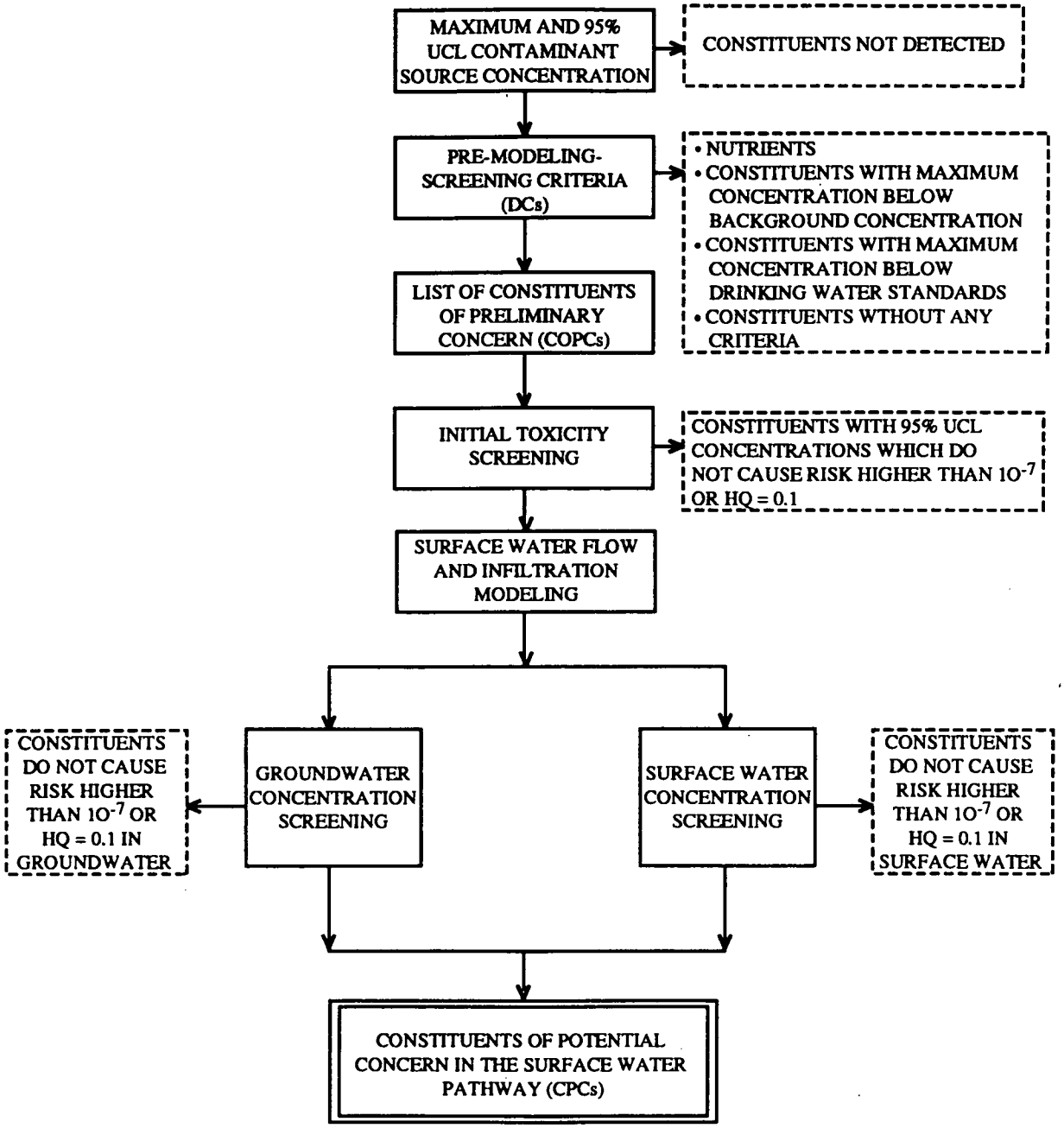
NOTE:
F&T = FATE AND TRANSPORT
OU = OPERABLE UNIT

FIGURE 5-7. OPERABLE UNIT 5 BASELINE CONTAMINANT SOURCES, PATHWAYS, AND MODELING FRAMEWORK



NOTE:
DCs = DETECTED CONSTITUENTS
COPCs = CONSTITUENTS OF PRELIMINARY CONCERN
CPCs = CONSTITUENTS OF POTENTIAL CONCERN
UCL = UPPER CONFIDENCE LEVEL
HQ = HAZARD QUOTIENT

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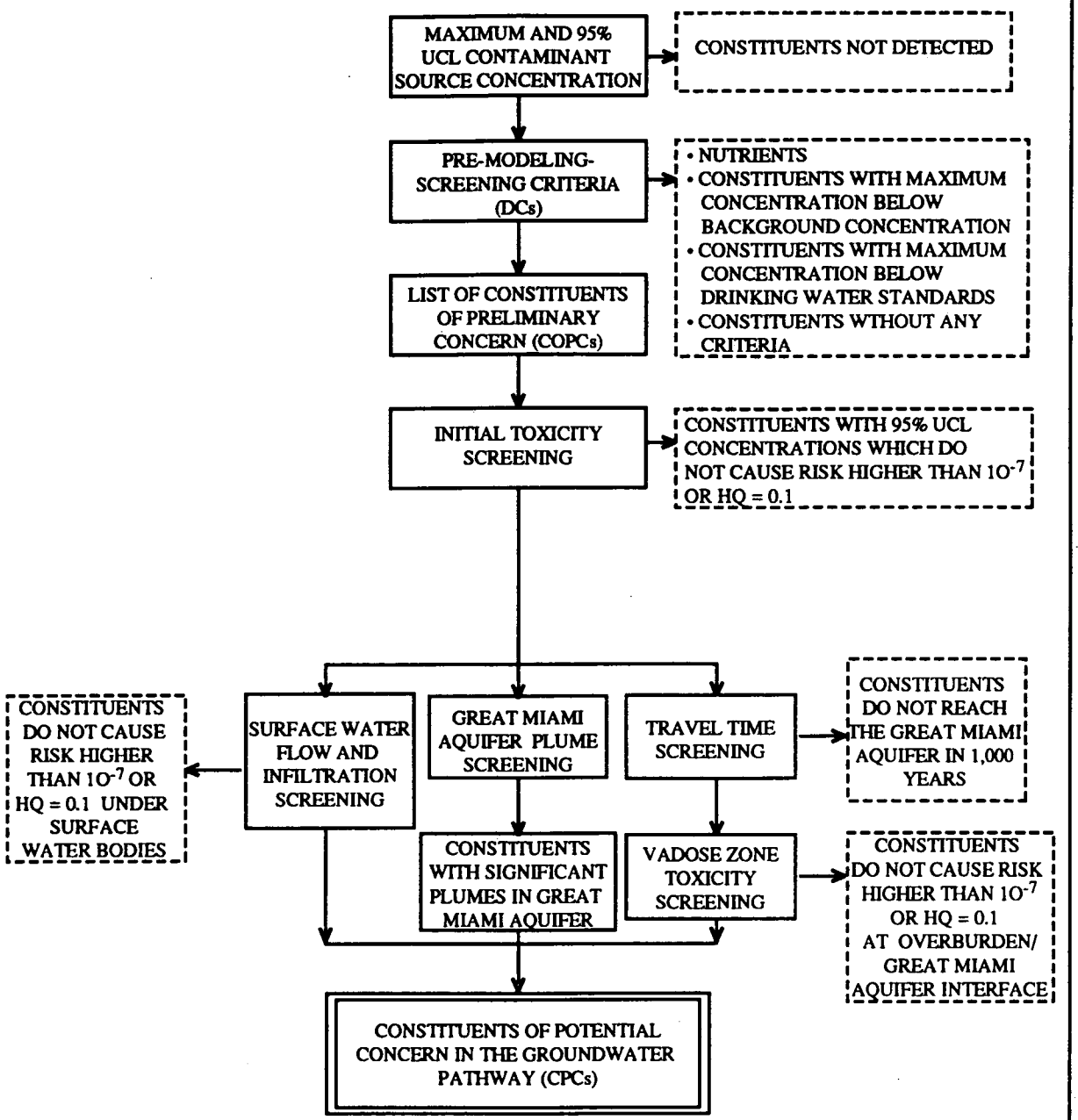
*TLJUSOU-5/PO-116U16CONSTIT SCRN-SW.EPS

FIGURE 5-8. CONSTITUENT SCREENING PROCESS - SURFACE WATER PATHWAY



NOTE:
DCs = DETECTED CONSTITUENTS
COPCs = CONSTITUENTS OF PRELIMINARY CONCERN
CPCs = CONSTITUENTS OF POTENTIAL CONCERN
UCL = UPPER CONFIDENCE LEVEL
HQ = HAZARD QUOTIENT

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*ILLI/SOU-5/PO-116/CONSTIT SCRN-GW(5-9).EPS

FIGURE 5-9. CONSTITUENT SCREENING PROCESS - GROUNDWATER PATHWAY

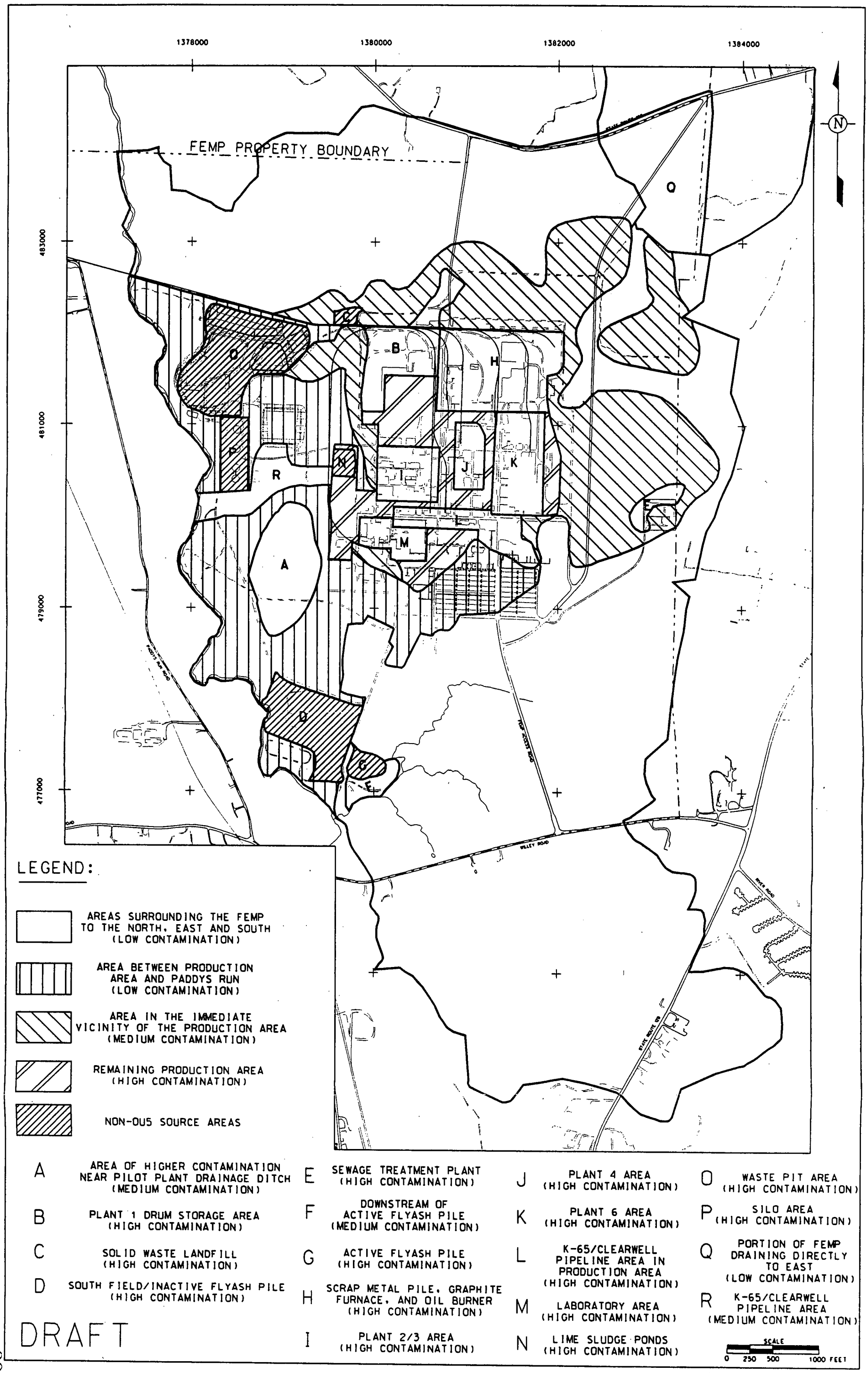
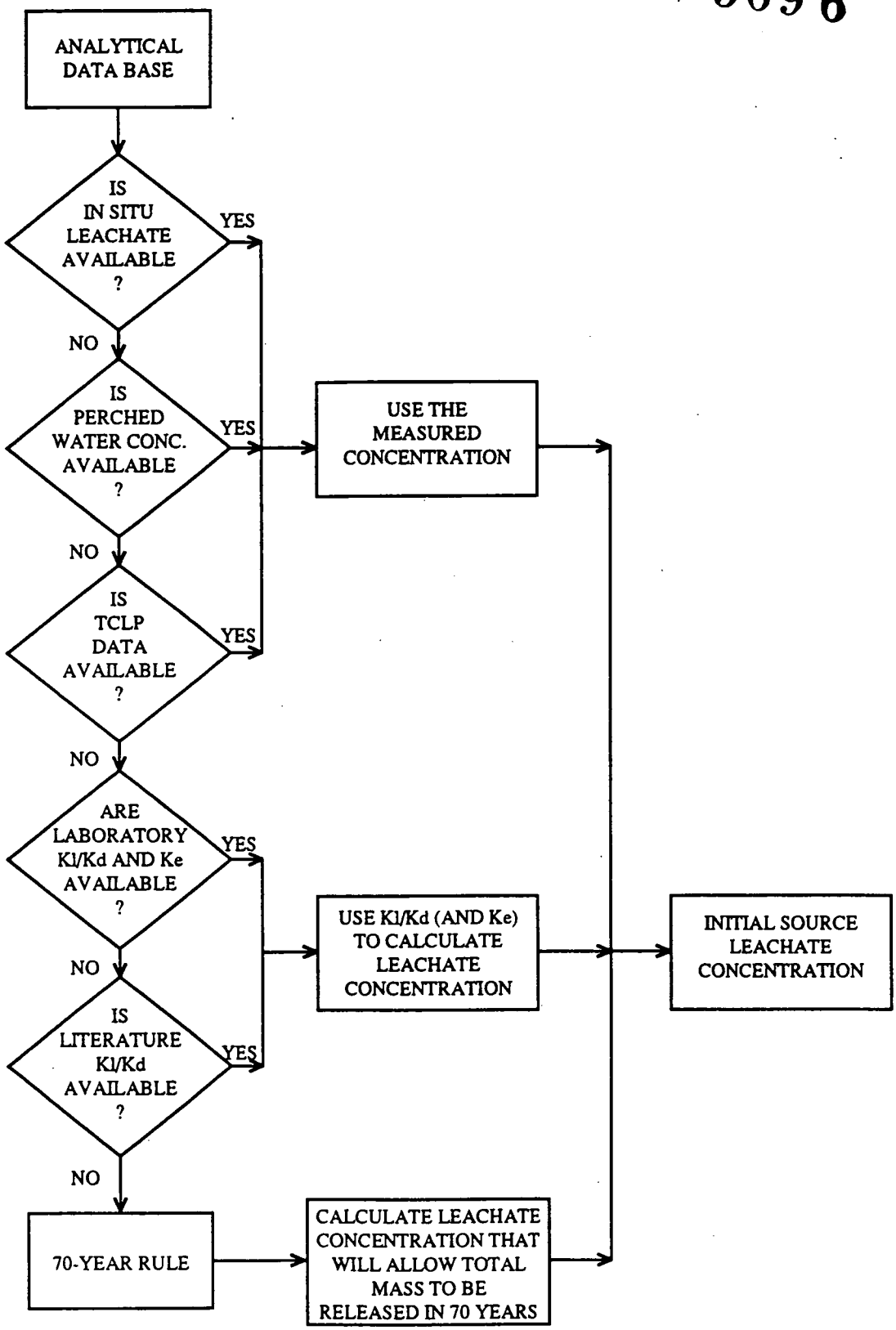


FIGURE 5-10. CONTAMINANT SOURCE AREAS



*VILLUSOU-5\PO-116\SOURCE LEACH(5-11).EPS

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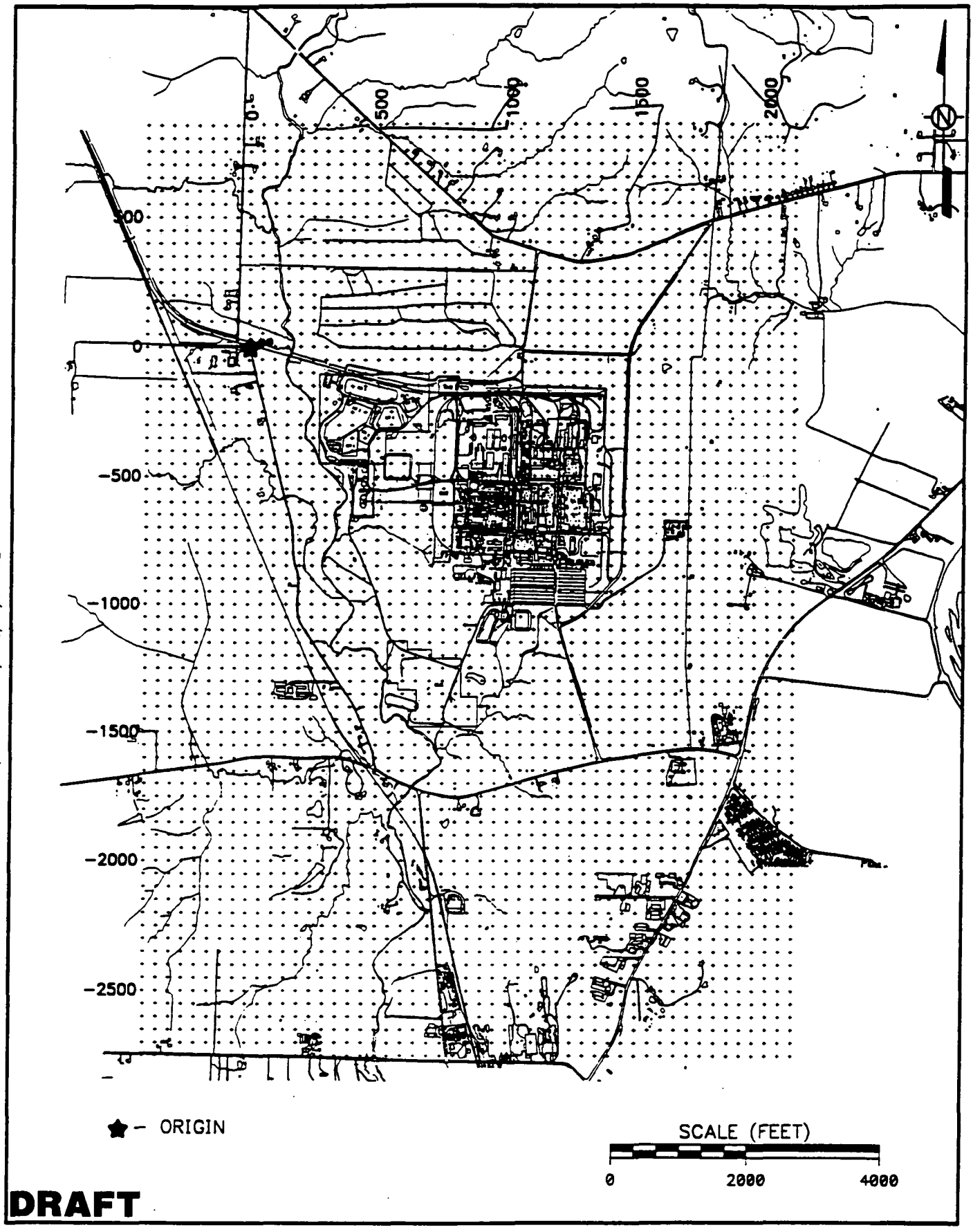
FIGURE 5-11. SOURCE LEACHATE CONCENTRATION ESTIMATION



ACAD: W:/DATA/CADD/TRACY/93091502.DWG OR (MARY C:\NG96\93091502.DWG) 02/21/94 MB

FIGURE 5-12 OPERABLE UNIT 5 CARTESIAN RECEPTOR GRID

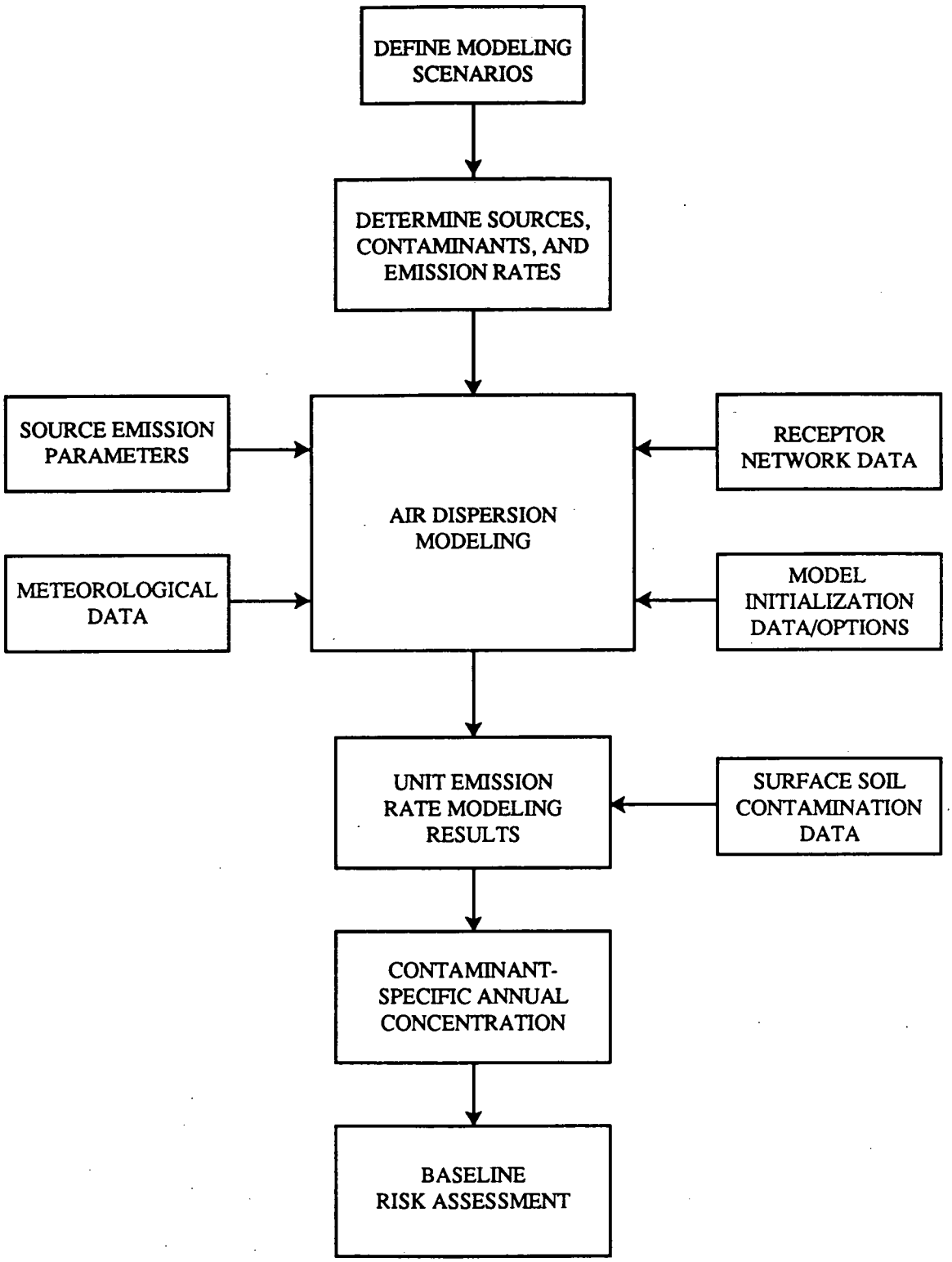


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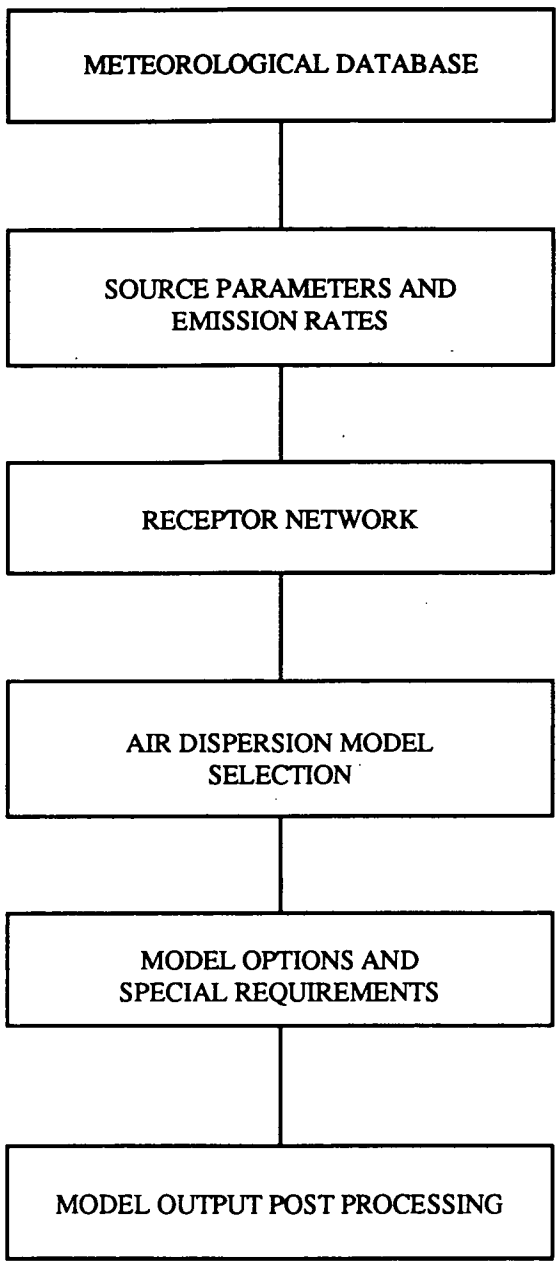
FIGURE 5-13. SEQUENTIAL FLOW DIAGRAM OF OPERABLE UNIT 5 AIR TRANSPORT ANALYSIS



"ILLUS\OU-5\PO-116\ATM PROTOCOL.EPS

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FIGURE 5-14. TECHNICAL ISSUES ADDRESSED IN THE OPERABLE UNIT 5 AIR TRANSPORT MODELING PROTOCOL

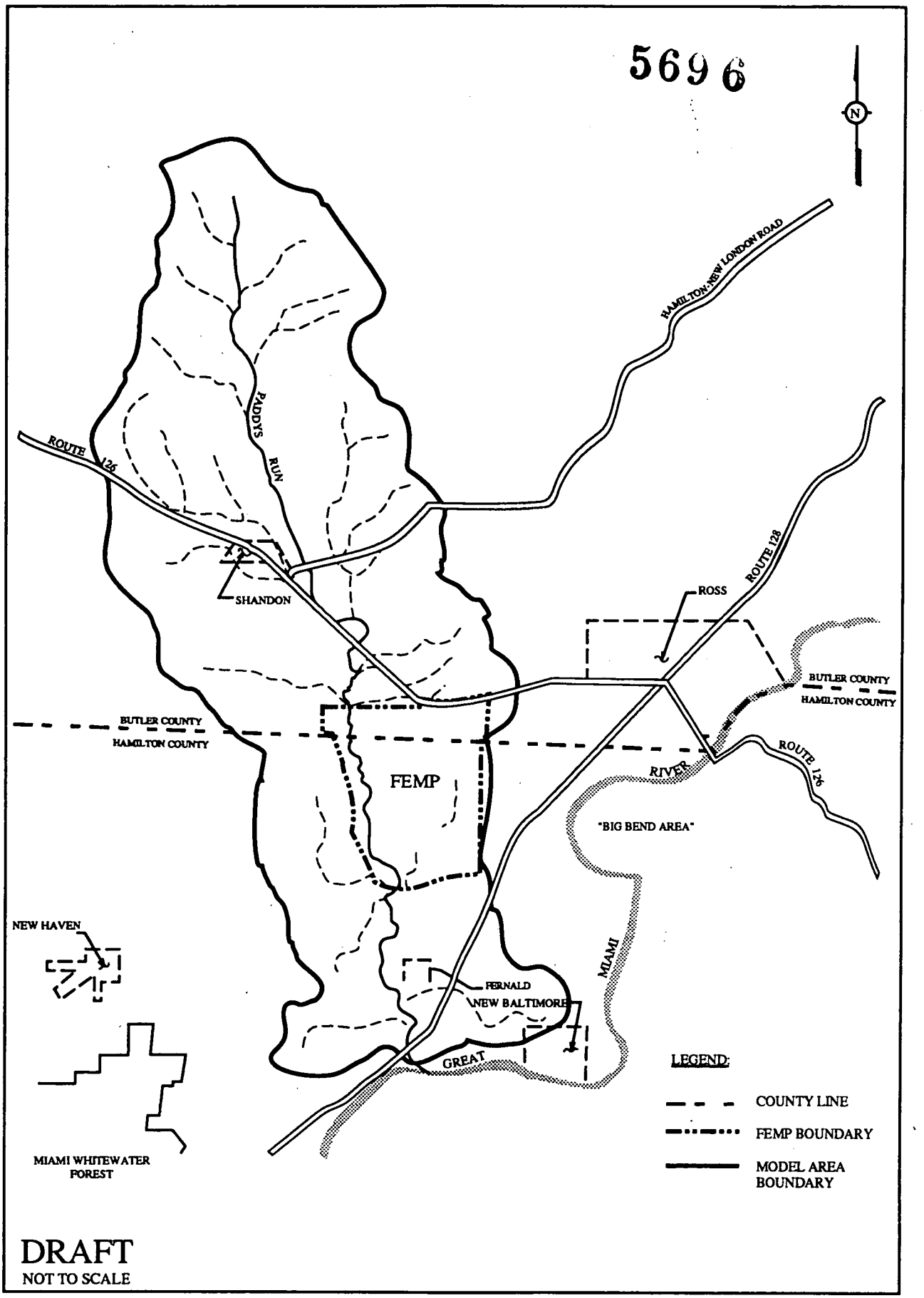
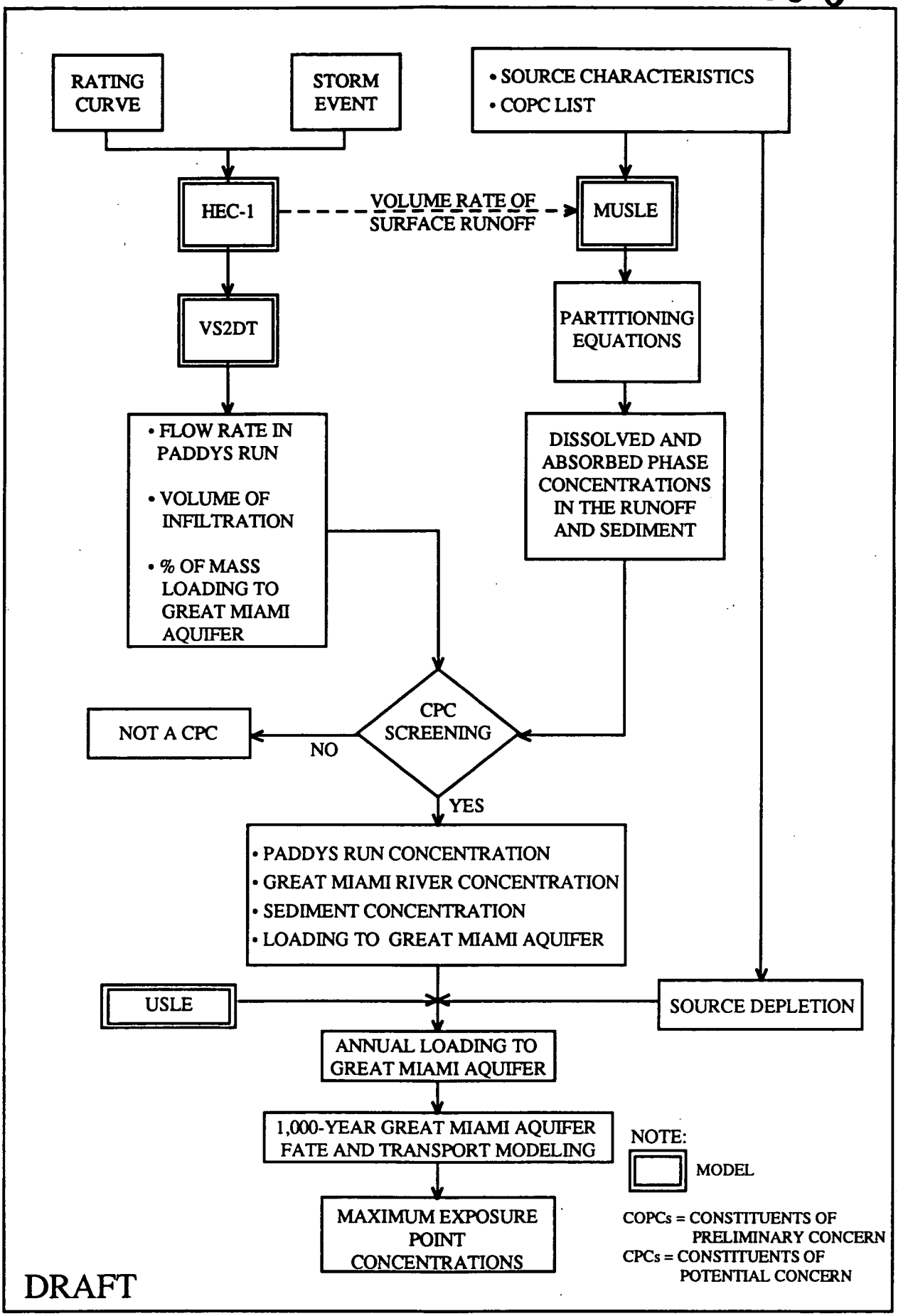


FIGURE 5-15. SURFACE WATER MODELING AREA



*ILLUS\OU-5\PO-116SW MODS & PROC.EPS

FIGURE 5-16. SURFACE WATER MODELS AND MODELING PROCEDURE

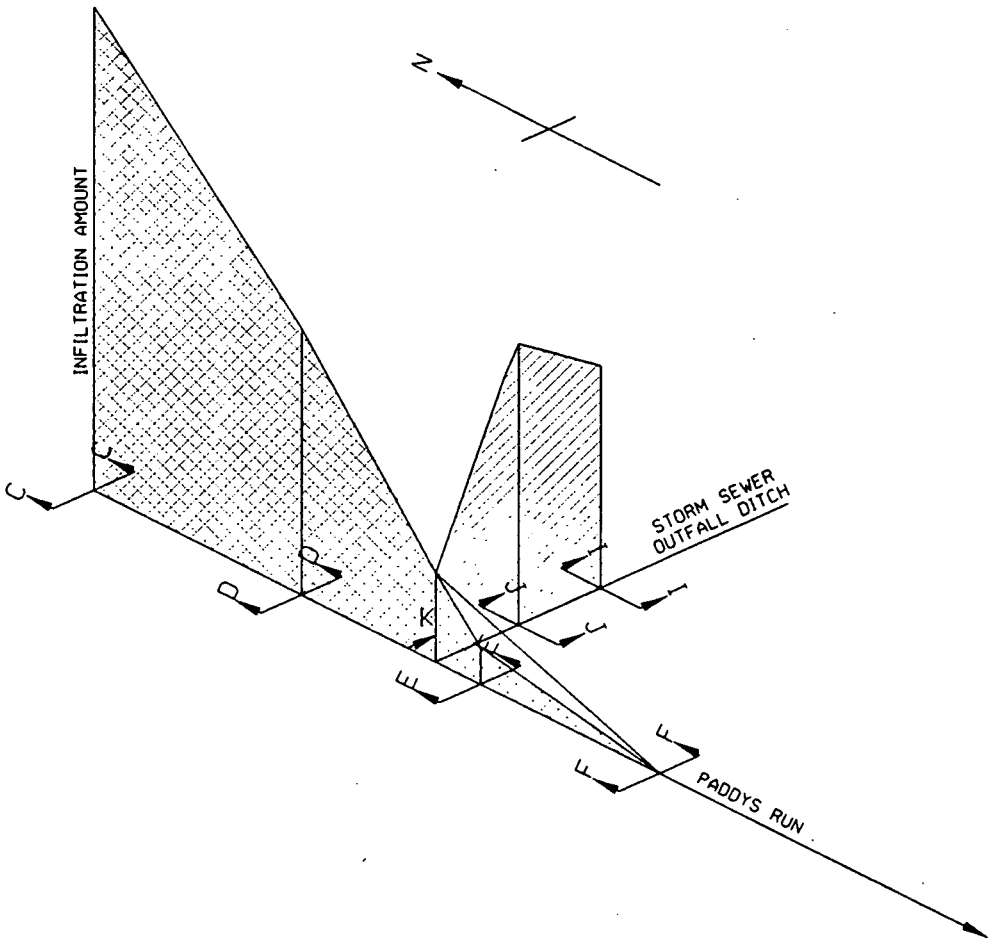


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FIGURE 5-17 REPRESENTATIVE SURFACE WATER INFILTRATION PATTERN

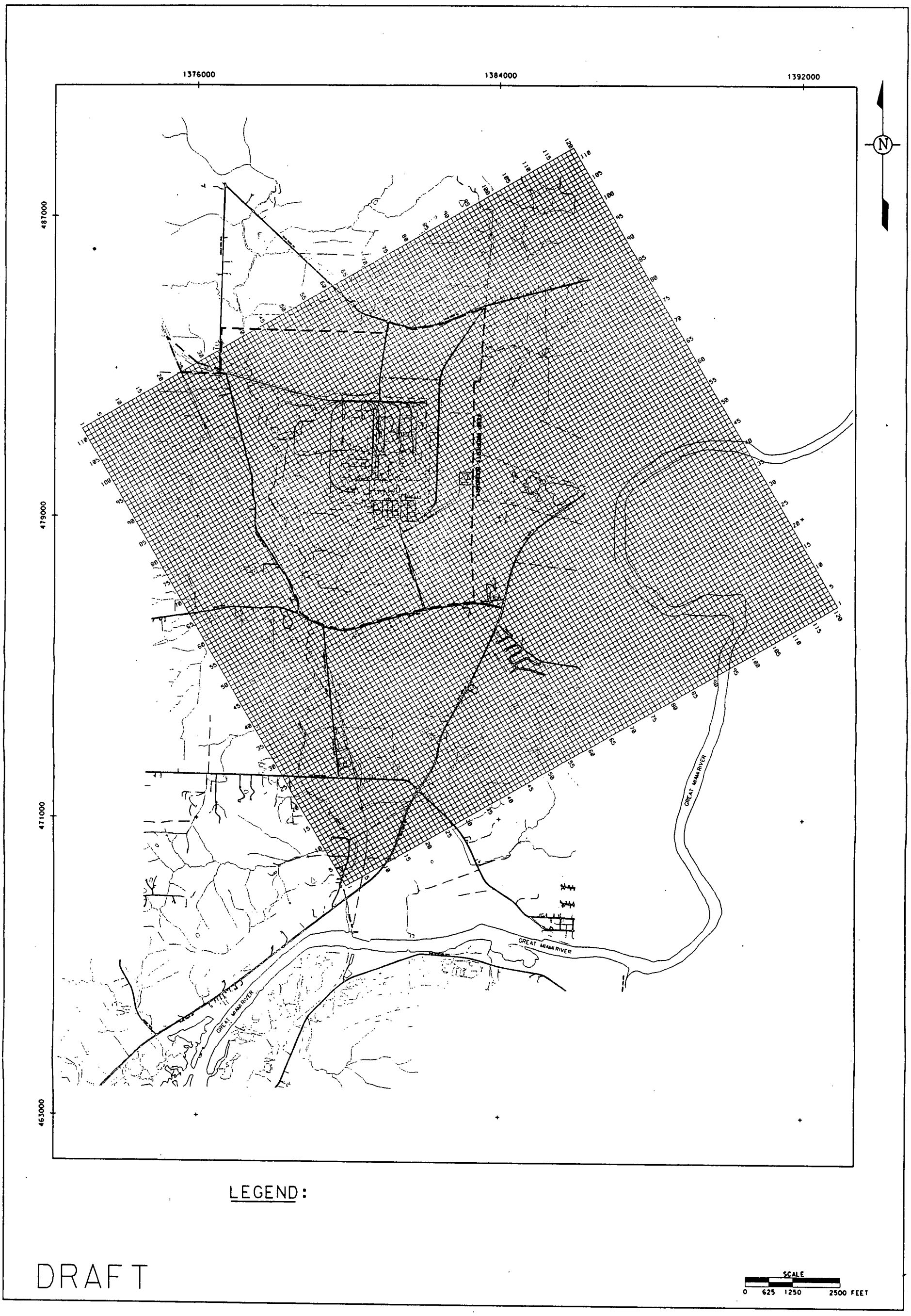

FIGURE 5-18 GROUNDWATER MODELING AREA

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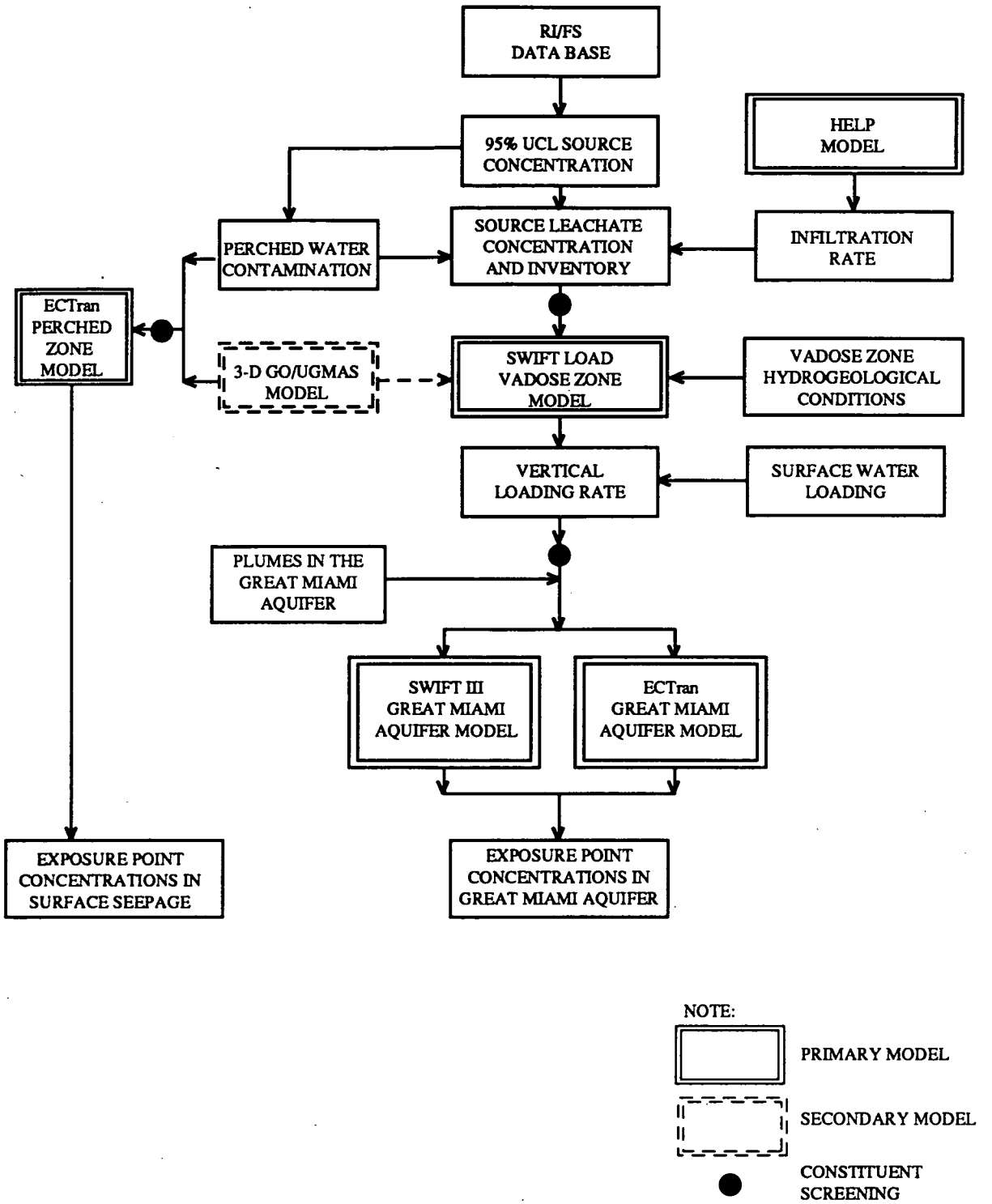

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*ILLUS\OU-5\PO-116\GW MODS & PROC.EPS

FIGURE 5-19. GROUNDWATER MODELS AND MODELING PROCEDURE

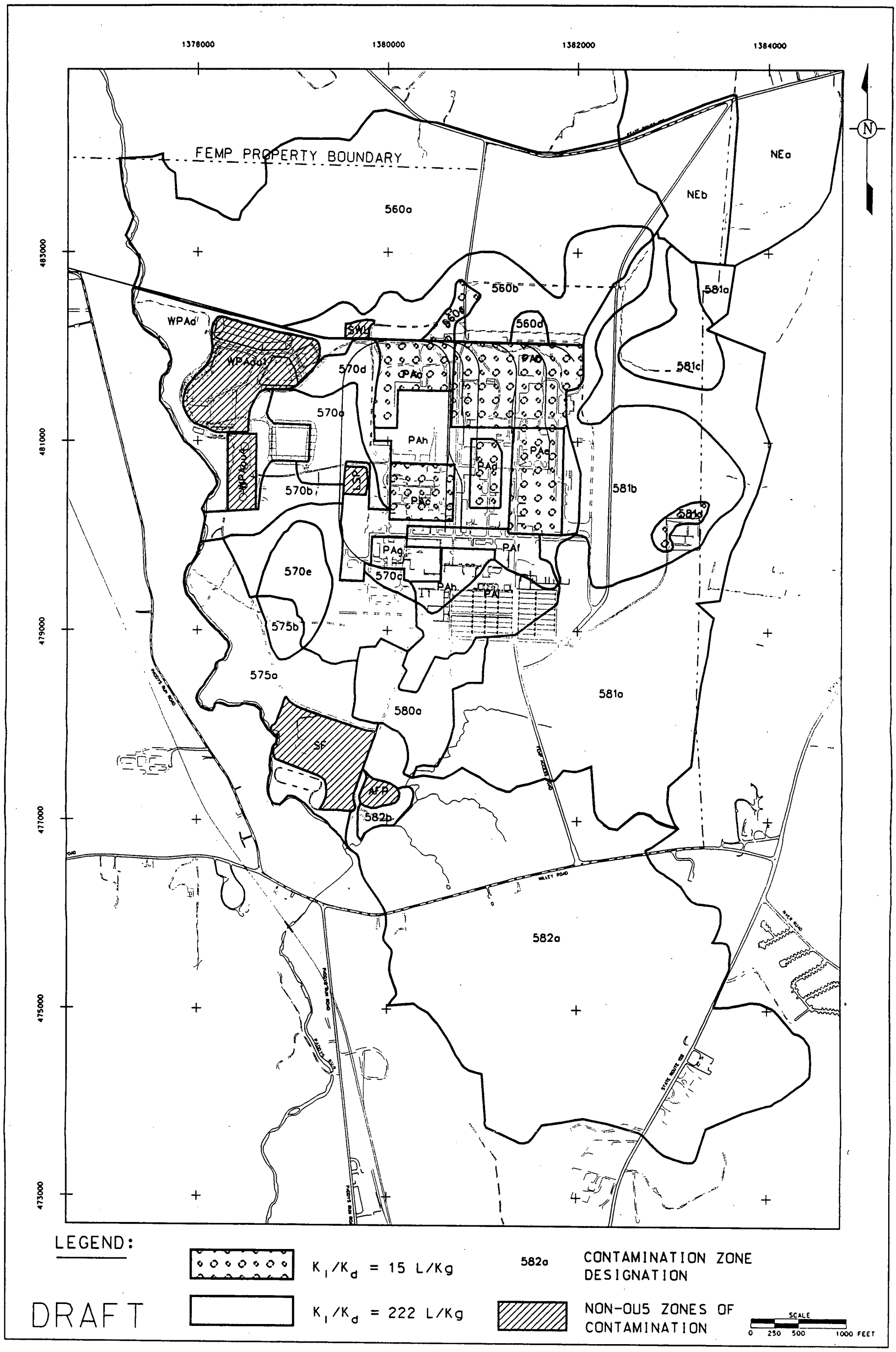


FIGURE 5-20. ZONES OF URANIUM K_1/K_d VALUES

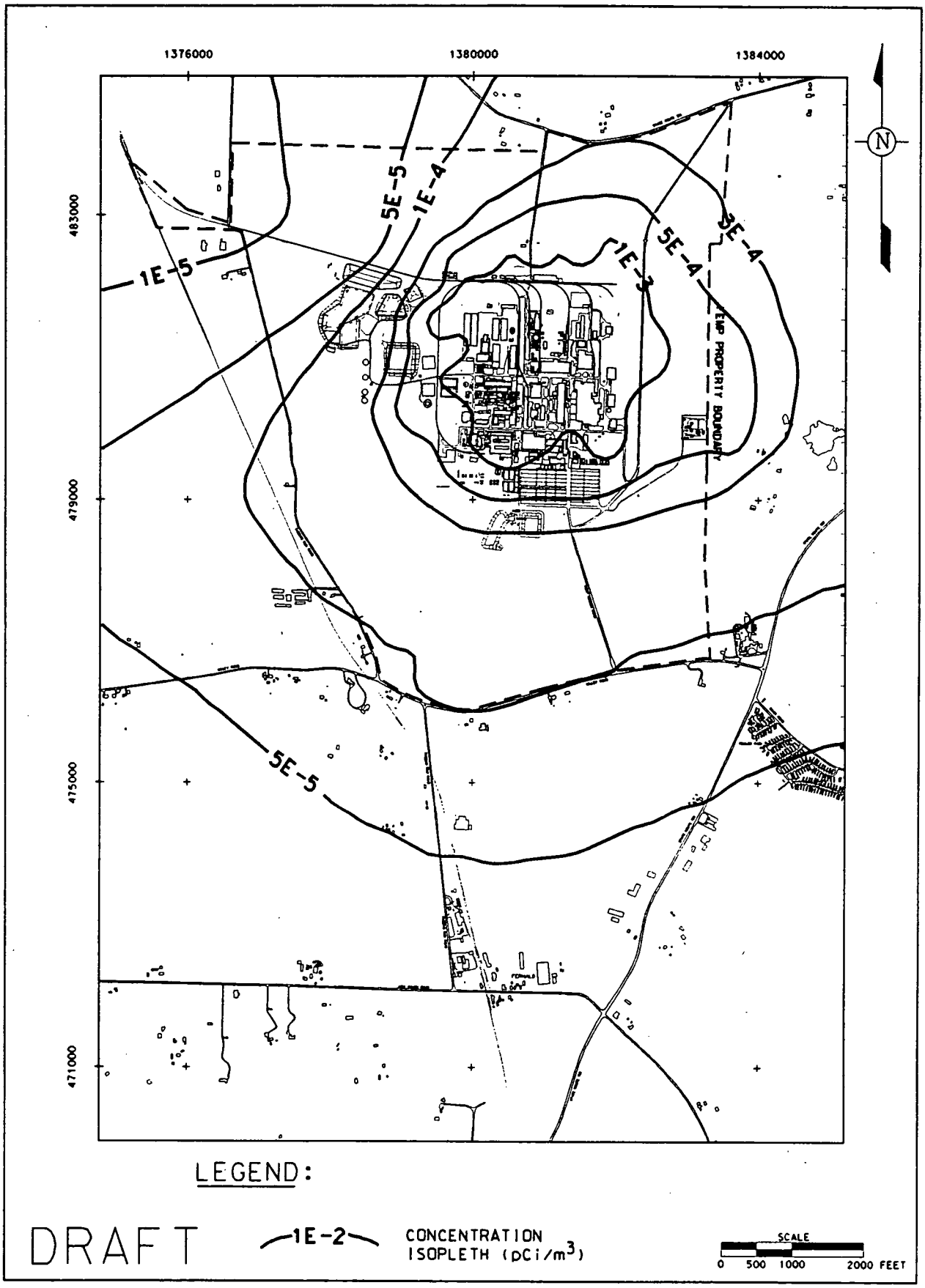


FIGURE 5-21a. ISOPLETHS OF RADIUM-226 CONCENTRATIONS IN PICOCURIES PER CUBIC METER FOR THE CURRENT SCENARIO

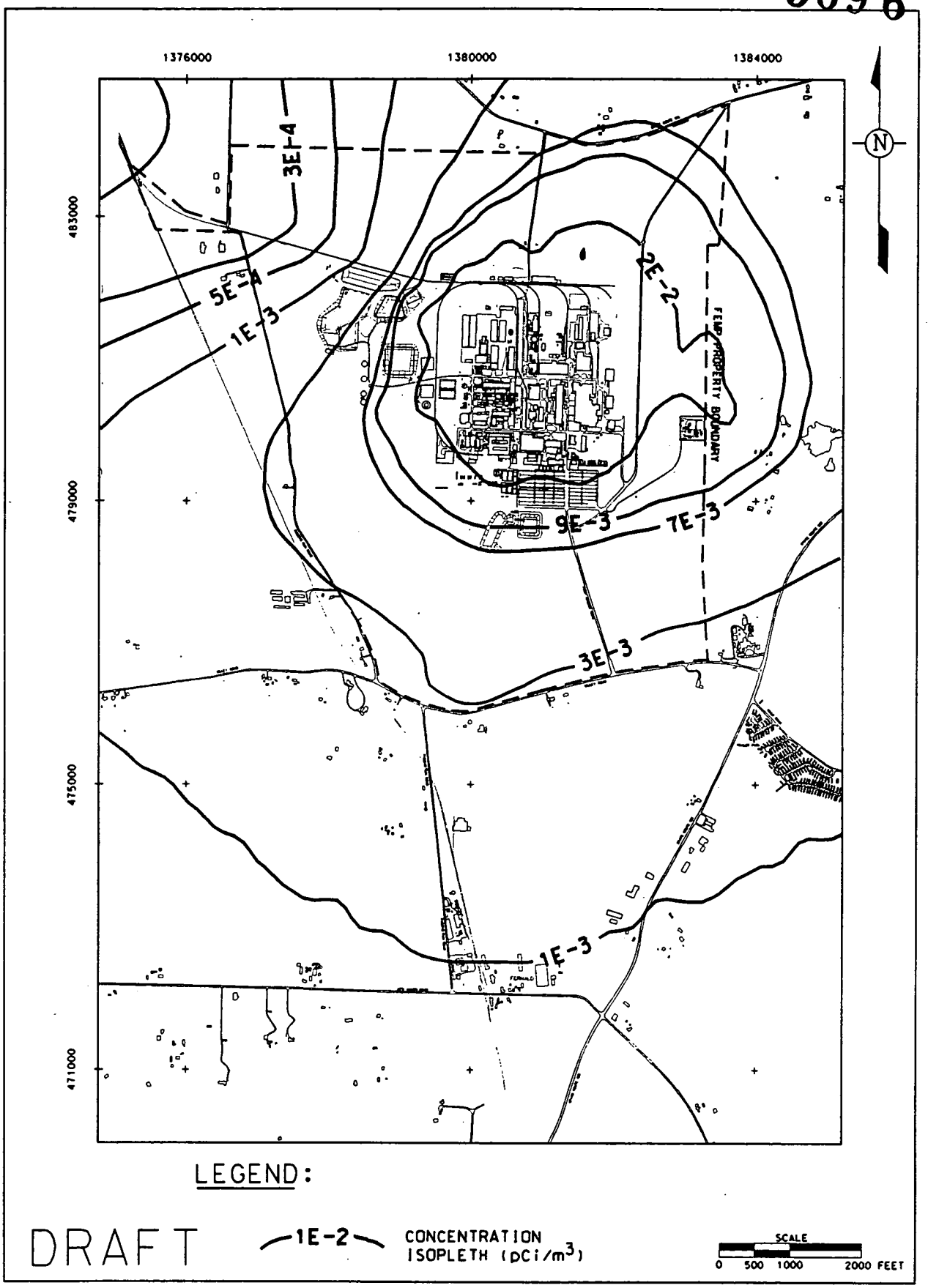


FIGURE 5-21b. ISOPLETHS OF RADIUM-226 CONCENTRATIONS IN PICOCURIES PER CUBIC METER FOR THE AGRICULTURE SCENARIO

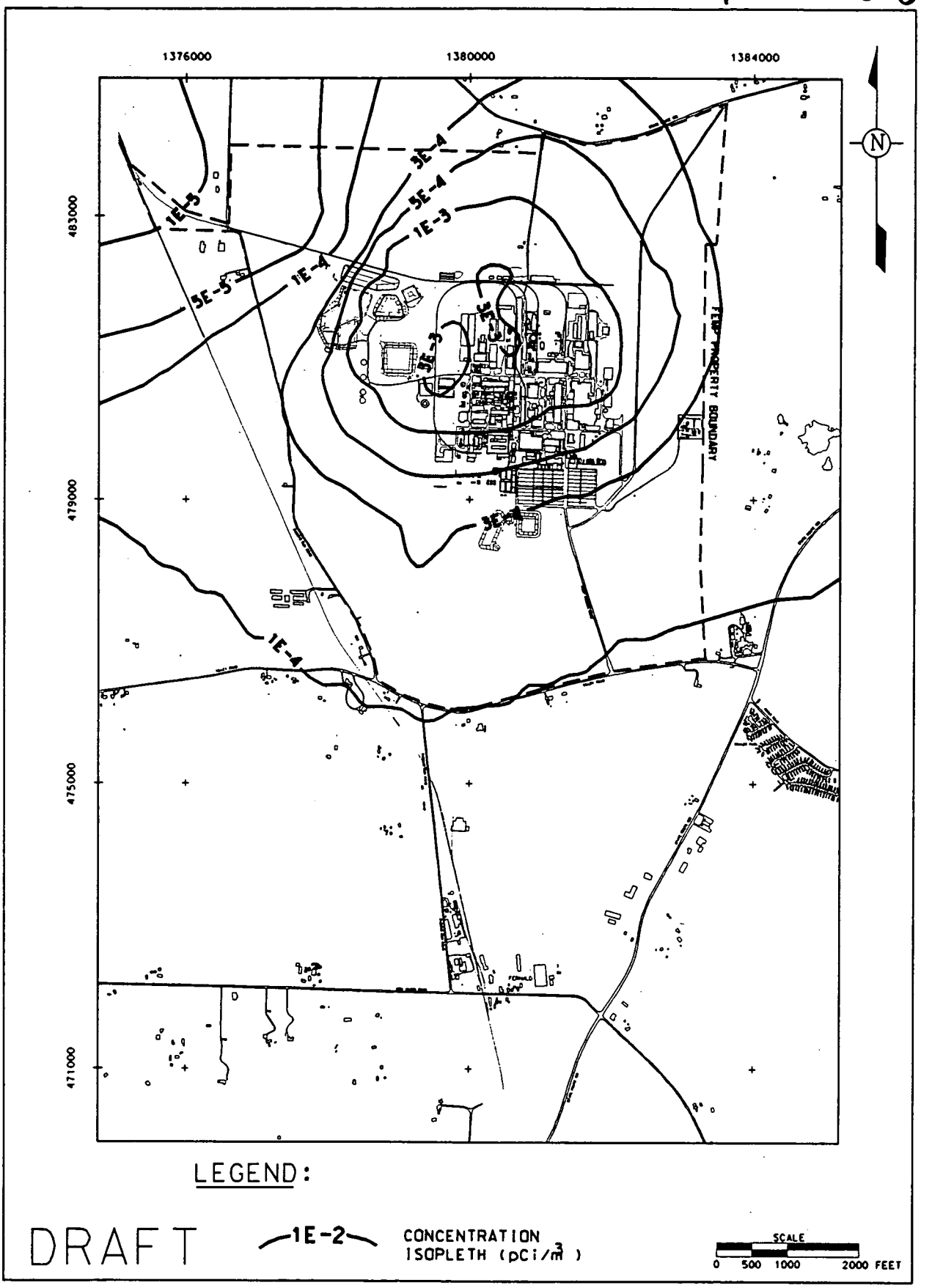


FIGURE 5-22a. ISOPLETHS OF THORIUM-230 CONCENTRATIONS IN PICOCURIES PER CUBIC METER FOR THE CURRENT SCENARIO

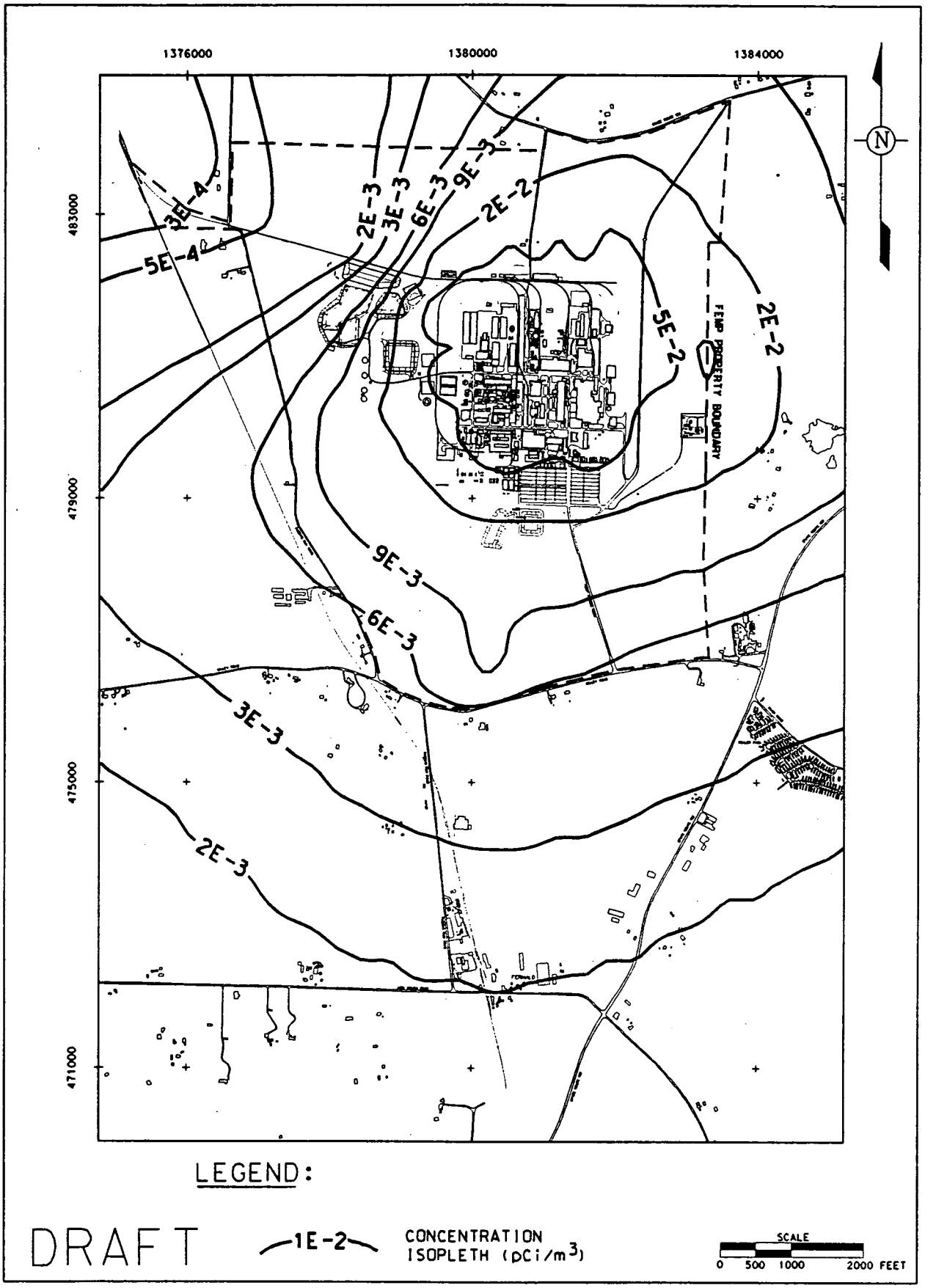


FIGURE 5-22b. ISOPLETHS OF THORIUM-230 CONCENTRATIONS IN PICOCURIES PER CUBIC METER FOR THE AGRICULTURE SCENARIO

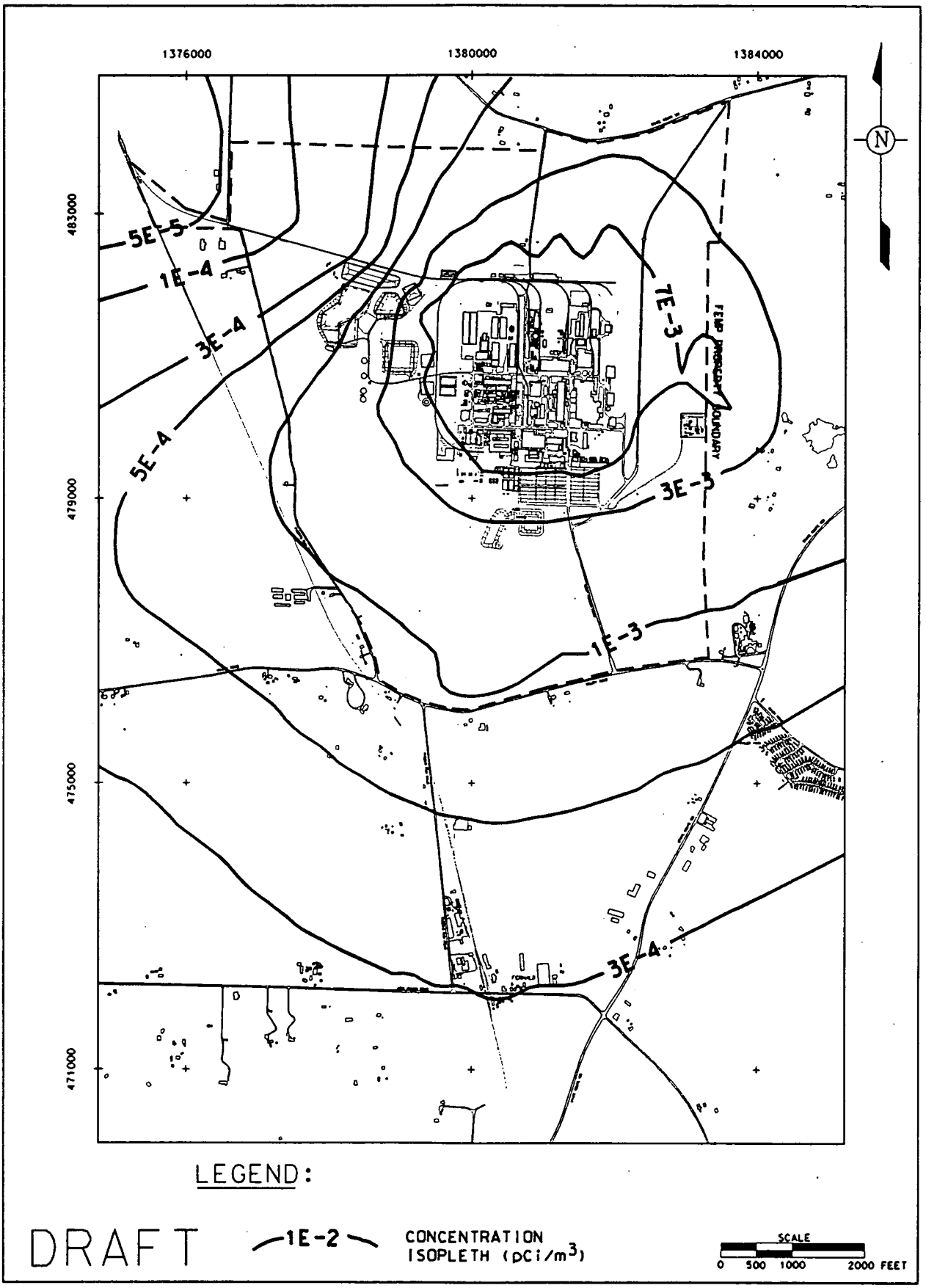


FIGURE 5-23a. ISOPLETHS OF URANIUM-238 CONCENTRATIONS IN PICOCURIES PER CUBIC METER FOR THE CURRENT SCENARIO

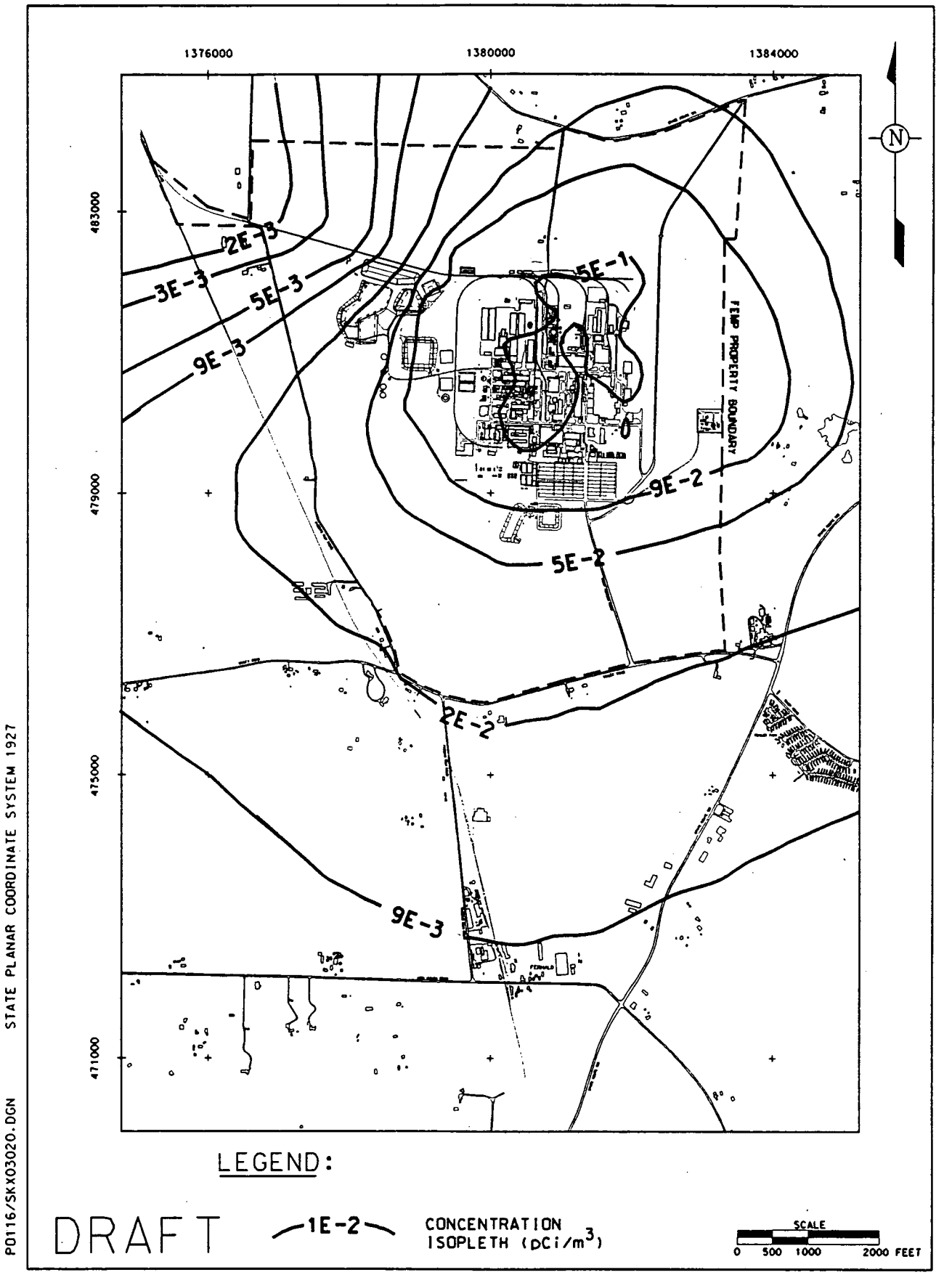


FIGURE 5-23b. ISOPLETHS OF URANIUM-238 CONCENTRATIONS IN PICOCURIES PER CUBIC METER FOR THE AGRICULTURE SCENARIO

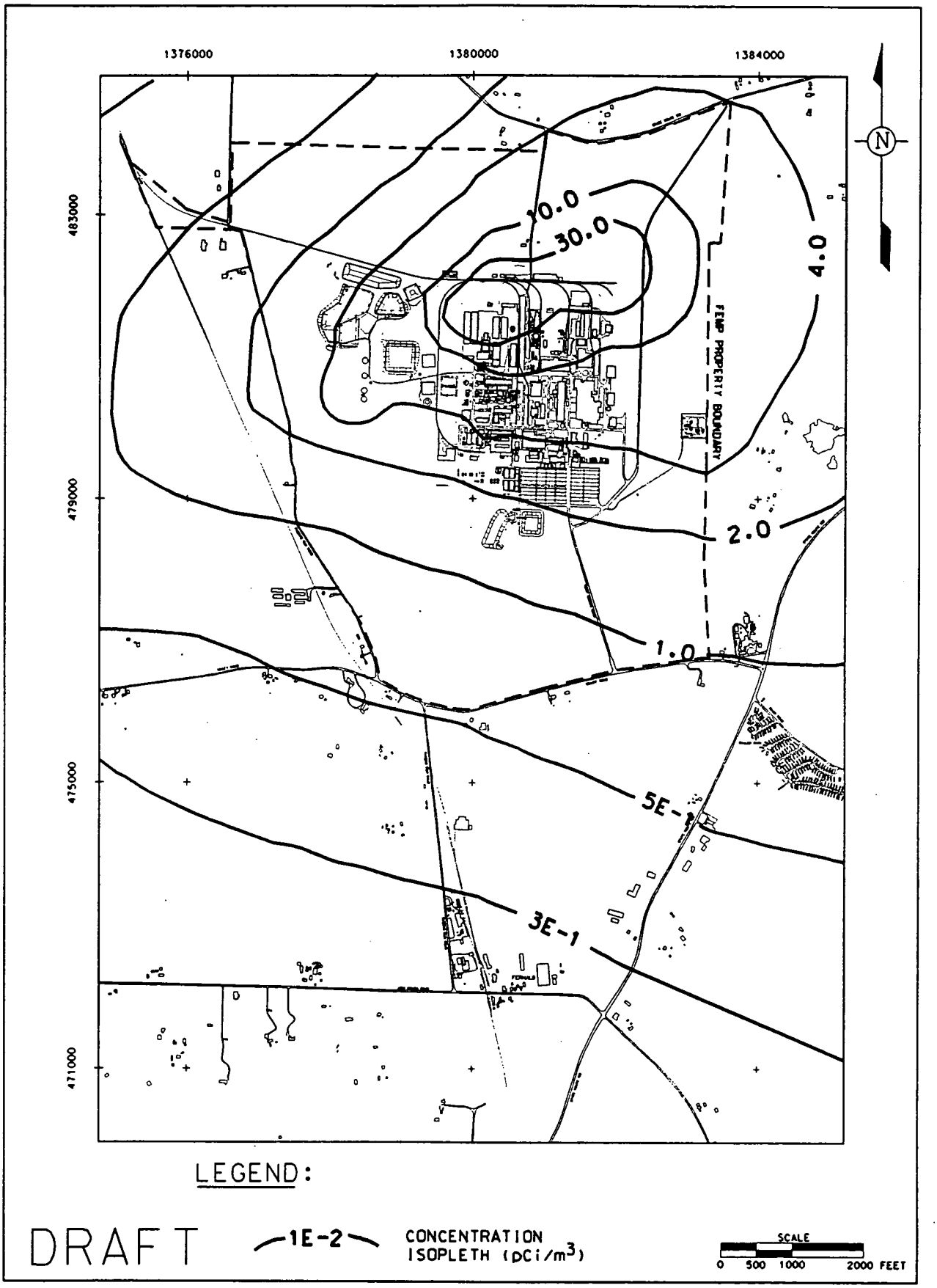


FIGURE 5-24. ISOPLETHS OF RADON-222 CONCENTRATIONS IN PICOCURIES PER CUBIC METER FOR THE CURRENT SCENARIO

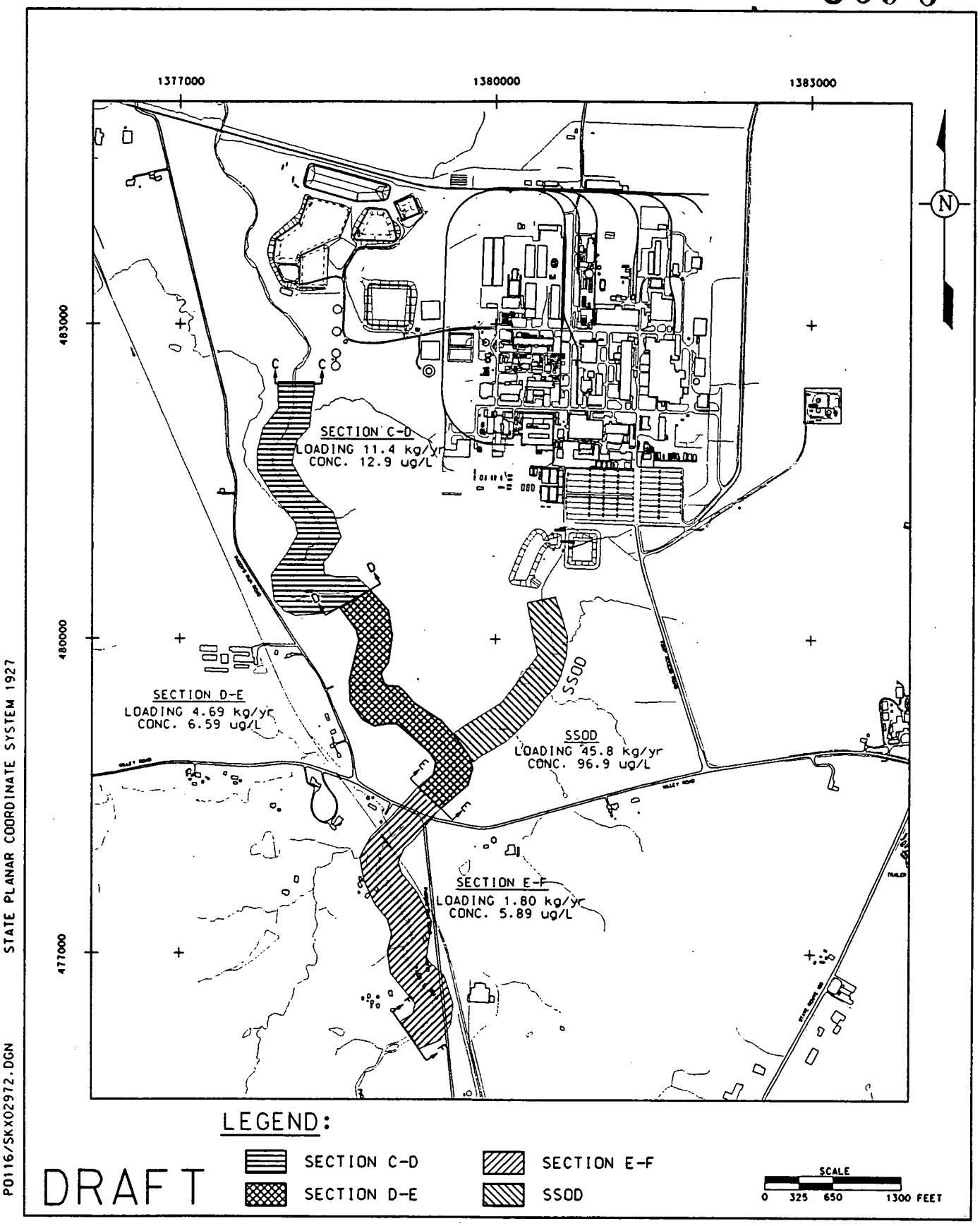


FIGURE 5-25. PREDICTED TOTAL URANIUM MASS LOADINGS INTO THE GREAT MIAMI AQUIFER AND CONCENTRATIONS OF U-238 ALONG PADDYS RUN AND STORM SEWER OUTFALL DITCH-BASELINE CONDITIONS

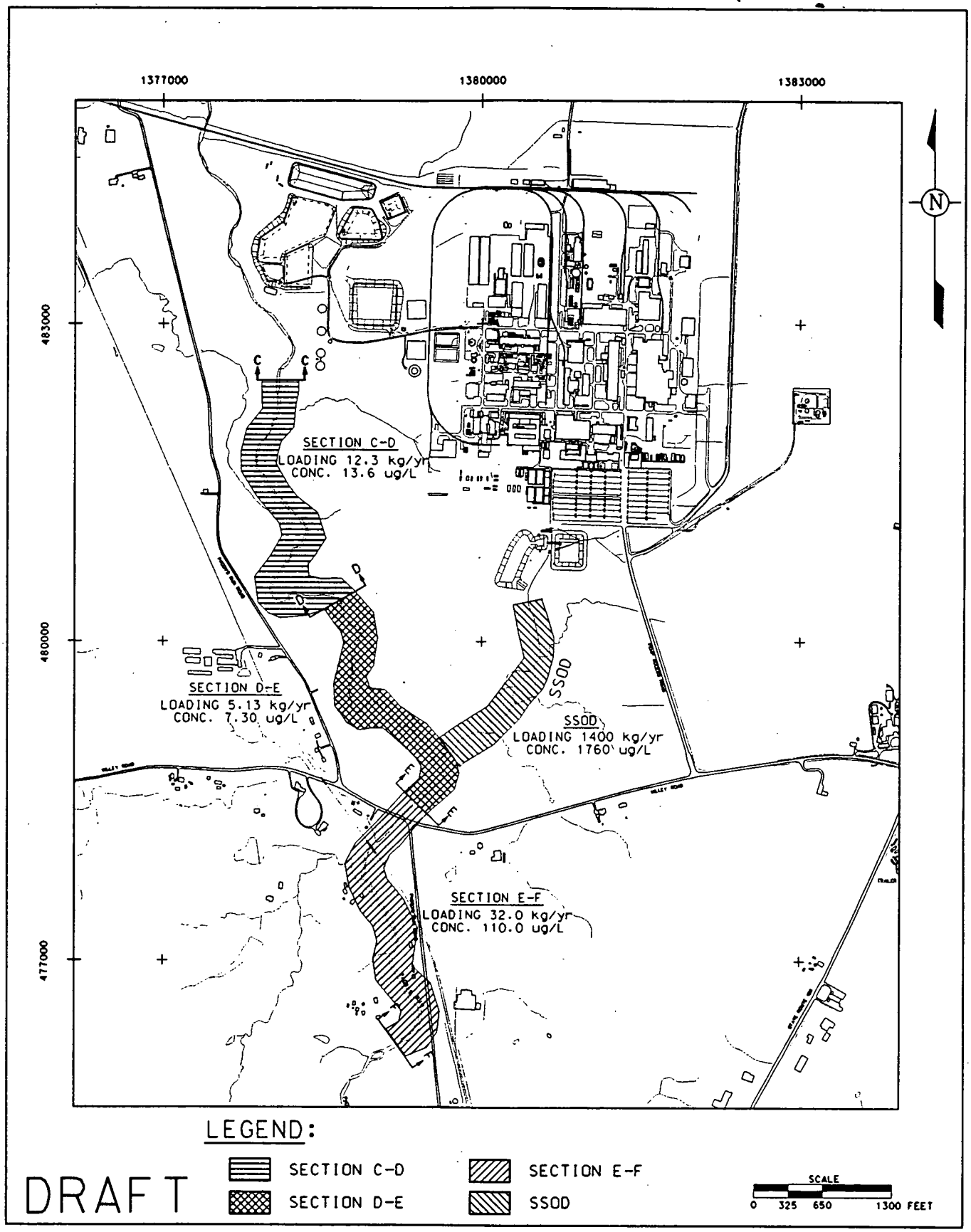
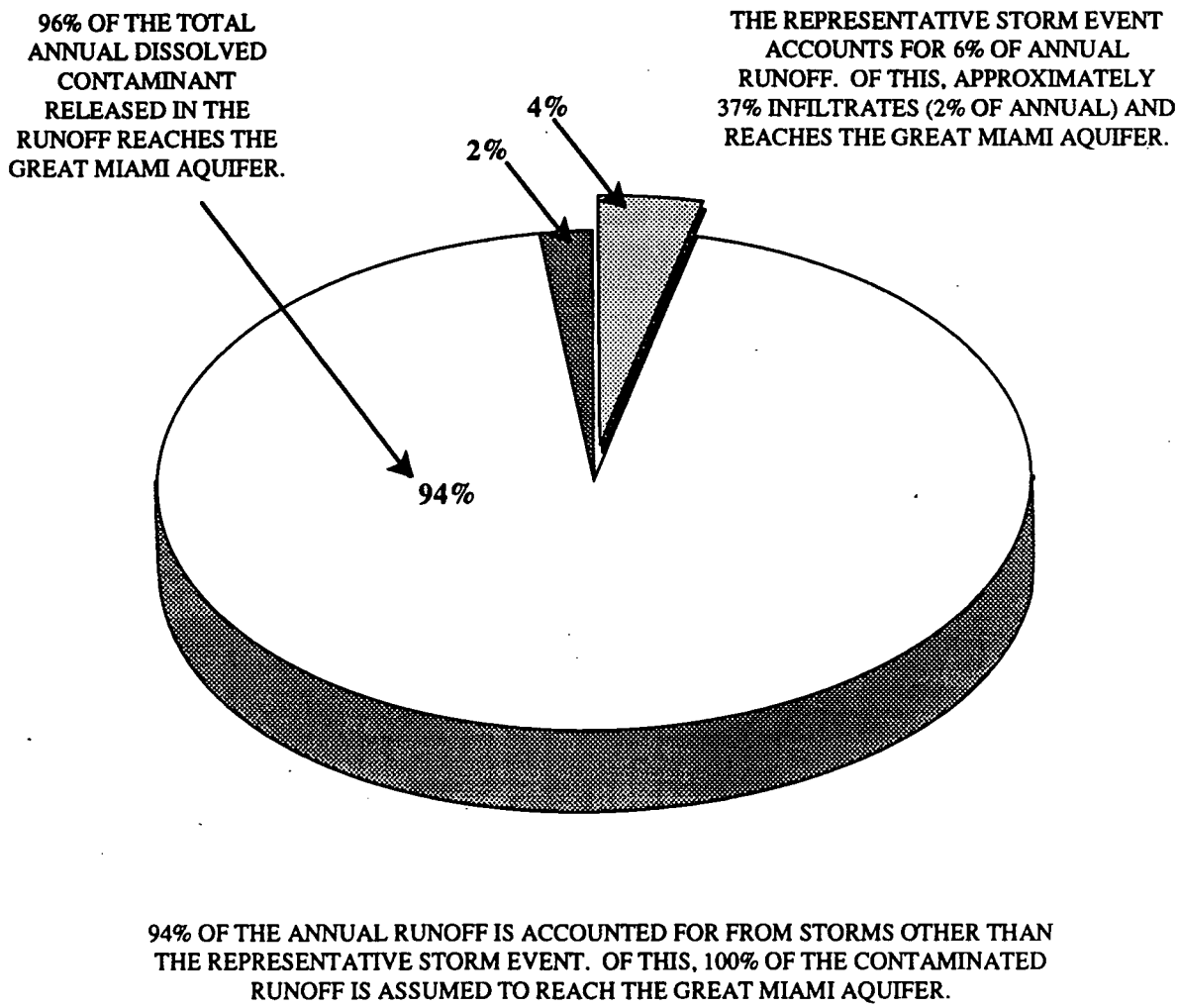


FIGURE 5-26. PREDICTED TOTAL URANIUM MASS LOADINGS INTO THE GREAT MIAMI AQUIFER AND CONCENTRATIONS OF U-238 ALONG PADDYS RUN AND STORM SEWER OUTFALL DITCH-FUTURE CONDITIONS



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"ILLUS\OU-5\PO-116\CONTAM RUNOFF.EPS

FIGURE 5-27. PERCENT OF ANNUAL CONTAMINATED RUNOFF THAT BECOMES LOADING TO THE GREAT MIAMI AQUIFER

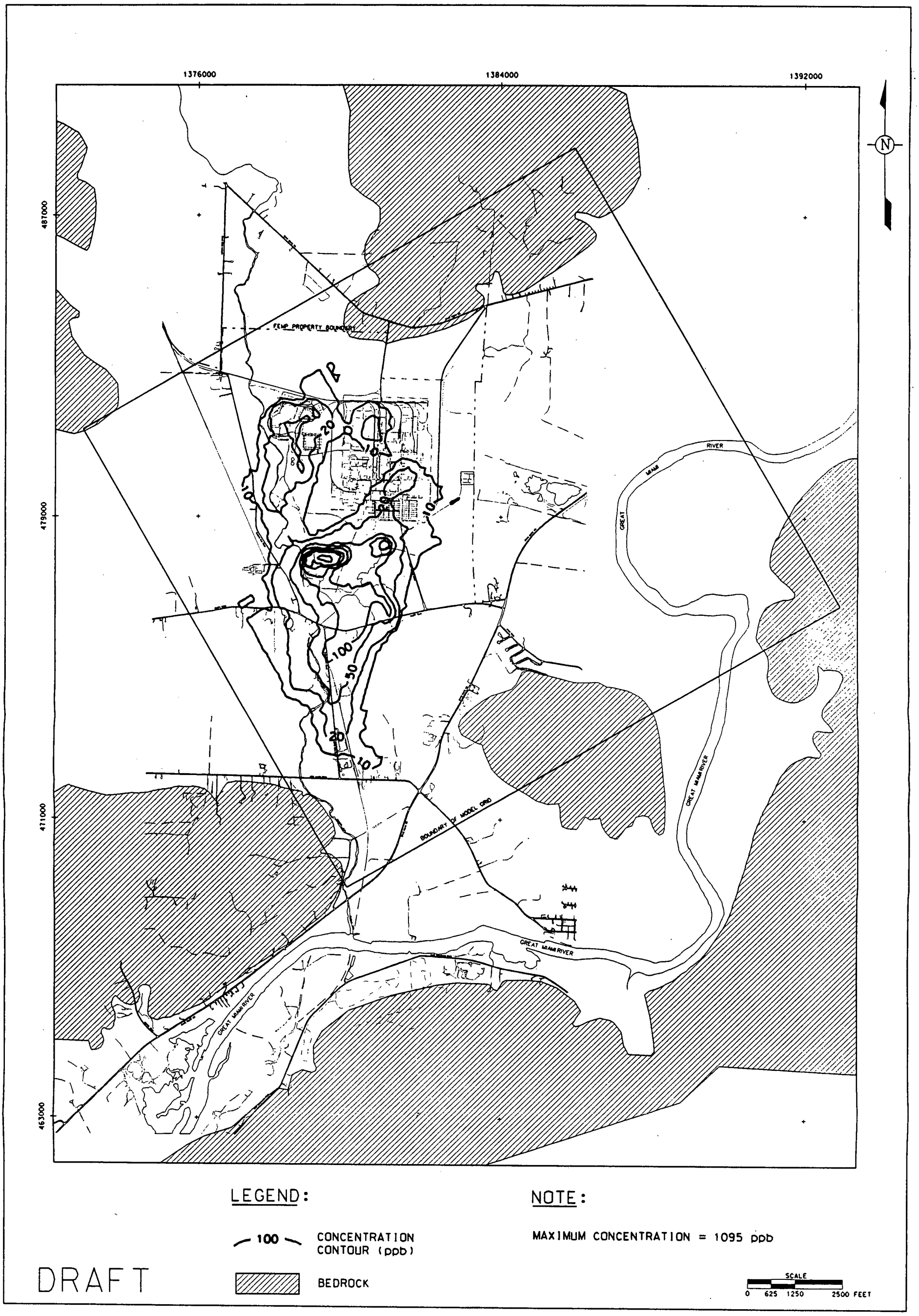

FIGURE 5-28. INITIAL TOTAL URANIUM CONCENTRATION CONTOURS IN THE GREAT MIAMI AQUIFER

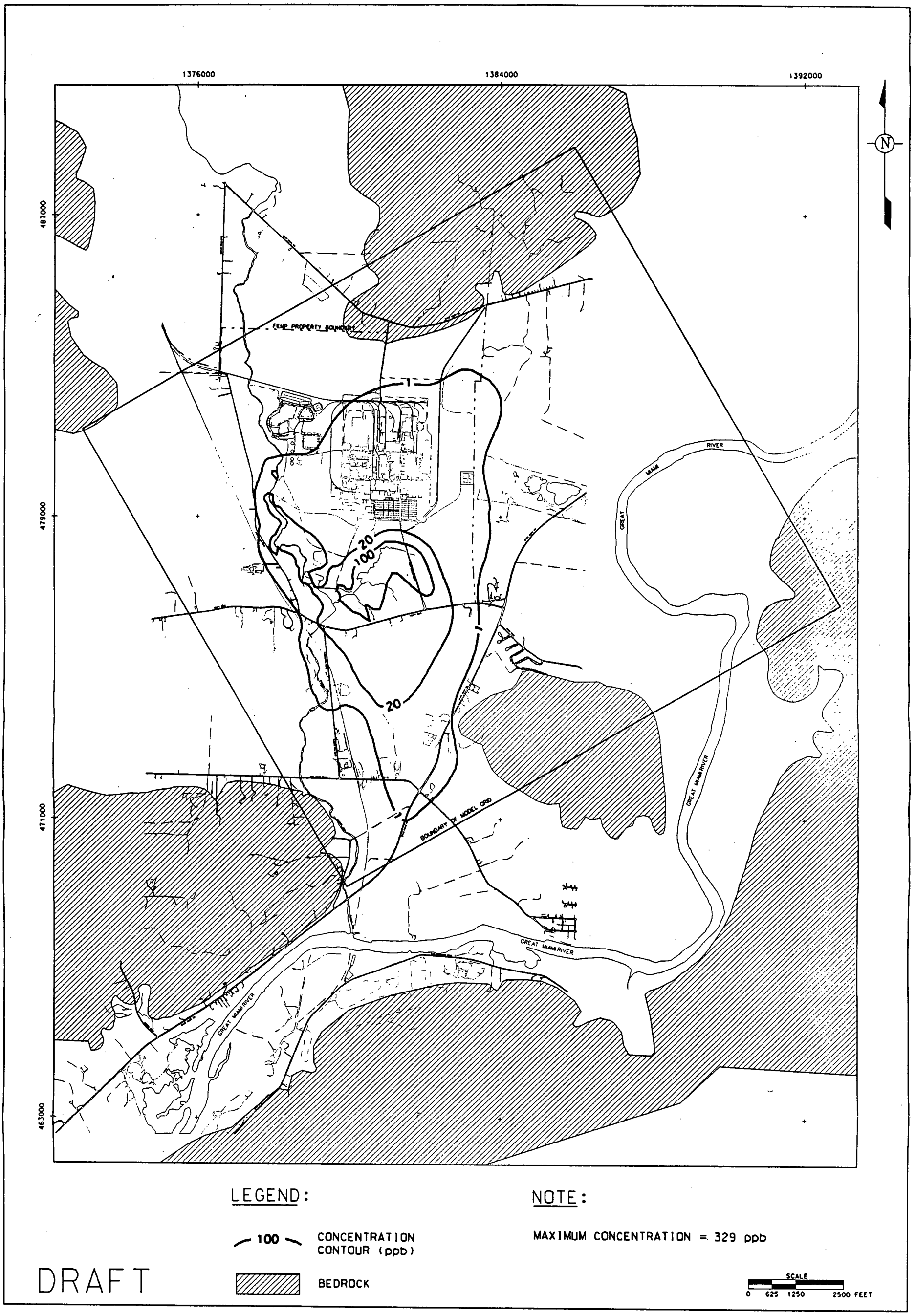

FIGURE 5-29. TOTAL URANIUM CONCENTRATION CONTOURS IN THE GREAT MIAMI AQUIFER AT THE END OF THE BASELINE CONDITION

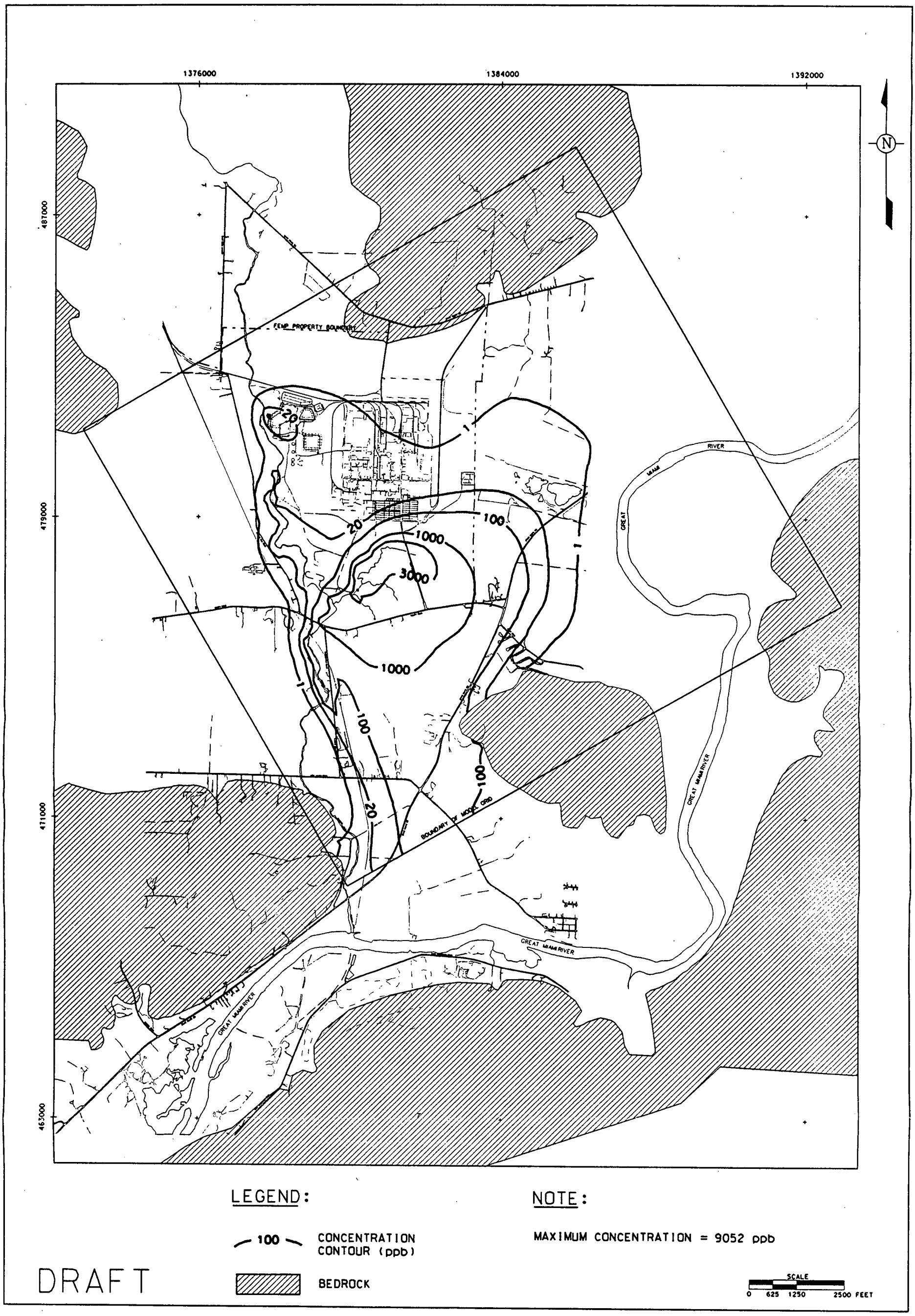

FIGURE 5-30. TOTAL URANIUM CONCENTRATION CONTOURS IN THE GREAT MIAMI AQUIFER WHEN THE MAXIMUM FENCELINE CONCENTRATION OCCURS

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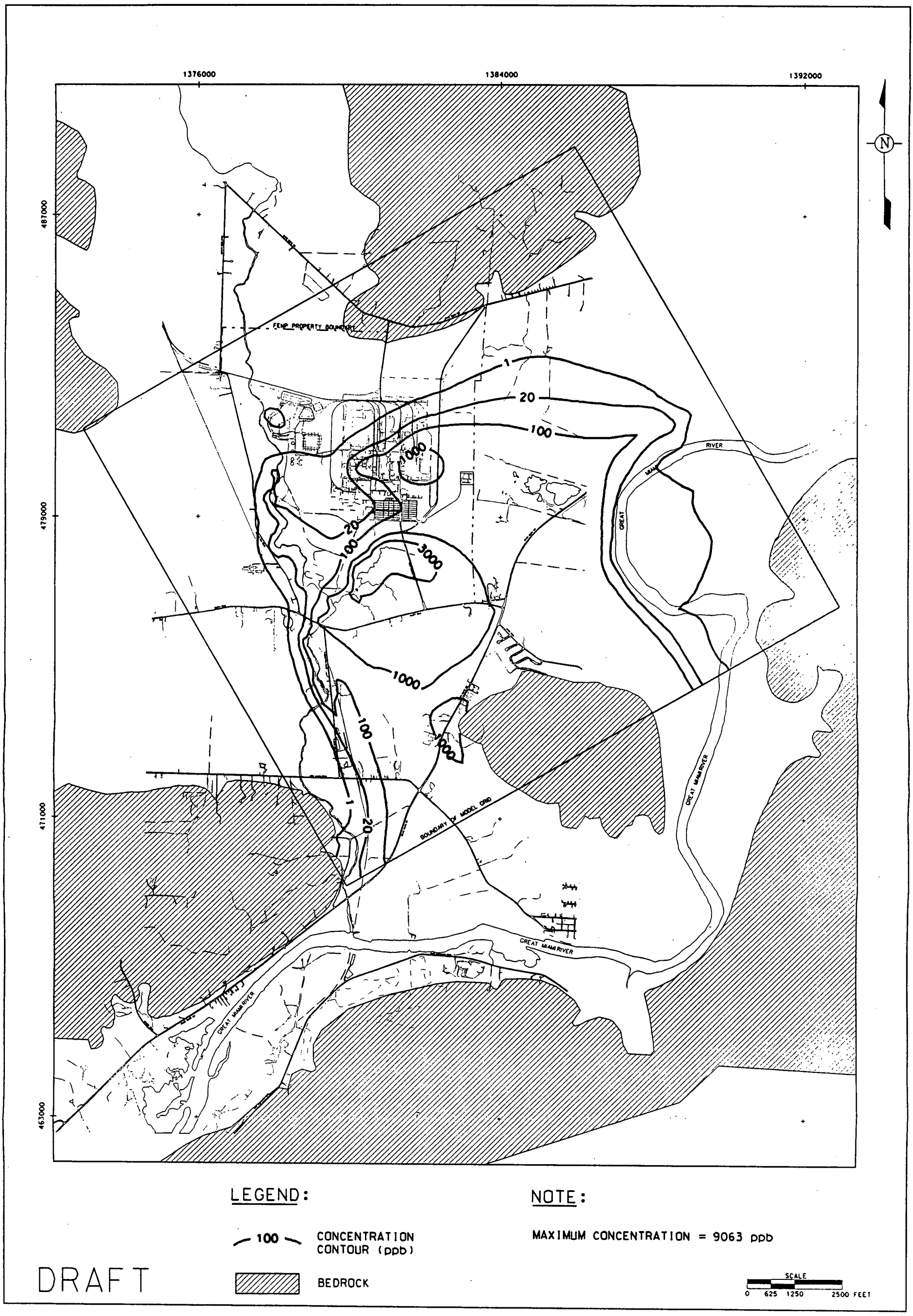

FIGURE 5-31. TOTAL URANIUM CONCENTRATION CONTOURS IN THE GREAT MIAMI AQUIFER AT THE END OF MODEL SIMULATION

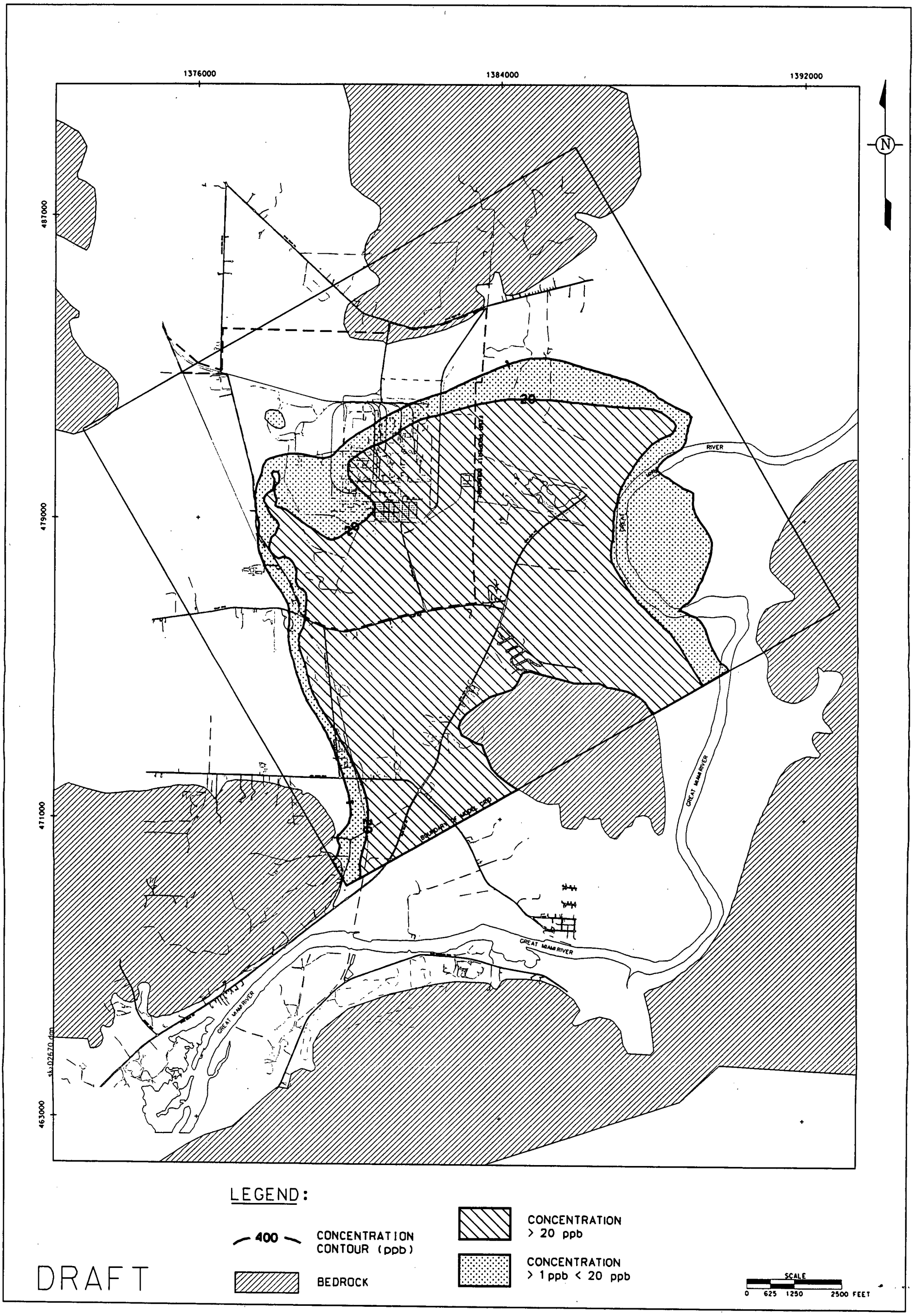

FIGURE 5-32. THE MAXIMUM EXTENT OF TOTAL URANIUM PLUME IN THE GREAT MIAMI AQUIFER

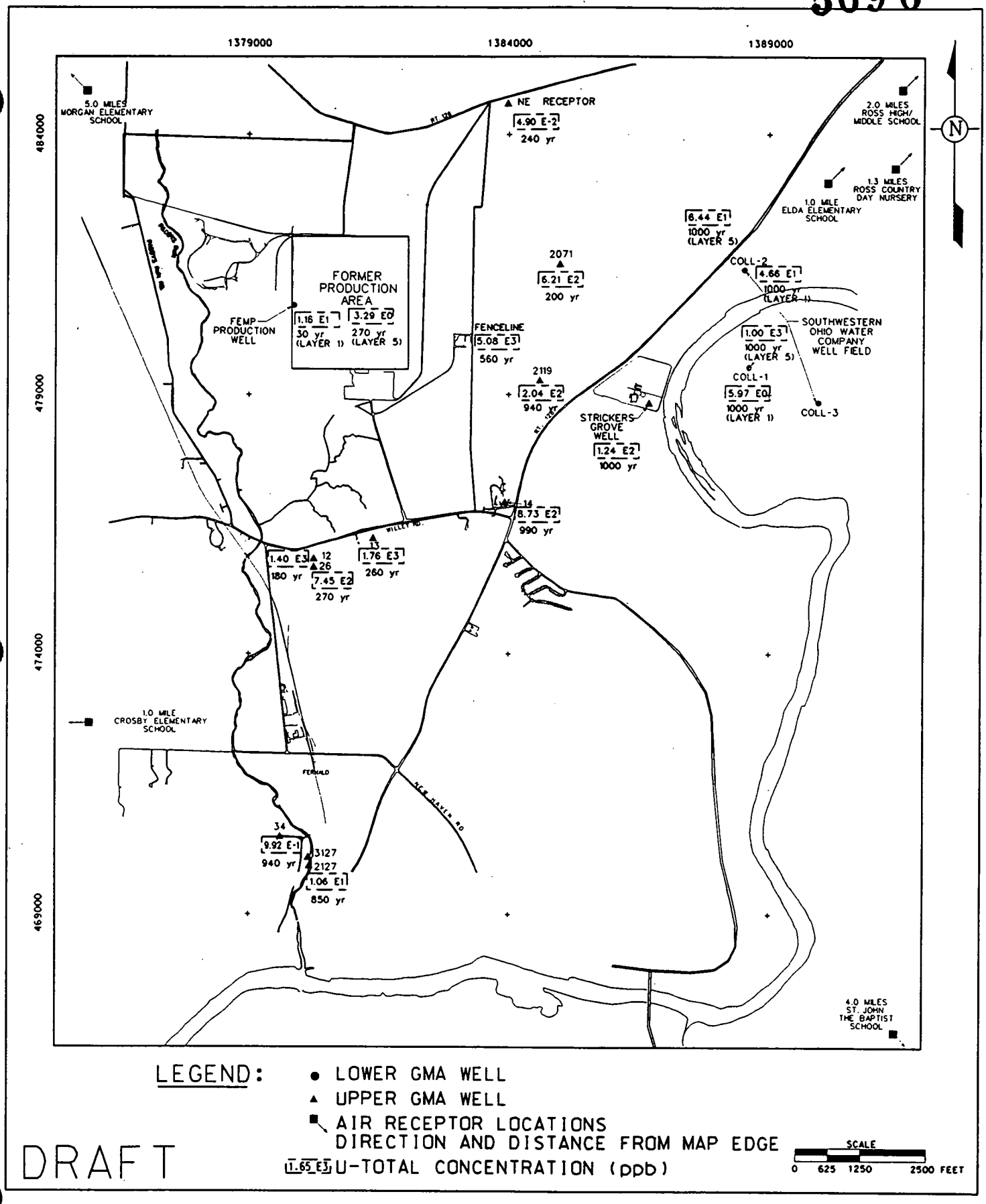

FIGURE 5-33. THE FUTURE MAXIMUM TOTAL URANIUM CONCENTRATIONS AT SPECIFIC GROUNDWATER RECEPTOR LOCATIONS

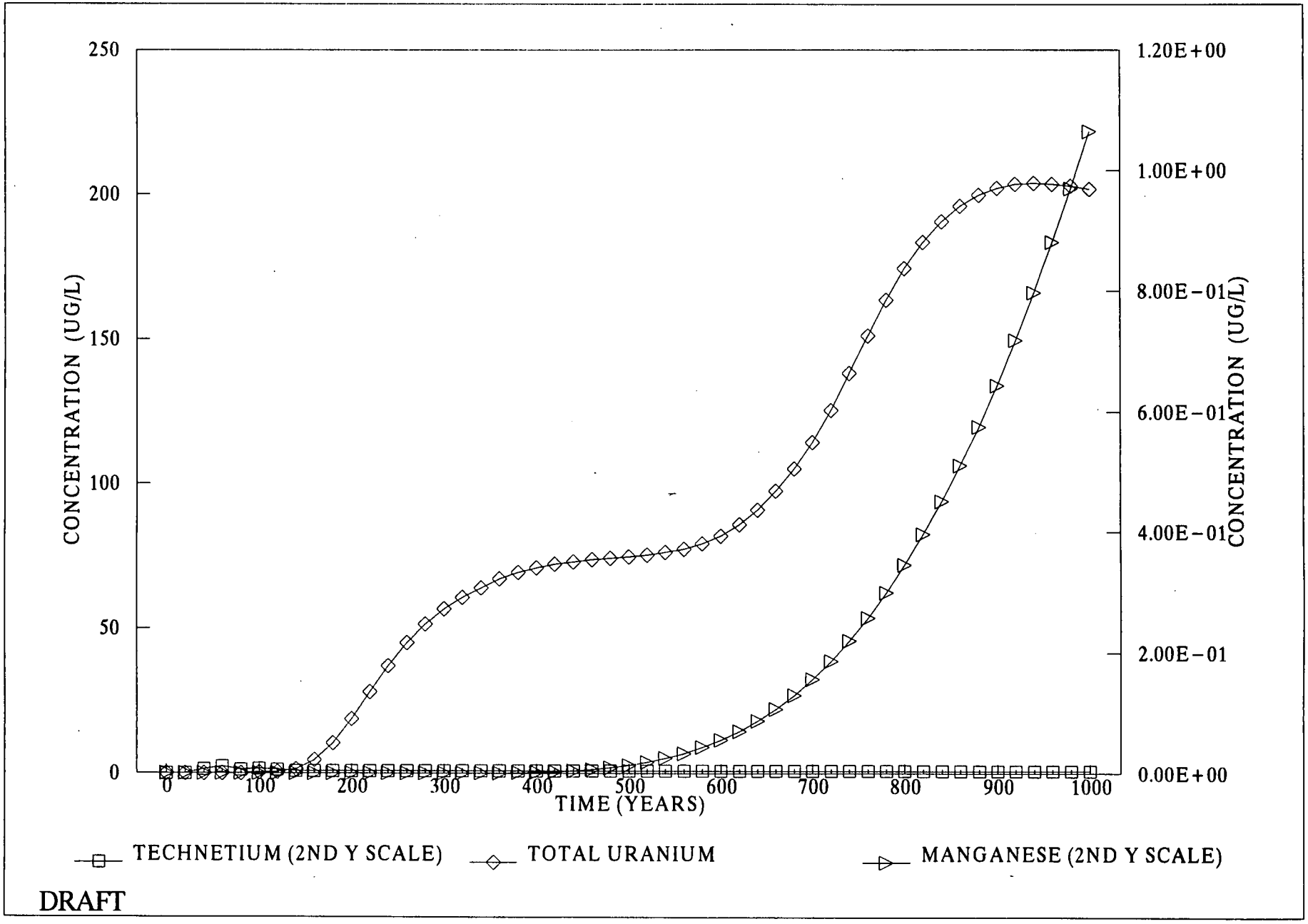

FIGURE 5-34. CONCENTRATION OF KEY CONSTITUENTS VERSUS TIME AT RECEPTOR WELL 2119

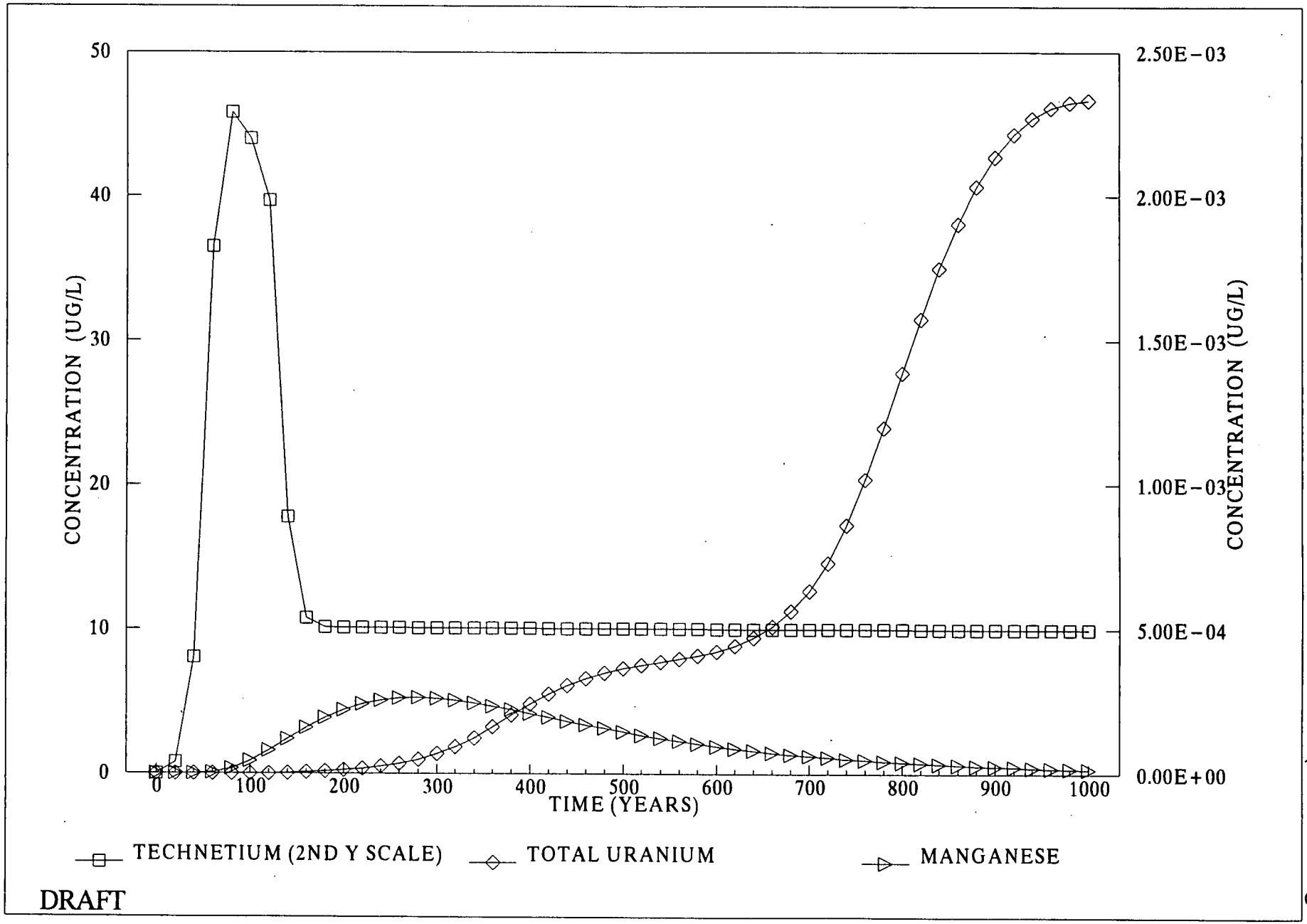

FIGURE 5-35. CONCENTRATION OF KEY CONSTITUENTS VERSUS TIME AT RECEPTOR WELL 13

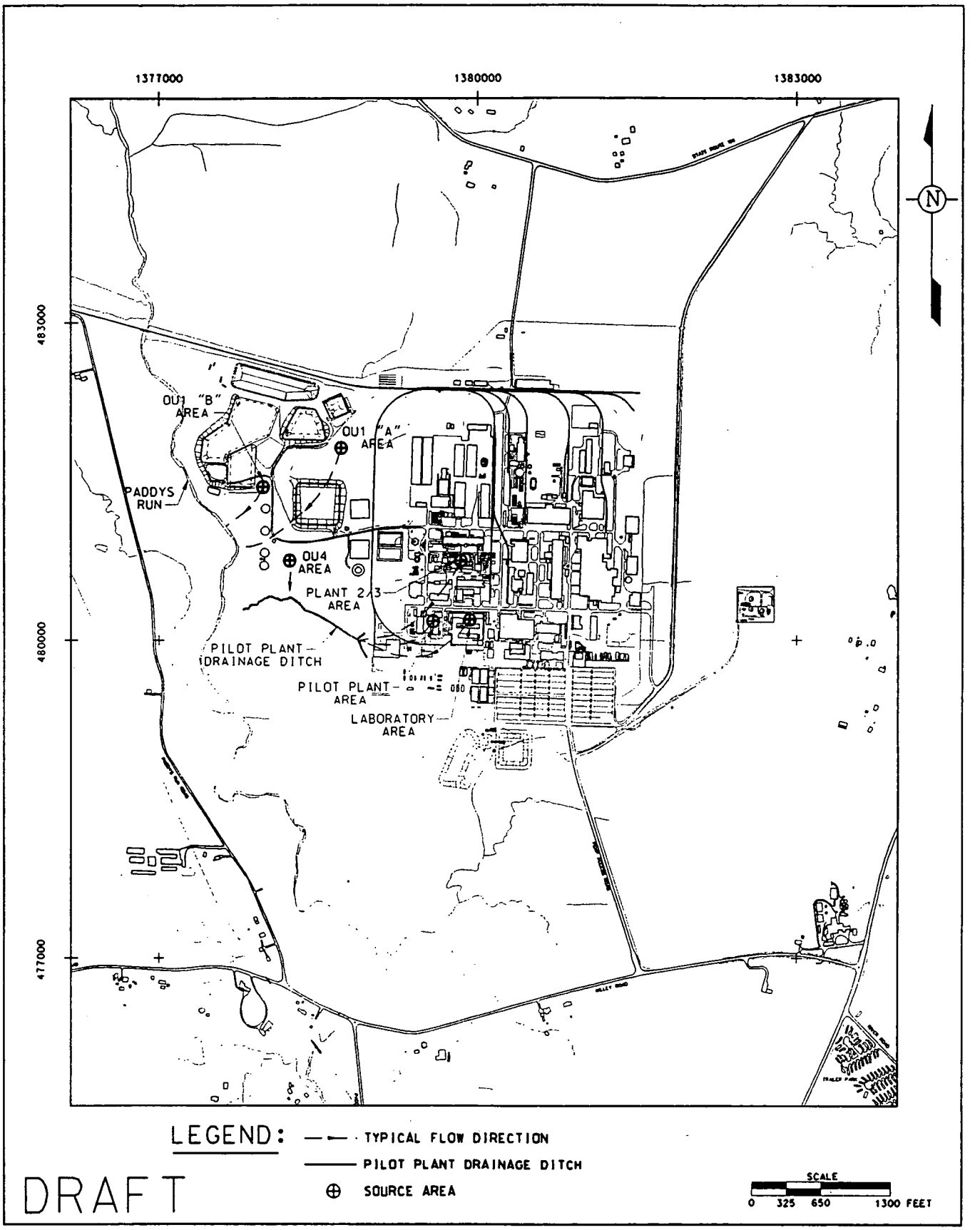

FIGURE 5-36 PERCHED WATER AS A LATERAL SOURCE TO SURFACE WATER

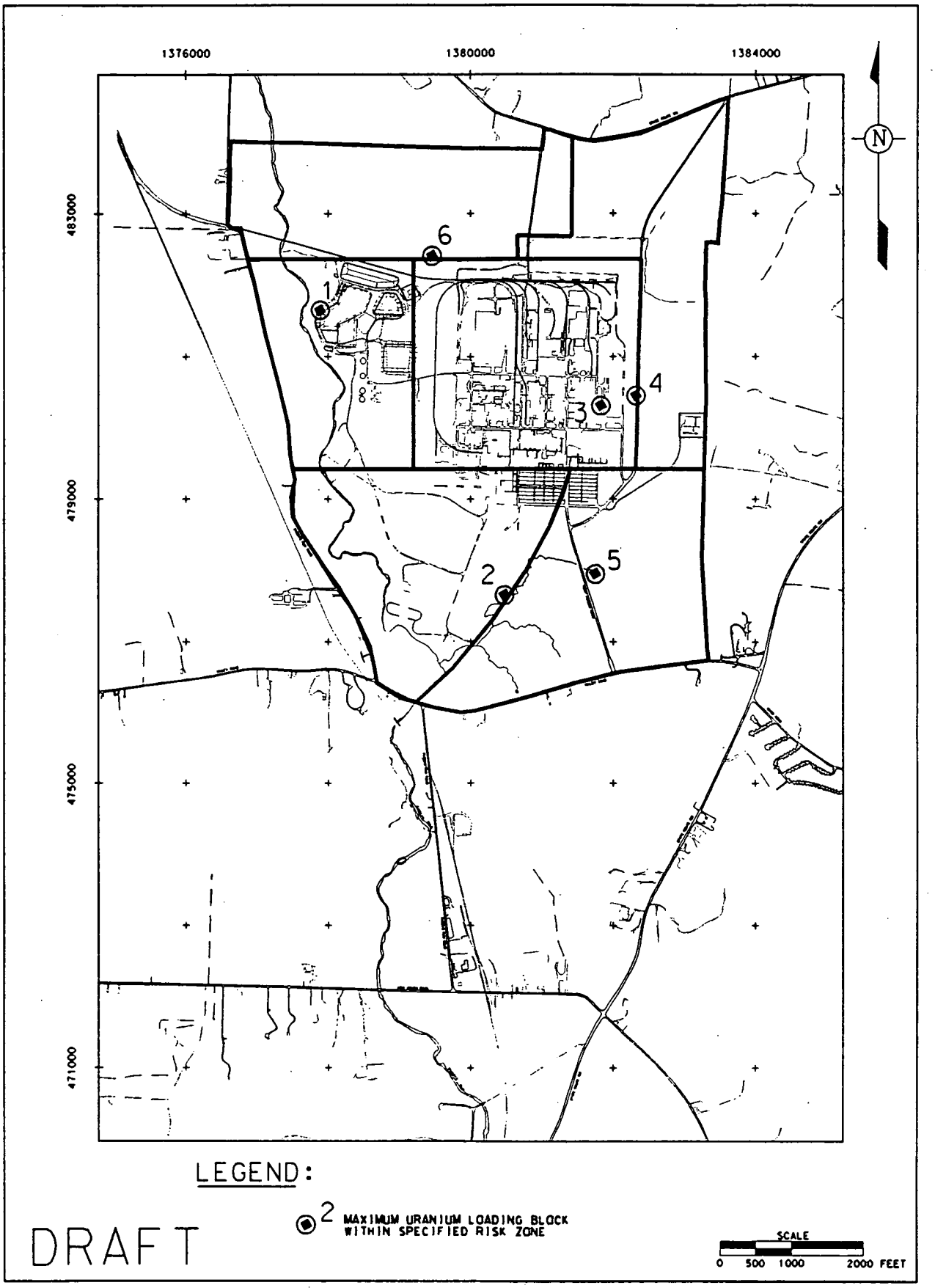

FIGURE 5-37. LOCATION OF RISK ZONE SPECIFIC MAXIMUM GREAT MIAMI AQUIFER URANIUM CONCENTRATIONS

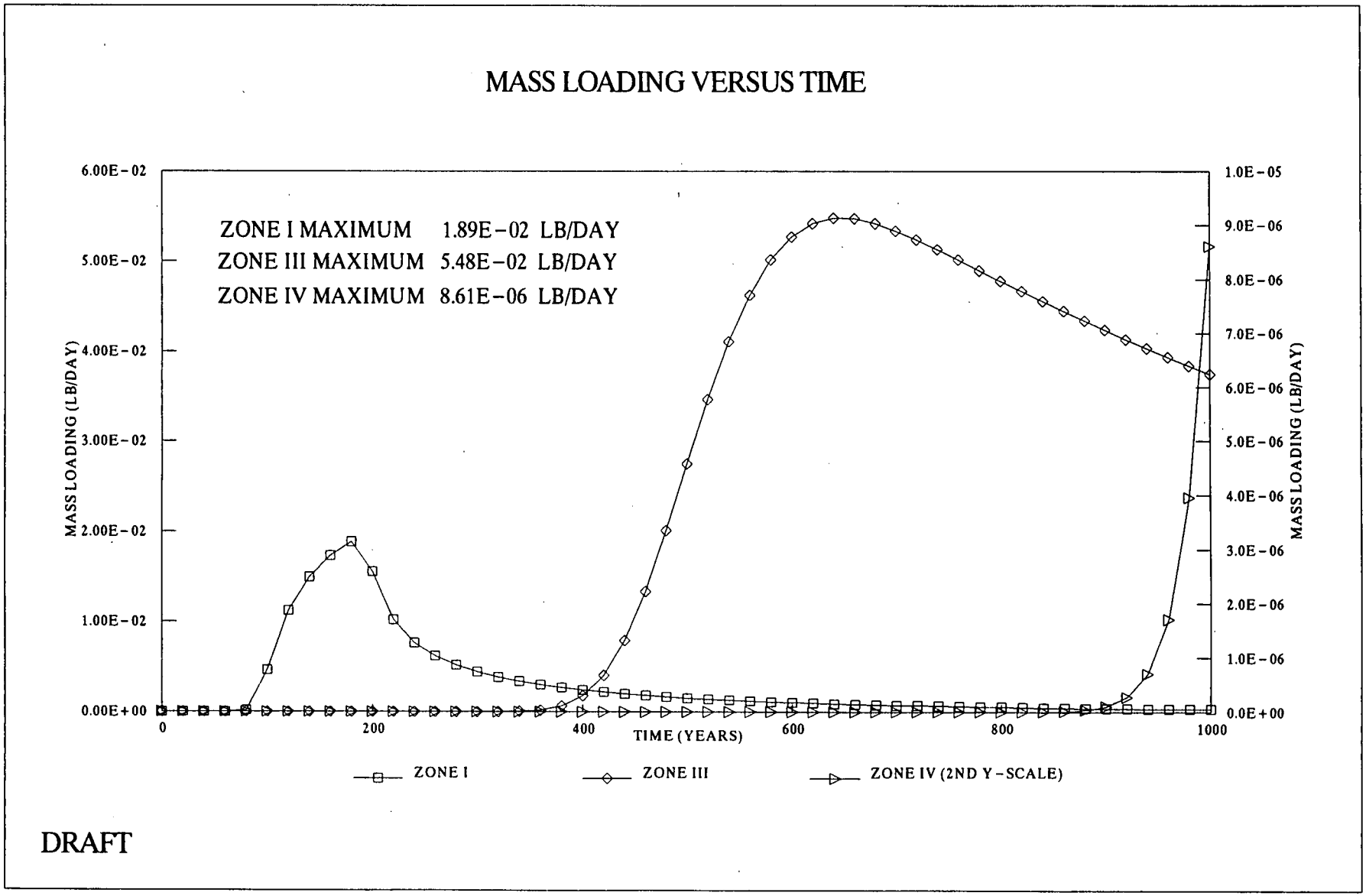

FIGURE 5-38 AREA SPECIFIC MAXIMUM TOTAL URANIUM LOADING CURVE

6.0 BASELINE RISK ASSESSMENT

Section 6.0 of this remedial investigation (RI) report provides an overview of the methods, results, and uncertainties associated with the human health baseline risk assessment conducted for Operable Unit 5. The baseline risk assessment is an estimate of the risk to hypothetical receptors exposed to site-related constituents, assuming no further remedial actions are performed aside from those already completed. The purpose of the baseline risk assessment is to estimate the possible risk to human health from exposure to the hazardous and radiological constituents detected in the Operable Unit 5 environmental media. Accordingly, the baseline risk assessment process uses information developed during site investigations to:

- Determine the constituents of potential concern (CPCs) for Operable Unit 5
- Assess the potential for human exposure
- Quantify potential exposures to receptors under current and future land use scenarios
- Characterize the nature and magnitude of potential baseline risks associated with Operable Unit 5 under current and potential future land-use scenarios.

The results of the baseline risk assessment will determine the need for remedial action, identify specific media and areas for which cleanup is appropriate, present a "baseline" of potential human health risks for the no-action alternative in the feasibility study (FS), and provide criteria for determining cleanup levels. A summary of the methods used and detailed calculations of the risk assessment are presented in Appendix A.

Section 6.1 states the objectives of the risk assessment, describes the risk assessment process, and provides an overview of Operable Unit 5. Section 6.2 discusses the sources of data, methods, and assumptions that identify the CPCs chosen for quantitative risk assessment. Section 6.3 presents the conceptual model for the exposure assessment, including land-use scenarios, source-term configurations, and potential receptors. It also summarizes methods used to calculate exposure point concentrations. Section 6.4 describes the toxic and carcinogenic incremental lifetime cancer risks (ILCR) and noncarcinogenic effects associated with exposure to the CPCs and also references the sections of the report containing quantitative toxicity data for CPCs.

Section 6.5 presents a summary of the risk assessment results, including a tabulation of the carcinogenic risk estimates and hazard indices (HIs) for each receptor under the land-use scenarios and source-term configurations previously described. Section 6.6 contains a discussion of the sources of uncertainty in the baseline risk assessment.

6.1 METHODS

The baseline risk assessment was performed in accordance with available EPA guidance for conducting risk assessments under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). It is also consistent with the Risk Assessment Work Plan Addendum (DOE 1992). Some procedures were modified, as necessary, to incorporate new information or guidance that were not available during the preparation of the Work Plan Addendum. Any differences between the Risk Assessment Work Plan Addendum and the methods used for this risk assessment are noted in Appendix A.

6.2 CONSTITUENTS OF POTENTIAL CONCERN (CPCs)

CPCs are those chemicals/radionuclides that are retained for quantitative evaluation in the baseline risk assessment. The selection of chemical and radionuclide CPCs for Operable Unit 5 is based on data developed in the Operable Unit 5 RI/FS investigations that characterized radiological and chemical constituents in environmental media. Data were collected in accordance with data quality objectives (DQOs) established in the Quality Assurance Project Plan (QAPP), as discussed in Section 2.10.

A comprehensive review of analytical data was conducted for the purpose of CPC selection.

The CPC screening process focuses on the chemicals and radionuclides that, based on their prevalence, concentration, and toxicity are considered to be of concern to human health. Organic constituents detected in a given environmental medium were selected as CPCs based on toxicity screening and frequency of detection. (A conservative toxicity screening value was used as a benchmark for CPC selection.) Radiological constituents and metals (and other inorganic chemicals) were selected as CPCs based on the results of statistical analyses which compared measured on-property concentrations of a constituent to background concentrations of that constituent in the same environmental media. Laboratory contaminants (identified during data validation), essential

macronutrients and micronutrient (calcium, etc.), ubiquitous minerals (silica, etc), were not selected as CPCs.

The selection of CPCs for Operable Unit 5 included a critical review of site data characterizing the soil, surface water and sediment, and groundwater within the Operable Unit 5 study area. The data sets on which analyses were performed are presented in Section 4.0 and are tabulated in Appendices C, D, and E. The methods and results of the CPC screening process are described in Section A.2.0 of Appendix A, the Baseline Risk Assessment. The CPCs and their concentrations are presented in a series of tables in Appendix A, Attachment IV. Based on the information provided in Section 4.0 and the CPC selection presented in Section A.2, radiologicals (particularly uranium) are the predominant CPCs detected at the site.

6.3 EXPOSURE ASSESSMENT

The exposure assessment identifies the contaminant sources and pathways of chemical/radiological exposure and the plausible current and future land-use scenarios.

The conceptual model developed for the Operable Unit 5 baseline risk assessment considers potential risks to human health under current and future source-term conditions. The conceptual model for the current land-use/source-term scenario assumes that the land use is industrial and the storm water retention basin and outfall line are functional. Consequently, the majority of surface water drainage from the production area and the major waste storage/disposal areas (Operable Units 1 and 4) is controlled and is not impacting Paddys Run. These assumptions accurately reflect current site conditions. It is further assumed that the majority of the buildings and infrastructure in the former production area do not exist. This assumption is important because it allows the evaluation of the production area surface soil. A vegetative cover consistent with the surrounding rural area (approximately 85 percent) and the current industrial use of the site is in place. For purposes of contaminant modeling and risk assessment, under the current source-term configuration, the effects of radiological and chemical decay of the source are assumed to be minimal.

The conceptual model for the future land-use/source-term scenario considers the potential future industrial, residential, agricultural, or recreational land-use of the study area. The future source-term configuration is similar to the current source-term configuration except that it is assumed that the retention basins and outfall line are no longer functional. Thus, excess surface water runoff flows to

Paddys Run. For the purpose of contaminant modelings, 85 percent vegetative cover is assumed for the potential future industrial or recreational land use of the FEMP. A 50 percent vegetative cover is assumed for the potential future agricultural land use of the site.

The conceptual models for the Operable Unit 5 baseline risk assessment are discussed in greater detail in Section A.3.0.

Due to the unusually large size of Operable Unit 5, the site was divided into the following risk evaluation areas for the purpose of conducting the baseline risk assessment was based on the following:

- Site knowledge and history of Operable Unit 5
- Knowledge of the quantity and quality of the Operable Unit 5 analytical data
- Recognition of the special considerations necessary to evaluate production area contamination
- Knowledge of discrete areas of contamination outside the production area
- Knowledge of predominant air and groundwater flow patterns (on-property and off-property).

The on-property risk evaluation areas are as follows:

Area 1	The administration/health and safety buildings
Area 2	Main production facilities area
Area 3	Northeast corner of the production area
Area 4	Northwest corner of the production area
Area 5	Fire training area (just north of the production area)
Area 6	Sewage treatment plant area (located on the east boundary of the site)
Area 7	Northeast boundary area (east and northeast of the production area)
Area 8	Northwest boundary area (northwest of the production area)
Area 9	Waste storage disposal area (west of the production area)
Area 10	Area south of the production area.

These areas are identified in Appendix A, Figure A.3-3. CPC levels in these areas (or a combination of these areas) were evaluated in the baseline risk assessment. Additionally, CPCs detected in current or potential on-property grazing areas (i.e., areas currently [or potentially] leased to area farmers) in

the environmental media at the site boundaries, in the surface water of Paddys Run and the Great Miami River, and at discrete off-property receptor locations were evaluated.

The division of the operable unit into study areas avoids on overly complex and confusing risk assessment and provides area-specific risk information that will be useful in the Operable Unit 5 FS.

The following four land-use configurations are evaluated in the Operable Unit 5 baseline risk assessment:

- Current land use with access controls
- Current land use without access controls
- Future land use with access controls (government reserve)
- Future land use without access controls (agricultural use).

Under the first scenario (current land use with access controls), the site access restrictions historically provided by the U.S. Department of Energy (DOE) are assumed to be maintained and no further remedial actions have been undertaken other than those completed to date. The scenario further assumes that no members of the public have established on-property residence and the site remains under the institutional control of DOE. Potential receptors under this scenario include a groundskeeper, a visitor, an off-property farmer and child, a trespassing youth, a consumer of meat and milk products, and a user of the Great Miami River.

It is assumed that access to the main production area is unlikely for receptors other than the groundskeeper. Off-property receptors include children attending schools in the general vicinity of the FEMP.

If access controls are discontinued but the current land use continues (the second scenario), it will be assumed that all areas of the FEMP are open to receptors visiting, trespassing, or working on site. Six receptors were evaluated under this scenario. They are the groundskeeper, off-property farmer and child, the Great Miami River user, the visitor, consumer of meat and milk products, and the exploring youth.

If government use of the site changes, additional uses of the land (e.g., recreational land use) become possible. One such land use, the government reserve (the third scenario - future land use with federal

ownership), postulates that ownership of the site is retained by the government, but that site maintenance and strict access controls are relaxed. Four receptors were evaluated under this scenario. They are the groundskeeper, off-property farmer and child, and the Great Miami River user.

Three on-property recreational land-use scenarios were considered: 1) the wildlife reserve; 2) an undeveloped park with limited facilities; and 3) a developed park with attractive recreational facilities.

If the government were to relinquish all control over the site (future land use without access controls), unrestricted use of the site could permit exposure routes associated with development of residences, such as a home and farm, within the boundaries of Operable Unit 5. Access controls are assumed to be absent and no additional remedial actions are assumed to have been completed. The eight hypothetical receptors under this scenario include a reasonable maximum exposure (RME) resident farmer and child, a central tendency (CT) resident farmer, a RME farmer using the perched water, an off-property RME farmer and child, a user of Great Miami River water, and an on-property home builder.

Exposure pathways quantified in the baseline risk assessment for each land use configuration and receptor discussed in the preceding paragraphs are listed in Table A.3-1. The exposure pathways are discussed in detail in Section A.3.0 of Appendix A. That section includes a description of the methods used to quantify receptor exposures and a tabulation of the exposure input parameters (Tables A.3-20 and A.3-21) employed in exposure calculations. A flow diagram of the conceptual model for Operable Unit 5 depicted in Figures 6-1 and 6-2 provides an overview of contaminant sources (the environmental media), contaminant release and transport mechanisms, exposure pathways, and receptors critical to the baseline risk assessment.

Estimated exposure point concentrations used in exposure calculations are tabulated in Tables A.3-3 through A.3-19. Exposure point concentrations for soil, surface water and sediment, groundwater, and air are based on analytical data resulting from the RI/FS sampling and analytical programs. For certain scenarios, exposure point concentrations in air, the surface water in Paddys Run and the Great Miami River, sediment, and groundwater are based on environmental transport modeling from the defined Operable Unit 5 source terms. Exposures to the future on-property RME resident farmer due to consumption of groundwater considers two scenarios; water obtained from the Great Miami Aquifer and water obtained from the perched aquifer beneath Operable Unit 5. Section 5.0 and

Appendix F of this RI report address these modeling results in detail. The conceptual model described in Appendix A.3.0 contains the assumptions regarding source terms and potential release mechanisms on which the transport modeling is based.

6.4 TOXICITY ASSESSMENT

Two primary human health hazards are addressed in the toxicity assessment for Operable Unit 5; cancer induction and chemical toxicity. Cancer is a genotoxic effect and may be induced by exposure to a chemical carcinogen or from ionizing radiation from a radionuclide undergoing decay. Chemical noncarcinogenic toxicity refers to general toxicity that does not affect the genetic material and includes organ tissue effects. These effects are numerous and range from systemic effects such as kidney or liver damage to localized effects such as skin or eye irritation. For both cancer induction and chemical toxicity, dose-response data from human and animal studies were used to determine the reference doses of each constituent.

For cancer induction, it is assumed that no dose threshold exists, so for any dose of a carcinogen there exists a possibility, however small, of developing cancer. ILCRs are expressed in terms of the probability that a given receptor (person) will develop cancer due to estimated exposures. For example, if the receptor has an additional one chance in 10,000 of contracting cancer due to these exposures, the probability is expressed as a 10^{-4} (1/10,000) risk. Chemical intakes calculated in the exposure assessment are used in conjunction with the cancer slope factor (CSF) to determine the ILCR. Cancer risks from exposure to chemical carcinogens and exposure to ionizing radiation are considered separately in the Operable Unit 5 baseline risk assessment.

In the evaluation of potential exposures for the noncarcinogenic assessment, it is assumed that a dose threshold exists below which no toxic effect will occur. This threshold is used to develop an acceptable intake level (the reference dose/reference concentration [RfD/RfC]). To determine if Operable Unit 5 constituents may cause toxic effects, the estimated intake (calculated from the exposure assessment) is divided by the acceptable intake. This ratio is called the hazard quotient (HQ). When HQs for multiple CPCs are summed for a particular pathway, the resultant value is the HI. If the ratio of estimated intake to the acceptable intake is greater than 1, the site-related intake may exceed the threshold and potentially induce adverse health effects.

Quantitative toxicity factors (i.e., CSFs and RfDs are presented in Appendix A, Tables A.4-1 and A.4-3 for radionuclides and chemical constituents, respectively.

For risk assessment purposes, mixtures of dioxins and furans are evaluated using the U.S. Environmental Protection Agency's (EPA's) toxicity equivalency method. This approach uses derived toxic equivalent factors (TEFs) to convert the concentration of dioxin or furan congeners into an equivalent concentration of 2,3,7,8-TCDD. Table A.4-4 presents the TEFs for a variety of congeners.

Carcinogenic risks associated with polynuclear aromatic hydrocarbons (PAHs) are also evaluated using a TEF approach. This approach considers the relative potency of the individual PAHs and allows site-specific relative concentrations to be expressed in the risk assessment. The relative potency factors for PAHs are presented in Table A.4-5. Results were also presented in Attachment VII assuming that all carcinogenic PAHs were as potent as benzo(a)pyrene.

6.5 RISK CHARACTERIZATION RESULTS

Risk estimates are derived by combining the results of the exposure assessment and the toxicity information to quantitatively estimate the degree of hazard associated with exposure to CPCs. The results are characterized based on ranges of generally acceptable risk under CERCLA, an ILCR of 10^{-4} to 10^{-6} or an HI equal to or less than 1 (EPA 1990e).

As described in Section A.3.0, several hypothetical receptor populations were evaluated for carcinogenic and chemical toxicity risk for both current and future land-use scenarios. Exposures addressed under the current land use are based on the current source term. Measured values were used to determine exposure point concentrations for the current source term for all media except for air values, which are modeled.

Unlike other operable units, Operable Unit 5 has not presented a separate risk evaluation for a future source term that differs dramatically from current conditions. This is because contaminated environmental media, which are the responsibility of Operable Unit 5, are not anticipated to undergo drastic alterations over time. However, under the future land-use scenario, exposure point concentration values will vary slightly from the current land use because:

- The on-property storm water drainage pattern is assumed to change (i.e., the storm water retention basin and outfall line are assumed to be nonfunctional).
- Contamination in groundwater (particularly the Great Miami Aquifer) will migrate with the natural flow pattern as predicted in groundwater modeling efforts.
- Radionuclides present in the environmental media will decay at their unique and predictable rates resulting in slight alterations in quantity and quality of radiological constituents.
- Modeled constituent concentrations will usually vary from their measured counterparts due to uncertainties and conservative assumptions inherent in modeling.

Section 6.5 is organized around risk summary tables (6-1 to 6-7) which present total risks of chemical carcinogens, total risks of radiologicals, total carcinogenic risk, and HIs for each receptor evaluated. All detailed (constituent and pathway-specific) risk information is contained in Attachment A.VII.

6.5.1 Risk Summaries for Current Land Use With Access Controls

Table 6-1 summarizes cancer risk estimates and HIs for the groundskeeper, visitor, and trespassing youth under current land use with access controls as evaluated for the Operable Unit 5 study area. Table 6-1 also summarizes risks to the consumer of meat and milk products for the current land use with access controls as evaluated for the three on-property grazing areas selected for this scenario. Risks are presented below by land use and receptor. Risk values broken down by pathway and constituent can be referenced in Appendix A, Attachment VII.

6.5.1.1 Groundskeeper - Current Land Use With Access Controls

CPC concentrations in all 10 defined receptor areas were evaluated to estimate carcinogenic and noncarcinogenic risks for the groundskeeper receptor. Two exposure timeframes were used. The groundskeeper evaluated in Areas 1 through 4 was assigned an exposure time of 250 days per year and is viewed as a maintenance person, in these areas. In Areas 5 through 10 it was assumed that this receptor was exposed only 35 days per year (a timeframe anticipated to be more consistent with a true groundskeeper). This compensates for the disparity in property improvements between the former production area (Areas 1 through 4) and the mostly undeveloped remainder of the site (Areas 5 through 10). The majority of the carcinogenic and noncarcinogenic risk estimated for this receptor is attributable to CPCs from direct contact (e.g., incidental ingestion) with soil and external radiation via soil.

For the groundskeeper receptor in the former production area (Areas 1 through 4), total carcinogenic risk ranged from 1 x 10^{-3} for Areas 2 and 4 to 1 x 10^{-4} for Area 1. The dominant carcinogenic drivers were the isotopes of uranium and the isotopes of radium; radon, thorium-228, beryllium, arsenic, several carcinogenic PAHs (e.g., benzo(a)pyrene), and polychlorinated biphenols (PCBs). The total HI for the groundskeeper in the production area ranged from 0.78 in Area 1 to 5.4 in Area 4. The dominant chemical drivers were uranium, antimony, arsenic, and manganese. However, at least 50 percent of the noncarcinogenic risk is attributable to uranium. Only the HQ developed for uranium exceeds unity.

For the groundskeeper evaluated in the remainder of Operable Unit 5 (Areas 5 through 10), total carcinogenic risks ranged from 1 x 10^{-5} in Area 8 to 2 x 10^{-4} for Areas 6 and 9. The dominant carcinogenic drivers were the isotopes of uranium and radium and thorium-228. The total HI for the groundskeeper in Areas 5 through 10 ranged from 1.1 for Area 6 to 0.046 for Area 8. HQs developed for individual CPCs did not exceed unity. Only the HQ developed for uranium exceeded 0.1.

It should be noted that risks to the groundskeeper are not representative of risks to current on-property workers at the FEMP because the current and future source terms for the baseline risk assessment assume that the on site buildings do not exist, allowing exposure to contaminated soil underlying the buildings.

6.5.1.2 Visitor - Current Land Use With Access Controls

The evaluation for this receptor was limited to Area 1 (administrative section of the former production area) for current land use with access controls, and included Areas 2 through 4 for current land use without access controls. For purposes of simplicity, pertinent risk results are presented together in this section.

The total carcinogenic risk ranged from 3 x 10^{-5} in Area 1 to 5 x 10^{-4} in Area 2. The dominant carcinogenic drivers were the isotopes of uranium, radium, and thorium. The HI developed for all four production area risk areas was less than unity.

6.5.1.3 Trespassing Youth - Current Land Use With Access Controls

The trespassing youth was evaluated for Areas 5 through 10. The total carcinogenic risks estimated for the trespassing youth ranged from 3 x 10^{-6} for Area 8 to 6 x 10^{-5} for Area 9. The principal constituents contributing to risk were the isotopes of uranium and radium, thorium-228; arsenic; Aroclor-1260; and bis(2-ethylhexyl)phthalate. HIs for this receptor ranged from 1.8 for Area 6 to less than unity for all other areas. Uranium, cadmium, manganese, mercury, antimony, manganese and tetrachloroethene were the dominant chemical toxicants contributing to the noncarcinogenic risk. However, only the HI developed for uranium (Area 6) exceeds unity.

6.5.1.4 Off-Property User of Milk and Meat - Current Land Use With Access Controls

The off-property user of meat and milk is exposed as a result of the consumption of meat and milk products from animals grazing on contaminated forage or exposed to water and soil present in specified grazing areas. Under the current land use with access controls, Grazing Areas 1, 2, and 3 of Operable Unit 5 (see Figure A.3-5) were evaluated for this receptor.

The total carcinogenic risk estimated for the user of meat and milk products ranged from 1 x 10^{-4} in Grazing Area 3 to 3 x 10^{-4} in Grazing Area 1. The main carcinogenic drivers were arsenic, strontium-90, technetium-99, and benzo(a)pyrene. This is at variance with the radionuclide drivers of other pathways due to the relatively efficient biotransfer of these light and generally soluble radiological fission products. HIs developed for this receptor ranged from 7.0 in Grazing Area 2 to 9.8 in Grazing Area 1, with metals such as cadmium being the dominant chemical toxicants. It should be noted that cancer risks and HIs developed for Grazing Areas 1, 2, and 3 and may be attributable, in large part. to the conservative nature of the food pathway models used to estimate the bioconcentration of CPCs as well as the conservative statistical protocol used to determine the representative concentration.

6.5.2 Current Land Use Without Access Controls

The following two receptors were evaluated under current land use without access controls:

- The exploring youth (Areas 1 through 10)
- The consumer of meat and milk products (Grazing Area 4)

Table 6-2 summarizes the risks estimated for these receptors (as well as the risk estimated for the groundskeeper and visitor).

6.5.2.1 Exploring Youth - Current Land Use Without Access Controls

Cancer risk estimates developed for the exploring youth ranged from 8 x 10^{-5} in Area 2 to 3 x 10^{-6} in Area 8. The primary constituents contributing to risk were the isotopes of uranium, and radium, thorium-228, arsenic, benzio(a) pyrene, Arclor 1254 and 1260, beryllium and bis(2 ethylberyl) phtbalate. Hazard indices for this receptor were less than unity or marginally exceeded unity. Cancer risk estimates for the exploring youth exposed to the off-property surface water and sediment of Paddys Run did not exceed 1 x 10^{-6}.

6.5.2.2 User of Meat and Milk - Current Land Use Without Access Controls

Grazing Area 4 is a scattered assemblage of FEMP property (see Figure A.3-4) that is potentially suitable for cattle forage but due to current access restrictions is not being utilized for this purpose. Risks to the consumer of meat/milk from animals potentially grazing in this area at some point in the future are presented in Table 6-2.

The total carcinogenic risk to the user of meat and milk products from animals pasturing in Grazing Area 4 was 1 x 10^{-2}. This value is higher than those predicted for Areas 1 through 3 because Grazing Area 4 abuts the former production area and is more heavily contaminated than Grazing Areas 1 through 3. The main carcinogenic drivers were strontium-90, technetium-99, lead-210, Aroclor-1260, benzo(a)pyrene, benzo(b)fluoranthene, and benzo(k)fluoranthene. The HI developed for this receptor was 22. Antimony, cadmium, magnesium, mercury, silver, and zinc are the primary chemical toxicants contributing to the noncarcinogenic risk.

6.5.3 Current Land Use - Off-Property Receptor

Table 6-3 and 6-4 summarize carcinogenic and noncarcinogenic risks to off-property receptors under the current land-use scenario. Access controls are of no significance except that if access controls are in place, bottled water is supplied to nearby residents. The three off-site receptors evaluated for this scenario were the off-property farmer and child, and user of the Great Miami River water.

6.5.3.1 Off-Property Farmer - Current Land Use

Risks calculated for the off-property farmer at exposure points along the southern, eastern, western, and northern FEMP boundaries and the northeast and southeast corner of the FEMP are presented in Table 6-3 and 6-4. Total cancer risks ranged from 1.0 x 10^{-2} for the receptor on the southern boundary to 7 x 10^{-4} for the receptor at the southeast corner of the FEMP. The main carcinogenic

drivers were isotopes of uranium, radium, and thorium; arsenic; and beryllium. HIs for this receptor ranged from 230 for the receptor on the eastern boundary to 2.8 for the receptor at the southeast corner of the FEMP boundary. Heavy metals such as antimony, arsenic, and cadmium were the dominant chemical toxicants.

6.5.3.2 Off-Property Child - Current Land Use

Risks calculated for the off-property child receptor are also presented in Table 6-3 and ranged from 6×10^{-5} for the receptor at the southeast corner of the FEMP to 7×10^{-3} for the hypothetical receptor on the southern fenceline. Isotopes of radium, thorium, and uranium; arsenic; and beryllium were the principal contributors to risk. HIs for this receptor ranged from 13 for CPCs detected in/modeled for environmental media along the southeast corner of the FEMP to 970 at the northern boundary. Heavy metals such as antimony, arsenic, cadmium, and chromium are the dominant chemical toxicants.

6.5.3.3 Great Miami River User - Current Land Use

The Great Miami River user was evaluated using the exposure point concentrations at the confluence of Paddys Run and the Great Miami River and at the effluent line outfall.

The total carcinogenic risk to the Great Miami River user at the confluence of Paddys Run and the Great Miami River ranged from 6×10^{-4} (assuming household use of the Great Miami River) to 5×10^{3} (assuming recreational use of the Great Miami River). The principal carcinogenic contaminants were arsenic and bis(2-ethylhexyl)phthalate. The HI for this location ranged from 9.17 to 199. Bis(2-ethylhexyl)phthalate and di-n-octylphthalate were the dominant chemical toxicants.

The total carcinogenic risk estimated for the Great Miami River user at the outfall ranged from 1×10^{-3} (assuming household use of the Great Miami River) to 3×10^{-4} (assuming recreational use of the Great Miami River). The predominant carcinogens contributing to risk were arsenic and beryllium. The HI for this receptor ranged from 0.29 (assuming recreational use of the Great Miami River) to 1.39 (assuming agricultural use of the Great Miami River).

6.5.4 Future Land use - With Access Controls

Table 6-5 summarizes risks to the groundskeeper and recreational receptors evaluated under the future land use with access controls (government reserve). The groundskeeper exposure point concentrations

vary between current and future land use due to the shift in constituent concentrations from the decay of radionuclides over the 70-year time frame. CPC concentrations in all seven receptor areas designated under the future land use scenario were evaluated.

6.5.4.1 Groundskeeper - Future Land Use With Access Controls

The groundskeeper receptor was evaluated in the former production area, assuming a 250 days/year exposure frequency and in the remainder of the site using a 35 day/year exposure frequency. Total cancer risk estimates for ranged from 1.0×10^{-3} for the production area to 2×10^{-5} for the northwest area. The dominant carcinogens were the isotopes of uranium, radium, and thorium; beryllium; and cesium-137. Total HIs ranged from 4.5 for the production area to less than unity for the northwest, southwest, southeast, waste pit and shooting range areas. Uranium, antimony, beryllium, cadmium, manganese, and mercury in soil are the predominant contributors to the hazard index.

6.5.4.2 Recreational Receptors - Future Land Use With Access Controls

Exposure parameters and exposure point concentrations for the recreational receptors are presented in Appendix Section A.3.0. All seven Operable Unit 5 receptor areas were evaluated for this receptor.

Total cancer risk estimates developed for the potential future recreational use of the production area, the northeast area, and the waste pit area exceeded 1×10^{-4} regardless of the type of recreational land use considered. Cancer risk estimates for the northwest area and the shooting range area ranged from 2×10^{-6} to 6×10^{-6}. Cancer risk estimates for the southeast and southwest areas ranged from 4×10^{-5} to 6×10^{-5}. HIs for all areas are less than unity or marginally exceed unity. In most cases evaluated, uranium is a primary, if not the primary, contributor to noncarcinogenic risk.

6.5.5 Future Land Use - Without Access Controls

The following receptors were evaluated assuming a future land use without access controls (agricultural):

- On-property RME farmer
- On-property child
- On-property CT farmer
- On-property RME farmer using shallow perched groundwater as a sole source of drinking water
- On-site home builder.

This scenario implies that land-use restrictions for the FEMP have been dropped and the individuals are free to conduct activities on the property that are appropriate to the surroundings, which in this case are agricultural.

Table 6-6 presents a summary of risks developed for the on-property resident farmer in the seven risk areas evaluated under the future land use scenario.

6.5.5.1 On-Property RME Farmer - Future Land Use Without Access Controls

Risk estimates are summarized for the on-property RME farmer in Table 6-6. This scenario incorporates the maximum potential impacts that could be experienced by an individual pursuing an agricultural lifestyle on the FEMP property.

The total carcinogenic risk estimated for the on-property RME farmer ranged from 6×10^{-4} for the northwest area to 2×10^{-2} for the production area. The predominant carcinogenic contaminants in these areas were isotopes of uranium, radium, thorium; beryllium; arsenic; benzo(a)pyrene; and Aroclor-1260. HI values developed for this receptor were 11 for CPC concentrations in the northwest area and over 100 in the southeast and shooting range area. Uranium, magnesium, antimony, mercury, silver, and zinc were the dominant chemical toxicants.

The cancer risk estimated for the on-property farmer in all areas evaluated exceeds the EPA benchmark of 10^{-4}. The risk predicted for the air pathways is at least an order of magnitude lower than risk from the soil and groundwater pathways.

6.5.5.2 On-Property CT Farmer - Future Land Use Without Access Controls

A risk summary is presented for the on-property CT farmer in Table 6-6. This receptor incorporates exposure input parameters that are considered representative of the typical "average" individual. The same receptor source terms and exposure point concentrations used for the on-property RME farmer are acceptable for this receptor.

Total cancer risk estimates for the on-property CT farmer ranged from 2×10^{-3} production area to 4×10^{-5} for the northwest area. The predominant carcinogenic contaminants are the same as those specified for the on-property RME farmer. HIs for this receptor ranged from 4.1 for the northwest

area to 150 for the shooting range area. Significant chemical toxicants are the same as those specified for the on-property RME farmer.

As anticipated, risk values for the CT farmer were proportionally less than those for the corresponding RME farmer. Carcinogenic risks decreased by nearly an order of magnitude. However, the total HI decreased by only a factor of two. This discrepancy can be explained by the variance between the lifetime dose used in the carcinogenic pathway and the daily dose used when calculating chemical toxicity.

6.5.5.3 On-Property Child - Future Land use Without Access Controls

Table 6-6 includes the results of an assessment of risks to an on-property child assuming future land use without access controls. Because of the differences in intake parameters, particularly soil ingestion, the child receptor will generally have higher calculated risk.

The cancer risk estimate for the on-property child was 5×10^{-3} for the production area and 9×10^{-5} for a receptor in the northwest area. The important carcinogenic contaminants in these two areas were cesium-137, strontium-90, technetium-99, isotopes of radium, thorium, and uranium; the carcinogenic PAHs; and other carcinogenic organics. HI developed for this receptor were 260 in the production area and 95 in the northwest area. Uranium, silver, zinc, antimony, and mercury were the dominant chemical toxicants.

Cancer risk estimates for the on-property child fall between the risk values calculated for the RME farmer and CT farmer. The total HI values for the on-property child are significantly higher than either the RME or CT farmer receptors. The results of these calculations support the assumption that the child is a sensitive receptor for chemical toxins.

6.5.5.4 On-Property Perched Water - Future Land Use Without Access Controls

Cancer risk estimates for an on-property resident using the perched groundwater as a domestic water supply source are presented in Table 6-6. CPCs in the perched groundwater in the production area will be used to evaluate risks to this receptor. Groundwater modeling results confirmed that maximum CPC concentrations exist in the perched water at the present time. This means that the future exposure point concentrations used for this receptor can be based on current "measured" and not "modeled" concentrations.

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The total cancer risk estimates for the on-property user of perched water was 6 x 10^{-2} in the production area. The dominant carcinogenic contaminants in this area were isotopes of uranium and radium and pentachlorophenol. The HI developed for this receptor was 1500. Uranium was the primary chemical toxicant in the perched groundwater.

6.5.5.5 Home Builder - Future Land Use Without Access Controls

Total risks posed to an on-property home builder under future land use without access controls was considered under the future land-use scenario. This receptor is incorporated into the baseline risk assessment for the purpose of evaluating the risk to an individual conducting excavation of on-site subsurface soil for construction purposes.

The total carcinogenic risk to the on-property home builder ranged from 1 x 10^{-6} for the northwest and southeast areas to 5 x 10^{-5} in the northeast section of the FEMP. The predominant carcinogenic contaminants were isotopes of uranium, thorium and radium, and beryllium. HIs for this receptor ranged from 0.93 for the southeast area to 3.3 for the production area. Uranium was the dominant chemical toxicant.

6.5.6 Future Land Use - Off-Property Receptors

Table 6-7 summarizes cancer risk estimates and HIs for the off-property receptors under future land use. Access controls are of no significance to these receptors because exposure points are beyond the FEMP boundary. The three off-site receptors evaluated for this scenario were the off-property farmer and child and the user of Great Miami River water.

6.5.6.1 Off-Property Farmer - Future Land Use

Risks were evaluated and summarized for the off-property farmer under a future land-use scenario. Receptor locations at all four FEMP boundaries, the northeast and southeast corners of the FEMP, and three off-property well locations were evaluated.

The total carcinogenic risks estimated for the off-property farmer ranged from 4.0 x 10^{-2} for the receptor on the southern boundary to 1 x 10^{-4} for the hypothetical receptor at a well location near the Great Miami River. The main carcinogenic drivers were isotopes of radium and uranium; strontium-90, cesium-137; arsenic; and beryllium. HIs for this receptor ranged from 40 for the receptor on the eastern fenceline to 5.1 x 10^{-2} for a hypothetical receptor at off-property well Location

2071. Uranium, zinc, cyanide, magnesium, 4-methylphenol and manganese were the dominant chemical toxicants.

6.5.6.2 Off-Property Child - Future Land Use

Risks were calculated and summarized for the off-property child receptor under future land use. The receptor source terms, environmental media evaluated, and exposure point concentrations are identical to those specified for the off-property farmer previously discussed.

The total carcinogenic risk to the off-property child ranged from 9×10^{-3} on the southern fenceline boundary to 1×10^{-5} for a hypothetical receptor at off-property well Location 2119. The main carcinogenic drivers were strontium-90; isotopes of thorium and uranium; 4-methylphenol and beryllium. HIs for this receptor ranged from 160 for the eastern boundary receptor to 0.13 for a hypothetical receptor at off-property well Location 2071. Metals such as uranium and zinc were the dominant chemical toxicants.

6.5.6.3 Great Miami River User - Future Land Use

The Great Miami River user was evaluated under the future land use scenario (70+ years) with the assumption that the storm water retention basin is no longer in operation and the effluent line has ceased discharging runoff to the Great Miami River. Under these conditions, storm water runoff from Operable Unit 5 will generally follow site topography and flow to the Paddys Run storm sewer outfall ditch (SSOD) system in the southern and western sections of the study area. Paddys Run discharges to the Great Miami River. With this in mind, the single exposure point chosen for the user of the Great Miami River was the confluence of Paddys Run and the Great Miami River.

The total carcinogenic risk to the Great Miami River user was 2×10^{-4}, 8×10^{-5}, 5×10^{-4} for the recreational (i.e., fishing and swimming), agricultural, and household use scenarios, respectively. The primary carcinogenic contaminants of concern were uranium, Aroclor-1254, Aroclor-1260, and 4-methylphenol. Risks associated with the ingestion route of exposure predominate. The HI for the recreational and agriculture use patterns do not exceed unity. The HI for the household use scenario (HI = 1.82) slightly exceeds unity. Uranium and mercury are the primary contaminants contributing to the noncarcinogenic risk.

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6.5.7 Background Risks

All site-related risks in the risk assessment are calculated without accounting for the contribution from natural background. In many cases, the concentrations of CPCs in the soil in the Operable Unit 5 are at or only slightly above natural background concentrations, but the ILCRs or HIs for these background levels often exceed 10^{-4} and 1, respectively. Background contributions provide a useful point of comparison for site-related risk estimates.

Risks and HQs are calculated for background concentrations of CPCs in Operable Unit 5 environmental media. These results are presented in Tables A.7-8 through A.7-19. Exposure assumptions and models used for soil, groundwater, and perched groundwater background calculations are the same as those used for evaluating site-related risks to the RME on-property resident farmer. The assumptions used for calculating background risk from sediment and surface water were based on those used for calculating risk to the exploring youth. Soil concentrations used for background risk calculations are the upper confidence limit (UCL) values determined for the site-specific background soil sample analytical results.

Background risks from radionuclides and their short-lived progeny in soil (Table A.7-8) are in the range of 3.1×10^{-4} to 9.1×10^{-8}. The exposure pathway that contributes nearly all of this risk is external radiation exposure from radium-226, thorium-228, and radium-228 (and their short-lived progeny) in surface soil. It is important to note that, using CERCLA methods, the overall lifetime risk from natural background radiation sources (such as cosmic radiation, naturally occurring radionuclides in surface soil, and radon) is approximately 1×10^{-2}. Risks from arsenic and beryllium in soil at background concentrations exceed 1×10^{-4} and 1×10^{-5}, respectively.

Background HQs were calculated for natural background concentrations of inorganic chemicals in soil. Results of these calculations for the RME on-property resident adult are given in Table A.7-9. The soil concentrations used for these calculations are the UCLs of site-specific background soil sample analyses. The HQ for background concentrations of inorganics range from 2.4×10^{-6} for uranium to $1.2 \times 10^{+1}$. The HQs estimated using the background UCLs and the method described in Sections A.1 through A.5 exceed 0.1 for five metals including arsenic, mercury, cadmium, manganese, and thallium. The results of the background risk calculation and the potential for toxic effects to occur from natural background concentrations of radionuclides and inorganic chemicals suggest that the risk assessment methods have a conservative bias. The conservative bias encountered

when comparing background risk to the risk attributed to site constituents may make the background risk values appear significant. In reality, even these values seem minimal at approximately 1 percent of the total lifetime cancer risk from all background sources.

6.6 ECOLOGICAL ASSESSMENT

As per the Amended Consent Agreement with the EPA, the Operable Unit 5 remedial investigation is responsible for submitting a comprehensive baseline ecological risk assessment that provides detailed information concerning site ecological receptors and exposure pathways. The Site-Wide Ecological Risk Assessment is included as Appendix B of this RI Report.

6.7 UNCERTAINTY ANALYSIS

It is generally recognized that uncertainty is inherent in quantitative risk assessment. The objective of the uncertainty analysis is to identify key site-related variables that contribute most to uncertainty, and to characterize the nature and magnitude of the impact of these uncertainties on the conclusions of the risk assessment. The uncertainty analysis provides the risk manager with a summary of information that has direct bearing on the level of confidence in the quantitative risk estimation. A quantitative evaluation of uncertainty is not performed for individual risks in this study; however, a qualitative summary is provided in Section A.6 of Appendix A.

Uncertainty is a factor in each stage of the risk assessment process. Discussions of uncertainties in the Operable Unit 5 risk assessment are introduced in the section dealing with the initial selection of CPCs used to characterize exposure and risk, and also are included in the exposure assessment, the toxicity assessment, and the risk characterization sections. Section A.6.0 discusses Operable Unit 5-specific uncertainties in detail.

6.7.1 Uncertainty in Selection of CPCs

As described in Section A.2.0 of the Baseline Risk Assessment, there are several sources of uncertainty inherent in the CPC selection process. Constituents to be quantitatively addressed in the risk assessment are selected using an iterative process, which includes removal of essential nutrients, constituents present at levels comparable to background, and low toxicity compounds. The resulting CPCs are those constituents representing the greatest potential significance in the overall risk assessment based on toxicity, concentration, and frequency of detection. The constituents eliminated

as CPCs for the Operable Unit 5 baseline risk assessment are not expected to contribute significantly to risk and do not represent a significant source of health-based uncertainty.

6.7.2 Uncertainties in Exposure Assessment

The land-use assumptions, exposure scenarios, and receptors evaluated in the Operable Unit 5 risk assessment are largely defined by the Risk Assessment Work Plan Addendum (DOE 1992) and additional EPA and site guidance, and are also based on a number of professional judgments and assumptions. The primary sources of uncertainty associated with scenario development are: the definition of current and future land uses within the boundaries of Operable Unit 5, and the receptor source-term configuration selected as a basis for the risk assessment evaluation. The exposure scenarios and receptors evaluated in the risk assessment are conservative and are expected to result in significant overestimation of potential health risk.

A groundskeeper and trespassing youth are evaluated in the risk assessment as receptors who may have direct exposure to contaminants in Operable Unit 5 based on current land uses, with and without access restriction. Risk estimates for the groundskeeper are likely to be overestimated, because this receptor would enter the controlled areas of Operable Unit 5 only with the permission of DOE, so would be subject to FEMP health and safety requirements. The exploring child is assumed to wander on to the site in the absence of access controls under the current land-use scenario. This scenario appears reasonable because of the large area covered by Operable Unit 5 which may be an appealing place for a child to explore and play, potentially resulting in exposure to site-related constituents.

There is a high degree of uncertainty associated with the future-land-use scenario evaluated for Operable Unit 5, particularly the quantitative assessment of risks for an on-site resident farm family. There is a low probability that residential development will occur within the boundaries of Operable Unit 5 in the foreseeable future. In addition, there is a even lower probability that perched groundwater will be used by residents for potable purposes (either on- or off-property). It is also reasonable to assume that some level of site control, in the form of access control or institutional controls, will be maintained for Operable Unit 5, based on the history of the site and its significant institutional and community memory. The on-site resident farm family is included as the RME receptor for Operable Unit 5 based on guidance in the Work Plan Addendum. This receptor is more feasible for Operable Unit 5 than for other operable units of the FEMP because of the abundance of tillable land.

More feasible exposure scenarios for Operable Unit 5 are those addressing off-site receptors. These off-site receptors include the off-property farmer and child and the Great Miami River user. These exposure scenarios are consistent with current land use patterns and can thus be reasonably expected to occur in the present or future. The exposures for the mentioned receptors are those associated with off-site transport of site-related constituents, and result in levels of potential risk that are in most instances lower than those for on-property residential receptors.

The baseline risk assessment for Operable Unit 5 evaluates potential risks associated with previously defined current receptor source terms. As described in Appendix A, Section A.3.0, the future site configuration for Operable Unit 5 assumes that engineering controls in the area will not be maintained. In addition, the surface water runoff control system is assumed to have become nonfunctional, resulting in increased contaminant loading to Paddys Run. This particular combination of site conditions was selected as feasible and representative of reasonable maximum source-term conditions. It is important to note, however, that there are a wide variety of potential future site configurations that could have been applied in the risk assessment, and a degree of uncertainty is introduced by the selection of this particular configuration over another. For the Operable Unit 5 baseline risk assessment, it is assumed that all buildings and infrastructure in the former production area have been removed. The only alterations to the operable unit predicted between current and future land-use scenarios are an increase in vegetation in those areas now covered by gravel and concrete, and the failure of surface water drainage collection basins. This failure will result in the diversion of most of Operable Unit 5's surface water to the SSOD and Paddys Run which act as natural downgradient topographical collectors. Thus confidence is high that the major sources, exposure pathways, and important constituents have been identified using this configuration.

The inherent uncertainty associated with future land use and site configuration is managed in the Operable Unit 5 risk assessment by addressing a wide range of potential receptors and exposure conditions. The receptors evaluated represent exposure conditions considered as both reasonable maximum and average cases. Based on this conservatism and the diversity inherent in the evaluated scenarios, the resulting risk estimates are unlikely to underestimate potential health risks associated with exposure to site-related constituents.

Each exposure factor selected for use in this risk assessment has uncertainties associated with it. Standard assumptions regarding exposure frequency, duration, population characteristics, and

activities may not be representative of exposure conditions for all receptors. Generally these factors are based on surveys of physiological and lifestyle profiles across the United States. The attributes and activities studied in these surveys generally have a broad distribution. To avoid underestimation of exposure, the Operable Unit 5 risk assessment follows EPA's recommendation and uses RME assumptions that correspond to the 95th percentile for most of the exposure factors. In other words, the values used generally target the habits of a small percentage of the population representing the upper bound exposure conditions.

The availability of site characterization data (i.e., contaminant types, levels, and distribution) has a direct impact on the estimation of exposure concentrations. Specific and potentially significant sources of uncertainty with relevance to the calculation of exposure point concentrations are the adequacy of characterization data on a site as large as Operable Unit 5; assignment of validation qualifiers on data which indicate their usability for quantitative risk assessment; lack of data characterizing some environmental media that represent source terms for exposure; and the positive bias associated with some of the radiological sampling locations.

The analytical data for many chemical constituents were quite variable among the sampled areas. This demonstrates the difficulty in obtaining accurate information-based data acquired from separate sampling episodes across a site as large as Operable Unit 5. The variability in each data set was characterized by a distribution defined as normal, lognormal, or undefined and managed in the risk assessment by using conservative estimates for both the data sets used for risk assessment purposes. For example, the 95 percent UCL of the mean was selected as the exposure concentration of each constituent for normally and log normally distributed data sets; 95th percentile concentrations were used for data sets of undefined distribution; and maximum concentrations were identified as exposure concentrations in small data sets (less than seven samples).

There is a general scarcity of high quality analytical data for concentrations of organic parameters measured across the entire FEMP site. This is due in part to the difficulties encountered while conducting organic sampling and analysis including reduced holding times, volatilization and biodegradation in environmental media, and historical emphasis of the site sampling programs on radiological constituents. This limitation introduces some degree of uncertainty into the selection of CPCs and calculation of exposure point concentrations for organics in the environmental media in Operable Unit 5, in particular surface soil. A broad range of organic constituents have been

identified as CPCs for Operable Unit 5. In instances where data sets were limited, the maximum detected concentrations were used as the exposure point concentrations. These specific data limitations are of low to moderate significance in comparison with other sources of uncertainty such as those associated with the toxicity assessment and fate and transport modeling in the risk analysis.

Estimation of exposure point concentrations using environmental fate and transport modeling introduces a number of potentially significant uncertainties into the risk assessment results. This uncertainty results from the use of generalized assumptions regarding contaminant distribution and intermedia transfer processes, as well as from intrinsic uncertainties in the models applied to estimate environmental concentrations. Section 5.0 of this report and Appendix F provide detailed discussions of the inputs and uncertainties associated with the modeling process. To avoid underestimating the concentrations of contaminants in environmental media, transport parameters are chosen to calculate the upper bound of possible exposure point concentrations (and hence risks). Thus, the uncertainties associated with modeled concentrations may be significant.

The partitioning of contaminants between soil and vegetation (crops for human consumption and food for livestock) is not well characterized for most compounds. Available data are used to make order-of-magnitude estimates of plant/soil partitioning relationships. The biotransfer factors that express contaminant partitioning between animal intake and animal-based food products (such as meat and dairy products) can only be estimated to within about 2 orders of magnitude (McKone and Ryan 1989). These limitations have important implications for Operable Unit 5, where food-related pathways are significant for some receptors.

6.7.3 Uncertainty in Toxicity Assessment

Considerable uncertainty is associated with the qualitative (hazard assessment) and quantitative (dose-response) toxicity assessment process. The hazard assessment characterizes the nature and strength of evidence of causation, or the likelihood that a constituent that induces adverse effects in animals will induce adverse effects in humans. Hazard assessment of carcinogenicity is evaluated as a weight-of-evidence determination, using either the International Agency for Research on Cancer (IARC) (1987) or EPA (1986c) guidance. Positive animal cancer test data suggest that humans contain tissue(s) that may be stimulated into a carcinogenic response. However, the animal data cannot necessarily be used to predict the target tissue in humans. However, in the hazard assessment of noncancer effects,

positive animal data suggest the nature of the effects (i.e., the target tissues and type of effects) anticipated in humans (EPA 1989i).

Uncertainty in hazard assessment arises from the nature and quality (sensitivity and selectivity) of the animal and human data. Uncertainty is decreased when similar effects are observed across species, strain, sex, and exposure route; when the magnitude of the response is clearly dose-related; when metabolic data indicate a similar fate in animals and humans; when postulated toxicokinetic mechanisms are similar for humans and animals; and when the CPC is structurally similar to other chemicals for which the toxicity is more completely characterized.

Uncertainties in the dose-response evaluation are inherent in the determination of a slope factor or unit risk for the carcinogenic assessment and derivation of an RfD or RfC for the noncarcinogenic assessment. Uncertainty is introduced during interspecies (animal to human) extrapolation, which, in the absence of quantitative pharmacokinetic, dosimetric, or mechanistic data, is usually based on consideration of interspecies differences. Uncertainty also results from intraspecies, or individual, variation. Finally, uncertainty varies with the degree of confidence in the key study (from which the quantitative estimate is derived) and the database. For cancer effects, the uncertainty associated with dose-response factors is mitigated by assuming the 95 percent upper bound limit for the slope factor. A source of uncertainty regarding quantitative risk estimation for the carcinogenic assessment is the method by which data from high doses in animal studies are extrapolated to the low-dose range expected for environmentally exposed humans. The linearized multistage model, which is used in nearly all quantitative estimations of human risk from low dose exposures, is based on a nonthreshold assumption of carcinogenesis. A body of evidence, however, suggests that epigenetic carcinogens, as well as many genotoxic carcinogens, may have a threshold below which they are noncarcinogenic (Williams and Weisburger 1991); therefore, evidence suggests the use of the linearized multistage model may be conservative for chemicals that exhibit a threshold for carcinogenicity.

Uncertainty in the derivation of RfDs is mitigated by the use of uncertainty and modifying factors. An uncertainty factor is applied in the derivation of the RfD or RfC to mitigate poor quality of the key study or gaps in the database. Additional uncertainty for noncancer effects arises from use of an effect level in the estimation of an RfD or RfC, because this estimation is predicated on the assumption of a threshold below which adverse effects are not expected. Therefore, an additional uncertainty factor is usually applied to estimate a no-effect level. Additional uncertainty arises from

estimation of an RfD or RfC for chronic exposure from less than chronic data. Unless empirical data indicate that effects do not worsen with increasing duration of exposure, an additional uncertainty factor is applied to the no-effect level in a subchronic study. As a result, a combination of uncertainty and modifying factors may exceed 100, 1000, or more for a particular compound. These uncertainty factors for the CPCs in Operable Unit 5 are discussed in Appendix A, Section A.6.

To summarize, the uncertainty associated with the toxicity assessment is chemical-specific because it depends on the existing information used to derive the dose-response factor. In general, this uncertainty tends to be high (overestimates risks by 2 or more orders of magnitude) for the chemical risk assessment, but tends to be lower (overestimate risks by an order of magnitude or less) for radionuclides. This difference is the result of animal versus human data used for chemical and radiological compounds, respectively.

6.7.4 Risk Characterization

Uncertainty in risk characterization results from assumptions made regarding additivity of effects from exposure to multiple compounds from various exposure routes. High uncertainty exists when summing ILCRs or HIs for several substances across different exposure pathways. This assumes that each substance has a similar effect and/or mode of action. Often dissimilar compounds affect different target organs, have different mechanisms of action, and differ in their ultimate fate and clearance in the body. Because the types of interaction (additive, synergistic or antagonistic) between different chemicals have generally not been quantified, risk characterization does not consider antagonistic or synergistic effects and assumes additivity. Therefore, this uncertainty cannot be discussed based on its impact on the risk assessment because it has the potential to either overestimate or underestimate potential human health risks.

The additivity of risks from radionuclides and chemical carcinogens is the subject of considerable debate. EPA guidance (1989b) indicates that the two sets of estimates should be considered separately because (1) chemical CSFs are developed using laboratory experiments and radionuclide toxicity values are based on human epidemiological data, and (2) chemical CSFs represent an upper bound limit value while radionuclide slope factors are "best estimates." Therefore, cancer risks from exposure to radionuclides are presented separately from those from chemical CPCs.

6.7.5 Summary of Uncertainties in Operable Unit 5 Baseline Risk Assessment

Section A.6.0 presents a detailed discussion of the uncertainties described in the preceding summary. Generally, uncertainty arises wherever data gaps exist. Data gaps in the risk assessment were mitigated by making conservative assumptions for individual parameters. Significant uncertainty results for those particular pathways that required fate and transport modeling to support the exposure assessment. Such uncertainty was generated for the air and groundwater pathways of exposure. The high degree of uncertainty, therefore, must be addressed in the interpretation of risk from these media. Certain exposure pathways for a particular medium also tend to have higher or lower uncertainty depending on their assumptions. For example, incidental ingestion of soil by residents tends to have significantly less uncertainty than ingestion of fruits, vegetables, meat, and milk grown and raised on contaminated soil due to the less complex exposure pathways. To assess these indirect exposure pathways, assumptions must be made regarding contaminant uptake from soil to plant and plant to livestock that are not required for the soil ingestion pathway.

The receptors with the highest uncertainty in the current source term are the off-property resident farmer and off-property user of meat/milk from livestock grazed on site. The off-property resident farmer scenario was evaluated based on modeled concentrations for the air pathway and results in high uncertainty. The bioaccumulation of CPCs into meat and milk were modeled, and as a result, provide moderate to high uncertainty for this receptor. These particular receptors include the on-property resident farmer, the Great Miami River user, and the off-property user of meat and milk. For the on-property RME resident farmer and home builder, the highest uncertainty is associated with the assumed future land use and potential exposure pathways. Uncertainty associated with the off-property resident farmer and Great Miami River user is primarily the result of surface water, groundwater, and air modeling used to support those scenarios. The modeling assumptions were conservative, and this resulted in conservative estimates for the exposure point concentrations.

In summary, the cumulative uncertainties identified with site data, exposure parameters, fate and transport, toxicity assessment, and risk characterization are judged to be moderate and may potentially result in an overestimation of risk in Operable Unit 5 by 2 or more orders of magnitude.

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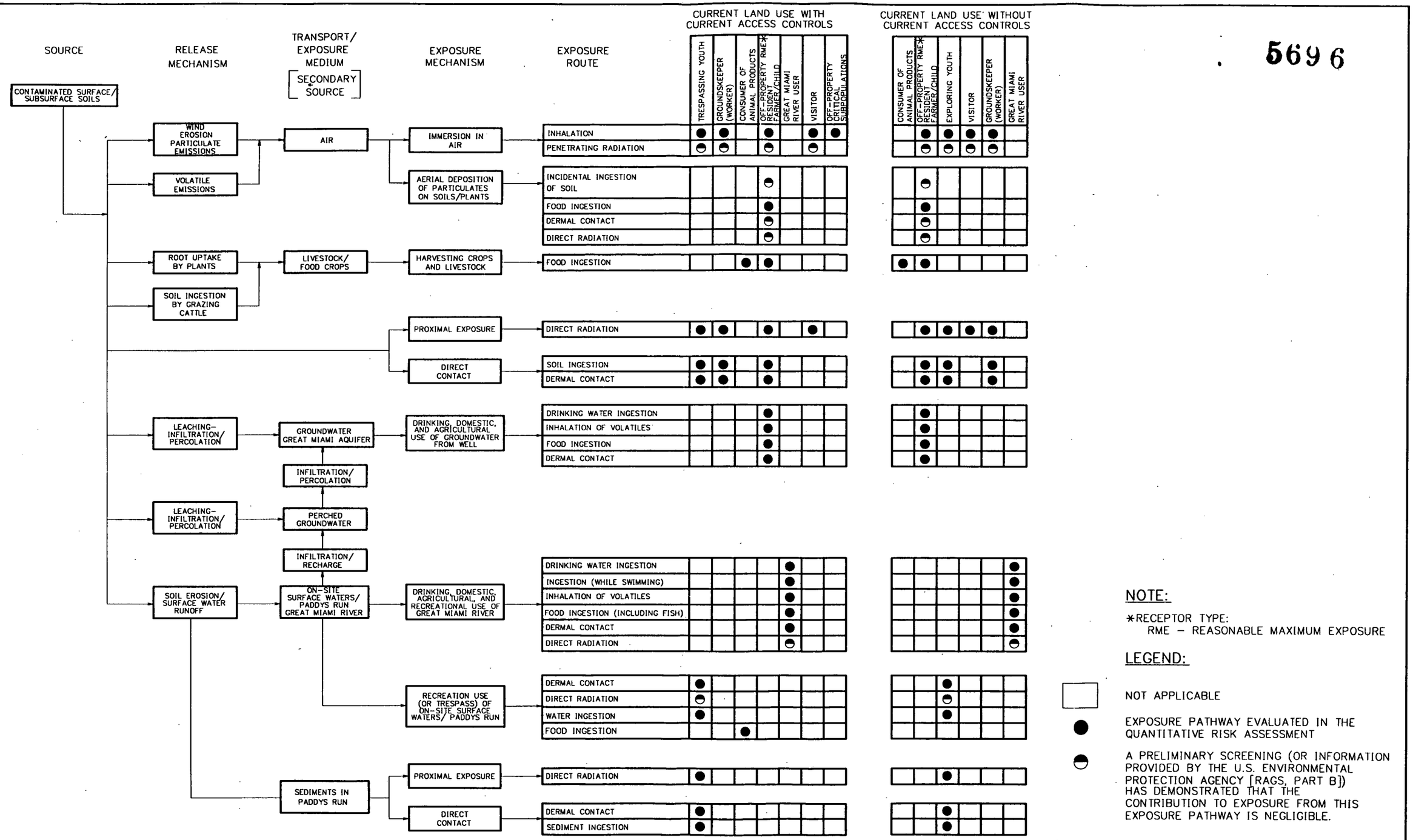
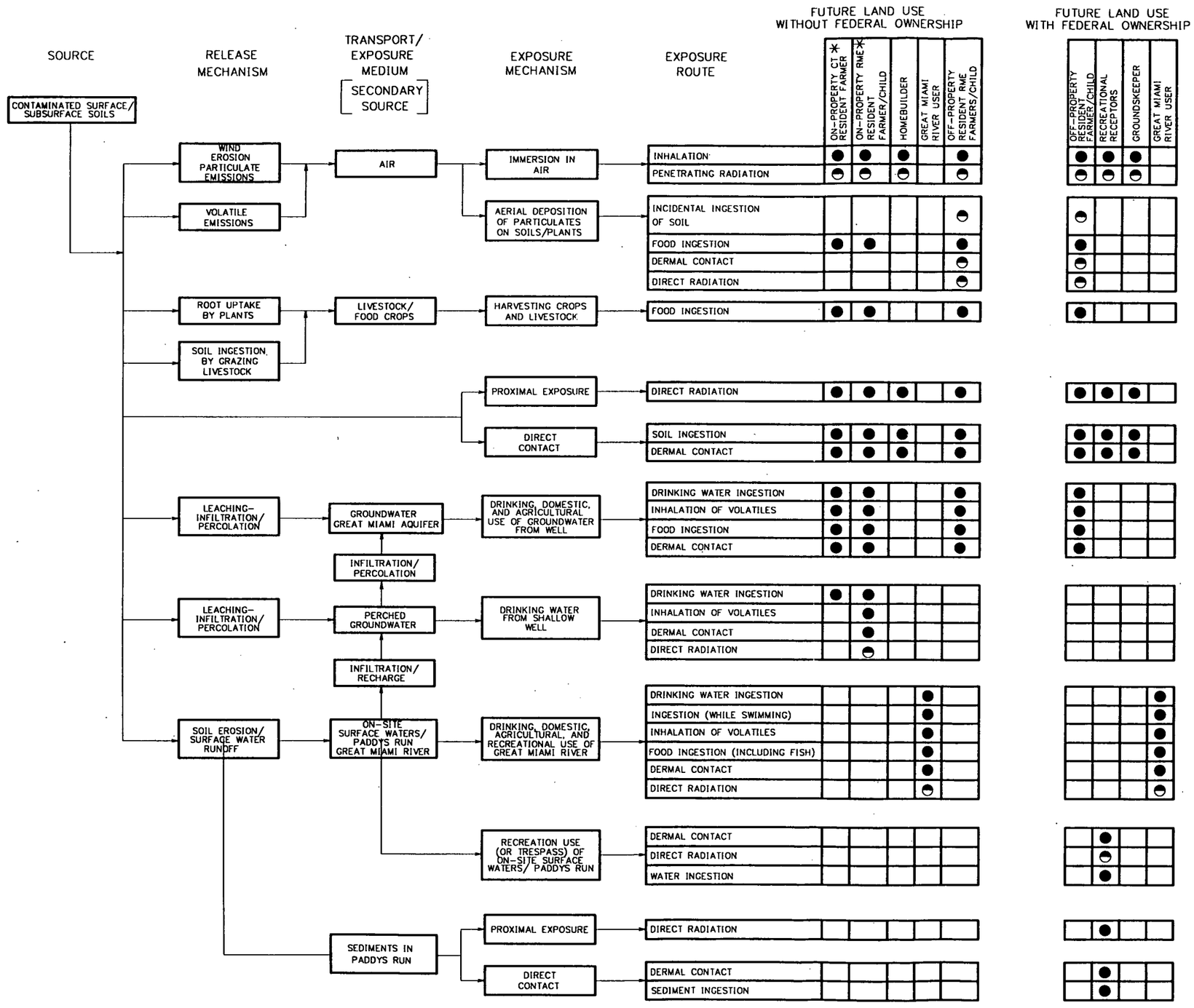


001223

FIGURE 6-1
OPERABLE UNIT 5
CONCEPTUAL MODEL
CURRENT SOURCE TERM
AND LAND USE SCENARIOS

ACAD: W:/DATA/CADD/NG96/93121602.DWG 06/10/94 MB

5696



NOTES:

*RECEPTOR TYPE:
CT – CENTRAL TENDENCY
RME – REASONABLE MAXIMUM EXPOSURE

LEGEND:

NOT APPLICABLE

EXPOSURE PATHWAY EVALUATED IN THE QUANTITATIVE RISK ASSESSMENT

A PRELIMINARY SCREENING (OR INFORMATION PROVIDED BY THE U.S. ENVIRONMENTAL PROTECTION AGENCY [RAGS, PART B]) HAS DEMONSTRATED THAT THE CONTRIBUTION TO EXPOSURE FROM THIS EXPOSURE PATHWAY IS NEGLIGIBLE.

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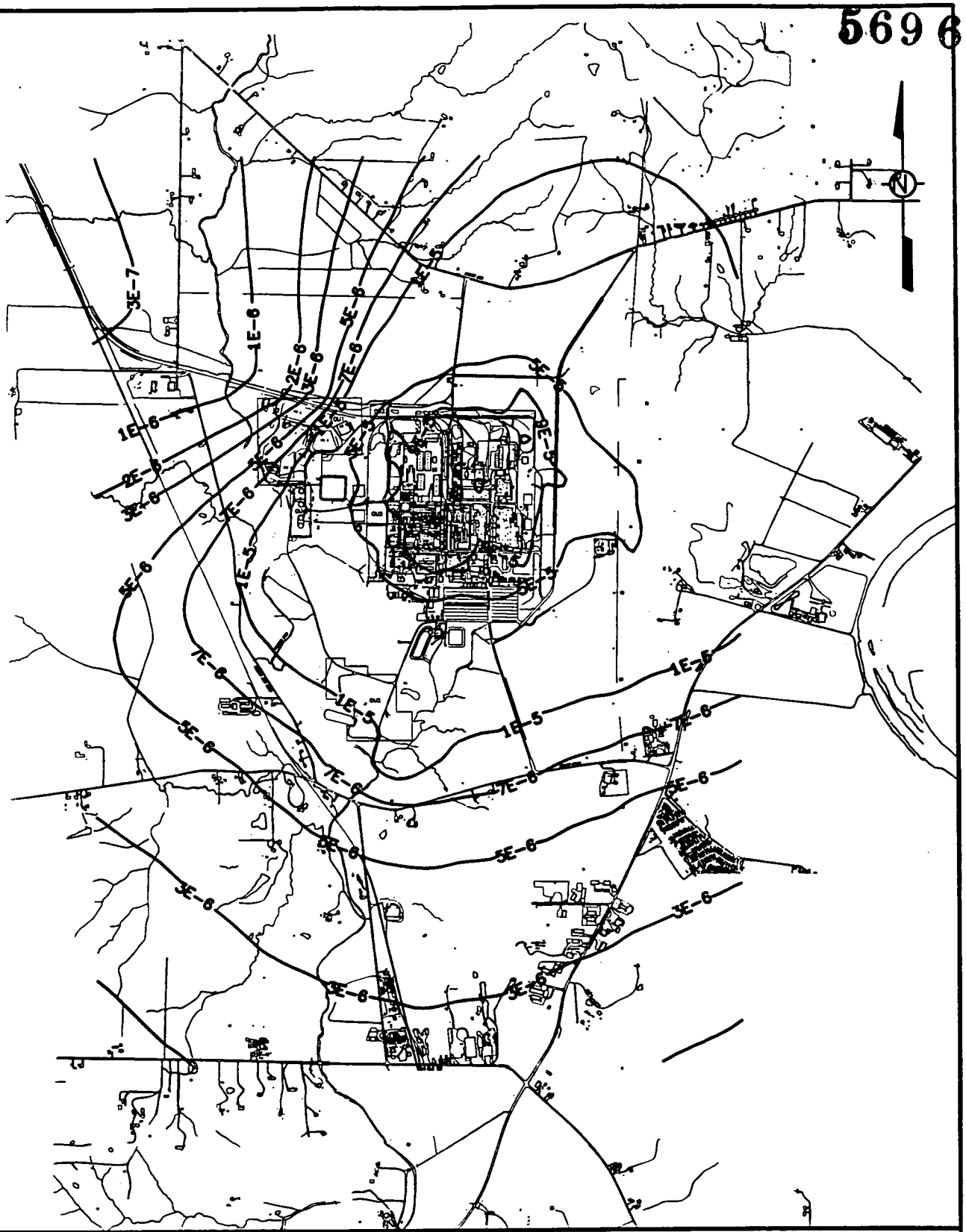
001224

FIGURE 6-2
OPERABLE UNIT 5
CONCEPTUAL MODEL
FUTURE SOURCE TERM AND
LAND USE SCENARIOS



LEGEND:

3E-6 ESTIMATED CARCINOGENIC RISK ASSOCIATED WITH THE ISOTOPES OF URANIUM AND RADIUM-226 VIA THE SUM OF ALL AIR PATHWAYS.

SCALE IN FEET

0 2000 4000

DRAFT

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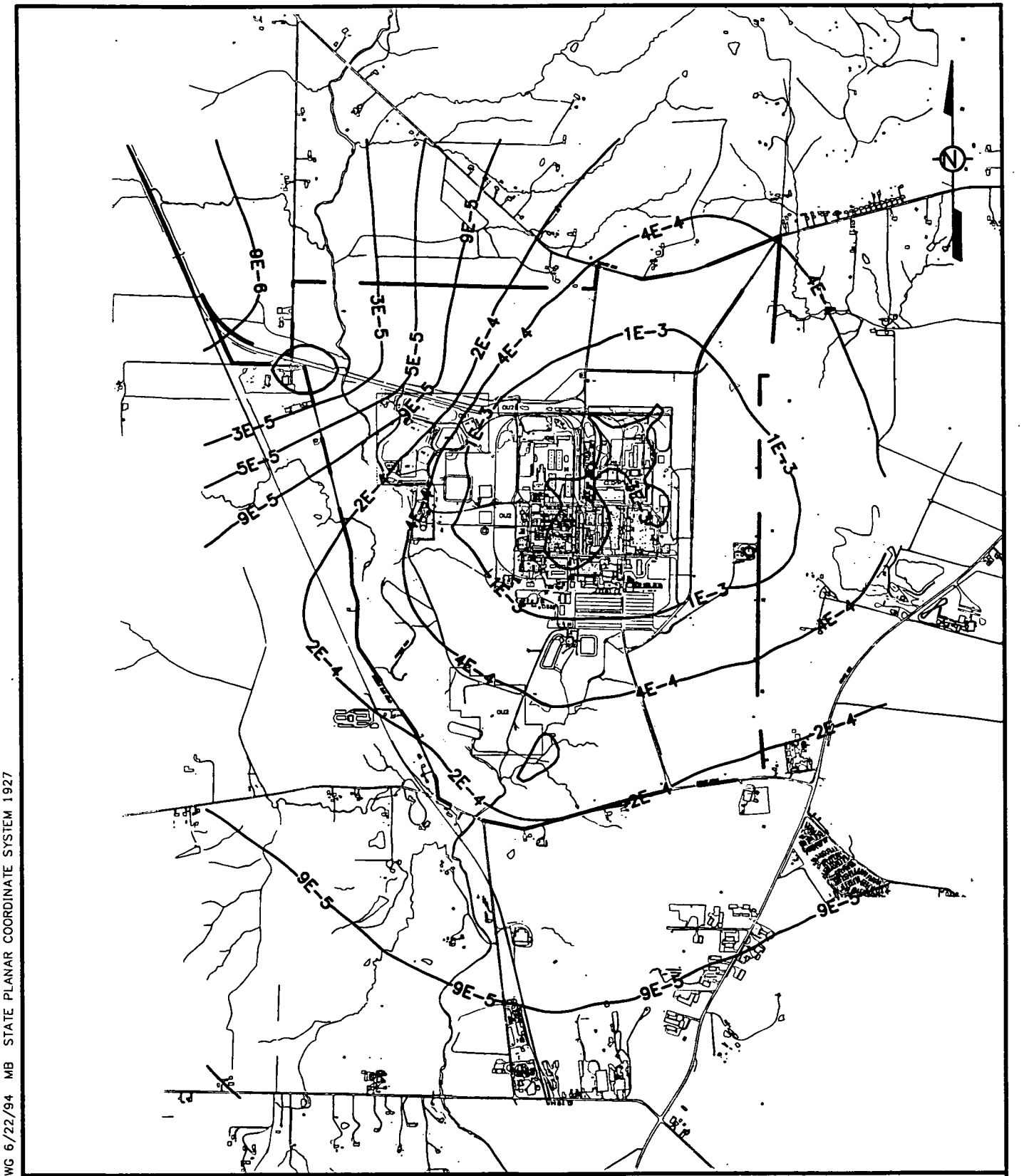
FIGURE 6-3. TOTAL ESTIMATED AIR PATHWAY RISK, CURRENT SCENARIO, FOR U-238, U-234, U-235/U-236, Ra-226



LEGEND:

3E-6 ESTIMATED CARCINOGENIC RISK ASSOCIATED WITH THE ISOTOPES OF URANIUM AND RADIUM-226 VIA THE SUM OF ALL AIR PATHWAYS.

001226

SCALE IN FEET

0 2000 4000

DRAFT

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FIGURE 6-4. TOTAL ESTIMATED AIR PATHWAY RISK, AGRICULTURAL SCENARIO, FOR U-238, U-234, U-235/236, Ra-226

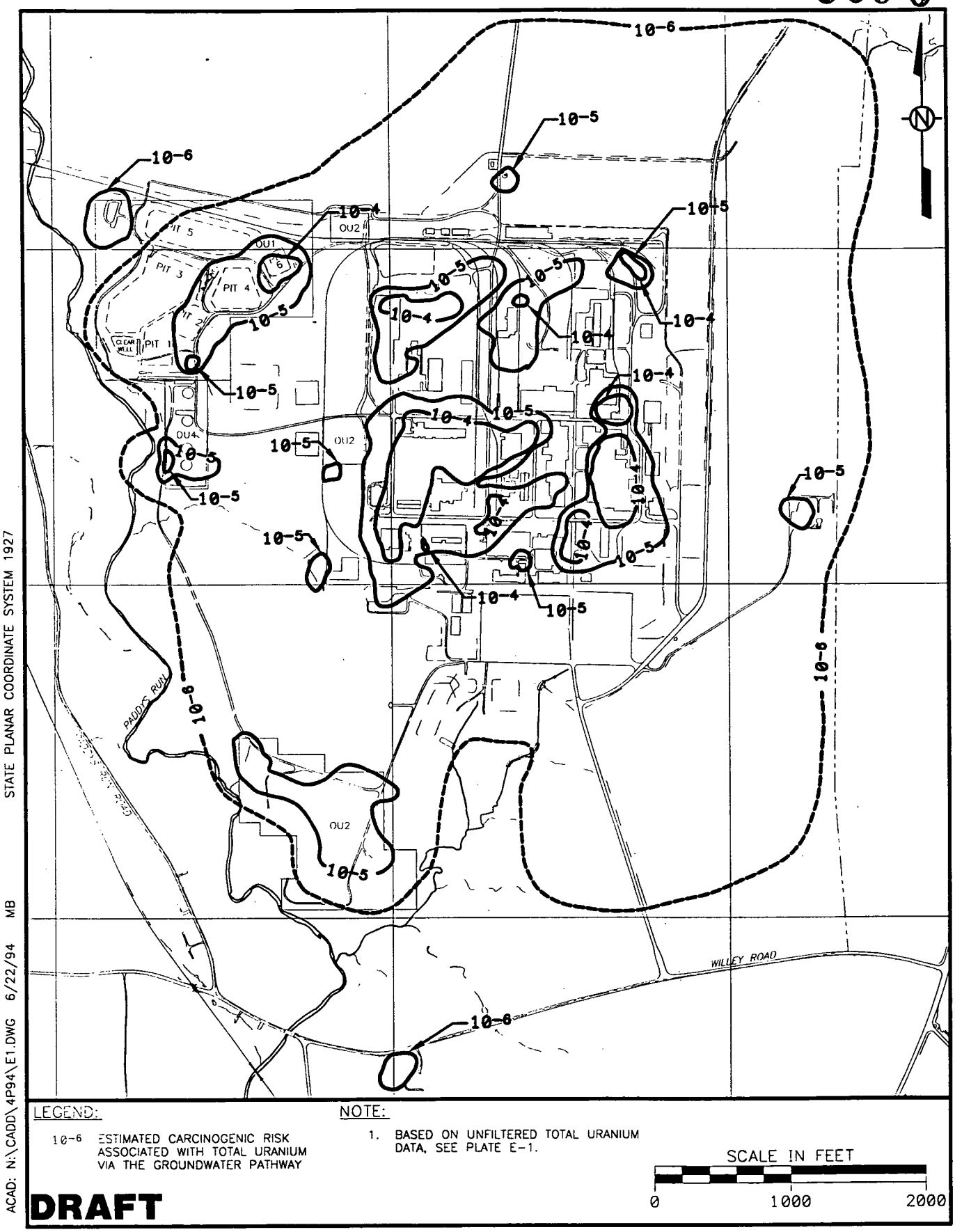


FIGURE 6-5. ESTIMATED CANCER RISK FOR TOTAL URANIUM IN GROUNDWATER TYPE 1 WELLS

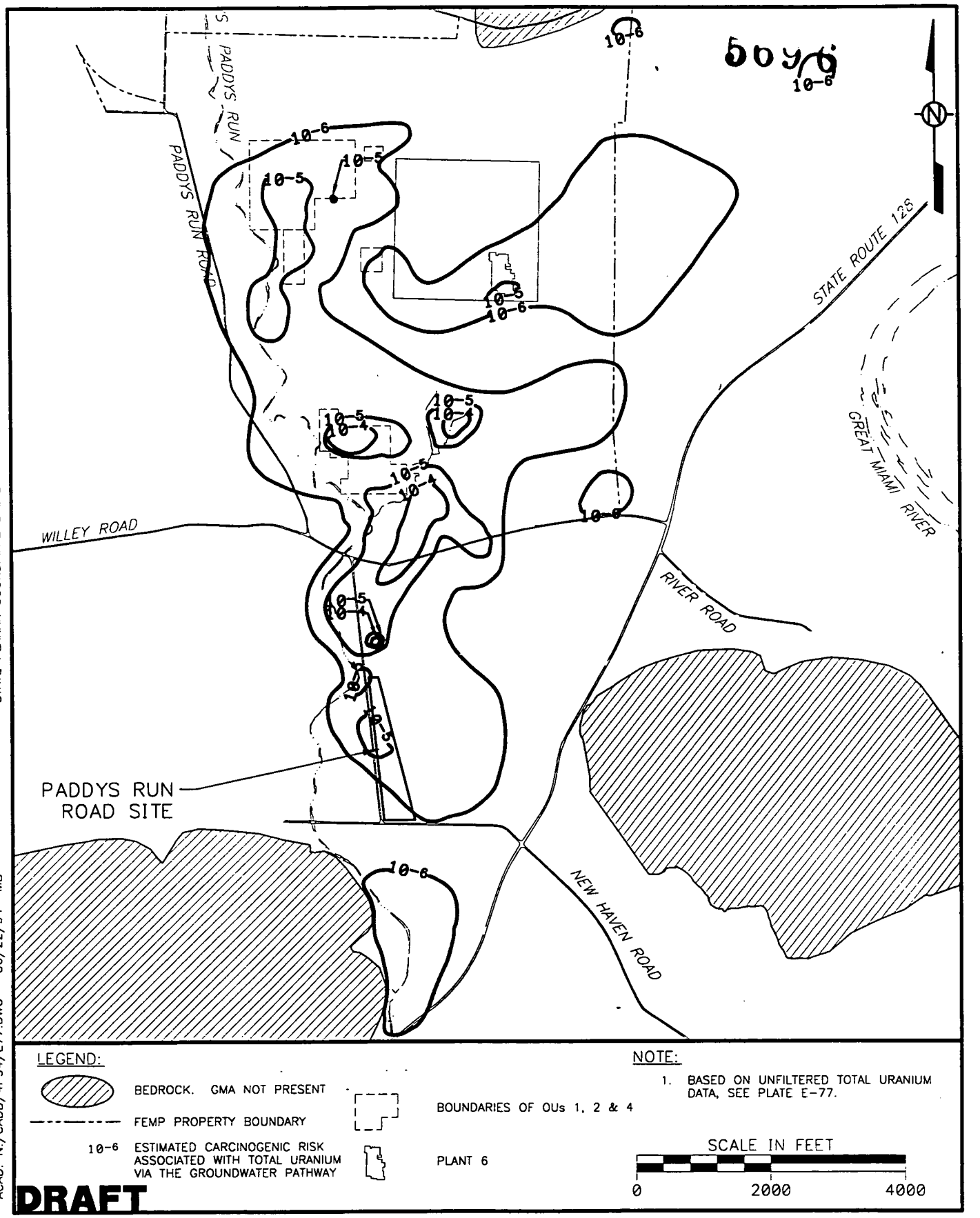
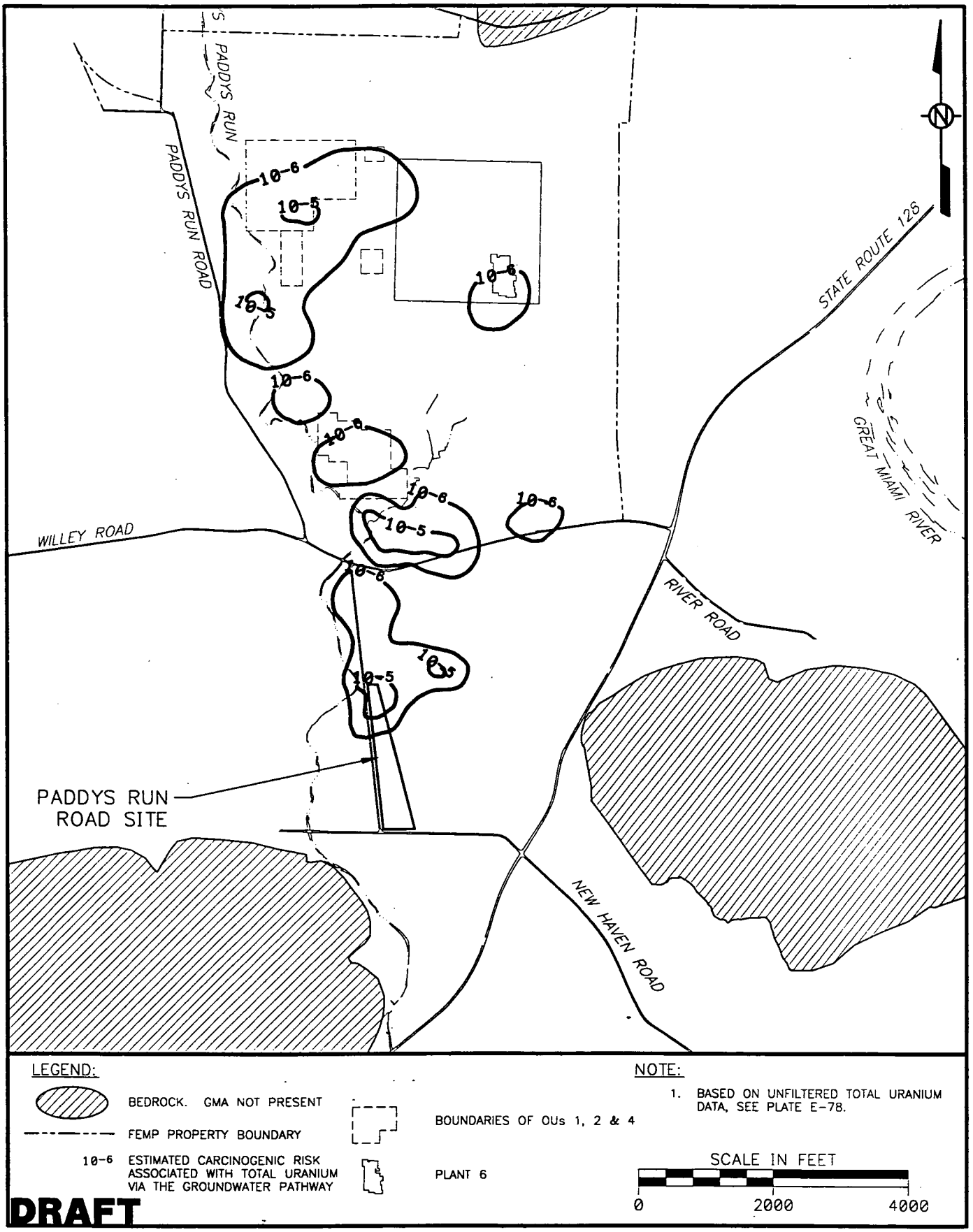


FIGURE 6-6. ESTIMATED CANCER RISK FOR TOTAL URANIUM IN GROUNDWATER, TYPE 2 WELLS



STATE PLANAR COORDINATE SYSTEM 1927

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FIGURE 6-7. ESTIMATED CANCER RISK FOR TOTAL URANIUM IN GROUNDWATER TYPE 3 & 4 WELLS

7.0 SUMMARY AND CONCLUSIONS

The primary objective of the Remedial Investigation (RI) is to define the nature and extent of contamination in Operable Unit 5 in a manner sufficient to perform baseline risk and ecological risk assessments and to develop and evaluate viable remedial action alternatives. This objective has been achieved.

This section provides an overall summary of the RI. Topics addressed include:

- Facility description and history of operations
- Study area investigations
- Physical characteristics of the site
- Nature and extent of contamination
- Contaminant fate and transport
- Baseline risk assessment
- Ecological risk assessment
- Data limitations and recommended actions
- Recommended remedial action objectives (RAOs)
- Conclusions.

7.1 FACILITY DESCRIPTION AND HISTORY OF OPERATIONS

The Fernald Environmental Management Project (FEMP) is a U.S. Department of Energy (DOE) facility constructed in 1951 to produce high purity uranium metal in support of U.S. defense programs. Production at the facility ceased in 1989 and the plant focused on environmental restoration and waste management activities. One of these activities, the remedial investigation/feasibility study (RI/FS), is being conducted pursuant to the terms of a 1990 Consent Agreement (as amended) between DOE and the U.S. Environmental Protection Agency (EPA). The purpose of the RI/FS is to identify effective cleanup actions for the FEMP that will address identified environmental concerns. The Ohio Environmental Protection Agency (OEPA) is also participating in the RI/FS process through direct involvement in review meetings and technical review of project documentation.

To promote a more structured and expeditious cleanup of the FEMP site, the facility and the environmental issues associated with it have been segmented into five operable units. Separate RI/FS documentation, including RI and FS reports and records of decision (RODs), are being issued for each of the five operable units at the FEMP.

Operable Unit 5 includes the following environmental media and surrounding impacted areas:

- Perched and regional groundwater
- Surface water
- Soil (not associated with other operable units)
- Sediment
- Flora
- Fauna.

7.1.1 Facility Description

The FEMP site occupies 1050 acres in southwestern Ohio, approximately 18 miles northwest of downtown Cincinnati. Several villages are within a few miles of the site, including Fernald, New Baltimore, Ross, New Haven and Shandon. The site consists of three primary areas: the former production area, the waste storage area, and adjacent forest/pasture land. The former production area consists of a 136-acre tract situated near the center of the site. The waste storage area is located west of the former production area and is where virtually all processing wastes were deposited.

7.1.2 Operating History

The primary mission of the facility was to produce high-purity uranium metal products and ship them to other facilities for use in the nation's weapons program. This was accomplished by chemically and physically purifying a variety of feed materials, converting uranium compounds into uranium metal, casting the uranium metal into various shapes, and machining these castings to specified dimensions. Some of these materials (for example, uranium trioxide received as slightly enriched recycled material from the Hanford Purex Plant) contained trace quantities of fission products such as technetium-99 and transuranics such as plutonium-239.

Small amounts of thorium were processed at the FEMP on several occasions from 1954 through 1975. The FEMP serves as the nation's thorium repository for DOE and storage facilities are maintained on-property for a wide range of thorium materials. Thorium-bearing materials are no longer being received at the FEMP for storage. Existing thorium inventories have been declared waste and are being over-packed and shipped to DOE's Nevada Test Site for disposal.

The FEMP began operations in 1951 upon completion of the pilot plant, the site's first operational facility, followed by Plant 6 in 1952; Plant 1, Plant 2/3, Plant 4, Plant 5, and Plant 8 in 1953; and Plants 7 and 9 in 1954.

Production peaked in 1960 at approximately 12,000 metric tons of uranium. A product decline began in 1964 and reached a low in 1975 of about 1230 mtu. During the 1970s, consideration was given to closing the FEMP. Thus, capital improvements and staffing were minimized. The staffing level, which peaked at 2891 personnel in 1956, slowly declined to 662 personnel in 1972 and then to 538 personnel in 1979. In 1981, production levels significantly increased and there was a rapid staff buildup for several years. The renewed need for uranium metal resulted in the implementation of a major facilities restoration program. Then, production ceased in the summer of 1989 and plant resources were focused on environmental cleanup activities. In June 1991, the site was officially closed as a federal production facility. To indicate its evolution to a new mission, the site was renamed the Fernald Environmental Management Project (FEMP). On December 1, 1992, Fernald Environmental Restoration Management Company (FERMCO) assumed responsibility for the site as the first environmental restoration management contractor for DOE.

7.1.3 Environmental Media Contamination

Contaminants from material processing and related activities were discharged into the environment through air emissions, wastewater discharge, storm water runoff, and discharges from production operations, as well as leaks and spills.

Airborne Releases

During the period 1951 through 1993, the FEMP discharged more than 179,000 kilograms of uranium to the atmosphere from point sources and fugitive air emissions. The major portion of the emissions, 83 percent, came from Plant 8, Plant 2/3, Plant 4, and Plant 5. In addition to the uranium, approximately 6500 kilograms of thorium were released to the atmosphere. Most of the thorium releases originated from Plant 8, Plant 9, the pilot plant, and Plant 2/3.

The Centers for Disease Control is currently reevaluating historical emissions. The preliminary estimates from the draft report are an average of 250 percent higher than those reported here. However, the significant issues are the chemical form of the emissions and the area where the emissions were deposited. Approximately 73 percent of the total airborne emissions was in a form considered minimally leachable, 24 percent was in a moderately leachable form, and approximately 2 percent was in a form considered most leachable. Also, due to the high weight of uranium and thorium and the associated inability to remain suspended in air for a long period of time, most

airborne releases were deposited on the ground within 1 mile of their source. Hence, the majority of the contaminant emissions were deposited within the FEMP property boundary.

Since process operations at the FEMP ceased in 1989, airborne emissions have decreased significantly. However, as final remediation of the site occurs, an increase in emissions is possible as contaminated materials are moved for final disposition.

Wastewater Discharges

Releases of radiological and nonradiological contaminants to environmental media have occurred as the result of FEMP processes involving the generation, storage, and disposal of wastewater. In some instances (e.g., National Pollutant Discharge Elimination System permit) the discharges were and are regulated. Unregulated and unmonitored releases have also occurred over the FEMP's history as the result of leaks, spills, and overflows caused by equipment failure or storm events. Such releases resulted in contaminant migration to soil, surface water/sediment and groundwater.

Approximately 80,200 kilograms of uranium and 490 kilograms of thorium were discharged from the FEMP in wastewater through the year 1993. Most (67 percent) of the uranium releases in wastewater occurred between 1952 and 1967. Most thorium releases, 66 percent, occurred between 1967 and 1974. Uranium and thorium discharged in wastewater from the FEMP were either in solution or in the form of suspended solids carried from the site through the outfall line to the Great Miami River.

The FEMP currently controls liquid effluents and provides appropriate treatment before they are discharged. Twenty-four hour, composite samples are taken before the effluent flows to the Great Miami River and the data are reported to EPA. The amount of uranium discharged through the effluent line has not decreased significantly since production operations ceased in 1989, and is not expected to decrease significantly in the near future. This is because additional contaminated streams are being routed through the treatment system that previously were not being discharged (South Plume groundwater) or were discharged through a drainage ditch (storm water runoff from the waste pits, former production area and parking lot).

Storm Water Runoff

Storm water runoff has been and is a significant pathway for the migration of contaminants in environmental media. Contaminated soil (through air deposition and spills) and waste storage areas

(piles, pads, pits, etc.,) are all sources which release contaminants via storm water runoff. The runoff then conveys the contaminants into surface water, groundwater, or wastewater effluent.

The FEMP reports an estimate of uranium in uncontrolled storm water runoff into Paddys Run to the EPA. Based on a series of grab samples collected in various on-property drainage ditches that convey water into Paddys Run, the FEMP had developed a general estimate of 10 pounds of uranium for every inch of rain. In November 1992, this estimate was reduced to 6.3 pounds, due to completion of several storm water control projects.

Production Operations

Production operations were also significant sources of contaminant releases to groundwater in the production and waste storage areas. Several characteristics of the FEMP production cycle, facilities, and equipment contribute to the incidence of unmonitored releases of contaminants to groundwater. First, several of the processes used large quantities of acids to digest, extract, and treat the uranium materials. Second, the process operations involved the use of floor sumps, piping (above and below ground), storage tanks, other drums/containers, and waste pits which were used to collect, store, and transport materials either within the plants or to other plants or waste handling areas. Third, many of the process facilities and equipment continued to be used far beyond their design lives. In some cases, materials were contained in floor sumps which were leaking, or which were not designed to accommodate the part of the process for which they were used. A 1988 report identified 137 operations suspected of prior unmonitored discharges to the environment (WMCO 1988). Finally, the plants in the production area are situated in a portion of the FEMP site which has a number of perched water-bearing zones interspersed in the glacial till, close to the ground surface.

There are no readily available records from the 1950s to the mid-1980s concerning major or minor incidents of spills or leaks of process feed materials, process chemicals, intermediate products, or final products to groundwater. When WEMCO assumed management of the FEMP, incident records were more rigorously kept. These records do not reveal any major leaks or spills directly affecting groundwater.

Thirty removal actions and other measures have been completed or are ongoing to abate, minimize, stabilize, mitigate, or eliminate releases of hazardous materials before final remedial action.

7.1.4 Prior Investigations

More than 40 investigations have been conducted in and around the FEMP site. These have included geologic investigations, surface water and sediment investigations, surface soil investigations, hydrogeologic investigations, environmental surveys, vegetation and wildlife studies, and contaminant release studies. The studies were performed by the DOE, other government agencies such as the U.S. Geological Survey (USGS) and the Ohio Department of Health, universities, and subcontracted environmental firms. The results of these studies were used in scoping the FEMP RI/FS as well as, in some cases, to supplement data collected during the RI/FS sampling.

7.1.5 Project Background

Over the past 10 years, DOE has worked with EPA and OEPA to develop a framework to achieve environmental compliance at the FEMP site. The RI/FS process at the facility began in 1986 in accordance with a Federal Facility Compliance Agreement (FFCA) between DOE and EPA. The FFCA was amended in 1990 by a Consent Agreement, which was amended in 1991. These documents implemented the operable unit concept, established a schedule for completion of the RI/FS process for the five operable units, and ensure that environmental impacts associated with FEMP activities are being thoroughly and adequately addressed.

In 1987, OEPA issued a Director's Findings and Orders which identified regulatory requirements for the site. This was followed by a consent decree between DOE and OEPA that included requirements for proper waste characterization, control of wastewater and runoff in the waste pit area, hazardous waste management, and groundwater assessment. This was revised by a Stipulated Amendment to Consent Decree in 1993 that specifies schedules for various activities and additional hazardous waste management requirements.

In accordance with DOE policy, National Environmental Policy Act values are being integrated into the RI/FS process. In addition, DOE and OEPA have recently initiated planning for a strategy to address closure of remaining inactive hazardous waste management units in a manner which integrates Resource Conservation and Recovery Act (RCRA) closure requirements with the remedial actions conducted under CERCLA.

7.2 STUDY AREA INVESTIGATIONS

Site investigations associated with Operable Unit 5 were designed and implemented to provide an understanding of the nature and extent of contaminants within environmental media and the physical setting in which these contaminants reside. These investigations were conducted to acquire data sufficient to conduct an assessment of the risks to human health and the environment in the absence of remedial actions and evaluate viable remedial action alternatives in the FS. Site investigations targeted all environmental media and viable pathways of exposure to receptors, including surface water and sediment, surface and subsurface soil, groundwater, and direct radiation. Potentially impacted biological and cultural resources were also inventoried and examined.

7.2.1 Data Requirements

The original RI/FS Work Plan, which was issued in January 1987 and approved in May 1988, provided a summary of known or suspected sources of potential hazardous substance releases at the FEMP and assessed the sufficiency of environmental characterization data, available at that time, to adequately fulfill the needs of the RI/FS process. On the basis of this scoping process, distinct known or suspected sources of contamination and a number of areas exhibiting environmental media contamination were identified. The initial field program was designed to verify the presence of known sources or areas of media contamination; characterize the type and concentration of contaminants present; and provide direction to further site investigations. This phased approach to collecting the appropriate type and quantity of characterization data necessary to satisfy the previously identified RI objectives is typically employed at sites involving multiple sources, contaminants, and exposure pathways where there are significant cross-media impacts and where complex technical and regulatory issues exist. Field implementation of the RI site investigations was initiated in July 1987 with sampling in and around identified source areas. The investigations then systematically expanded from those areas to define the limits of environmental media contamination. Data from these field investigations were progressively evaluated, with plans for additional studies subsequently defined and implemented.

Plans to support this phased characterization process, including the original RI/FS Work Plan and over 30 addenda, were developed by the FEMP and provided to EPA and OEPA for review, comment, and approval. These plans described characterization efforts to be undertaken to provide data to support the objectives of the five operable units. Between July 1987 and December 1993, 1329 borings were installed, 755 of which were completed as monitoring wells. Approximately

14,000 samples were collected to supplement existing data to describe the nature and extent of environmental media contamination associated with the FEMP site.

The RI focused on the FEMP property and adjacent areas where environmental media contamination was known or suspected. The media or pathways addressed by the Operable Unit 5 site investigations included:

- Surface and subsurface soils on and off of the FEMP property
- Surface water and sediment associated with on- and off-property drainage ditches, Paddys Run, and the Great Miami River
- Water quality and flow characteristics of the perched groundwater system on the FEMP property
- Regional groundwater quality and flow characteristics in the Great Miami Aquifer under and off the FEMP property
- Air quality on and off of the FEMP property
- Direct radiation on and immediately adjacent to the FEMP property
- Surface water infiltration to the Great Miami Aquifer and on-property perched groundwater
- Terrestrial ecology on the FEMP property and adjacent areas
- Aquatic ecology in the wetlands on FEMP property as well as in Paddys Run and the Great Miami River.

A variety of data sources have been relied upon for the characterization of Operable Unit 5, in addition to the data set collected pursuant to the RI/FS Work Plan and issued addenda. These additional sources of data include:

- FEMP Environmental Monitoring (EM) Program
- RCRA Groundwater Program
- Removal actions performed in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
- Final Interim Report (litigation support study)
- Hydrogeologic Study of the FEMP Discharge to the Great Miami River

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- Miami University studies
- Characterization Investigation Study (CIS).

7.2.2 Surface Mapping

Investigative activities conducted to support the RI/FS process or other site programs included photogrammetric surveys. Because there were no comprehensive topographic or planimetric maps of the FEMP site before the initiation of RI activities, detailed mapping of the FEMP facilities and the Fernald, Ohio area was accomplished through photogrammetric surveys to support facility investigations, design activities, and cleanup operations. The information gathered from this effort was used to support the description of the nature and extent of contamination and fate and transport modeling with respect to water erosion, surface water hydrology, and wind erosion.

7.2.3 Meteorological Measurements

Meteorological conditions, including wind speed and direction, precipitation, and temperature, are monitored by the site meteorological tower. Wind speed/direction and ambient temperature data were used as input into the atmospheric dispersion models used for the fate and transport modeling of airborne contaminants from Operable Unit 5. These parameters are automatically recorded by a computer-based data collection system. Routine calibrations are conducted semiannually on the entire meteorological data collection system. Routine preventive maintenance is conducted quarterly. Other required maintenance is conducted as needed.

7.2.4 Environmental Investigations

As listed in Table 7-1, a number of surface water and sediment, surface soil, subsurface soil, perched and Great Miami Aquifer groundwater, air and direct radiation, and biological resources investigations have been completed. Data from these programs were used to describe the nature and extent of contamination associated with Operable Unit 5, support the quantification of risk to potential receptors exposed to the affected media, and in some cases provide data for use in models.

7.2.5 Quality Assurance

Investigations and sampling programs performed as part of the RI/FS were conducted in accordance with the requirements of the RI/FS Quality Assurance Project Plan (QAPP) (DOE 1988) or the replacement CERCLA Site-wide Quality Assurance Project Plan (SCQ) (DOE 1993). Any variance

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from the field or analytical procedures identified in these quality assurance plans are recorded in the specific project files and were evaluated during the data validation and analysis processes.

Other data sets employed by the RI, but not conducted as part of the RI/FS, were either completed under the terms of the RI/FS QAPP, the SCQ or their own project-specific quality programs. An assessment was completed on the quality of the data sets not generated pursuant to the QAPP or SCQ. A number of factors were examined to assure the quality of the information and the adequacy of the data sets for use in the RI/FS process. These factors included consideration of the age of the data, analytical methods used, detection limits, and available documentation regarding QA/QC procedures and data collection methods.

There were 340 project surveillances and 11 independent program audits performed from 1985 through 1992 for the CIS and RI/FS programs. The surveillances covered field and sampling phases of work performed. Identified program or procedural deficiencies were documented through nonconformance reports that were forwarded to project management for review and assessment. There are no open issues regarding quality surveillance or nonconformance reports for Operable Unit 5 tasks between 1985 and 1992. There are no findings from the audits that impact the samples or the usability of data collected for Operable Unit 5.

7.2.6 Data Management and Data Validation

The combined data set used to support the RI was evaluated and prioritized to be consistent with the data requirements and objectives of the RI. The data was compiled into a central database and evaluated for completeness and accuracy.

In general, all contaminant concentration data that supported the definition of "source term concentrations" employed in the quantitative baseline risk assessment were subjected to a rigorous data validation process. Data rejected by this process were removed from these data sets before being used in the risk assessment process. The validated portions of data sets from other select nonvalidated data sets were used, as appropriate, to support the description of the nature and extent of contamination.

7.3 PHYSICAL CHARACTERISTICS OF THE SITE

An understanding of the physical characteristics of the Operable Unit 5 study area and the contaminant pathways is essential to determine how contamination has been transported through the environmental media in the past and to model what will happen in the future.

7.3.1 Surface Features

The advance and retreat of continental glaciers not only shaped the local topography at the FEMP but also created the hydrogeologic setting. The FEMP site and surrounding area lie at the southern edge of the Till Plains section of the Central Lowland physiographic province. The bedrock of the province is characterized by broad structural and sedimentary basins and domes.

Topography

The topography in the area of the FEMP includes gently rolling uplands with steep hillsides along the major streams, such as the Great Miami River. The main topographic feature in the vicinity of the FEMP is the New Haven Trough, a relatively broad, flat-bottomed valley flanked on either side by bluffs that rise to a maximum of 300 feet above the general level of the valley floor. Maximum elevation along the northern boundary of the FEMP property is a little more than 700 feet above mean sea level. The production and waste storage areas rest on a relatively level plain at an elevation of about 580 feet. The plain slopes from an elevation of 600 feet along the eastern boundary of the FEMP to 570 feet at the K-65 silos and then drops off towards Paddys Run at an elevation of 550 feet. All natural surface drainage on the FEMP is from east to west and south into Paddys Run, with the exception of the extreme northeast corner where approximately 23 acres drain east toward the Great Miami River.

In 1952, the production area was extensively graded to create a land surface that sloped evenly from north to south. Rough grading maps from 1952 indicate that up to 10 feet of surface material was removed from the northeast half of the production area and used to fill low areas in the south and southwest portions. During construction of the waste pits, that area was extensively regraded. The top of the berm on the west side of Pit 3 and the Clearwell is approximately 30 feet above the original grade. Further south, along the edge of the Paddys Run Valley, the South Field and flyash piles were placed partly on glacial overburden and partly on the Great Miami Aquifer where the glacial overburden had been eroded away by Paddys Run.

7.3.2 Meteorology

On-site wind data shows that prevailing winds are generally from the southwest and west-southwest. The average annual precipitation for the Greater Cincinnati area for the 30-year period from 1963 through 1992 was 40.86 inches and ranged from 27.99 inches in 1963 to 57.58 inches in 1990. The highest precipitation occurs during the spring and early summer. The average annual snowfall for the 30-year period from 1963 through 1992 was 22.9 inches, with the heaviest snowfall usually occurring in January.

The regional climate is defined as continental, with temperatures ranging from a monthly average of 29.2°F in January to 75.7°F in July. The average number of days per year with a minimum temperature of 32°F or less is 109 days, and the average number of days per year with a maximum temperature of 90°F or greater is 20 days. Maximum frost depth ranges from 30 to 36 inches.

The average potential evapotranspiration exceeds precipitation in June, July and August by 2.1, 3.5 and 3.3 inches, respectively, causing a depletion of soil moisture. The result is that evapotranspiration has an impact on the potential migration of contaminants in the perched groundwater system by removing water from the glacial overburden in the summer months. In addition, many shallow drainages and seeps as well as portions of Paddys Run dry up in late May or June and remain dry until late in the fall. Therefore, during the summer, perched groundwater is removed by evapotranspiration rather than migrating laterally to drainages.

The water budget for the FEMP area is based on an annual average precipitation of approximately 41 inches. The 50-year annual average water loss due to evapotranspiration is approximately 26 inches. Based on these two values approximately 15 inches of the annual precipitation is available for surface water runoff and aquifer recharge. Of this 15 inches, it is estimated that, where glacial overburden is present, approximately 6 inches recharges the Great Miami Aquifer and 9 inches becomes surface water runoff.

These estimates for recharge and surface water runoff are consistent with previous studies and calibration results of the SWIFT Great Miami Aquifer Model (DOE 1994j). Spieker (1968a) estimated that the annual rainfall recharge rate to the Great Miami Aquifer in the Fairfield-New Baltimore area ranges from 6 to 21 inches. This area of coverage is much larger than the RI study area and extends far to the north where hydrogeologic conditions are different from those found at the

FEMP. Walton and Schaefer (1956) estimated Great Miami Aquifer recharge for an area just east of the FEMP property. They estimated that recharge in the area of the Southwestern Ohio Water Company (SOWC) pumping wells was 8.5 inches/year. This estimate was made for a year of near-average precipitation. Glacial overburden does not overlie the Great Miami Aquifer in the area of the SOWC wells but does overlie the Great Miami Aquifer beneath the FEMP property. The glacial overburden serves to restrict infiltration; therefore, recharge over the FEMP site should be lower than the recharge of 8.5 inches/year at the SOWC wells.

Calibration of the SWIFT Great Miami Aquifer model and hydraulic conductivities of glacial overburden sediment also support a recharge to the Great Miami Aquifer in the lower end of the 6-15 inches per year range. The geometric mean of the horizontal hydraulic conductivity for the gray clay in the glacial overburden, calculated from slug tests, is 1.87×10^{-6} cm/s. Vertical hydraulic conductivity is usually smaller than horizontal hydraulic conductivity due to bedding plans and depositional features that impede the downward movement of groundwater. A 1 order of magnitude difference is realistic, which indicates the vertical hydraulic conductivity of the gray clay is in the 10^{-7} cm/s range. A recharge value of 6 inches/year implies a vertical hydraulic conductivity in the 10^{-7} cm/s range, under a unit hydraulic gradient (DOE 1994j). This leaves approximately nine inches of precipitation each year available for the surface water runoff pathway.

7.3.3 Surface Water Hydrology

The FEMP is located within the Great Miami River Basin drainage. The Great Miami River is the receiving stream for the FEMP waste water discharge and represents the main surface water feature in the vicinity of the FEMP. The river flows generally to the southwest and has a drainage area of approximately 3360 square miles at the Hamilton gauge, which is located about 10 miles upstream from the FEMP discharge.

The average discharge of the Great Miami River at the FEMP outfall line has been estimated to be 3460 cubic feet per second (cfs) or 2.2 billion gallons per day. The maximum discharge recorded for the Great Miami River at Hamilton occurred on March 26, 1913, and was estimated to be 352,000 cfs. The maximum discharge since the construction in 1922 of five retaining basins, located approximately seven miles upstream of Hamilton, was 108,000 cfs on January 21, 1959. The 7-day, 10-year low flow at the site is 280 cfs.

Surface Drainage on the FEMP

Natural surface drainage from the FEMP is primarily to Paddys Run. Paddys Run originates north of the site, drains southward along the west side of the FEMP, and enters the Great Miami River approximately 1.5 miles south of the FEMP. Paddys Run is an ungauged, intermittent stream that flows primarily between January and May, with an estimated discharge for this period ranging between 0.2 and 4.0 cfs. Paddys Run loses flow to the underlying aquifer along much of its course on and south of the FEMP due to its highly permeable channel bottom which is eroded into the Great Miami Aquifer.

A principal drainage feature of the FEMP is a tributary to Paddys Run known as the storm sewer outfall ditch (SSOD). The SSOD historically conveyed surface water runoff from the production area directly to Paddys Run when the capacity of the storm sewer lift station was exceeded. This drainage course originates east of the former production area, flows southwest across the southern portion of the site, and enters Paddys Run near the southwest corner of the property. The stream bottom in the southern portion of this drainage course is composed of sand and gravel which is part of the Great Miami Aquifer. Given the geologic similarity, the vertical seepage rates through the stream bottom are similar to Paddys Run. Like Paddys Run, the SSOD drainage course loses flow to the underlying aquifer and is generally dry in the summer and fall, with flows occurring during and immediately after precipitation.

Aquifer Recharge from Surface Streams

Under the FEMP, there is only minor recharge to the Great Miami Aquifer due to the very low hydraulic conductivity of the glacial overburden. In areas where streams have cut through the glacial overburden, there is a much greater potential for infiltration due to the high hydraulic conductivity of the Great Miami Aquifer. Infiltration modeling indicates that recharge through the Paddys Run channel and the SSOD to the Great Miami Aquifer occurs at a rate of approximately 14 inches per year.

A high degree of correlation exists between the Paddys Run hydrograph and the regional aquifer hydrographs, indicating a very strong hydraulic connection between the stream and the regional aquifer. Because Paddys Run and the SSOD normally lose flow to the Great Miami Aquifer, these streams are a major pathway for contaminant transport. The surface water discharges from the

former production area to the SSOD and from the waste storage area to Paddys Run are the major direct pathway of contaminants to the aquifer.

The rate of rainfall controls the recharge and the rise and fall of the groundwater table under the FEMP. However, it is not so much the magnitude of monthly rainfall as the frequency and duration of storms that controls sustained recharge. Recharge consistently begins in the last month or two of each year. Several factors combine to cause this, and the length of the rainfall event is one of the more significant factors. Summer rain occurs as sudden, often severe, short thunderstorms which dump large amounts of water in a short time period. The low hydraulic conductivity of the clay-rich soil in the glacial overburden retards infiltration, and most of the rainfall from summer storms runs off in flash floods. In the summer the short duration storms with rapid runoff do not recharge the perched groundwater system and provide only a short duration recharge to the Aquifer via Paddys Run and the SSOD.

In contrast, rainfall in the late fall and winter occurs in the form of steady showers that extend for periods of several hours to several days. The lower precipitation rate and longer duration allows surface water to saturate the soil and recharge the perched groundwater system. The runoff from these rainfall events was also of longer duration, sustaining a longer period of recharge while the rain is falling. Between rainfall events in the winter and spring the perched groundwater in the glacial overburden north of the FEMP discharges to the upper reaches of Paddys Run through seeps and provides a base flow between storms. This base flow moves downstream to the FEMP and infiltrates the Great Miami Aquifer through the bed of Paddys Run, sustaining recharge between storm events. Thus the longer duration of the rainfall events, the sustained flow from seeps upstream, and the reduced impact of evapotranspiration combine to sustain recharge to the aquifer during the winter and spring.

7.3.4 Geology and Soil

The Illinoian age outwash deposits in the buried valleys and the Wisconsin age glacial overburden are of primary concern in the RI because they both contain groundwater. Groundwater is the pathway most likely to transport contaminants to off-property receptors. The valley fill has regional significance and the glacial overburden, due to its limited lateral extent, has local significance under the FEMP property itself.

Geologic History

The FEMP overlies a 2- to 3-mile-wide buried Pleistocene Valley known as the New Haven Trough. This valley was eroded by the ancestral Ohio River during the Pleistocene and was subsequently filled with glacial outwash sand and gravel that were in turn covered by glacial overburden as a younger glacier advanced across the area. The outwash deposits under the FEMP are a part of the Great Miami Aquifer, which is a widely distributed buried valley aquifer. The valley fill aquifer system is a major source of potable and industrial water in southwestern Ohio.

Bedrock Geology and Seismology

Bedrock in the area of the FEMP is shale and fossiliferous limestone of Middle and Late Ordovician age. It outcrops on steep valley walls and in numerous interstate highway road cuts in southwestern Ohio. In the area included in the RI at the FEMP, the bedrock layers are essentially horizontal, contain little or no usable groundwater, and are not a part of any significant contaminant pathway.

There are no major faults, active or inactive, in the vicinity of the FEMP. The historical record of seismicity and the absence of post-Wisconsin glaciation faults show that significant damage from local earthquakes at the FEMP is unlikely (seismic risk zone one).

Glacial Geomorphology

During the mid- to late-Pleistocene period, three major continental glaciers advanced to the north of the Cincinnati area: the Kansan, Illinoian, and Wisconsin. A small ice lobe moved down what is now Paddys Run and deposited clay-rich till on top of the valley fill outwash deposits at the FEMP. As the ice retreated, sand and silt were washed into the lake that formed on the FEMP behind the terminal moraine. The till deposited by the advancing ice, the lake fill that was deposited behind the terminal moraine, and gravel and silt from the recessional moraine, make up the glacial overburden.

Great Miami Aquifer Outwash Deposits

During the Illinoian glacial retreat, the Deep Stage Valley, including the New Haven Trough, was filled with about 200 feet of glacial outwash sediment deposited by water running from the margins of the glaciers. The sediment consisted mainly of well-sorted sand and gravel distributed by braided streams that crisscrossed the valley floor. The thick sand and gravel deposits in the bedrock troughs formed the present-day Great Miami Aquifer. A blanket of poorly sorted clay-rich glacial overburden was deposited on top of the outwash sediment during the Wisconsin ice advance. Since the retreat of

the Wisconsin glacier, the streams in the FEMP area have removed part of the glacial overburden left by the ice sheet. Postglacial erosion by Paddys Run and the Dry Fork of the Whitewater River has exposed the Great Miami Aquifer along their beds where they cross the New Haven Trough. Postglacial erosion by the Great Miami River has removed portions of the glacial overburden that covered the Aquifer and left terrace remnants that stand topographically higher than surrounding bottom lands.

In the area of the FEMP, the thickness of the Great Miami Aquifer varies from 120 to 200 feet in the center of the valley and tributary valleys to only a few feet along the valley walls. Regionally the glacial deposits are homogeneous and are typically described as well-sorted sand and gravel with only minor amounts of silt and clay.

Within the coarse-grained sediment of the Great Miami Aquifer, a clay interbed underlies most of the FEMP and parts of the area to the west. The clay interbed layer is uniform in texture and contains only a small amount of silt and sand. It was deposited in a lake or low-energy stream environment and in some samples displays thin light and dark layers called varves. The interbed pinches out to the south and east, extends an unknown distance to the west, and grades into glacial till deposits to the north in the Shandon Tributary. The clay interbed lies about 100 to 125 feet below the land surface and generally about 60 to 80 feet below the water table. Because of this interbed, which acts as an aquitard, the aquifer beneath the FEMP is divided into upper and lower halves.

Geology of the Glacial Overburden

The FEMP is built upon a sequence of Wisconsin Age till, lacustrine sediment, and loess deposits that overlie the outwash deposits in the buried valley aquifer. To distinguish the Wisconsin Age deposits from the Illinoian outwash deposits, the former is collectively referred to as glacial overburden. The glacial overburden beneath the FEMP is predominantly clay-rich till that contains lenses of coarser grained sediment. The glacial overburden is saturated beginning approximately 3 to 5 feet below the ground surface. The dominance of fine-grained particles in the till at the base of the glacial overburden restricts the vertical migration of water to the underlying Great Miami Aquifer.

7.3.5 Groundwater Geochemistry

The principal geochemical processes that control groundwater chemistry are dissolution of minerals and solids in the soil by rainwater and adsorption/ion exchange reactions between the groundwater

and soil particles. As groundwater chemistry will reflect the solids it is in contact with, it is important to establish the mineralogical composition of the soil in the vadose and saturated zones so that the origin of dissolved solids (i.e., solute) in the groundwater can be evaluated. Additionally, the aqueous form (i.e., speciation) of the solute in the groundwater provides important information for assessing the nature and extent of groundwater contamination.

Rainwater/Glacial Overburden Chemistry

Rainwater falling on the glacial overburden will react with minerals/solids and organic material to form porewater that ultimately becomes groundwater. The composition of groundwater solute is controlled primarily by the solubility of various minerals or leaching of solids in the soil. In any given mixture of minerals or solids, the most soluble or leachable phases will have the greatest influence on the solute composition. Carbonate minerals, which make up approximately 50 percent of the glacial overburden, buffer the pH of the perched groundwater system in the range of 7 to 8, and play the most important role in establishing the composition of groundwater solute.

Silicate minerals present in the glacial overburden (e.g., quartz, feldspar, and clay) have less influence on the chemistry of the groundwater due to their low solubilities (relative to carbonate minerals) at near neutral pH values. These minerals provide silica, potassium, sodium, aluminum, and various trace metals to the groundwater via dissolution and ion exchange reactions. The weathered surface area of these minerals plays an important part in the adsorption of ions from the groundwater.

Groundwater Composition

The composition of groundwater in the glacial overburden and Great Miami Aquifer is dominated by calcium and magnesium cations and the bicarbonate anion. Based on charge equivalent units, calcium constitutes approximately 60 percent, magnesium about 30 percent, and sodium plus potassium about 10 percent of the total cations. Bicarbonate plus carbonate constitutes about 80 percent of the anions, followed by sulfate and chloride. The charge equivalent percent for calcium plus magnesium is approximately equal to bicarbonate, indicating the groundwater compositions reflect dissolution of calcite and dolomite.

Mineral saturation indicies indicate the groundwater is saturated with the minerals common in the area, implying that groundwater has equilibrated with the soil and sediment in the glacial overburden and Great Miami Aquifer.

7.3.6 Hydrogeologic Setting

Figure 7-1 illustrates the major features influencing the hydrogeology of the FEMP. Groundwater in the glacial overburden is perched above the water table of the Great Miami Aquifer. The water table in the glacial overburden is situated approximately 3 to 5 feet beneath the ground surface and generally lies within the elevation range of 560 to 602 feet under the FEMP. The slope of the water table follows surface topography and dips to the west and southwest. The gradient varies, but beneath the production area it generally ranges between 0.008 and 0.015. The vertical gradient through the glacial overburden is 1, as unsaturated conditions exist beneath the deposit. The water table in the Great Miami Aquifer slopes to the east and south, toward the Great Miami River, and generally lies at an elevation between 518 to 530 feet under the FEMP. The gradient ranges from 0.0008 in the New Haven Trough to 0.002 in the Paddys Run Outlet.

The glacial overburden is both heterogeneous and anisotropic. It consists of clay, silt, sand and gravel, and has a bulk composition of 60 to 80 percent silt and clay. The upper portion of the glacial overburden is oxidized (yellow-brown in color), but the lower portion is not (gray in color). Most of the sand and gravel is situated beneath the western portion of the FEMP in lacustrine deposits.

Horizontal hydraulic conductivities in the glacial overburden calculated from slug test results range from 1.87×10^{-6} cm/s (gray clay) to 3.07×10^{-2} cm/s (brown gravel). The gray clay found at the base of the glacial overburden is the least permeable sediment type and dominates the transport capability of the vertical pathway. Core permeability measurements for the gray clay yield a hydraulic conductivity of 2.25×10^{-8} cm/s. Slug test results yield a hydraulic conductivity of 1.87×10^{-6} cm/s. The porosity of the gray clay is approximately 26 percent, the moisture content (by weight) is approximately 14.3 percent, and the gray clay is saturated.

Horizontal seepage velocities in the glacial overburden, for a gradient of 0.008, range from 3.138×10^{-3} ft/day to 0.08 ft/day and for a gradient of 0.015, range from 5.885×10^{-3} ft/day to 0.16 ft/day. Horizontal advective time of travel, using seepage velocities and assuming a time of travel distance of 2000 feet, ranges from 931 years to 34 years using a gradient of 0.015. Vertical seepage velocities

through the gray clay range from 0.846 ft/yr to 1.846 ft/yr. Vertical advective travel times through the gray clay (using calculated seepage velocities) range from 41.4 years to 13.5 years.

The Great Miami Aquifer lies beneath the glacial overburden, consists of sand and gravel outwash, and occupies a buried valley that roughly follows the Great Miami River channel. Overall the aquifer is not as heterogeneous or anisotropic as the glacial overburden deposit. Hydraulic conductivity in the Great Miami Aquifer, in the FEMP area, is approximately 300 to 500 ft/day. The horizontal to vertical ratio of hydraulic conductivity ranges from 5 to 15. Porosity is approximately 30 percent and the storage coefficient is 0.2.

Horizontal seepage velocities through the Great Miami Aquifer range from 1.1 ft/day (in the New Haven Trough) to 2.75 ft/day (in the Paddys Run Outlet).

Outwash deposits in the Great Miami Aquifer are capable of sustaining yields of gallons of water per minute range. The glacial overburden at the FEMP is only capable of sustaining a yield of approximately 1 gpm for periods longer than a week, and this yield is limited to small areas located beneath Plant 8 and Plant 1 (where the hydraulic conductivity ranges between 1.5×10^{-3} cm/s to 8.4×10^{-3} cm/s) and to a small channel located in the waste pit area.

Contamination must either move through or around the glacial overburden via surface water runoff to reach the Great Miami Aquifer. The low hydraulic conductivity of the gray clay, 1.87×10^{-6} cm/s (slug tests), appears to control the movement of fluids. The base of the glacial overburden is saturated, but directly beneath the glacial overburden, unsaturated conditions are present. The glacial overburden appears to be acting like a sponge that is very slowly dripping into the unsaturated sediment which lies above the water table of the Great Miami Aquifer.

7.3.7 Demographics, Land Use, and Archaeological/Historical Resources

Demographics

The FEMP is located approximately 18 miles northwest of Cincinnati, the focal point of a regional market encompassing eight counties in Ohio, Kentucky, and Indiana. These eight counties also define the Cincinnati Consolidated Metropolitan Statistical Area, which had a 1990 population of more than 1.7 million. An estimated 22,927 residents lived within a 5-mile radius of the FEMP site in 1990.

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There are no residences on the FEMP property. Employees of DOE and their contractors comprise the working population whose activities take place in structures that occupy approximately 203 acres near the center of the property.

Scattered residences and several villages are located near the FEMP property. Some of the nearest residences are along the western side of Paddys Run Road, a road that closely parallels the western property boundary. A dairy farm is located on Willey Road just outside the southeast corner of the boundary; leased grazing areas include land inside the FEMP boundary. Several residences located south of the FEMP property boundary are located over the South Plume, that portion of the Great Miami Aquifer along Paddys Run contaminated by uranium.

No schools, day care centers, hospitals, or commercial/recreational fisheries are located within one mile of the FEMP property.

Land Use

The land adjacent to the FEMP site is primarily devoted to open land use, such as agriculture and recreation. Commercial activity is generally restricted to the village of Ross, approximately 3 miles northeast of the facility, and along S.R. 128 just south of the village. Industrial use is concentrated in the areas south of the FEMP property, along Paddys Run Road, in the village of Fernald, and in a small industrial park on S.R. 128 between Willey and New Haven roads. Concentrations of residential units are situated immediately north of the FEMP site in Ross, directly east in a trailer park adjacent to the intersection of Willey Road and S.R. 128, and southeast in New Baltimore. Other residences are scattered around the area, generally associated with farmsteads. The Camp Ross Trails site, formerly owned by the Great Rivers Girl Scout Council, is located within 1 mile to the northeast of the FEMP property.

Because the area had been intensively used for agricultural purposes before the establishment of the FEMP, there is no land on or in the vicinity of the FEMP property where a natural environment remains intact. The land closest to this description would be recreated prairie in the Miami Whitewater Forest.

Groundwater Use

The buried valley aquifer of the Great Miami River Basin has been designated as a sole-source aquifer by the EPA. The buried aquifer is considered to be the sole source of drinking water for more than 600,000 people in southwestern Ohio.

Groundwater is the major source of water for industrial and domestic use in the area. The water is provided to consumers by commercial and municipal well fields and by private groundwater wells. The estimated total pumping from the major well fields downgradient of the FEMP averages more than 18 Mgd. Within the greater Hamilton-New Baltimore area, there are seven major groundwater users who pump more than 100,000 gpd from the buried valley aquifer of the Great Miami River Basin. Additionally, there are many smaller industrial, commercial, agricultural, and private groundwater users in the area.

In 1952, the SOWC installed a large-diameter radial collector well in the sand and gravel glacial outwash deposits east of the Great Miami River near Ross, Ohio. The collector well was pumped for industrial water supply purposes at an average rate of 10 Mgd from 1952 to 1955. Its effective radius of influence is 200 feet. In 1955, a second collector well was installed with an effective radius of 212 feet to establish an adequate water supply for 13 industries in the Mill Creek Valley area. Historical data from the 1950s indicate that the average pumping rate from the collector wells was approximately 14 Mgd after completion of the second well. From 1980 to 1992, this pumping rate increased to 18.4 Mgd. From 60 to 76 percent of the total flow from the collector wells comes from induced recharge from the Great Miami River. In 1986, a third collector well was installed for emergency use only. Total flow of the three wells is expected to remain at approximately 18 Mgd for the near future. However, the pumping rate has been assumed to increase to 25 Mgd due to potential increased service demand.

Other industrial groundwater users within a 5-mile radius of the FEMP pump an average of only 325 gpm from the aquifer.

The water supply distributed by public water systems within the two counties surrounding the FEMP is primarily derived from the buried valley aquifer system of the Great Miami River Basin. Water supply calculations performed by the Ohio-Kentucky-Indiana Regional Council of Governments in 1988 indicated that the Great Miami Aquifer provides all of the potable water for Butler County and

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48 percent of the potable water for Hamilton County. The Cincinnati-Bolton water plant and the Southwest Regional Water District maintain well fields east and northeast of the FEMP to supply domestic users. DOE is partially funding the installation of a public water supply in the vicinity of the FEMP. The Hamilton County Department of Public Works is responsible for the design and construction of this new service and the Cincinnati Water Works will own, maintain, and operate the system after completion. Construction of the public water supply is divided into four phases with anticipated start of construction of Phase I in August of 1994. Scheduled completion of Phase IV is the first quarter of 1995. The FEMP will cease pumping groundwater and become a major user of the new public system.

The Southwest Regional Water District and the Harrison Township Water Company provide water to residents within a 5-mile radius of the FEMP. The Southwest District provides service to the majority of Morgan and Ross Townships. Its treatment plant, located 1.5 miles northeast of the intersection of S.R. 128 and U.S. 27, has a peak capacity of 3.7 Mgd and an average flow of approximately 2.0 Mgd. Improvements to the facility and system are currently under way, pending approval of federal funding. Harrison Township operates a plant with a designed capacity of 2.4 Mgd, an operating peak capacity of 1.4 Mgd, and an average flow of 1.0 Mgd.

Some residents within a five-mile radius of the FEMP are not served by a water district and must rely on private wells for the provision of potable water. Some residences use bottled water or cisterns for water storage in areas having either poor water quality or a lack of available groundwater in the shallow subsurface. Cisterns are most prevalent in the uplands area, where bedrock is overlain by a thin veneer of glacial till.

There are several large farms in the vicinity of the FEMP. Two known irrigation wells on farms east of the site and northwest of S.R. 128 are currently being used to irrigate fields. One farm on New Haven Road south of the site, between S.R. 128 and the village of New Baltimore, also irrigates from a well located on the property. Farmers east and south of the FEMP, who are in proximity to the Great Miami River, irrigate their fields with water from the river.

Archaeological and Historical Resources

The area surrounding the FEMP site has a large and diverse archaeological and historical resource base. Within a 2-mile radius of the FEMP boundary, there are three properties listed in the National

Register of Historic Places (NRHP); within 5 miles of the FEMP, there are six major archaeological sites, and within 3 miles, there are three Indian mounds.

Historic resources in the area are also abundant. Within a 2-mile radius of the FEMP boundary there are three properties listed in the NRHP and 12 more have been inventoried and deemed eligible for inclusion.

7.3.8 Ecology

Current FEMP land management practices directly impact the structure and composition of on-property terrestrial communities and result in a relatively high biotic diversity. Most of the FEMP is maintained in early stages of succession by mowing, grazing, bush hogging, and bulldozing. These practices cause habitat fragmentation and heterogeneity, as well as the reduction of corridors important in the stabilization of many plant and animal communities. The most severely disturbed terrestrial habitat is the inactive flyash area. Relatively undisturbed habitats are restricted to the narrow riparian community along Paddys Run and several small woodlots.

The fishery of the Great Miami River has been stable over the last 9 years (1984-1992). There is no indication that the FEMP has had any discernible effects on the abundance, condition, or species richness of the fish communities in the Great Miami River.

Extensive reaches of Paddys Run are usually dry during the summer and fall. Although this results in the loss of aquatic invertebrates in these areas, the populations are quickly reestablished when flowing water returns. Species diversity is similar to values reported for streams receiving moderate amounts of pollution and are also typical of macroinvertebrate community values for other streams in the area.

No federally listed threatened or endangered species were observed on the FEMP or in its immediate vicinity. However, two federally listed endangered species, the Indiana bat and the running buffalo clover have ranges overlapping the area of the FEMP. Several state listed threatened and endangered plant and animal species are also known to occur in this area or have been recorded during surveys on the FEMP property. Surveys are scheduled for the summer of 1994 to confirm the presence or absence of these species.

7.4 NATURE AND EXTENT OF CONTAMINATION

7.4.1 Background

Background data from samples collected at off-property locations were used to identify FEMP-generated constituents that exist in Operable Unit 5 at concentrations greater than those that occur naturally in soil, surface water, sediment and groundwater. In general, the 95th percentile concentrations for analytes in the environmental media was used to distinguish waste-related concentrations of constituents from those which occur naturally.

7.4.2 Sources

Contaminants in Operable unit 5 media originated in the processing, waste management and associated activities at the FEMP. These operations resulted in expected releases of contaminants to the environment (e.g., routine air emissions, fugitive air emissions, wastewater discharges, and storm water runoff) as well as nonroutine releases such as spills, leaks, etc. The result of these releases has been the creation of secondary sources of contamination and release which are the focus of Operable Unit 5.

Since the FEMP produced more than 362,000,000 kilograms of uranium metal during its production lifetime, uranium is anticipated to be the primary contaminant. Thorium was also refined at the FEMP (thorium-232) and was an impurity in uranium ores (thorium-230) and a constituent of wastes from other DOE facilities that were disposed of at the FEMP. Several fission and activation products are also expected, since the FEMP processed uranium that had been irradiated and reprocessed at Hanford.

Inorganic constituents were integral to the manufacturing process at the FEMP. The most predominant inorganic chemicals used in the production processes included nitric acid, hydrochloric acid, hydrofluoric acid, magnesium metal, calcium hydroxide, and calcium-magnesium carbonate. Magnesium fluoride was also a major by product of the operation. In addition, ore concentrates, which served as a feed material at the FEMP, included impurities such as arsenic, calcium, iron, magnesium, phosphorus, sodium, thorium, and vanadium.

Several primary uses of organic chemicals related to uranium production have been identified. A mixture of kerosene and tributyl phosphate was used as the solvent for extraction of uranyl nitrate following the nitration of uranium concentrates and recoverable waste. Other organic materials

included lubricants, cutting oils, coolants, water soluble oil, PCBs from lubricants and electrical equipment, pesticides, herbicides, solvents, and cleaning fluids. Many of the oils were burned at the FEMP which could have produced chlorinated dibenzo-p-dioxins/dibenzofurans, polynuclear aromatic hydrocarbons (PAHs) and phenols.

7.4.3 Air and Direct Radiation

The average radon level at the FEMP fence line from 1988 through 1993 was as follows:

Year	Average Radon Level at Fence Line (pCi/L)
1988	1.16
1989	0.74
1990	0.74
1991	0.90
1992	0.57
1993	0.96

The maximum radon concentration recorded at the FEMP fence line was 2.9 pCi/L observed at the radon monitoring station located at the southwest corner of the former production area. Since production ceased in 1989, the highest FEMP fence line radon level recorded was 1.7 pCi/L in 1993 at the northwest corner of the site. None of the observed concentrations exceeded either the DOE guideline of 3.0 pCi/L above background (DOE Order 5400.5) or the EPA guideline of 4.0 pCi/L for indoor radon levels (EPA1992).

The end of the FEMP's production mission has resulted in a measurable reduction in the concentration of air particulates. At present, the largest sources of air emissions are the boiler plant cooling tower mists and fugitive dust from the waste pit area and other areas where environmental cleanup activities are underway.

The FEMP operates nine on-property air monitoring stations to measure the concentration of total suspended particulates, uranium, and airborne radionuclides. The average annual level of airborne uranium at each FEMP fence line monitoring station was well below the DOE guideline of 0.1

pCi/m^3 during the period 1988 through 1993. Data show a general decrease in airborne uranium concentrations along the FEMP fence line since production operations ceased in 1989.

The FEMP periodically measures doses from direct radiation at several locations on-property and off-property. Measurements are normally made on a quarterly basis using a pressurized ionization chamber. The annual dose from direct radiation from all sources to the person living closest to the K-65 silos was estimated to be as follows:

Year	Radiation Dose (mrem)
1988	19.3
1989	14.9
1990	10.0
1991	9.1
1992	1.0
1993	1.0

The reduction from 1991 to 1992 is the result of a bentonite layer added to the K-65 silos in late 1991. For comparison, the annual dose due to background radiation is approximately 100 mrem per year (excluding radon) and DOE's limit for exposure to all sources and all pathways is 100 mrem per year (DOE Order 5400.5).

7.4.4 Surface Water and Sediment

The RI/FS surface water and sediment sampling program collected samples at locations within and around the FEMP during the years 1988 to 1993. Complementing RI sampling events are data from the FEMP Environmental Monitoring Program. Under this program, surface water and sediment samples were collected and analyzed for total uranium; data from 1986 to the present were reviewed for this report. Several additional environmental studies were performed during the past 5 years. Where pertinent in establishing a historical baseline or for illustration of temporal trends, data from these studies were also included in this report.

The primary drainageways on the FEMP are Paddys Run and the SSOD. Paddys Run traverses the western portion of the FEMP from north to south, and the Great Miami River is located

approximately 1 mile east of FEMP property. Surface water and sediment samples collected from the SSOD, Paddys Run, and the Great Miami River have, in general, been analyzed for a wider range of analytes than the smaller, intermittent drainageways which feed them.

Storm Sewer Outfall Ditch

The SSOD originates at the south parking lot and drains to Paddys Run. The SSOD is ephemeral, carrying water only during and following significant precipitation events and heavy snow melt. Currently, the SSOD carries all surface water flow from the open areas east and south of the production area. However, from the beginning of production at the FEMP through 1986, when the storm water retention basin was installed, the SSOD served as the primary receptor of storm water runoff from the production area storm sewer collection system.

Since the SSOD carries surface water only following storm events, regular sampling of surface water from this location has not been a part of the FEMP EM Program. Surface water data from Sampling Station W7 in Paddys Run, however, which is located downstream of the confluence with the SSOD, shows elevated total uranium concentrations in surface water from well before 1980 through 1986, followed by a sharp decrease in 1987. This decrease is due primarily to the completion of the storm water retention basin.

As part of the RI program, surface water samples were collected from the SSOD in 1988, 1989, and 1993. Total uranium was detected in all samples at concentrations ranging from 2 to 51.8 μg/L. One sample showed above-background concentrations of magnesium and sodium. The only other notable detection was the semivolatile bis(2-ethylhexyl)phthalate with concentrations ranging from 16 to 58 μg/L.

SSOD sediment samples were collected under the FEMP EM Program and the RI. Uranium was the most abundant radionuclide. Uranium concentrations varied from 3.3 to 11 mg/kg. Metals detected at above-background concentrations included beryllium, calcium, magnesium, sodium and zinc. Methylene chloride was detected at 6 mg/kg and six semivolatiles were detected at low concentrations.

Paddys Run

Paddys Run is an intermittent stream that flows south along the western edge of the FEMP to the confluence with the Great Miami River approximately 2.5 miles south of the FEMP. Historically, Paddys Run received both uncontrolled FEMP sheet runoff and runoff from drainage ditches within the FEMP boundaries. Numerous storm water runoff control projects and removal actions in the waste storage area and production area have nearly eliminated the primary sources of contamination to Paddys Run. Currently, all uncontrolled drainages except the northeast drainage ditch (which flows to the Great Miami River) discharge into Paddys Run or one of its tributaries. These uncontrolled drainage ditches continue to be pathways for contaminants to reach Paddys Run, the Great Miami River, and the Great Miami Aquifer.

Based on 1993 RI/FS data, the pilot plant drainage ditch had the highest concentration of total uranium (2890 μg/L) for surface water in the uncontrolled drainages to Paddys Run. This ditch originates approximately 400 feet west of the pilot plant and flows west into Paddys Run. The drainage ditch also collects surface water runoff from the area around the pilot plant, open fields west of the pilot plant, and storm water runoff from the eastern waste storage area. Indications are that the greatest impact to Paddys Run is near the point where the flow from the pilot plant drainage ditch enters. Total uranium concentrations of 1200 μg/L are occasionally reported at the sampling locations in Paddys Run near the pilot plant drainage ditch.

For surface water samples collected from the on-property portion of Paddys Run during the period 1988 to 1993, detected concentrations exceeded background (measured at an upstream location) for uranium-238, uranium-234 and strontium-90. In addition, the average on-property uranium concentration, 15.5 μg/L, exceeded Paddys Run background values by a factor of five. The average on-property concentrations of aluminum and silicon in Paddys Run were also determined to be above surface water background concentrations for Paddys Run. In general, the EM data show that uranium concentrations downstream of the north drainage ditch are twice background. The highest value was detected downstream of the pilot plant drainage ditch and the southwest drainage ditch. Uranium concentrations decreased downstream of the SSOD.

Surface water samples collected from off-property locations in Paddys Run to the south of the FEMP indicate reduced concentrations from on-property locations, ranging from 9.1 μg/L at Willey Road to 2.6 μg/L at State Route 128. The following constituents were detected at concentrations slightly

above the Paddys Run background values for these constituents: thorium-230, uranium-234, uranium-238, and total uranium. The maximum detected concentrations for each of these constituents occurred at different locations. In addition, the filtered concentrations for calcium, manganese, and silicon slightly exceeded the Paddys Run background concentrations for these constituents.

Radium-226, thorium-230 and total uranium were detected in sediment from the on-property portion of Paddys Run at slightly above background concentrations. The maximum concentrations for these radionuclides occurred downstream of the pilot plant drainage ditch and upstream of the fly ash piles. Thorium-230 was detected in one sample from Paddys Run.

In addition to radionuclides, the average detected concentrations of aluminum, barium, calcium, magnesium, manganese, nickel, potassium, vanadium, and zinc were found to be above the upstream background values for these analytes. In addition, during the 1993 RI/FS sediment sampling, several volatile and semivolatile organic chemicals, not previously detected, were identified. These included acetone, chloroform, carbon tetrachloride, methylene chloride and toluene. All were detected at 3 μg/kg or less at on-property locations. Semivolatiles detected were PAHs in the range of 100 to 350 μg/kg in the sediment taken from the last sampling point on Paddys Run before the stream exits the FEMP property.

Off-property sediment locations in Paddys Run were sampled for inorganic chemicals. One sediment sample was also analyzed for HSL organics. Although all metals were detected, only calcium, magnesium and zinc exceeded the sediment background concentrations for these inorganics. Only one organic compound, methylene chloride at a concentration of 6 μg/kg, was detected in an off-property sediment sample.

Great Miami River

The Great Miami River is the principal surface water feature of the FEMP and the ultimate receptor for groundwater in the vicinity of, and surface water discharged from the FEMP. The three principal pathways for FEMP discharges to enter the river are effluent from the outfall line, surface water flow from Paddys Run, and surface water runoff from the northeast portion of the FEMP property via the northeast drainage ditch.

Numerous sampling programs have investigated discharges to the Great Miami River by sampling upstream locations to establish background concentration values, and comparing background values to sampling points downstream of the outfall line and the confluence with Paddys Run. The RI/FS program collected data during 1988/89 and 1993. These data represent conditions in the river before and after production was halted at the site. In addition, EM data are used to illustrate temporal trends in total uranium concentrations.

Using results from the EM Program, surface water sampling data show that during the period from 1986 to 1993, the highest annual average concentration of uranium has been 2.5 μg/L, detected downstream of the confluence of Paddys Run with the Great Miami River. The data indicate that since 1991, average annual concentrations at all sampling locations have been below 2 μg/L. With regard to sediment samples, the data show no discernable difference between total uranium concentration in sediment from locations upstream and downstream of the FEMP outfall line.

As part of the 1988/1989 RI/FS sampling program, total uranium was detected in surface water samples at concentrations ranging from 1 to 7 μg/L. The highest concentrations were detected in samples collected between the FEMP outfall line and the confluence of Paddys Run with the Great Miami River. Thorium-228 was detected at levels ranging from 1.5 to 2.6 pCi/L. Thorium-230 was detected in one sample at 1.3 pCi/L at a location immediately downstream of the confluence of Paddys Run with the Great Miami River. Technetium-99 was detected in 19 samples at levels ranging from 30 to 95.9 pCi/L. Radium-228 was detected in one sample at 5 pCi/L. Metals were detected at concentrations comparable to background, and phenols were detected at concentrations ranging from 0.01 to 0.03 μg/L.

Sediment samples collected in 1988/89 showed no discernable increase in levels of radionuclides downstream of the outfall line or downstream of Paddys Run. Total uranium was detected at concentrations ranging from 1 to 3 μg/kg. The average activity levels for the uranium isotopes was at or less than background. Radium-226 was detected at twice background and thorium-230 was detected at three times background at a location downstream of the confluence of Paddys Run and the Great Miami River.

One round of surface water and sediment samples was collected as part of 1993 RI/FS activities. All samples were analyzed for HSL inorganic, volatile and semivolatile parameters, total and isotopic

uranium and thorium, and isotopic radium. Surface water samples were additionally analyzed for general water chemistry.

Total uranium was detected in all surface water samples at concentrations ranging from 0.4 to 2.8 μg/L. Isotopic uranium was not detected above background. The highest isotopic thorium activity was 0.7 pCi/L. Radium-226 was detected at activity levels ranging from 0.6 to 2.8 pCi/L. Trichloroethane was detected in one sample as were semivolatiles, bis(2-Ethylhexyl)phthalate and di-n-butyl phthalate.

Total uranium was detected in Great Miami River sediment collected in 1993 at concentrations ranging from 2 to 11 mg/kg. Interestingly, the highest total uranium value was detected at the sampling location farthest from the outfall line. The only other radionuclide detected above background was radium-226. Activity levels ranged from 0.4 to 0.8 pCi/g. Metals having average concentrations above background were barium, beryllium, calcium, chromium, cobalt, copper, lead, magnesium, nickel, potassium, selenium, sodium, and zinc. Volatiles chlorobenzene, carbon disulfide, and toluene were all detected in a sample. Semivolatiles acenapthene, chrysene, dibenzofuran, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, fluoranthene, fluorene, info(1,2,3-cd)pyrene, phenanthrene, pyrene were detected as was benzoic acid.

7.4.5 Surface Soil and Subsurface Soil

Extensive sampling of surface and subsurface soils has been conducted within the boundaries of the FEMP and at nearby locations outside the FEMP property. The sampling was conducted as part of the RI site investigation and other programs. These investigations were designed to characterize the nature and extent of soil contamination resulting from past FEMP activities and to permit quantification of baseline risks associated with the contamination. The nature and extent of soil contamination has been sufficiently characterized to perform a viable baseline risk assessment for Operable Unit 5 and evaluate and select remedial alternative(s).

Nature and Extent of Contamination Within the FEMP Boundaries

Within the boundaries of the FEMP, much of the soil sampling was conducted in areas where contamination would most likely be present because of activities known to have been conducted in the vicinity. This was supplemented with systematic sampling designed to evaluate potential

contamination from airborne releases and point-source releases. Tables 7-2 and 7-3 summarize the results of this investigation. These tables list the surface and subsurface soil areas evidencing detections of parameters at levels greater than five times background as well as indicating the geographic areas where these parameters were expected to be found, based on process history. Table 7-4 summarizes the detection of parameters outside of the 20 mg/kg envelope shown in Figure 7-2.

Radiological Parameters

Radiological contamination is predominantly characterized by total uranium, radium-226, and total thorium, based on decay chains and historic operations at the FEMP. Other radiological parameters will be found within the bounds of these three parameters. As shown in Table 7-2, the radiological contamination of surface soil is widespread throughout the production and waste storage areas as well as the areas adjacent to the production area. Subsurface soil contamination is limited to certain areas and parameters. Of the radiological contamination detected, uranium and its progeny were generally the only radionuclides found at significantly elevated levels at the FEMP. The uranium contamination, as expected, is widespread, whereas the occurrence of the other radiological constituents is localized and generally limited to the surface soil. With few exceptions, on-property radiological contamination is located within the 20 mg/kg contour for total uranium.

Total Uranium: Concentrations of uranium in excess of background are found consistently throughout the former production area and in portions of the administrative and laboratory areas. The pervasive uranium contamination is a result of processing uranium, which was the original mission of the FEMP. It has been estimated that during the 38-year production life of the FEMP, more than 179,000 kilograms of uranium and nearly 6500 kilograms of thorium were released to the atmosphere from the production facilities.

Above-background levels of uranium are found throughout the FEMP at depths as great as 20 feet. The highest concentrations of uranium in the surface soil, greater than 10,000 mg/kg, were found in the Plant 1 area, Plant 6 area, laboratory area, and scrap metal pile area. Total uranium contamination in the subsurface soil can be characterized as isolated occurrences underneath process and waste areas. The areas of highest subsurface uranium contamination, those with concentrations greater than 100 mg/kg, were found localized near former processing facilities and in-ground sumps

where acid-solutions of uranium and liquid wastes were handled in large volumes. Total uranium concentrations in surface soil within the FEMP boundary typically ranged from 10 to 100 mg/kg.

Radium-226: Radium-226 contamination is limited to process areas and storage areas where elevated levels were expected. The Plant 1 area and scrap metal pile are the two areas evidencing radium-226 activity greater than 1000 pCi/g. The only area of significant radium-226 contamination in the subsurface soil is the area west of the K-65 silos. The source of this contamination is likely the K-65 decant tank or spills associated with the filling of the silos.

Total Thorium: Elevated levels of thorium and its decay products were generally found in localized areas near former processing and storage locations. All thorium detections were within the uranium envelope. The highest concentrations of total thorium, exceeding 1000 mg/kg, were within the scrap metal pile and laboratory areas. These occurrences were not pervasive, but isolated areas of major contamination. Thorium contamination was detected primarily in the surface soil and was limited to a depth of less than 10.0 feet in the subsurface soil.

Fission and Uranium Activation Products: Fission and uranium activation products present are associated with recycled uranium that was processed at the FEMP. This is uranium that has been irradiated in a nuclear reactor for the production of energy, weapons material, or man-made radionuclides. Irradiated uranium was chemically processed to remove fission and activation products prior to its shipment to the FEMP, but some residual levels remain. These fission and activation products are found sporadically but generally located within the uranium envelope.

Inorganic and Organic Parameters

The majority of inorganic contamination is located in the surface soil. The primary inorganic contaminants at the FEMP are beryllium and cadmium. The only known source of cadmium is as an impurity in the uranium ore feed material, while the primary source of beryllium is not known (see Table 4-9). Silver was detected in both the surface and subsurface soil at low levels sporadically across the site. Selenium was found in the subsurface soil, although no background level is available and detections in the subsurface soil are low.

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Volatile organic and semivolatile organic compounds and PCBs were detected in select samples in the vicinity of all of the major processing and supporting facilities Table 4-9). With few exceptions, the organic detections were located within the uranium envelope.

Nature and Extent of Contamination Outside the FEMP Property

Total uranium concentrations were observed at levels slightly above background on the property surrounding the FEMP. The locations where uranium detections exceeded background were mainly in the areas east, northeast and southwest of the FEMP. The levels generally ranged from 5 to 6 mg/kg in these areas. The probable source of the elevated levels of uranium is airborne releases from areas within the FEMP. However, such low analyte levels as those stated above might be considered to be typical minor variations in analytical results. Although the levels of uranium and its isotopes do exceed background, the exceedance is minor and may be attributable to the accuracy of analytical measurement. There were also isolated areas of significant contamination located along the outfall line and along the eastern boundary adjacent to the sewage treatment plant.

7.4.6 Perched Groundwater

Seven broad areas where uranium and other contaminants are present at above-background concentrations in the perched groundwater have been identified as follows:

I. Production area
II. Sewage treatment plant area
III. South Field/flyash pile area
IV. K-65 silos area
V. Waste pit/solid waste landfill area
VI. Fire training area
VII. Lime sludge ponds area

The generalized dimensions of these seven areas of contamination are displayed in Figure 7-2. Also shown is the 5 μg/L isoconcentration contour for total uranium, based on unfiltered samples. The extent of all other predominant contaminants generally falls within the portrayed extent of uranium contamination.

Table 7-2 summarizes the maximum concentration detected for each contaminant in each of the seven contamination areas. The greatest number of constituents and the highest reported concentrations above background occur in perched groundwater beneath the production area. The least number of

constituents and the lowest reported concentrations occur in perched groundwater near the Lime Sludge Ponds. The results of RI characterization of perched groundwater provide sufficient information to characterize risk and to determine appropriate response actions in the FS.

7.4.7 Great Miami Aquifer Groundwater

Uranium is the principal groundwater contaminant in the Great Miami Aquifer. The extent of every other contaminant, except sulfate, falls within the limits of uranium contamination as defined by the 5 ug/L contour line of total uranium based on unfiltered samples (see Figures 7-3 and 7-4).

The primary sources of contamination to the Great Miami Aquifer are six point or line sources, which produce six distinct contaminant plumes. Table 7-3 summarizes the extent of contamination for each parameter and the maximum contaminant concentrations occuring in each respective plume. Two of the six FEMP plumes, South Plumes A and B, are comingled with contaminant plumes that originate from an independant industrial facility located south of the FEMP, the PRRS. The plumes that extend away from the six FEMP sources are each different in terms of the lists of constituents which comprise the contamination in each plume.

Contamination of the Great Miami Aquifer is largely confined to the uppermost portion of the aquifer. In general, each plume is most laterally extensive at the top of the aquifer (i.e., Type 2 well locations - a total of 340 acres based on the 5 μg/L total uranium contour), less laterally extensive with lesser concentrations at the middle of the aquifer (i.e. Type 3 well locations - a total of 120 acres), and essentially nonexistent at the bottom of the aquifer (i.e. Type 4 well locations).

Isolated occurrences of uranium and other contaminants have been detected at low concentrations at select locations outside of the six FEMP plumes. The uranium is primarily a result of deposition of FEMP air emmissions on surface soils. In most other cases there is no evidence that the low-level, above-background detections are site related and there is a strong possibility that the occurrences are due to natural variation of the constituents, agricultural activities, cross-contamination, or analytical error.

Low levels of uranium contamination also exist in groundwater along the west bank of the Great Miami River, south of the confluence of Paddys Run. The low levels of uranium contamination in this area were identified through sampling of private wells. The contamination is believed to have

resulted from infiltration of Great Miami River water into the bank of the river. This contamination is limited to a 100- to 200-foot-wide strip of land along the river bank.

The results of the RI characterization of the Great Miami Aquifer provide sufficient information from which to characterize risk and to determine appropriate response actions in the FS.

7.4.8 Biota

Radiochemical analysis was performed on samples of aquatic and terrestrial vegetation, benthic macroinvertebrates, fish and small mammals from on and off the FEMP property to examine potential bioaccumulation. Additionally, chemical analysis was performed on samples of grass leaves and roots, and two small mammals. Results of the biota sampling program are presented in Table 7-3. In general, the isotopes of uranium were detected in select samples at low concentrations from all sample groups. Comparison of these values to background or statistical analysis of the results is not appropriate due to lack of control values and the small data set. The fission products examined (i.e. strontium-90 and cesium-137) were generally not detected above laboratory detection limits. Select samples of grass roots and a single cucumber sample did indicate cesium-137 levels above detection limits. Analysis of the significance of these occurrences cannot be completed due to lack of control samples.

Limited analysis of samples was completed for inorganics, including metal and sulfates, and organics. These constituents were detected in collected samples of grass roots and leaves and small mammals.

7.4.9 HWMUs to be Addressed Under CERCLA

The foregoing RI report addresses 22 RCRA Hazardous Waste Management Units (HWMUs) that are proposed to be closed under the integrated RCRA/CERCLA closure process. Section 1.0 provides an overview of the waste management characteristics of the 22 HWMUs, while Section 4.0 provides information on the nature and extent of affected environmental media.

Twenty-one of 22 HWMUs directly overlie contaminated soil and/or contaminated perched groundwater. One of those 21 HWMUs, the fire training area, was conclusively determined to be the primary contributor to underlying soil and groundwater contamination. The remaining 20 HWMUs overlie contaminated media which contain above-background concentrations of RCRA constituent for which the individual HWMUs are possible sources. However, the 20 HWMUs are located in close

proximity to other potential sources that are also likely to be sources of observed contamination. Consequently, for those 20 HWMUs, it is not possible to link a particular contaminant conclusively to the HWMU. For such cases, the integrated CERCLA response action for soil and perched groundwater contamination will need to address area-wide contamination in a manner that addresses contamination of areas, and not contamination due to individual sources.

One HWMU, the biodentrification surge lagoon (BSL), is potentially underlain by uranium surface soil contamination, but is apparently not underlain by extensive groundwater contamination. The BSL does not appear to be contributing RCRA constituents to perched groundwater underlying the unit.

7.5 CONTAMINANT FATE AND TRANSPORT

The fate and transport models required to support the baseline risk assessment were developed and applied to predict contaminant movement from source areas to potential human or ecological receptors. Potential migration pathways through the environmental media were evaluated over a 1000-year time frame. The modeling provides information on future contaminant migration to off-property locations and allows future exposure predictions by extrapolating from known field data. The models, used in conjunction with monitoring data, predict future contaminant concentrations at potential exposure locations. Conservative assumptions and sensitivity analyses were used in the models to provide a "reasonable worst case" picture of contaminant fate and transport.

Environmental media evaluated for fate and transport modeling included:

- Air in the vicinity of the FEMP
- The Great Miami Aquifer underlying and down gradient of the FEMP
- Surface water and sediment in the vicinity of the FEMP
- Surface and subsurface soils outside of Operable Units 1, 2, and 4 boundaries
- Uncapped surface soil within the Operable Units 1, 2, and 4 boundaries
- Perched groundwater outside of Operable Units 1, 2, and 4 areas.

The Operable Unit 5 fate and transport modeling domain encompasses these environmental media and an area large enough to cover all major potential contaminant receptor locations identified in the baseline risk assessment.

7.5.1 Conceptual Model of Contaminant Migration

The fate and transport models used to support the baseline risk assessment need only simulate the migration of contaminants under the no-action scenario. However, due to on-going environmental management activities in Operable Unit 5 and the 1000-year time frame considered in the RI, the no-action or, more appropriately, "no-further-action" scenario requires clarification.

Because the storm water management systems and removal actions currently in operation at the FEMP are not expected to continue for 1000 years, two distinct time steps were defined in the no-action scenario. The "baseline condition" evaluates the first 70 years and includes current environmental management activities and existing levels of contamination in the environmental media without additional contaminant loading from other operable units. The "future condition" looks at the period from 70 to 1000 years and begins after the assumed termination of on-going storm water management and removal actions.

Sources

Past contaminant loadings from other operable units into the environmental media were included as contaminant sources and initial conditions. Operable Unit 5 sources include contaminated surface and glacial overburden soil, perched water in the galcial overburden, sediment along Paddys Run and the SSOD, and groundwater in the Great Miami Aquifer. Remedial actions in Operable Units 1, 2, 3, and 4 will significantly reduce the potential for future contaminant loadings from these areas. Therefore, under the no-action scenario, the other operable units are assumed to be remediated and no simulation of continuous contaminant loadings from them was required. Impacts of residual loadings from all operable units (including Operable Unit 5) after completion of the required remedial actions will be evaluated and quantified in the Operable Unit 5 Feasibility Study (FS).

Pathways

The following pathways were considered for contaminant transport from Operable Unit 5 sources:

- Air:
  - Volatilization of organic compounds, wind erosion of contaminated particulate matter, and the direct release of radon gas.

- Surface water:
  - Erosion of contaminated surface soil into Paddys Run and the SSOD.
  - Flow of contaminated surface runoff water into Paddys Run and SSOD.
  - Discharge of treated or untreated storm water and groundwater into the Great Miami River through the FEMP discharge outfall line.

- Groundwater:
  - Leaching of contaminants from contaminated soil through the vadose zone to the underlying Great Miami Aquifer.
  - Infiltration of contaminated perched groundwater through the vadose zone to the underlying Great Miami Aquifer.
  - Infiltration of contaminated surface water from Paddys Run and the SSOD to the Great Miami Aquifer.
  - Natural and induced flow of groundwater in the Great Miami Aquifer which can carry dissolved contaminants and, potentially, contaminants adsorbed to colloidal particles of up to 2 microns.

Because of the wide-reaching source areas and larger network of receptor locations/exposure points, the contaminant migration pathways of Operable Unit 5 cover a larger area than other operable units at the FEMP.

Physical and Chemical Processes

Physical and chemical processes can significantly affect the contaminant concentrations at potential receptor locations simulated in the air dispersion, air deposition, water infiltration, surface water flow, and groundwater flow fate and transport modeling. Field investigations, including geotechnical tests, aquifer tests, field observations, and meteorological records have been designed and conducted to characterize such constituent-specific processes, including decay, leaching, adsorption, and desorption, and geochemical conditions. In the absence of field data, data from published literature and model calibrations were used.

7.5.2 Model Descriptions

All models used for Operable Unit 5 contaminant fate and transport modeling are improved or newly developed according to a previously submitted overall model improvement plan and the requirements

of the Operable Unit 5 baseline risk assessment. Development and application of these models have been presented to EPA and OEPA in a series of technical information exchange meetings. Both technical defensibility and consistency with previous models for other operable units were emphasized in the modeling process.

Air Model

Air transport modeling was conducted using a specific modeling protocol. The objective of the protocol was to use the most representative emission source data and on-site meteorological data to calculate maximum annual average concentrations for all contaminants in the current and future scenarios.

The ISCLT2 model was used to calculate annual average concentrations using a number of model options that allow the user to specify the atmospheric conditions of pollutant dispersion, the type of emission source and emission source parameters. All emission sources were assumed to result from either the resuspension of contaminated particulate matter due to wind erosion or the release of radon gas. All Operable Unit 5 source areas were defined as area sources and emission rates were in units of grams or picocuries per second per square meter ($pCi/s/m^2$).

A receptor grid covering approximately 3113 acres was used to determine the maximum on- and off-property concentrations for all emission scenarios. The receptor grid consisted of 5246 receptor locations having a uniform 164-foot spacing. A discrete receptor network was also used to calculate annual average concentrations for all CPCs at the following locations:

- Crosby Elementary School
- Morgan Elementary School
- Elda Elementary School
- St. John Elementary School
- Ross Middle/High School
- Ross Country Day Nursery School
- Knollman dairy farm
- Two locations south and east of the FEMP along the Great Miami River
- Paddys Run Road
- Village of Fernald

Surface Water Model

Modeling of surface water for Operable Unit 5 was completed in two stages. The movement of surface water, rainfall, runoff, and infiltration was performed first. The results of this work are presented in the Surface Water Flow and Infiltration Model (SWF&IM) Summary Report (DOE 1993c). The results of the SWF&IM were then incorporated into this report and used to calculate contaminant transport in the surface water pathway.

The surface water modeling task for Operable Unit 5 was completed as follows:

- The general/regional hydrology and hydraulic calculations were performed once with the results presented in the SWF&IM report
- The SWF&IM results were used for each waste source area
- For each waste area, each COPC was screened to determine if the COPC needed to be modeled further in the surface water pathway as a CPC
- If the COPC was not screened out, its concentrations in the surface water, sediment and its loading to the Great Miami Aquifer were calculated.

The calculated amounts of contamination infiltrating through the streambeds of Paddys Run and the SSOD were used as loading terms to the groundwater solute transport model. Loadings for two cases were calculated; one from the single representative storm event and another average rate to represent all of the storm events occurring during the year.

The contaminant loading to the Great Miami Aquifer was simulated for 1000 years in the groundwater solute transport model. Because of this long time frame, two processes of soil depletion were considered; erosion of the contaminated surface soil and decay of the source contaminants. The Universal Soil Loss Equation (USLE) (EPA 1988) was used to estimate the yearly loss of soil due to erosion from each subbasin. USLE calculations indicated that the source soil would not completely erode away during the 1000-year time frame. Therefore, depletion of the source soil by erosion was not significant and was not retained in the procedure. The effects of radioactive decay and biodegradation were considered in calculating the source concentrations at the beginning of the future conditions (70 years after the baseline conditions). The loadings from the surface waters to the Great Miami Aquifer were calculated at the baseline and future time points and were assumed to be constant between these points.

Groundwater Model

The upper surface of the glacial overburden contains secondary porosity features (fractures and bioturbations). The density of these secondary porosity features decreases with depth and essentially controls the depth of active infiltration. No credit was taken for contaminant attenuation by this weathered zone. Therefore, the contaminant migration pathway, for the purpose of transport modeling, begins beneath the weathered surface layer.

A one-dimensional vertical conceptual model of flow and transport through the overburden (ODAST) was used for all the CPCs in the fate and transport model. The ECTran model was used to screen and simulate lateral migration in perched groundwater of more mobile CPCs from source areas closer to surface water exposure points. These source areas include the waste pit area, the silo area, Plants 2/3, Plant 8, the Pilot Plant, and the laboratory building.

To model the vadose zone, five representative cross sections and their distribution throughout the Operable Unit 5 area were created for infiltration modeling (HELP). This resulted in an infiltration rate which, in combination with existing contaminant concentrations in the perched groundwater, was used to model transport through the vadose zone (SWIFT LOAD) to produce a vertical loading rate. This, in combination with existing contaminant concentrations in the plumes in the Great Miami Aquifer, was used to model transport through the aquifer (SWIFT III and ECTran) to determine exposure point concentrations.

The saturated portion of the Great Miami Aquifer was represented by six model layers in the SWIFT model. Model layers were designed to coincide with the depth of Type 2, Type 3, and Type 4 monitoring wells, the clay interbed, and the top of bedrock contours. Higher recharge rates through surface water bodies (i.e., Paddys Run, SSOD, the northeast drainage ditch, and the Great Miami River) were incorporated in the model. The higher of filtered and unfiltered groundwater concentrations for each location were used for transport model calibration and determination of initial aquifer conditions. This approach provided additional conservatism in estimates of groundwater concentrations at receptor locations, considering the potential for colloidal transport.

Twenty-seven Operable Unit 5 contaminant source areas (excluding six areas in Operable Units 1, 2, and 4 from the surface water pathway) were defined using contours of total uranium concentrations in shallow soil sample data (< 1.5 feet deep) and the boundaries of surface water drainage basins. Five

additional deeper source areas in the production area (i.e., two in the vicinity of Plant 2/3, two in the vicinity of Plant 6, and one near the laboratory building) were defined based upon three-dimensional solid block modeling of uranium in the glacial overburden.

7.5.3 Model Results

Air Model Results

Radionuclides were the predominant contaminants associated with the Operable Unit 5 air transport analyses. The maximum annual average on-property values calculated for the radionuclide contaminant group were associated with uranium-238, uranium-234, thorium-230, and radium-226. On-property values for these contaminants for the hypothetical future condition were in the range of 1.30×10^{-2} pCi/m^3 for radium-226 to 4.50×10^{-2} pCi/m^3 for uranium-238. The location of the maximum value for each contaminant was different; however, all were generally located from the south-central portion of the former production area to approximately 300 feet east of the eastern fence line. The values for other radionuclides were one to four orders of magnitude lower than those listed. Maximum off-property values for these contaminants ranged from 1.20×10^{-3} pCi/m^3 for radium-226 to 1.20×10^{-2} pCi/m^3 for thorium-230. Again, the location of these maximum levels was different but generally 650 feet east of the southeast quadrant of the former production area. Also, the values for other radionucluides were one to four orders of magnitude lower.

The results of radon modeling for both the hypothetical future and current conditions indicate a maximum on-property value of 352 pCi/m^3 just east of the northeast corner of the fence line around the former production area, a maximum off-property value of 8.2 pCi/m^3 approximately 650 feet east of the northeast corner of the former production area fence line, and a maximum value at a discrete receptor of 1.4 pCi/m^3 at the East receptor (near the Great Miami River).

The maximum calculated annual average concentrations for the inorganic contaminant class were associated with many of the more commonly occurring soil inorganics, such as aluminum, calcium, iron, and magnesium. Maximum annual average concentrations of other inorganics for the hypothetical future condition included barium at 3.20×10^{-3} μg/m^3, lead at 1.00×10^{-2} μg/m^3, manganese at 1.20×10^{-2} μg/m^3, and zinc at 3.00×10^{-3} μg/m^3. The general location of the maximum on-property concentrations for the inorganics group was near the center of the production area. Maximum off-property concentrations for arsenic, cadmium, lead and zinc were generally an

order of magnitude lower than the maximum on-property concentrations and generally located 650 feet east of the southeast quadrant of the former production area.

The maximum annual average concentrations for the volatiles, semivolatiles and PCB contaminant groups were also calculated to occur near the center of the production area. Maximum annual average on-property concentrations for the volatiles, semivolatiles and PCB groups were 1.00×10^{0} $\mu g/m^3$ for trichloroethene and 5.20×10^{-1} $\mu g/m^3$ for tetrachloroethene. Maximum annual average off-property concentrations for these groups were generally 1 to 2 orders of magnitude lower than the calculated on-property concentrations, although the concentrations for trichloroethene and tetrachloroethene were 3.90×10^{-1} $\mu g/m^3$ and 1.90×10^{-1} $\mu g/m^3$, respectively, located approximately 550 feet north of the northeast quadrabt of the former production area.

Surface Water and Sediment Results

Baseline Condition:

The maximum sediment concentration for radionuclides, 552 mg/kg of total uranium, was calculated to occur in the pilot plant drainage ditch. This drainage ditch receives storm water from areas in and around the pilot plant . The maximum sediment concentration of other radionuclides was predicted to occur in Paddys Run near the South Field (technetium-99 at 6.0×10^{-4} mg/kg) and the northside drainage ditch (neptunium-237 at 9.07×10^{-4} mg/kg). Maximum concentrations for inorganics were predicted to occur in several different drainage subbasins, with the highest concentrations in the East Side drainage ditch (31,500 mg/kg for magnesium, 2880 mg/kg for manganese, and 1650 mg/kg for lead). The highest concentrations predicted for organic contaminants were in the northside drainage ditch (2.14 mg/kg for benzo(a)pyrene and 1.70 mg/kg for benzo(a)anthracene).

Magnesium (169 mg/L) was predicted to be the predominant contaminant in surface water, followed by manganese (.26 mg/L), cyanide (.12 mg/L), and total uranium (.10 mg/L), all in Paddys Run. The maximum concentrations in the Great Miami River at the mouth of Paddys Run were predicted to be associated with these same contaminants (magnesium at 14 mg/L, manganese at 0.02 mg/L, cyanide at 0.01 mg/L, and total uranium at 0.008 mg/L).

The maximum concentration and yearly loading to the Great Miami Aquifer from the surface water bodies were calculated for three channel reaches in Paddys Run and the SSOD. The loadings and the concentrations were predicted to be highest under the SSOD for most of the CPCs. This is due to the

higher contamination in areas which feed the SSOD and the higher infiltration percentages in the SSOD. The highest concentrations and loadings were for magnesium (160 mg/L and 88,000 kg/yr), manganese (0.3 mg/L and 151 kg/yr), cyanide (0.1 mg/L and 63 kg/yr), and total uranium (0.1 mg/L and 46 kg/yr).

Future Condition:

For most of the CPCs, the maximum concentrations in the sediment were predicted to occur in the SSOD or the East Side drainage ditch. These high concentrations are due to the modeled conditions of removing the buildings in the production area and exposing the contaminated soil. The maximum sediment concentrations for radionuclides were predicted in the SSOD (3380 mg/kg for total uranium, 192 mg/kg for thorium-232, and 0.01 mg/kg for thorium-230). The maximum sediment concentrations for inorganics were predicted to occur in the East Side drainage ditch (31,500 mg/kg for magnesium, 2880 mg/kg for manganese, and 1650 mg/kg for lead). These are the same concentrations as predicted in the baseline condition since the inorganics were assumed not to decay and this subbasin lies outside of any of the storm water controls. The highest concentrations predicted for organic contaminants were for Aroclor-1254 (2.09 mg/kg) and 4-methylphenol (1.23 mg/kg) in the SSOD.

The predicted maximum surface water concentrations in Paddys Run are associated with magnesium (207 mg/L), total uranium (2 mg/L), manganese (0.28 mg/L), and cyanide (0.1 mg/L). The predicted maximum concentrations in the Great Miami River at the mouth of Paddys Run are associated with these same contaminants (magnesium at 18 mg/L, total uranium at 0.17 mg/L, manganese at 0.02 mg/L, and cyanide at 0.01 mg/L. Concentrations were not calculated at the discharge outfall line since, under the future conditions, it was assumed that this line and the rest of the storm water controls will not be in operation.

Concentrations and loadings were calculated for three channel reaches in Paddys Run and the SSOD. For most CPCs, the loadings and the concentrations were predicted to be highest under the SSOD. This is due to the elevated levels of contamination in the areas which feed the SSOD combined with higher infiltration percentages in the SSOD. The highest predicted concentrations and loadings were for magnesium (183 mg/L and 159,000 kg/yr), total uranium (1.8 mg/L and 1400 kg/yr), manganese (0.3 mg/L and 212 kg/yr), and cyanide (0.1 mg/L and 106 kg/yr).

Groundwater Results

The ECTran model used to simulate lateral migration of contaminants in the perched groundwater shows that, while uranium, thorium and other heavy metals will not reach Paddys Run or its tributaries, some of the more mobile chemicals (e.g., technetium-99 and 1,1-dichloroethene) will. These constituents, which are contained in perched groundwater in the southwest portion of the FEMP, will reach the pilot plant drainage ditch, thus contributing to the Paddys Run pathway. The areas to the southeast of Operable Units 1 and 4 serve as the primary sources.

With regard to vertical migration through the glacial overburden, uranium breakthrough (the amount of time required for substantial uranium mass to migrate vertically to the Great Miami Aquifer under baseline conditions with no engineering controls) in the Plant 6 area will occur in approximately 350 years. Break through times for other perched groundwater sources include: Plant 2/3 - approximately 950 years; sewage treatment plant - approximately 1000 years; Plant 9 - approximately 1000 years; and the fire training area - greater than 1000 years.

At the end of the baseline condition (i.e., 70 years), during which the South Groundwater Contamination Plume recovery well system and storm water runoff controls were assumed to be in operation, the current South Plume will be significantly reduced in both size and concentration. This is because sources under the other operable units will be flushed out since the source terms will be minimized as a result of remedial actions. However, even with the storm water retention basins, the surface water loadings of total uranium from areas around the former production area, through the upper section of the SSOD, can still create a significant plume in the vicinity of the SSOD.

The production area will become the major source of groundwater contamination to the east of the FEMP. The Southwestern Ohio Water Company wells may also be impacted in the distant future. The FEMP fence line concentration of total uranium is predicted to reach its maximum in the 560th year. This maximum concentration will occur on the east side of the FEMP. The extent of the 1000-year total uranium plumes is similar to the total uranium plot at 560 years, indicating that an "equilibrium" condition will be reached, at least away from the major sources. The maximum concentration drops from 39 mg/L to 11 mg/L, however, because production area loading has been curtailed.

Based on the modeled uranium conditions, it is clear that the time required to wash out the groundwater contamination at the FEMP by natural processes is beyond the time frame of the simulation (i.e., 1000 years). Under the no-action scenario, groundwater conditions in the Great Miami Aquifer will continue to deteriorate.

Time and location of maximum loadings vary for each constituent based upon source mass, initial concentration, constituent attenuation, vadose zone layer thicknesses, and vadose zone layer hydraulic properties. For several constituents, the Plant 6 and Plant 9 areas produced maximums because these areas typically have higher concentrations of constituents and because of the simulated increased hydraulic conductivity in this area. Total uranium had the highest loading of 0.05 pounds per day; almost 2 orders of magnitude greater than the next highest CPC. The vertical loading to the Great Miami Aquifer is negligible until around 350 years, at which time it increases sharply to its maximum of 0.05 pounds per day at 650 years. The mass loading then decrease gradually to a value of 0.04 pounds per day at 1000 years.

The maximum concentration of total uranium in the Great Miami Aquifer, 42 mg/L, occurs beneath Plants 6 and 9 areas at 500 years. At the eastern FEMP fence line, a maximum total uranium concentration of 5080 μg/L occurs at 560 years. The total uranium concentrations for other receptors are less than these values, although some have values greater than 1 mg/L. The concentration at the time of the total uranium maximum for each receptor was reported for the other primary CPCs at the same locations to provide an estimate of total risk. This point in time was used since the risk assessment showed that total risk is dictated by uranium due to its higher concentrations and typically higher risk factors than the other CPCs.

Sensitivity/Uncertainty Analyses

Sensitivity and uncertainty analyses were performed for the major fate and transport models used for Operable Unit 5. In general, fate and transport modeling only presents one set of conditions using the best available value for each model parameter. The purpose of the sensitivity/uncertainty analyses is to define the potential range of modeled results.

Of the parameters parameters which were evaluated for the sensitivity of the surface water and sediment concentration results, K_d was the most sensitive. The other parameters tested did not have a significant effect on surface water and sediment concentrations. The loading of contaminants to the

Great Miami Aquifer from surface water is primarily controlled by the infiltration amount and the concentration of contaminants in the surface water. The infiltration amount and the concentration of contaminants in the surface water, and therefore, loading to the Great Miami Aquifer, are relatively insensitive to the runoff volume. Variation of other parameters produces a change in total infiltration of 30 percent or less. Since the infiltration volume accounts for only a small amount of the total loading to the Great Miami Aquifer, this is considered acceptable.

The ECTran and SWIFT models were used to perform the sensitivity/uncertainty analyses of the GMA Model. The results these analyses show that the baseline model output is within an order of magnitude of the maximum cases from these two models. Since other portions of risk assessments typically contain several orders of magnitude of uncertainty, that attributable to the GMA Model is relatively minor.

These sensitivity/uncertainty analyses discussed above for the GMA Model did not consider uncertainties associated with contaminant loading terms such as source leachate concentration and mobility of uranium in the overburden. This was done to focus on the GMA Model parameters only. However, the source term loading is expected to be the most important factor determining future impacts to the Great Miami Aquifer.

For the baseline condition, it was assumed that soluble uranium contamination in areas outside of the former production area, where air deposition was the primary pathway, was depleted (K_l and K_d equal to 222 L/Kg). For the sensitivity/uncertainty analysis, it was assumed that 25 percent of the uranium in these areas was soluble and mobile (K_l and K_d equal to 15 L/Kg) and that all uranium in the leachate was mobile. This simulation indicated that no additional uranium would reach the Great Miami Aquifer in 1000 years than that determined in the baseline condition.

7.6 BASELINE RISK ASSESSMENT

Baseline risk is risk to hypothetical receptors, due to the presence of contaminants within Operable Unit 5, which may occur under various hypothetical scenarios if no remedial actions were taken to correct noted environmental deficiencies. Thus, baseline risk provides a measure of risk against which the reduced risk associated with various remedial action alternatives may be compared. This baseline provides a measure of the relative effectiveness of different remedial action alternatives.

7.6.1 Exposure Scenarios

Baseline risks are calculated for hypothetical contaminant exposures to receptors under four separate land-use scenarios. The land-use scenarios include current land use with access controls, current land use without access controls, future land use with access controls, and future land use without access controls.

Under the first scenario, current land use with access controls, the site is assumed to remain under federal ownership and access restrictions historically provided by the DOE are assumed to be maintained. There has been no remediation of the Operable Unit 5 environmental media beyond that completed to date. However, it is assumed that remediation has been completed for Operable Units 1, 2, 3, and 4. Contaminated buildings, concrete, and gravel in the former production area have been removed and the contaminated soil currently under the former production area buildings exposed and engineering controls continue to function. The scenario assumes that no members of the public have established residence in the Operable Unit 5 on-property area. Further, the scenario assumes that DOE maintains a site-specific health and safety program to ensure that nonremediation workers and visitors are properly protected. Hypothetical on-property receptors under this scenario include a trespassing youth, an on-site worker (groundskeeper), a visitor, and a consumer of milk and meat from cattle allowed to graze at specified on-property grazing areas. Hypothetical off-property receptors include an off-property resident farmer, an off-property resident child, and an off-property user of surface water from the Great Miami River.

Under the second scenario, current land use without access controls, the FEMP is assumed to have been turned over to an industrial concern other than the DOE. Access restrictions currently provided by the DOE are assumed to be discontinued. In addition, as in the first scenario, no further remedial actions are assumed to have been taken beyond those completed to date and those planned for the other operable units. The scenario further assumes that no members of the public establish residence

within the Operable Unit 5 on-property area. Potential receptors under this scenario include an on-property exploring youth and a consumer of meat and milk from cattle allowed to graze in presently restricted on-property areas. Off-property receptors (and exposure results) will be identical to the preceeding scenario, since they occur at hypothetical locations outside of the FEMP access control boundary.

Under the third scenario, future land use with access controls, the site is assumed to remain under federal ownership as a government reserve. Access controls are assumed to remain in place. Contaminant concentrations at points of exposure, however, entail maximum values calculated from fate and transport modeling over a 1000-year time frame, rather than current-condition (measured) values. Potential receptors for this scenario include an on-site worker (groundskeeper) and an "expanded trespasser" that couples the hypothetical risks of an off-property child with those of a trespassing youth. Off-property hypothetical exposures for this scenario will be identical to those accompanying the fourth land use scenario described below.

The fourth land-use scenario, future land use without access controls, includes exposure routes that require development time, such as establishing a home and a farm within the Operable Unit 5 on-property area. Access controls are assumed to be absent and no remedial actions are assumed to have been taken. In addition, members of the public are assumed to have established residence within the Operable Unit 5 on-property boundaries. Hypothetical on-property receptors under this scenario are a reasonable maximum exposure (RME) resident farmer, a central tendency (CT) resident farmer, a resident child, a RME farmer using perched groundwater, and a home builders. Hypothetical off-property receptors include an off-property resident child, an off-property farmer, and an off-property surface water user of the Great Miami River. Maximum contaminant concentration values derived from fate and transport modeling are again used in this scenario.

As indicated above, the risk calculations are performed for the current and future land-use categories using two differing contaminant source term values. The current land-use categories use current-condition (measured) contaminant source terms, and the future land-use categories use projected (maximum) contaminant levels determined from 1000-year fate and transport model simulations. Otherwise, identical methods and calculation steps are employed to calculate the hypothetical risk levels.

7.6.2 Selection of Constituents of Potential Concern

Radiological and hazardous chemical CPCs for use in the Operable Unit 5 risk assessment were identified using statistical methods and toxicological analyses and by comparing the list of constituents detected in Operable Unit 5 with both the COCs determined for the other operable units and the major site-related constituents known to have been used/stored at the FEMP. Constituent data used included characterization results for the environmental media present within Operable Unit 5 and background concentrations established for the surrounding site area. The CPCs are selected by the comparison of site-related data to background data, using several statistical procedures. To conduct the comparison between the site-related measurements and the background data for a constituent, two tests were used in sequence: a "location" test (Students t-test or Wilcoxon Rank Sum [WRS] test), followed by the "95th Percentile Test." If either of the test results rejects the null hypothesis, i.e., the distribution of measurements at the site appears to be shifted to the right (to higher measurements) of the background distribution, the constituent is considered to be a CPC. The constituent is not included as a CPC only if both test results indicate that there was not a "significant difference" between the two distributions. For cases where the location tests could not be performed due to small sample sizes or large portion of non-detects, and the 95th Percentile Test suggests that the site data are not different from the background data, professional judgment by risk assessors was used to make the final determination. Justifications for the CPC selections and final determinations are provided in the footnotes of the risk tables contained in Appendix A.

In accordance with EPA guidance (EPA 1989a), other criteria are applied after statistical guidance, to determine CPCs. Chemicals identified during chemical analysis may be omitted from the list of CPCs if they are (1) common laboratory contaminants found in the sample at a concentration less than 10 times the blank; (2) essential elements (sodium, potassium, calcium, magnesium, iron, etc) and are known to be nontoxic; (3) chemicals that are ubiquitous in nature (aluminum, silicon, and chloride, etc.) and inappropriate for hazard analysis; (4) chemicals found infrequently and in only one medium; (5) chemicals found at very low concentrations and known to be nontoxic; (6) chemicals that are identified only as a chemical group and cannot be quantitatively addressed in a risk assessment; and (7) chemicals that are from off-site anthropogenic sources (autos, local factories, etc.) unless they present a significant risk.

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7.6.3 Risk Characterization Results

Risks resulting from carcinogenic contaminants are assessed in terms of the ILCR they present to human populations over and above that to which humans are already exposed. Statistics show approximately a 1 in 3 probability (approximately 33 percent) (American Cancer Society 1993) that the average human will acquire cancer. As established by federal regulation, risks from waste sites should generally not add greater than 1 in 10,000 (1×10^{-4}) to 1 in 1,000,000 (1×10^{-6}) probability of acquiring cancer over the average lifetime of a potentially exposed human, nor present a hazard index (HI) greater than 1.0 when exposed to noncarcinogenic contaminants.

The results from the Operable Unit 5 baseline risk assessment are presented in Tables 7-4 and 7-5. Table 7-4 summarizes the maximum carcinogenic risks for select hypothetical receptors for all four land use scenarios. The results for all receptors are included in Section 6. Table 7-5 provides a similar summary for the non-carcinogenic constituents, based on HI results. The highest reported risk values (for both carcinogenic and non-carcinogenic constituents) are associated with the future land use scenarios, where projected maximum contaminant source concentrations are used in the calculations.

Of the hypothetical scenarios presented, the current land use with access controls scenario most closely approximates current conditions at the FEMP. However, conservative assumptions were made, consistent with those made for other scenarios, to ensure that the calculated baseline risk represents an upper bound. Under this scenario, the maximum carcinogenic risk (1×10^{-2}) is to the hypothetical off-property farmer living on the southern fence line of the FEMP. The constituents providing the maximum contributions to this risk value were arsenic, 1,1-dichloroethene, and 1,2-dichloroethane, primarily delivered through the groundwater ingestion pathway. This hypothetical receptor is assumed, for conservative purposes, to be ingesting contaminated groundwater from the South Plume that extends beyond the FEMP fence line. Further, it assumed that this receptor consumes groundwater containing the maximum concentrations of contaminants detected in that area at a rate of 2 liters per day for his entire assumed 70 year lifetime. These assumptions account for over 60 percent of the total risk to that receptor. Under actual conditions, this groundwater is not being utilized and alternate water supplies are provided to users in the South Plume area.

The maximum HI developed for exposures to a receptor under this land use scenario was 830 for the off-property child on the eastern FEMP fence line. The groundwater pathway again dominates and

heavy metals (zinc and chromium) are the key toxicants, accounting for over 75 percent of the HI value.

Of the remaining scenarios, the future land use without access controls represents the most conservative "no-action" scenario considered under the risk assessment. Within this scenario, the dominant carcinigenic risk (6×10^{-2}) applies to a farmer assumed to have established a residence in the former production area, using perched groundwater as the water supply. Maximum contaminant levels derived from the fate and transport modeling for all media are used. The constituent providing the maximum contribution to this risk value was uranium-238, with significant risk attributable to uranium-234 and thorium-232. The primary pathway was from direct radiation through exposure to soil. A maximum total HI of 1500 was calculated for this same receptor under the same land use scenario, with over 74 percent attributable to total uranium and mercury.

7.6.4 Ecological Risk Assessment

The primary purpose of the Site-Wide Ecological Risk Assessment was to determine if radiological and nonradiological contaminants associated with actions at the FEMP represent a current or future risk to ecological receptors inhabiting this facility and nearby off-property areas, including the Great Miami River. These receptors include all organisms, exclusive of humans and domestic animals, that may be potentially exposed to FEMP contaminants.

The Site-Wide Ecological Risk Assessment focused on those on- and off-property areas not likely to be remediated (i.e. not included in Operable Units 1, 2, 3 or 4), based on human-health concerns. This was based on the assumption that remediation of the other operable units would reduce riskd to both human and ecological receptors. The site was segmented into study areas, as illustrated in Figure 7-3, to facilitate the completion of the assessment. On-property study areas were defined by habitat type (for example, grassland) and the size of the home range of receptor species used in the models developed to quantify total radiation doses. In addition to these study areas, hazards associated with contaminant concentrations in soil in off-property areas, as well as sediment and surface water contaminant concentrations from the Great Miami River, were assessed.

The results of this assessment determined that surface soil contamination by uranium in study area C represented the single greatest source of risk to terrestrial ecological receptors, both in terms of total radiological dose and as a heavy metal. Soil concentrations of uranium and other radionuclides

outside this area resulted in absorbed doses below the target level dose of 36.5 rad/year used to evaluate potential risk to these receptors.

Other soil contaminants were present in various on-property locations, but with the exception of manganese, appeared to be relatively limited in distribution. Comparisons of the following soil contaminants to benchmark criteria, considered protective of ecological receptors, indicate that the receptors that come in contact with these inorganic soil contaminants may be at risk: aluminum, cadmium, manganese, molybdenum, silver, and zinc. Organic soil contaminants present in concentrations that may represent a risk to ecological receptors were confined to study areas A and B and included benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, chrysene, and fluoranthene.

No toxicologically based criterion could be identified for uranium in sediment. Although a review of the literature suggests that this contaminant is characterized by limited biological availability, the concentrations present in sediment collected from on-property locations on Paddys Run greatly exceeded upstream concentrations and may pose a risk to benthic organisms inhabiting this portion of the creek. Sediment uranium concentrations were low or undetected in samples collected from off-property locations.

In addition to the potential risk associated with uranium, sediment collected from on-property Paddys Run locations also contained barium, cyanide and manganese in concentrations that exceeded sediment benchmark criteria. Benthic organisms associated with this portion of Paddys Run are at risk as a result of exposure to these sediment contaminants. Manganese was the only off-property Paddys Run sediment contaminant present in concentrations that may adversely impact aquatic biota. This contaminant was also present in sediment collected from the Great Miami River downstream from the FEMP NPDES outfall as were barium, phenanthrene, iron, lead and zinc.

The maximum concentrations of aluminum, ammonia, bis(2-ethylhexyl) phthalate, cadmium, and lead measured in surface water samples collected from on-property locations on Paddys Run exceeded benchmark criteria. Mean surface water contaminants present in samples collected from this location in concentrations greater than background were aluminum, bis(2-ethylhexyl) phthalate, and lead. Of these contaminants, bis(2-ethylhexyl) phthalate contributed the most to the average cumulative risk posed to aquatic biota inhabiting this portion of the stream. Terrestrial organisms exclusively using this reach of Paddys Run or drainageways in study areas A, E, and G as a source of drinking water,

may be at risk. However, risks to ecological receptors ingesting water from the pilot plant drainage ditch are far higher.

Concentrations of bis(2-ethylhexyl) phthalate greater than the benchmark criterion were also measured in surface water samples collected from off-property locations on Paddys Run. In addition to this contaminant, the maximum concentrations of ammonia and lead also exceeded benchmark criteria. However, only ammonia and bis(2-ethylhexyl) phthalate contributed to the average cumulative risk in this section of the creek. The majority of risk posed to aquatic biota inhabiting this section of the creek was associated with elevated concentrations of ammonia. Terrestrial biota ingesting water from off-property locations on Paddys Run may also be at risk.

Representative concentrations of ammonia exceeding the benchmark criterion were only detected in surface water samples collected from the Great Miami River upstream of the FEMP NPDES effluent outfall. Mercury was the only other contaminant present in surface water samples greater than the benchmark criterion and contributed significantly to the cumulative risk posed to aquatic biota inhabiting this reach of the river. Terrestrial ecological receptors relying exclusively on this portion of the Great Miami River may also be at risk.

Cadmium, iron, and lead were identified as contaminants that may be adversely impacting aquatic biota inhabiting the Great Miami River downstream of the FEMP NPDES effluent outfall and upstream from its confluence with Paddys Run. Terrestrial ecological receptors relying exclusively on this portion of the Great Miami River as a source of drinking water may also be at risk.

More contaminants were present in concentrations exceeding benchmark criteria in surface water samples collected from the Great Miami River downstream from its confluence with Paddys Run than were present in samples collected from upstream locations on the river or from sampling areas on Paddys Run. Values for aluminum and silver were far greater than benchmark values and contributed significantly to the cumulative risk posed to aquatic biota inhabiting this portion of the river. The relatively large number of surface water contaminants associated with this portion of the Great Miami River also represents a significant risk to terrestrial biota that rely exclusively on this section of the river as a source of drinking water.

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The results of the Site-Wide Ecological Risk Assessment indicate that a number of contaminants are present in soil, surface water and sediment in concentrations that may pose a risk to ecological receptors. These contaminants include uranium and a number of other heavy metals. Not only do these contaminants pose a current risk to ecological receptors but, because they do not degrade, continued release of these contaminants may result in a long-term risk to ecological receptors.

7.6.5 Uncertainties

The types and magnitudes of uncertainties associated with each stage of the process are of major importance for risk assessments at the FEMP. Uncertainties associated with calculations that occur in the early stages of the process become magnified as the results of the calculations are used in the later stages of the process.

Generally, risk assessments carry two types of uncertainty: measurement uncertainty, which refers to the usual variance that accompanies scientific measurements; and uncertainty associated with inadequate data to complete the toxicity and risk assessments.

The ultimate goal of the risk assessment process is to provide an objective, realistic, and balanced risk estimate for risk management decisions. Until recently, Superfund risk assessments based on the Risk Assessment Guidance for Superfund (EPA 1989a) yield calculated risks only for RME individuals, with risk estimates actually exceeding the high end risk.

Adequacy of the Data Base

The database used for assessing risk can contribute a large degree of uncertainty to the selection of constituents of potential concern and the development of exposure point concentrations. Overall the databases used for soil and groundwater are adequate for risk assessment purposes. However, for sediment and surface water at some locations, the exposure point concentrations were derived from relatively few samples. Hence, in such circumstances, the maximum values were used. Therefore the probability of underestimating risk due to an inadequate database is low.

Selection of Constituents of Potential Concern

The cumulative impacts of the uncertainties associated with the selection of CPCs on the results of the exposure and risk assessments are judged to be minor. This is because the majority of the risk for most receptors is attributable to exposures to uranium, thorium, and radium and their progeny in the

surface soil of Operable Unit 5. The relative contribution from this group of radionuclides to the total risk are so great in most instances that the total risk would not change significantly if most of the other constituents were added or deleted from the list of constituents selected for evaluation in this risk assessment.

Exposure Point Concentrations

The uncertainties associated with exposure point concentrations collectively tend to overestimate the concentrations expected in groundwater and from aerial deposition. The use of these modeled concentrations may result in risk one or two orders of magniture larger than actually would occur.

Selection of Receptors

The receptors selected for evaluation in this assessment generally reflect and encompass those types of activities which can define the RME individual. Some of these receptors, such as the on-property farmer living in the former production area, may possibly exist in the future but do not represent probable receptors. Risks to such a receptor may overstate risk from the property when considered against more plausible land-use alternatives.

Selection of Exposure Factors

Each exposure factor selected for use in this risk assessment has some uncertainty associated with it. Generally these factors are based on surveys of physiological and lifestyle profiles across the United States. The attributes and activities studied in these surveys generally have a broad distribution. To avoid the underestimation of exposure, this risk assessment follows EPA's recommendation and uses the 95th percentile for most of the exposure factors.

A major uncertainty associated with predicting future exposures at the FEMP is the future disposition of the property itself. Because it is not possible to accurately predict what the future uses of the land may be, or how much remediation the site may undergo, the most conservative (rather than the most likely) land use is evaluated, as stipulated by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). As noted in Section A.3.0, one of the on-property residents evaluated under future land use for Operable Unit 5 is the resident farmer. An agricultural receptor is assumed to represent the upper-bound values for the exposure assessment. Comparison of the RME adult to the central tendency adult illustrate the range of uncertainty associated with the application of the future land-use scenario to Operable Unit 5.

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Toxicity Assessment

Considerable uncertainty is associated with the qualitative (hazard assessment) and quantitative (dose-response) evaluations of a CERCLA risk assessment. The hazard assessment deals with characterizing the nature and strength of the evidence of causation, or the likelihood that a chemical that induces adverse effects in animals will induce adverse effects in humans.

A significant source of uncertainty for calculating risks from radionuclides in surface soil is the use of EPA slope factors for external radiation exposure. In deriving these slope factors, EPA has assumed that an individual continuously stands on an infinitely thick slab of soil with a uniform radionuclide concentration. To manage complicated calculations for photon attenuation and scattering in soil, EPA has assumed that the activity in the slab source is present on an infinite plane with uniform surface concentration. The slope factors for external radiation exposure are, therefore, based on calculated exposures (and associated risks of cancer incidence) from the hypothetical plane source.

In addition, EPA calculates slope factors for ingestion of many radionuclides using the maximum value for the gastrointestinal absorption factor. The actual chemical form(s) that influence the magnitude of this absorption factor have not been considered.

Summary of Uncertainties in Operable Unit 5 Baseline Risk Assessment

Uncertainties encountered during the preparation of this assessment are based on the unique considerations inherent in Operable Unit 5. While many of the uncertainties are shared between operable units, others are specific to Operable Unit 5. This is due primarily to the much larger area of Operable Unit 5 and the volume and variety of environmental media evaluated.

Many of the quantities used to calculate exposures and risks in this report are selected from a distribution of possible values. For the RME scenarios, the value representing the 95th percentile is generally selected for each parameter to ensure that the assessment bounds the actual risks from a postulated exposure. This risk number is used in risk management decisions, but does not indicate what a more average exposure might be or what risk range might be expected for individuals in the exposed population. To address these issues, a central tendency risk estimate was prepared for the maximally exposed.

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7.6.6 Constituents of Potential Concern

Table 7-11 lists the risk-based constituents of potential concern (CPCs) for the Operable Unit 5 study area.

7.6.7 Preliminary Remediation Goals

Table 7-12 presents the preliminary remediation goals (PRGs) for uranium by media, because uranium is the predominant contaminant in Operable Unit 5. A complete list of PRGs by media is included in Appendix A.7.

7.7 POTENTIAL DATA LIMITATIONS AND RECOMMENDED ACTIONS

This section discusses limitations of the characterization data collected under the RI. The primary objective in characterizing the nature and extent of contamination in the RI was to collect data sufficient to:

- Perform the baseline and ecological risk assessments
- Support the development and evaluation of remedial alternatives under the FS for Operable Unit 5.

Characterization activities performed under the Operable Unit 5 RI focused on obtaining the quality and quantity of data necessary to meet the stated RI objectives.

During the course of collecting and evaluating data for the Operable Unit 5 RI, the reduced quality or quantity of certain data sets imposed limits in meeting the stated RI objectives. Table 7-6 summarizes observed data limitations, identifies their significance toward achieving the RI objectives, and provides actions taken or recommended to resolve these limitations. As apparent in the table, acceptable means to resolve the data limitation were identified. Each of the data limitations is summarized, however, to demonstrate that it was recognized and addressed as part of the RI.

In general, the majority of the data limitations identified were resolved within the scope of the RI. Those uncertainties requiring further mitigation, while not imposing errors of omission within the scope of the RI, will be appropriately managed within preliminary stages of the FS and through completion of treatability studies.

This identification of data limitations and the recommended actions is not intended to discredit the RI, but to highlight the fact that the nature and extent of contamination are determined and the risks are

calculated for hypothetical receptors using well-defined and strict methods. Refinements of Operable Unit 5 characterization data, exposure assessment models, and risk characterization information could reduce uncertainties in the RI and in the baseline risk assessment methods. However, there is no benefit to be gained since projected risk greatly exceeds acceptable regulatory thresholds for remedial action.

7.8 RECOMMENDED REMEDIAL ACTION OBJECTIVES

The contaminated environmental media in Operable Unit 5 represent a current source of exposure to human and ecological receptors. This existing contamination could also be further transported through the environment due to natural air resuspension and surface water and groundwater migration. RAOs for contaminated media must be formulated to achieve the overall goal of protecting human health and the environment by isolating, removing or treating the contaminated media.

During the early stages of the RI/FS, as stated in the Site-Wide Characterization Report, preliminary remediation goals (PRGs) were developed and used as action levels to determine if chemical and radiological constituents in the environment needed to be addressed further. This RI Report identified CPCs for each affected media and their associated baseline risks to human health and the environment, which along with the PRGs are factored into the establishment of RAOs. Specific PRG values are currently under refinement and will be fully discussed and presented in the Operable Unit 5 FS Report.

The primary goals of RAOs are to ensure site-wide compliance with:

- Chemical-specific applicable or relevant and appropriate requirements (ARARs) and other TBC factors
- EPA guidance for risk to public health from exposure to hazardous substances
- EPA guidance for risk to ecological receptors from exposure to hazardous substances
- Regulatory standards for control of radiation and radioactivity in the environment.

In accordance with EPA guidance, RAOs are being used as the basis for developing detailed remedial alternatives in the FS. RAOs for each media were developed as part of the Operable Unit 5 Initial

Screening of Alternatives Report and are summarized in Table 7-7. A number of response actions or remedial action alternatives are under consideration to achieve these RAOs. These remedial action alternatives, in addition to the no-action alternative, include both environmental media removal/extraction and nonremoval alternatives. The nonremoval/extraction alternatives range from simple containment of the contaminated soil to in situ stabilization of soil coupled with containment technologies. The removal alternatives involve various combinations of waste removal technologies, post-removal actions, and waste disposal actions. The postremoval actions include soil stabilization, soil washing, water treatment, and on-property disposal of soil and treatment sludges in an engineered waste disposal facility, or off-site disposal. These remedial alternatives are being evaluated under the Operable Unit 5 FS where they will be fully developed to satisfy the established RAOs.

7.9 FINDINGS AND CONCLUSIONS

The following is a summary of the findings and conclusions as presented in this RI report:

7.9.1 Facility Description and History of Operations

- The FEMP was operated from 1952 through 1989 to produce high purity uranium materials to support defense related activities. Limited processing of thorium was also conducted at the FEMP.
- Most hazardous substances found at FEMP were introduced as impurities in feed materials (i.e., uranium ore, uranium ore concentrates, thorium compounds, and irradiated uranium from plutonium production facilities) or used in the production process.
- Process knowledge was used extensively in guiding characterization efforts and identifying sources of contamination in environmental media.

Sources of Contamination

- In excess of 179,000 kilograms (394,000 pounds) of uranium and 6500 kilograms (14,000 pounds) of thorium are estimated to have been released as particulates from FEMP dust collector and wet scrubber stacks over the 38-year production history of the facility. The Centers for Disease Control is currently reevaluating historical emissions.
- In excess of 80,200 kilograms (177,000 pounds) of uranium and 490 kilograms (1100 pounds) of thorium are estimated to have been released to the Great Miami River through the FEMP outfall pipeline.
- From the beginning of production at the FEMP through 1986, when the storm water retention basin was installed, the SSOD, which discharges to Paddys Run, served as the primary receptor of storm water runoff from the production area storm sewer collection system.

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- Paddys Run has been the primary pathway for off-property migration of contaminated surface water from the FEMP. Paddys Run has eroded through the glacial overburden and flows directly across the underlying Great Miami Aquifer. Thus, in addition to facilitating the off-property migration of FEMP surface water, Paddys Run is a direct pathway for contamination to the aquifer by streambed infiltration.

- The Great Miami River is the principal surface water feature of the FEMP and the ultimate receptor for groundwater in the area of, and surface water discharged from the FEMP. The three principal pathways for FEMP discharges to enter the river are effluent from the outfall line, surface water flow from Paddys Run, and surface water runoff from the eastern portions of the FEMP property.

- Unmonitored releases of hazardous substances to soil took place during production operations. These releases were most significant in areas of the facility where concentrated acids were used and wet processing took place, such as Plant 2/3, Plant 6, Plant 8, Plant 9 and the Pilot Plant.

- Resuspension of particulates and vertical transport of leachate from the Operable Units 1, 2 and 4 waste units resulted in environmental media contamination within the waste storage area.

- Releases of waste water from underground piping systems and in-ground sumps occurred, resulting in localized contamination of subsurface soil and perched groundwater in the glacial overburden.

- The form of the contaminants released to the environment significantly influences the leachability into the environment. For example, of the total airborne emissions from the processing plants, 73 percent was in a form considered minimally leachable, 24 percent was in a moderately leachable form, and 2 percent was in a form considered most leachable.

7.9.2 Study Area Investigations

- Extensive site investigations were performed to assess the nature and extent of contamination in all affected media, both on- and off-property. Potentially impacted biological and cultural resources were inventoried.

- Site investigations employed a phased characterization approach. Investigations were systematically expanded based upon the progressive evaluation of collected data. More than 30 individual addenda were issued to the RI/FS Work Plan to accommodate this phased characterization approach.

- More than 1300 borings were completed, of which 750 were completed as monitoring wells. More than 14,000 environmental samples were analyzed, adding to a comprehensive environmental database which now contains more than 1.5 million discrete data elements.

- A rigorous data validation process was applied to all analytical data used to support the risk assessment process. This process required the development of a "first of its kind" radiochemical data validation procedure.

- All RI samples were collected in strict accordance with standard operational protocols defined within the RI/FS Work Plan, including addenda, and quality assurance plans.

7.9.3 Physical Characteristics of the Site

- The FEMP is located in the Great Miami River basin with natural surface drainage primarily to the west toward Paddys Run. This tributary loses flow to the underlying Great Miami Aquifer along most of its path due to its highly permeable channel bottom which is eroded into the Great Miami Aquifer.
- The FEMP rests on a 20- to 50-foot thick glacial overburden which overlies a buried sand and gravel aquifer. The glacial overburden is predominantly saturated, clay-rich till that contains interbeds of coarser grained sediment. Water in the glacial overburden is considered to be perched above the Great Miami Aquifer.
- The migration of water within the glacial fill is very slow. Maximum vertical flow velocity is approximately 2 feet per year and the maximum horizontal flow velocity is approximately 70 feet per year.
- Maximum horizontal flow velocity in the Great Miami Aquifer is approximately 1000 feet per year.
- Under the FEMP, the Great Miami Aquifer is 150- to 200- feet thick and is divided into upper and lower portions by a clay interbed up to 20 feet thick. The aquifer generally flows from west to east with a southerly component under the southern portions of the FEMP. The Great Miami Aquifer has been designated as a sole-source aquifer by the EPA under the provisions of the Safe Drinking Water Act.
- No federally listed threatened or endangered biological species have been observed on the FEMP or in the immediate vicinity. Several state listed threatened and endangered plant and animal species are known to occur in the region of the FEMP or have been recorded during surveys on the FEMP property.

7.9.4 Nature and Extent of Contamination

- Because the FEMP processed more than 362,000,000 kilograms (398,000 tons) of uranium metal during its production lifetime, uranium is anticipated to be the primary contaminant. Thorium-232 was also refined at the FEMP. Isotopes of uranium and thorium, as well as various inorganics, were impurities in uranium ores and ore concentrates. Several fission and activation products are also expected, since the FEMP processed recycled uranium that had been irradiated and reprocessed at Hanford.
- Predominant inorganic chemicals used in the production processes included nitric acid, hydrochloric acid, hydrofluoric acid, magnesium metal, calcium hydroxide, and calcium-magnesium carbonate. Organic materials included lubricants, cutting oils, coolants, water soluble oil, PCBs from lubricants and electrical equipment, pesticides, herbicides, solvents, and cleaning fluids.

Air and Direct Radiation

- The maximum radon concentration recorded was 2.9 pCi/L observed at a radon monitoring station located at the southwest corner of the former production area in 1988. None of the observed concentrations exceeded either the DOE guideline of 3.0 pCi/L above background or the EPA limit of 4.0 pCi/L for indoor radon concentrations.

- The average annual concentration of airborne uranium at each FEMP fence line monitoring station was well below the DOE guideline of 0.1 pCi/m^3 during the period 1988 through 1993. Data show a general decrease in airborne uranium concentrations along the FEMP fence line since production operations ceased in 1989.

Surface Water and Sediment

- Several removal actions and other projects have mitigated the majority of releases of contaminated surface water runoff from the site. However, several uncontrolled site drainages continue to adversely affect the water quality in Paddys Run.

- During the period from 1986 to 1993, the highest annual average concentration of uranium in the Great Miami River was 2.5 μg/L, detected downstream of the confluence of Paddys Run with the Great Miami River. The data indicate that since 1991, annual concentrations at all sampling locations have been below 2 μg/L. Total uranium was detected in Great Miami River sediment collected in 1993 at concentrations ranging from 2 to 11 mg/kg.

Soil

- Above-background concentrations of uranium were detected in surface soil from across much of the FEMP, with the most elevated concentrations residing under the process areas and the sewage treatment plant areas. Surface soil containing uranium concentrations slightly elevated (5 mg/kg) from background were detected up to 3 miles from the FEMP.

- Elevated uranium concentrations were detected to depths of over 20 feet in portions of the FEMP production area and at select other on-property locations, typically aligned with areas where large quantities of acids or other liquids were used in the former uranium purification process. Elevated radium concentrations were found in surface soil at isolated locations in the former production area, the waste storage area, and the subsurface soil west of the K-65 silos.

- Elevated concentrations of thorium were found in surface soil in areas adjacent to former thorium processing facilities and storage areas.

- The occurrence of above-background concentrations of inorganic constituents were noted at widespread locations across the former production area in surface soil, and sporadically in subsurface soil. Volatile and semivolatile

organic constituents and PCBs were found in select samples in the vicinity of all major FEMP processing facilities.

- The vast majority of contaminants at the FEMP are generally contained within the area defined by the 20 mg/kg uranium isoconcentration line.

Perched Groundwater

- The principal groundwater contaminant is uranium, detected in unfiltered samples at above-background concentrations in 268 of 275 perched groundwater wells (97 percent). The area of uranium contamination with concentrations greater than 5 μg/L covers an area over 500 acres.
- Characteristic patterns of inorganic contamination were identified in the perched groundwater beneath Plant 2/3, Plant 6, Plant 9, the K-65 silos, and the waste storage area.
- Organic compounds were found in perched groundwater, generally in low concentrations, in virtually all areas of the former production area as well as the waste storage area.
- The extent of other radionuclide (including technetium-99), inorganic, organic, and general chemistry parameters generally falls within the extent of uranium contamination.
- Seven broad areas where uranium and other contaminants are present at above background concentrations in the perched groundwater and which have multiple sources to which contamination is attributed include:
  - Production area
  - Sewage treatment plant area
  - South Field/flyash pile area
  - K-65 silos area
  - Waste pit/solid waste landfill area
  - Fire training area
  - Lime sludge pond area.
- Slightly elevated uranium contamination exists outside these seven major areas, primarily as a result of air deposition of plant air emissions and subsequent leaching by infiltrating rain water.

Great Miami Aquifer Groundwater

- Uranium is the principal groundwater contaminant in the Great Miami Aquifer. The extent of every other contaminant, except sulfate, generally falls within the limits of uranium contamination is defined by the 5 μg/L contour line of total uranium based on unfiltered samples.
- The primary sources of contamination to the Great Miami Aquifer are six point or line sources, which produce six distinct contaminant plumes. The plumes that extend away from the six FEMP sources are each different in terms of the lists of constituents which comprise the contamination in each plume.

- Two of the six FEMP plumes, South Plumes A and B, are commingled with contaminant plumes that originate from an independent industrial facility located south of the FEMP, the PRRS.
- Contamination of the Great Miami Aquifer is largely confined to the uppermost portion of the aquifer. In general, each plume is most laterally extensive at the top of the aquifer covering a total of over 300 acres.
- Low concentrations (up to 2 parts per trillion) of technetium-99 were detected in characteristic patterns beneath the waste storage area.
- Uranium progeny, as well as thorium-232 and its progeny, and fission/activation products (with the exception of technetium-99), were only detected in isolated wells.

Biota

- Isotopes of uranium were detected in select samples at low concentrations from all sample groups.
- The fission products, strontium-90 and cesium-137, were generally not detected above laboratory detection limits. Select samples of grass roots and a single cucumber sample did indicate cesium-137 levels above the detection limits.

7.9.5 Contaminant Fate and Transport

- All models used for Operable Unit 5 contaminant fate and transport modeling are improved or newly developed according to a previously submitted overall model improvement plan and the requirements of the Operable Unit 5 baseline risk assessment. Development and applications of these models were presented to EPA and OEPA in a series of technical information exchange meetings.
- Radionuclides were the predominant contaminants associated with the Operable Unit 5 air transport analyses. The maximum annual average on-property concentrations calculated for the radionuclide contaminant group were associated with uranium-238 uranium-234, radium-226, and thorium-230. The maximum calculated annual average concentrations for the inorganic contaminant class were associated with the more commonly occurring soil inorganics such as aluminum, calcium, iron, magnesium, and potassium. Maximum off-site concentrations for arsenic, cadmium, iron, and lead were generally an order of magnitude lower than the maximum on-property concentrations. The maximum annual average concentrations for the volatiles, semivolatiles and PCB contaminant groups occurred within the center of the production area. Maximum annual average off-site concentrations for the volatile, semivolatile and PCB groups were generally 1 to 2 orders of magnitude lower than the calculated on-property concentrations.
- The maximum sediment concentration, 3380 mg/kg total uranium, was calculated to occur in the storm sewer outfall ditch. Most of the other radionuclides were predicted to also have their maximum concentration in the storm sewer outfall ditch.

- Maximum sediment concentrations for inorganics were predicted to occur in the east side drainage ditch. The maximum concentration predicted was for magnesium (31,500 mg/kg). The highest concentration predicted for an organic contaminant was for Aroclor-1254 (2.09 mg/kg) in the storm sewer outfall ditch.

- Magnesium was predicted to be the predominant contaminant in surface water, followed by total uranium, manganese, and cyanide. The predicted maximum concentration of total uranium in Paddys Run was 0.17 mg/L. The maximum uranium concentration in the Great Miami River at the mouth of Paddys Run was predicted to be 0.008 mg/L.

- The maximum concentration and yearly loading to the Great Miami Aquifer from the surface water bodies were predicted to be highest under the SSOD for most of the CPCs. The highest loading and concentration were for magnesium with a predicted concentration under the SSOD of 183 mg/L and a loading of 159,000 kg/year.

- At the end of the baseline condition (i.e., 70 years), during which the South Groundwater Contamination Plume recovery well system and storm water runoff controls were assumed to be in operation, the current South Plume will be significantly reduced in both size and concentration.

- The production area will become the major source of groundwater contamination to the east of the FEMP. The FEMP fence line concentration of uranium-238 is predicted to reach its maximum (which will occur on the east side of the FEMP) in the 560th year.

7.9.6 Risk Assessment

Baseline Risks

- Sufficient information was assembled during the course of the RI to permit the assessment of baseline risk to hypothetical receptors. Due to identified data limitations, certain assumptions were made, the aggregate of which are judged to positively bias the potential risk (i.e., over estimate risks to the RME receptor). The confidence level of the risk assessment, however, is sufficient to support risk-management decisions.

- Risk assessment for current land use and the current level of access control estimates the incremental lifetime risk of acquiring cancer (ILCR) to a maximally exposed off-property farmer of up to 1×10^{-2} (1 chance in 100).

- The maximum estimated risk to a future farmer residing and farming in the former production area is up to 6×10^{-2} or 6 chances in 100 of acquiring cancer over a 70-year residence.

Ecological Risks

- A number of contaminants are present in soil, surface water and sediment in concentrations that may pose a risk to ecological receptors. These contaminants include uranium and a number of other heavy metals.

7.9.7 Data Assessment

- The data as assembled in the RI is sufficient to meet the stated objectives of the RI by providing a detailed understanding of the nature and extent of constituents originating from the FEMP, their impact on the surrounding environment, and the associated risks posed to human health and the environment, both at present and for future postulated conditions.
- The RI is sufficient to meet the information needs of the Operable Unit 5 FS and to support the analysis of potential remedial action alternatives.
- No additional site characterization activities are planned or necessary to support decision-making and preparation of a ROD.

7.9.8 Final Conclusion

The baseline risk assessment for Operable Unit 5 has succeeded in establishing an upper bound that is sufficient for risk mangers to make decisions regarding the need for remedial actions. Based on the results of the site investigations and risk calculations, the risks associated with Operable Unit 5 exceed generally accepted regulatory thresholds, thereby necessitating remedial activities. Viable remedial action alternatives will be evaluated in the Operable Unit 5 FS.

TABLE 7-1

ENVIRONMENTAL INVESTIGATIONS AT THE FEMP

Work Plan Title	Media	Program Start Date
Tarzwell, 1952 Report on Fish Population and Environmental Conditions...	G	'51
Trautman, 1957 The Fishes of Ohio	G	'57-'81
Environmental Monitoring Program	B, C	'60s
Bauer, et al. 1978 Fishes of Paddys Run Creek and the Dry Fork of the Whitewater River	G	'72-'73
Environmental Monitoring - Ongoing Produce	G	'73-94
Pomeray, et al. 1977 Final Report on Ecological Assessment of the FMPC	G	'77-'79
OEPA, 1982, 1989 Macroinvertebrate Surveys of the Great Miami River	G	'82-'89
Environmental Monitoring - Ongoing Milk	G	'83-'94
Miller et al. Unititled Fish Studies on the GMR	G	'84-92
Environmental Monitoring - Ongoing Fish	G	'84-'93
Environmental Monitoring - Ongoing Grass sampling	G	'84-'94
RCRA Detection Program	C	'85
USGS, 1985-1990 Water Quality Data collected from Great Miami River	G	'85-'90
Remedial Investigation/Feasibility Study Acute and Chronic Toxicity Measurements of Wastewater Discharged...	G	'86-'87
Remedial Investigation/Feasibility Study Biological Resources Program (Task 3.5)	G	'86-'87
Facemire et al. 1990 Biological and Ecological Site Characterization of the FMPC	G	'86-'87
Guttman and Redding Radionuclide Contamination as an Influence... Periodical Cicada Populations	G	'87
Pre-RI/FS Wells	B, C, G	Pre Aug '87
RI/FS Work Plan	A, B, C, F	Aug '87
Hydrogeologic Study of FMPC Discharge to the Great Miami River	F	Sep '87
RCRA Groundwater Sampling	C	Nov '87
Off-site Groundwater Sampling	C	'88
Remedial Investigation/Feasibility Study Site-Wide Characterization Report (Indian bat and Tiger beetle studies)	G	'88

TABLE 7-1 (Continued)

Work Plan Title	Media	Program Start Date
Remedial Investigation/Feasibility Study Salamander Studies	G	'88-'93
Drum Baling Area Investigation	A, E	Mar '88
RCRA Groundwater Quality Assessment Program	C	May '88
Production & Additional Suspect Area Work Plan	A, C, D	Nov '88
24-Well Program	B, C	Nov '88
10-Well Program	B	Mar '89
RCRA Groundwater Sampling	C	Jun '89
Paddys Run Road Site RI/FS	B	Jun '89
Bench-Scale Groundwater Permeability Study	B	Jun '89
Possible Hydrocarbon Contamination Sampling	A, C	1990 ??
Remedial Investigation/Feasibility Study Wetlands Delineation	G	'90
31-Well Program	B, C	Jan '90
Outfall Pipeline Borings/Manhole 180	D	Feb '90
South Plume Groundwater Sampling Plan	B	Mar '90
Additional Monitoring Well Program	B, C	May '90
Addendum - 6 Additional Wells	B	Jun '90
Additional Monitoring Well 3032	C	Sep '90
8 Additional Groundwater Monitoring Wells	A, C	Sep '90
Paddys Run South Seepage Investigation	B	Oct '90
Guttman et al. 1990, 1992 Sampling and Genetic Analysis of off-site Treefrogs	G	'90
Guttman et al. 1990, 1992 Characterization of the Treefrog Null Allele	G	'91
Osborne et al. 1991, 1992 Characterization of the Treefrog Null Allele	G	'91
Osborne et al. 1991, 1992 Characterization of Reproduction and Growth of 1991 American robins...	G	'91
Remedial Investigation/Feasibility Study Engineered Waste Management Facility	G	'91
Waste Pit Area Runoff Control (WPAROC) Hand Augering	E	April '91
Add-on to PASA Work Plan	A	Mar '91
Additional Sampling Activities for OU2	A, D	May '91
Plant 1 Pad Hand Augering Pre-Excavation Sampling and TCLP Metals	E	May '91
K-65 Silo Berm Vertical Boring & Analysis Plan	D	Summer '91
K-65 Silo Subsoils & Perched Groundwater Sampling & Analysis Plan	D	Jul '91

TABLE 7-1 (Continued)

Work Plan Title	Media	Program Start Date
OU1 Waste Pit Soil & Groundwater Samples	A	Jul '91
Underground Storage Tank Assessment 91	E	Jul '91
Work Plan Addendum to the Perched Water Removal Actions (Plants 2/3, 6 & 8 Recovery Wells)	A	Aug '91
Soil Investigation Plan for Dike Stability Analysis of Waste Pits 3, 5 & the Clearwell	A, D	Sep '91
Work Plan Addenda - FMPC Plant 8 Core Sampling	D	Sep '91
Miscellaneous Additional Wells for OU5	B, C	Nov '91
Engineered Waste Management Facility Sampling & Analysis Plan	A, C, D	Dec '91
Integrated Technology Demonstration Program	E	Dec '91
Miller et al. Electrofishing Survey of the GMR Sept. 92 Annual Report	G	'92
OU2 RI/FS Resampling Activities	D	Feb '92
RCRA/CERCLA Background Soil Sampling Plan	D	Mar '92
Plant 1 Pad Post-Excavation	E	Mar '92
5 Additional Borings & 2 Wells for the Engineered Waste Management Facility	A, C, D	Mar '92
4 RCRA Well Program	C	May '92
Additional Groundwater Sampling for Full HSL Analyses - Perched Groundwater Removal Action	A	Jun'92
OU5 RI/FS Work Plan Addenda	A, D, E	Jun '92
South Groundwater Contamination Plume Removal Action, Part 5	B, D	Jul '92
Sampling & Analysis Plan of Boring/Monitoring Well 1433 in the Southfield	B	Jul '92
Solid Waste Incinerator Area Sampling	E	Jul '92
South Plume Groundwater Contamination Removal Action Parts II and III	E	Jul '92
Field Support for Uranium Soils Integrated Demonstration	D	Aug '92
OU5 Work Plan Addendum for Excavation of Trenches in the Northeast Area at the FEMP	D	Aug '92
Installation of One Monitoring Well at Location 0166	B	Sep '92
RCRA Phase I Perimeter Well Installation Program	B, C	Sep '92
Sewage Treatment Plant Incinerator Area Sampling Phases II and III	E	Sep '92
Annual Sampling of 7 Perched Groundwater Removal Action Extraction Wells	A	Oct '92
Work Plan Addendum for the OU5 Outfall Line Investigation Groundwater Sampling	C	Dec '92
EBASCO Wetlands Delineation Report of the FEMP Butler and Hamilton Counties, OH	G	'92-93
Parsons, 1993 Floodplain Determination	G	'93
Remedial Investigation/Feasibility Study Sloan's Crayfish Survey	G	'93

TABLE 7-1 (Continued)

Work Plan Title	Media	Program Start Date
RCRA Phase II - Waste Pits & Production Area Well Installation	C	Jan '93
South Plume Groundwater Recovery System - Part 5, Phase II	B	Mar '93
Additional Characterization of Vadose & Perched Water in the K-65 Area	A	Mar '93
Sampling & Analysis Plan for RI/FS Work Plan Addendum - OU2	A, B, C, D, F	Apr '93
Pilot Plant Drainage Ditch Seepage & Surface Water Background Investigation	F	Apr '93
Snapshot Monitoring Well Sampling & Surface Water & Sediment Sampling	A, B, C, F	Apr '93
South Plume Groundwater Recovery System: Design, Monitoring Well Installation & Well Abandonment	B	May '93
Additional Monitoring Well Installation & Well Abandonment	A, B, C	May '93
RI/FS Work Plan Addendum - OU1	A, C	Jun '93
Plugging & Abandonment of Well No. 67 in the KC-2 Warehouse	C	Jun '93
Surface & Subsurface Soil Sampling Investigation	A, D, E	Jul '93
Great Miami Riverbank Characterization	D	Jul '93
FEMP Trap Range Investigation (surface soils)	E	Jul '93
Site Investigation to Support OU4 On-site Disposal Alternatives	D	Aug '93
FEMP Glacial Till/Vadose Zone Hydraulic Investigations Work Plan	B, C, D	Sep '93
Southwest Field Investigation	D, F	Dec '93

A - Perched groundwater
B - South plume
C - Eastern migration
D - Glacial overburden soil
E - Surface soil
F - Surface water/sediment
G - Biological resources

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TABLE 7-2
FEMP SURFACE SOIL
CONSTITUENTS DETECTED AT 5 X BACKGROUND

	Plant 1 Area	Plant 2/3 Area	Plant 4/5/7 Area	Plant 6 Area	Plant 8 Area	Plant 9 Area	Sewage Treatment Plant Area	Pilot Plant Area	Laboratory Area	Administration Area	Electrical Substation Area	Maintenance Building	Tank Farm and Boiler House	D&D Building and Drum Baling Area	Scrap Metal Pile	Graphite Furnace	KC-2 Warehouse Area	Fire Training Area	Trap Range	Area West of K-65 Silo	K-65/Clearwell Line West	Clearwell Line East	Outfall Pipeline	Great Miami Riverbank Characterization	Southwest Field Area	Northeastern Area of FEMP	Southern Area of FEMP	Western Area of FEMP	Northwestern Area of FEMP	Area Outside of FEMP Adjacent Boundary	Area 2-5 Miles Outside of FEMP Boundary
Radionuclides																															
Uranium-238	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●			●		●			●	●	●	●	●	
Total Uranium	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	
Uranium-234	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●		●			●	●	●	●	●	
Thorium-230	●	●	●			●	●	●	●	●				●	●	●		●			●					●	●	●			
Radium-226	●	●					●	●						●	●					●	●						●	●			
Uranium-235/236	●	●	●	●	●	●	●	●	●	●		●		●	●	●	●	●	●	●	●					●	●	●	●	●	
Thorium-232	●					●	●	●	●					●	●						●					●		●			
Total Thorium	●	●		●		●	●	●	●					●	●			●			●					●		●			
Radium-228	●	●				●	●	●	●					●	●											●		●			
Thorium-228	●	●		●		●	●	●	●					●	●						●					●		●			
Neptunium-237		X				X															X							X	X		
Plutonium-239/240		X					X	X	X			X				X		X	X	X	X						X	X			
Plutonium-238		X	X	X			X	X	X	X								X			X							X			
Strontium-90	●	●				●	●		●					●	●	●		●								●	●	●	●		
Technetium-99	X	X		X	X	X	X	X	X	X		X		X	X	X		X		X	X		X			X	X	X	X	X	
Ruthenium-106		X																			X						X	X			
Cesium-137	●																														
Metals																															
Aluminum																															
Antimony	X				X		X											X	X	X	X					X	X	X	X		
Arsenic																●															
Barium									●							●															
Beryllium		●			●																					●					
Cadmium	●	●		●		●		●	●			●	●			●		●		●								●			
Calcium	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●					●	●	●	●		
Chromium																															
Cobalt																															
Copper											●			●	●																
Cyanide												●				●			●							●			●		
Iron																															
Lead		●		●			●				●	●		●	●		●		●		●										
Magnesium	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●					●	●	●	●		
Manganese																															
Mercury	●	●																	●												
Molybdenum	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X					X	X	X	X		
Nickel																															
Potassium																															
Selenium																●												●			
Silicon																															
Silver	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X		X	X					X	X	X	X		
Sodium	●			●	●	●		●	●	●		●			●	●	●											●			
Thallium																															
Vanadium																															
Zinc	●						●					●			●		●	●													
Organic Compounds																															
Volatiles	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X			X					X	X	X	X	X	
Semi-Volatiles	X	X	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X		X					X	X	X	X	X	
Pesticides	X			X						X		X				X		X			X					X		X	X	X	
PCBs	X	X		X		X	X		X	X	X	X	X	X	X	X	X	X			X							X			
Dioxins/Furans																X		X										X			

● Detection greater than 5 times background

X Constituent detected but no background level obtained

Expected contamination

TABLE 7-3
FEMP SUBSURFACE SOIL
CONSTITUENTS DETECTED AT 5 X BACKGROUND

	Plant 1 Area	Plant 2/3 Area	Plant 4/5/7 Area	Plant 6 Area	Plant 8 Area	Plant 9 Area	Sewage Treatment Plant Area	Pilot Plant Area	Laboratory Area	Administration Area	Electrical Substation Area	Maintenance Building	Tank Farm and Boiler House	D&D Building and Drum Baling Area	Scrap Metal Pile	Graphite Furnace	KC-2 Warehouse Area	Fire Training Area	Trap Range	Area West of K-65 Silo	K-65/Cleanwell Line West	Cleanwell Line East	Outfall Pipeline	Great Miami Riverbank Characterization	Southwest Field Area	Northeastern Area of FEMP	Southern Area of FEMP	Western Area of FEMP	Northwestern Area of FEMP	Area Outside of FEMP Adjacent Boundary	Area 2-5 Miles Outside of FEMP Boundary
Radionuclides																															
Uranium-238	●	●	●	●	●	●	●	●	●	●					●	●				●	●			●		●		●		●	
Total Uranium	●	●	●	●	●	●	●	●	●	●		●		●	●	●		●		●	●		●	●		●		●		●	
Uranium-234	●	●	●	●	●	●	●	●	●						●	●				●	●			●		●		●		●	
Thorium-230		●		●	●		●														●										
Radium-226																				●											
Uranium-235/236		●	●	●	●	●	●	●	●						●	●					●							●			
Thorium-232								●																							
Total Thorium						●		●							●																
Radium-228	●							●							●																
Thorium-228								●										●													
Neptunium-237																					X	X									
Plutonium-239/240		X		X																X								X			
Plutonium-238				X					X											X	X						X	X			
Strontium-90	●	●		●	●	●	●								●					●						●		●	●	●	
Technetium-99	X	X		X	X	X	X	X								X				X	X							X	X	X	
Ruthenium-106																															
Cesium-137		X			X	X	X													X			X	X				X		X	
Metals																															
Aluminum																●				●											
Antimony		X		X																											
Arsenic																				●											
Barium								●				●								●											
Beryllium	●		●																	●											
Cadmium	●			●				●				●	●			●												●			
Calcium																				●											
Chromium																				●											
Cobalt																				●											
Copper																				●											
Cyanide				●								●				●				●											
Iron																				●											
Lead																				●											
Magnesium																															
Manganese																				●											
Mercury		●																													
Molybdenum																															
Nickel																				●											
Potassium																				●											
Selenium	X	X		X	X			X	X				X			X				X								X			
Silicon																															
Silver	X	X		X		X		X	X			X	X	X	X	X		X		X						X		X			
Sodium								●																							
Thallium																															
Vanadium																				●											
Zinc	●																			●											
Organic Compounds																															
Volatiles	X	X	X	X		X		X	X	X		X	X	X	X	X		X		X	X	X				X		X	X	X	
Semi-Volatiles	X	X	X	X		X	X		X	X		X	X		X	X		X		X	X					X		X			
Pesticides	X									X		X				X															
PCBs	X	X		X					X			X				X		X			X					X		X	X	X	
Dioxins/Furans																		X													

● Detection greater than 5 times background.

X Constituent detected but no background level obtained.

Expected contamination.

001304

TABLE 7-4
ISOLATED DETECTIONS OF PARAMETERS OUTSIDE THE 20 MG/KG URANIUM ENVELOPE

	Detections Within 20 mg/kg Uranium Envelope	Trap Range	Near Sewage Treatment Plant	Near K-65 Silos	Southern Area	Northwestern Area	Northeastern Area
Radionuclides							
Uranium-238	Yes						
Total Uranium	Yes						
Uranium-234	Yes						
Thorium-230							
Radium-226	—			—			
Uranium-235/236	Yes						
Thorium-232	Yes						
Total Thorium	No						
Radium-228	Yes						
Thorium-228	Yes						
Neptunium-237	Yes						
Plutonium-239/240	Yes						
Plutonium-238	Yes						
Strontium-90	No			●	■	■	■
Technetium-99	Yes						
Ruthenium-106	Yes						
Cesium-137	Yes				●		●
Inorganics							
Aluminum	Yes						
Antimony	No			X			
Arsenic	No	◐		◐	●		
Barium	No	●				●	
Beryllium	No				◐	◐	
Cadmium	No			■			
Calcium	No	■		■	■	■	
Chromium	No	◐		●			
Cobalt	No		◐				
Copper	No	◐		●	●	●	
Cyanide	No	■			◐	■	
Iron	No	●					
Lead	No	■				●	
Magnesium	No	■		■	■	■	
Manganese	No		◐				
Mercury	No	■					
Molybdenum	No	X			X	X	X
Nickel	No			●		●	●
Potassium	No					●	●
Selenium	No					●	
Silicon	Yes						
Silver	No			X			
Sodium	No				◐	◐	
Thallium	Yes						
Vanadium	No						
Zinc	No					◐	
Organic Compounds							
Volatiles	No			X	X	X	
Semi-Volatiles	Yes						
Pesticides	Yes						
PCBs	Yes						
Dioxins	Yes						

● Detection above but < 2 X 95th percentile background value.
◐ Detection 2 to 5 X 95th percentile background value.
■ Detection greater than 5 X 95th percentile background value.
X Detection where background level not recorded.
○ Detection less than 95th percentile background value.

PARAMETER	Radionuclides																	Inorganics																									Organic Compounds		General Chemistry				
	Uranium-238	Total Uranium	Uranium-234	Thorium-230	Radium-226	Uranium-235/236	Thorium-232	Total Thorium	Radium-228	Thorium-228	Neptunium-237	Plutonium-239/240	Plutonium-238	Strontium-90	Technetium-99	Ruthenium-106	Cesium-137	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Cyanide	Iron	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Potassium	Selenium	Silicon	Silver	Sodium	Thallium	Vanadium	Zinc	Volatiles	Semivolatiles	Ammonia	Chloride	Fluoride	Nitrate	Sulfate
Filter Status	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F	U/F	F	F	F	F	F	F	F	F	F	F	U	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	U	U	U	U	U	U	U
AREA																																																	
Production Area Contamination Area I						X					X	X				-	X			-	•					X		X		•							X	•			X				X				•			
Sewage Treatment Plant Area Contamination Area II				•		X			•	-	-	-	-	-		-	X		-	-	-	-	-	•	-	-	-	-	•	-	•		-	-	-	-	-	•	-	•	-	•	-	X	X	-	•	-		•
OU2 Southern Waste Units Contamination Area III						X			•		X	-	-	X	-	-	-		-	-	-	-	-	•	-	-	-	-	-	•			-	-	-	-	X	•	-	-	-	•	-	X	X	-	-	-	•	•
OU4 K-65 Silos Contamination Area IV				-		X	-	-		•	-	-	-	-	-	-	-			-	-	-			•	X	•	X	-	-			-		-		X	•	-		-		•		X	X	-		-		
OU1/OU2 Waste Storage Area Contamination Area V						X				-	-	-		-	-				•	•	•				X		X		-				-				X				X		•		X	X					
Fire Training Area Contamination Area VI						X					X	X	-		-	-	X		-	-	-	-	-	-	-	-	X	-	-	•		-	-	•	-	-	X	•	-	-	-	-	-	X	X	-	-	-	-	-
OU2 Lime Sludge Ponds Area Contamination Area VII						•	X			•	•	-	-	-	•	-	-	-	-	-	-	-	-	•	-	-	-	-	-	-	•		-	-	-	-	-	-	-	-	-	-	-	-	X	-		-	-	•

LEGEND

- Not analyzed.
- - Not above 95 percentile background value.
- X Detection where background value not determined
- • Detection above but < 2X 95 percentile background value
- Detection 2X to 5X 95 percentile background value.
- Detection greater than 5X 95 percentile background value.

TABLE 7-5
SUMMARY OF PARAMETER OCCURRENCE IN
IN SEVEN PERCHED GROUNDWATER
CONTAMINATION AREAS

DRAFT

PARAMETER

Radionuclides: Uranium-238, Total Uranium, Uranium-234, Thorium-230, Radium-226, Uranium-235/236, Thorium-232, Total Thorium, Radium-228, Thorium-228, Neptunium-237, Plutonium-239/240, Plutonium-238, Strontium-90, Technetium-99, Ruthenium-106, Cesium-137

Inorganics: Aluminum, Antimony, Arsenic, Barium, Beryllium, Cadmium, Calcium, Chromium, Cobalt, Copper, Cyanide, Iron, Lead, Magnesium, Manganese, Mercury, Molybdenum, Nickel, Potassium, Selenium, Silicon, Silver, Sodium, Thallium, Vanadium, Zinc

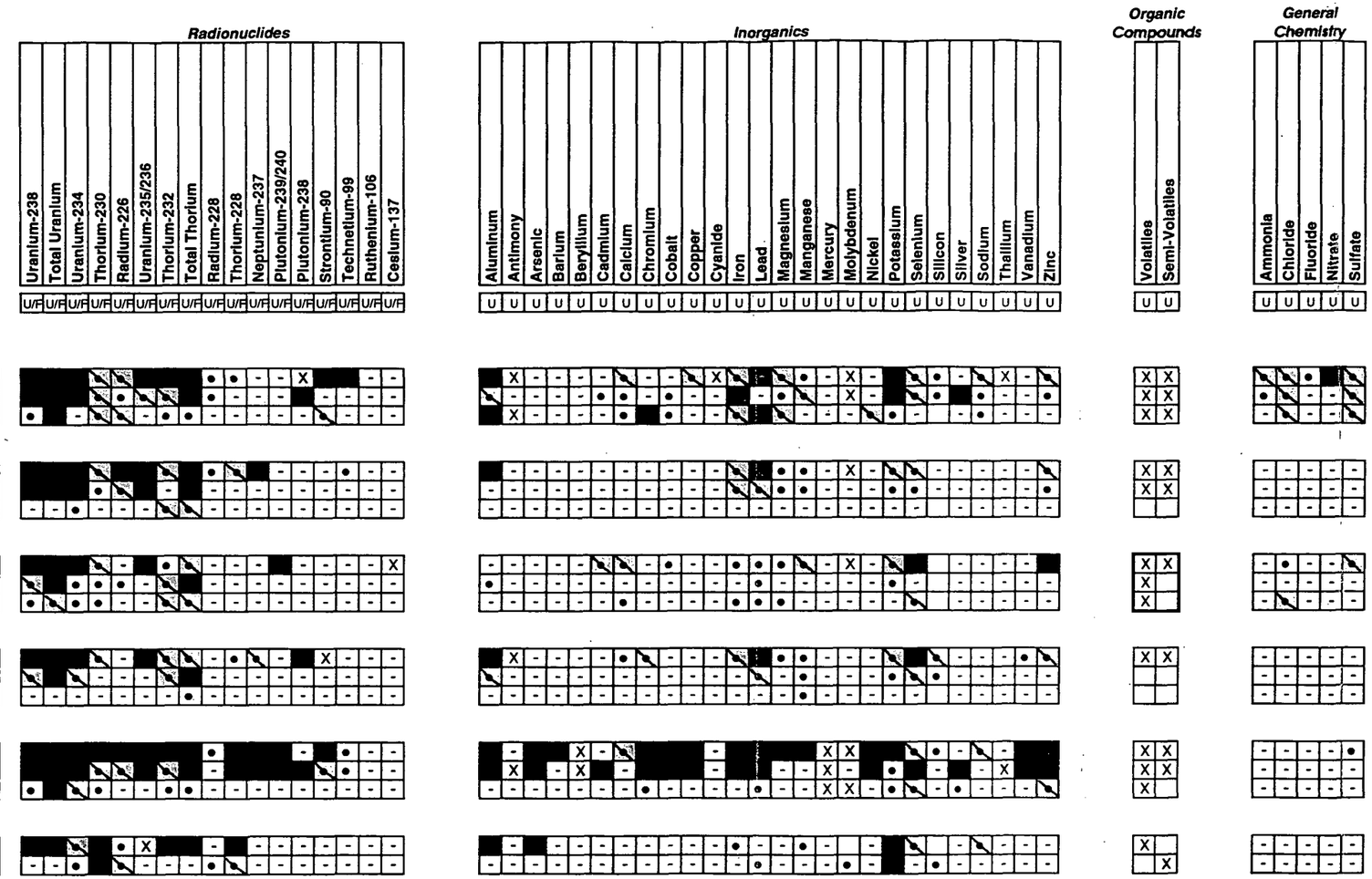
Organic Compounds: Volatiles, Semi-Volatiles

General Chemistry: Ammonia, Chloride, Fluoride, Nitrate, Sulfate

Filter Status: U/F

AREA

Waste Storage Area A Plume - Type 2
Waste Storage Area A Plume - Type 3
Waste Storage Area A Plume - Type 4
Waste Storage Area B Plume - Type 2
Waste Storage Area B Plume - Type 3
Waste Storage Area B Plume - Type 4
Plant 6 Plume - Type 2 Wells
Plant 6 Plume - Type 3 Wells
Plant 6 Plume - Type 4 Wells
South Plume A - Type 2 Wells
South Plume A - Type 3 Wells
South Plume A - Type 4 Wells
South Plume B - Type 2 Wells
South Plume B - Type 3 Wells
South Plume B - Type 4 Wells
South Plume C - Type 2 Wells
South Plume C - Type 3 Wells



LEGEND

- Not analyzed.
- - Not above 95th percentile background value.
- X Detection where background not determined.
- ● Detection above but < 2X 95 percentile background value
- Detection 2X to 5X 95 percentile background value.
- Detection greater than 5X 95 percentile background value.

TABLE 7-6
SUMMARY OF PARAMETER OCCURRENCE IN SIX GREAT MIAMI AQUIFER PLUMES

DRAFT

TABLE 7-7

RESULTS OF BIOTA SAMPLING

Media/Constituent	Above Background	Location	Comment
Garden Produce and Crops			
Isotopic Uranium	No	Off-Property, NE, SE, & NW of FEMP	
Cesium-137	Yes	Off-Property, 0.6 mi NW of FEMP	Single cucumber sample. Other samples below the detection limit.
Strontium-90	No	Off-Property, NE, SE, & NW of FEMP	
Vegetation			
Isotopic Uranium	Detected (No Background values)	On-Property to the NW, NE & East of Production Area; Along Paddys Run	Forb leaves and roots, grass, leaves and roots. One cattail and one moss sample from Paddys Run.
Cesium-137	Yes	On-Property to the SE & SW and along Paddys Run	Grass roots
Strontium-90	No	On-Property Locations	
Inorganics	Detected (No background values)	On-Property to the NW, East & SE of Production Area; On-Property along Paddys Run	Grass roots and leaves.
Organics	Detected	On-Property to the NW, East & SE of Production Area; On-Property along Paddys Run	Three samples of grass roots and leaves.
Mammals			
Isotopic Uranium	Yes	On-Property to the NW	One Unidentified Small Mammal. Not Detected In Four Other Small Mammal Samples.
Cesium-137/Strontium-90	No	On-Property Locations	

TABLE 7-7 (Continued)

Media/Constituent	Above Background	Location	Comment
Inorganics	Detected/No Background Values	On-Property to the SW of Production Area	Two Samples of Small Mammals.
Benthic Macroinvertabrates in Paddys Run			
Isotopic Uranium	Detected/No Background	On & Off-Property Locations	One Sample from Each Location.
Cesium-137/Strontium-90	No	On & Off-Property Locations	
Benthic Macroinvertabrates in Great Miami River			
Isotopic Uranium	Detected (No background values)	South of Outfall	Detected in Single Sample.
Cesium-137/Strontium-90	No	South of Outfall	
Fish in Paddys Run			
Isotopic Uranium	Detected (No background values)	NW & West of Production Area	One sample each of Bluegill & Crayfish and Crab.
Cesium-137/Strontium-90	No	NW, West and SW of Production Area	
Fish in Great Miami River			
Isotopic Uranium	Detected (No background values)	South of Outfall	Single Crayfish, Bluegill and Sucker.
Cesium-137/Strontium-90	No	South of Outfall	

TABLE 7-8

SUMMARY OF MAXIMUM CALCULATED INCREMENTAL LIFETIME CANCER RISK FOR ALL SOURCES AND PATHWAYS*

Land Use	Type of Risk	Grounds-keeper	Trespassing Youth	Exploring Youth	Off-Property Farmer	Visitor	On-Property RME Farmer	On-Property CT Farmer	On-Property (Perched Water) RME Farmer	Off-Property Child
Current Land Use With Access Control	Radiological Risk	1×10^{-3}	6×10^{-5}	NA	7×10^{-4}	3×10^{-5}	NA	NA	NA	7×10^{-5}
	Chemical Risk	1×10^{-4}	6×10^{-6}	NA	1×10^{-2}	4×10^{-9}	NA	NA	NA	4×10^{-3}
	Total Risk	1×10^{-3}	6×10^{-5}	NA	1×10^{-2}	3×10^{-5}	NA	NA	NA	4×10^{-3}
Current Land Use Without Access Control	Radiological Risk	1×10^{-3}	NA	7×10^{-5}	1×10^{-3}	5×10^{-4}	NA	NA	NA	8×10^{-5}
	Chemical Risk	1×10^{-4}	NA	8×10^{-6}	3×10^{-2}	5×10^{-9}	NA	NA	NA	7×10^{-3}
	Total Risk	1×10^{-3}	NA	8×10^{-5}	3×10^{-2}**	5×10^{-4}	NA	NA	NA	7×10^{-3}
Future Land Use As Government Reserve	Radiological Risk	1×10^{-3}	NA	NA	2×10^{-3}	NA	NA	NA	NA	1×10^{-4}
	Chemical Risk	6×10^{-5}	NA	NA	4×10^{-2}	NA	NA	NA	NA	9×10^{-3}
	Total Risk	1×10^{-3}	NA	NA	4×10^{-2}	NA	NA	NA	NA	9×10^{-3}
Future Land Use As Residential and Agricultural Land	Radiological Risk	NA	NA	NA	2×10^{-3}	NA	2×10^{-2}	1×10^{-3}	4×10^{-2}	1×10^{-4}
	Chemical Risk	NA	NA	NA	4×10^{-2}	NA	7×10^{-3}	3×10^{-4}	2×10^{-2}	9×10^{-3}
	Total Risk	NA	NA	NA	4×10^{-2}	NA	2×10^{-2}	2×10^{-3}	6×10^{-2}	9×10^{-3}

NA - Not applicable.
*Note: Risk estimates include contributing risk from background concentrations of naturally occurring substances in environmental media.
**Note: Assumes a hypothetical farmer who consumes South Plume groundwater containing the maximum measured concentrations at a rate of 2 liters per day over a 70-year lifespan.

TABLE 7-9

SUMMARY OF MAXIMUM CALCULATED HAZARD INDEX FOR ALL SOURCES AND PATHWAYS

Land Use	Type of Risk	Grounds-keeper	Trespass-ing Youth	Exploring Youth	Off-Property Farmer	Visitor	On-Property RME Farmer	On-Property CT Farmer	On-Property (Perched Water) RME Farmer	Off-Property Child
Current Land Use With Access Control	Chemical Hazard Index	5.4	1.8	NA	160*	0.00099	NA	NA	NA	830
Current Land Use Without Access Control	Chemical Hazard Index	5.4	NA	1.8	230*	0.0014	NA	NA	NA	270
Future Land Use As Government Reserve	Chemical Hazard Index	4.5	NA	NA	40	NA	NA	NA	NA	160
Future Land Use As Residential and Agricultural Land	Chemical Hazard Index	NA	NA	NA	40	NA	370	150	1500	160

NA - Signifies not applicable.
*Note: Assumes a hypothetical farmer who consumes South Plume groundwater containing the maximum measured concentrations at a rate of 2 liters per day over a 70-year lifespan.

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TABLE 7-10

POTENTIAL DATA LIMITATIONS OF THE OPERABLE UNIT 5 REMEDIAL INVESTIGATION

Potential Data Limitation	Significance to Alternatives Evaluation	Significance to Baseline Risk Assessment	Recommended Action/Justification
Surface Water/Sediment			
Limited characterization of surface water and sediment in two site drainage ditches, the northeast drainage ditch and the east side drainage ditch.	Increased uncertainty about the specific areas and volumes of soil and/or sediment potentially requiring remedial action. This increases uncertainty in the cost estimates associated with all alternatives considered for remediation of soil and sediment.	Increased uncertainty in the baseline risk assessment due to the limited availability of confirmatory data to identify the CPCs and establish source-term concentrations for surface water and sediment in the drainage ditches. Conservative assumptions have been used to ascertain risks from the surface water and sediments found in these ditches. Therefore, this could potentially result in an overestimation of the risk associated with these ditches.	No further data is required for the RI/FS process. Data has been collected from the soil found in the areas drained by these two ditches. These data were sufficient to perform fate and transport modeling of surface water runoff and infiltration from these areas. Model output was compared to data collected downstream in the northeast drainage ditch and from three feeder ditches to the east side drainage ditch. The modeling output was found to be conservative; i.e. predicted total uranium concentrations were higher than results from samples collected in the ditches. Further investigation of these ditches may be necessary during remedy implementation. The need for additional investigations will depend on final remediation goals selected for the Operable Unit 5 ROD. This, however, is a remedy implementation issue that does not require resolution for the (FS) to proceed. Sufficient information is available to establish risk-based remedial goals, develop and evaluate remedial alternatives, and select a remedy for presentation in the ROD.

TABLE 7-10 (Continued)

Potential Data Limitation	Significance to Alternatives Evaluation	Significance to Baseline Risk Assessment	Recommended Action/Justification
Surface Soil - Lateral Extent of Contamination			
Limited data are available to confirm the significance and extent of elevated concentrations of constituents detected in isolated soil samples outside the well-characterized 20 mg/kg total uranium in surface soil isopleth. Table 4-42 depicts these areas.	Increased uncertainty regarding the definition of soil volume exhibiting elevated concentrations of constituents which may potentially require remedial action.	Increased uncertainty in the derivation of risk estimates for receptors in these areas. Since the presence or absence of the constituents cannot be confirmed, the risk assessment assumed that the suspect values are supportable and represented viable mechanisms for exposure and risk to receptors. Thus this data limitation presents a potential for overestimating risk.	No additional sampling is necessary to support the RI/FS process. The extensive surface and subsurface soil data set provides a reliable delineation of the nature and extent of the CPCs in areas on the FEMP property. The data set provides a sound foundation for the comparative analysis of the alternatives which may be considered for the remediation of soil. Outside the boundary of the extent of uranium contamination in soil, delineated by the 20 mg/kg isopleth, there are four areas which can be related to site activities. These are the trap range, the northern third of the fire training area, the area adjacent to the northwest corner of Operable Unit 1, and the area west of Operable Unit 4. In the trap range area remedial alternatives will likely be based principally on the removal of lead in soil rather than uranium. The northern third of the fire training area and the areas adjacent to Operable Units 1 and 4 may require the same treatment as areas within those units. Outside these areas there are elevated concentrations of CPCs which are unrelated to known source areas. The areas are isolated and could be due to sampling errors, laboratory errors, or the result of pre-FEMP agricultural activities. Because these areas are isolated and will not impact the selection of overall remedial actions selected for primary regions of elevated concentrations, the investigation to confirm the presence or absence of isolated areas of elevated concentration should occur independently of the assessment of remedial actions for the surface soil. While such data would reduce uncertainty about the volume of soil potentially requiring action and the associated FS cost estimates, the data would not be a major factor in the comparative analysis of alternatives. Further investigations of these areas may be necessary on a case-by-case basis to determine whether land areas represented by the isolated detections require remediation. The need for additional evaluation will be dependent on final remediation goals selected for the Operable Unit 5 ROD. This, however, is a remedy implementation issue that does not require resolution for the FS to proceed. Sufficient information is available to establish risk-based remedial goals, develop and evaluate remedial alternatives, and select a remedy for presentation in the ROD.

TABLE 7-10 (Continued)

Potential Data Limitation	Significance to Alternatives Evaluation	Significance to Baseline Risk Assessment	Recommended Action/Justification
Surface Soil - Removal/Disturbance			
Surface soil over approximately 10 percent of the production area has been disturbed since the RI/FS characterization was initiated. An undetermined amount of these disturbed soils have been removed.	Increased uncertainty in the quantity of contaminated surface soil may result in an overestimate of the amount of surface soil requiring remediation. This increases uncertainty in the cost estimates associated with all alternatives considered for remediation of on-property soil.	Increased uncertainty in the baseline risk assessment due to a possible overestimate of the quantity of contaminated surface soil.	In excess of 10 percent of the production area surface soil was disturbed during the characterization of surface soil under the RI/FS. Surface soil was removed as part of removal actions, facility construction activities, and maintenance activities. The removed soil was boxed for disposal or stockpiled. Removal Action 17 has been initiated to improve the storage of potentially contaminated soil and debris. Construction of four new storage facilities will be completed by May, 1995. Disturbed soil is located in discrete regions across the production area and do not represent a reduction in the general surface soil contamination levels recorded in the production area. Therefore, while these activities resulted in a slight reduction in the total quantity of surface soil to be addressed, they did not impact the overall areal extent of surface soil contamination to be addressed under the FS. Estimates of surface soil volumes containing elevated concentrations of CPCs will be presented in the FS based upon the results of the RI, area-specific process knowledge, and knowledge of excavation, removal and other activities which could impact the concentration of CPCs in surface soil. Appropriate alternatives will be developed and evaluated to ensure that changes in the volume of surface soil potentially requiring remediation will be adequately addressed. Following remedy selection and identification of cleanup goals, additional sampling will be performed during remedial design and remedial actions to validate the FS estimates of affected media.

TABLE 7-10 (Continued)

Potential Data Limitation	Significance to Alternatives Evaluation	Significance to Baseline Risk Assessment	Recommended Action/Justification
Subsurface Soil - Vertical Extent of Contamination			
The density of data available to characterize the vertical extent of subsurface soil contamination is significantly less than that to characterize the subsurface soil above 20 feet.	Increased uncertainty in the quantity of subsurface soil which may require remediation. This increases uncertainty in the cost estimates associated with all alternatives considered for remediation of on-property soil.	Increased uncertainty in the baseline risk assessment due to the availability of limited data to establish the extent of source terms and their concentrations. To be conservative, the baseline risk assessment uses subsurface soil from above 20 feet as representative of the entire depth and therefore accounts for the highest potential concentrations. However, existing data indicate that contaminant concentrations below 20 feet are less than in the interval above.	No additional sampling is required to support the RI/FS process. Type 2, 3 and 4 wells were installed within the FEMP production area as part of the RI/FS. During their installation, subsurface soil samples were collected at preestablished intervals along the entire depth of the well. In addition, more than 300 borings and more than 200 wells were installed in the former production area, as well as other suspect areas, as part of the Production and Additional Suspect Areas (PASA) Investigation Program. This program employed process knowledge regarding the types and volumes of material handled to guide intrusive sampling activities to areas suspected of unmonitored releases to the glacial overburden adjacent to or beneath the production facilities. Based on EPA comments, borings were installed to a maximum depth of 20 feet or until perched water was encountered to avoid compromising the barrier properties of the glacial till. The soil boring analytical results indicate that broad areas of the FEMP contain elevated concentrations of uranium at shallow depths (i.e., 0 - 1.5 feet). At a depth of 20 feet, contamination is localized and centers around areas where known or suspected releases of CPCs occurred. It is therefore considered that the placement of the borings and the evaluation of the constituents in the collected samples were sufficiently broad to characterize FEMP production area source terms to the extent necessary to support the baseline risk assessment. Estimates of media volumes containing elevated concentrations of CPCs will be presented in the FS based upon the results of the previously mentioned investigation and area-specific process knowledge. Appropriate alternatives will be developed and evaluated to ensure that subsurface soil at depths below those sampled and analyzed are adequately addressed. Following remedy selection and identification of cleanup goals, additional sampling will be performed during remedial design and remedial actions to verify the FS estimates of affected media and to certify that final cleanup goals have been attained.

TABLE 7-10 (Continued)

Potential Data Limitation	Significance to Alternatives Evaluation	Significance to Baseline Risk Assessment	Recommended Action/Justification
Off-Property Soil			
The RI relies on the data set from the Litigation Study, conducted before the RI, to define the nature and extent of contamination in off-property surface soils. While this data set provides information from over 300 sampling points, the sampling density is less than that conducted on-property.	Increased uncertainty in the specific areas and volumes of surface soil potentially requiring remedial action. This increases uncertainty in the cost estimates associated with all alternatives considered for remediation of off-property soil.	Increased uncertainty in the baseline risk assessment due to reliance on a data set which was not specifically validated per the QAPP/SCQ.	No additional sampling is required to support the RI/FS process. With the exception of surface water runoff through ditches to Paddys Run and the northeast drainage ditch, wastewater discharged to the Great Miami River, and riprap placed along the bank of the Great Miami River adjacent to the outfall pipeline to prevent erosion, the occurrence of above-background concentrations of FEMP constituents off-property would be attributable to air deposition. Under the RI/FS, limited random sampling was performed off-property and systematic sampling was performed along the entire north and east boundaries of the FEMP property. This sampling was performed to: 1) demonstrate the usability of the Litigation Study data set; 2) develop a relationship between sampling performed under the RI/FS QAPP and that performed under the Litigation Study Quality Assurance Plan; and 3) verify the distribution of the CPCs in areas subject to air deposition from FEMP operations. The data sets from the RI/FS and the Litigation Study were found to be consistent. The Litigation Study provided data adequate to define the relationship between constituent concentrations and distance from the FEMP. The data set from the Litigation Study was validated to the extent necessary to support on-going litigation at the FEMP in 1986 and 1987. As such, the data is considered sufficient to perform a risk assessment, evaluate remedial action alternatives and to derive final remedial action goals. Following remedy selection and establishment of cleanup levels, additional sampling will be performed during RD/RA to verify the specific boundaries of areas requiring remediation.

TABLE 7-10 (Continued)

Potential Data Limitation	Significance to Alternatives Evaluation	Significance to Baseline Risk Assessment	Recommended Action/Justification
Outfall Line			
Limited characterization data is available along the outfall line from the FEMP sewage treatment plant to the Great Miami River. Limited characterization data is available for the riprap placed along the banks of the Great Miami River near the discharge of the FEMP outfall line.	Increased uncertainty in the quantity of surface and subsurface soils which will potentially be removed during remedial actions. Increased uncertainty regarding the quantity of rip rap which may be removed during remedial actions.	Increased uncertainty in the baseline risk assessment due to the availability of limited data to establish potential source-term concentrations.	No additional sampling is required to support the RI/FS process. The FEMP outfall line consists of a cast iron pipe installed in 1951. Similar pipe used in the petroleum industry has demonstrated useful lifetimes in excess of 100 years. Visual inspection of the outfall line and pressure tests performed in 1989 confirmed its general integrity. One section failed a pneumatic test indicating potential leakage over that section of the line. This line was taken out of service in 1993 when the new outfall line became operational. The RI/FS included the installation of a monitoring well immediately downgradient from the potentially leaking section of pipe. This well has since been sampled on three occasions. None of the validated samples revealed significantly elevated concentrations of constituents attributable to the FEMP (i.e., all less than two times background). Systematic borings were completed along the outfall line. Samples revealed slightly elevated concentrations of FEMP-related constituents, indicating potential leakage. The existing sampling program provides sufficient data to estimate the volume of affected media necessary to bound potential remedial actions which may be considered for the outfall line as part of the feasibility study. Available characterization data coupled with the estimate of affected media provide the basis upon which to complete the baseline risk assessment. Due to access limitations, additional characterization adjacent or beneath the pipeline is impractical before removal of the line. Surface soil sampling and surface radiological measurements were completed at the location of the suspect riprap placed at the bank of the Great Miami River. Efforts were impeded by the characteristics of the material (i.e., large pieces of concrete surrounded by soil). Available characterization data coupled with information gained from interviews with long-term FEMP employees provide a sufficient basis to assess risk and complete estimates of the volume of affected media. A removal site evaluation is currently underway to assess the need to implement a more expedited response action at this location. Additional characterization data will be collected during the implementation phase of remedial actions to guide excavation activities and to certify that cleanup objectives have been met.

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TABLE 7-10 (Continued)

Potential Data Limitation	Significance to Alternatives Evaluation	Significance to Baseline Risk Assessment	Recommended Action/Justification
Perched Groundwater - Lateral Extent of Contamination			
Limited data is available regarding the presence or absence of elevated concentrations of CPCs in perched groundwater on and off property in areas of potential air deposition.	Increased uncertainty in the definition of affected media potentially requiring remedial action. For purposes of alternative evaluation, the FS will define areas requiring action on the basis of conservative estimates using available measured surface soil and perched groundwater quality data and modeled transport from the surface soil to the perched groundwater.	Increased uncertainty in the risk assessment due to pathways associated with perched groundwater to hypothetical on-and off-property receptors residing in areas containing perched groundwater where glacial overburden exists. The baseline risk assessment was conducted using measured values, where available, or values derived from transport modeling. This approach bounds and potentially overestimates the risk to hypothetical receptors.	No further data is required to support the RI process. Available data from the RI, including CPC concentrations, measured leachability and K_d values for site soil, establishes a technical basis for estimating the existing and future concentrations of CPCs in perched groundwater due to the vertical migration of surface soil contamination. This relationship, developed by direct measurement and predictive modeling, has been employed by the RI to support the baseline risk assessment in evaluating potential exposures to future on- and off-property receptors residing in areas surrounding the FEMP. This approach will also be used during the FS to support the establishment of final cleanup goals and to evaluate viable remedial action alternatives. While additional investigations could be performed to verify the above-noted predictive estimates, any refinements would not alter the establishment of final cleanup goals for surface soil and perched groundwater and would not impact the overall remedy selection. Additional data would reduce uncertainty in cost estimates for FS alternatives involving perched groundwater. The reduced uncertainty in estimating would not represent a significant cost consideration due to the extensive areas of affected perched groundwater at the FEMP site. Additional data may be required during remedial design, pending selection of remedial goals in the Operable Unit 5 ROD.

TABLE 7-10 (Continued)

Potential Data Limitation	Significance to Alternatives Evaluation	Significance to Baseline Risk Assessment	Recommended Action/Justification
Perched Groundwater - Vertical Extent of Contamination			
The density of data available to characterize the vertical extent of contamination in the perched groundwater is significantly less than that to characterize the perched ground-water above a depth of 20 feet.	Increased uncertainty in the quantity of perched groundwater which may require remediation. This increases uncertainty in the cost estimates associated with all alternatives considered for remediation of perched groundwater.	Increased uncertainty in the baseline risk assessment due to the availability of limited data to establish the extent of source terms and their concentrations. To be conservative, the baseline risk assessment uses perched groundwater data from above 20 feet as representative of the entire depth and therefore accounts for the highest potential concentrations. However, existing data (3 lysimeter nests) indicate that contaminant concentrations below 20 feet are less than in the interval above.	No additional sampling is required to support the RI/FS process. More than 200 wells were installed in the former production area, as well as other suspect areas, as part of the Production Area and Additional Suspect Area (PASA) Investigation Program. This program employed process knowledge regarding the types and volumes of material handled to guide intrusive sampling activities to areas suspected of unmonitored releases to the glacial overburden adjacent to or beneath the production facilities. Based on EPA comments, borings were installed to a maximum depth of 20 feet or until perched water was encountered to avoid compromising the barrier properties of the glacial till. Available data from the RI, including CPC concentrations, measured leachability, and K_d values for site soil, establishes a technical basis for estimating the existing and future concentrations of CPCs in perched groundwater due to the vertical migration of surface and subsurface soil contamination. This relationship, developed by direct measurement and predictive modeling, has been employed in the RI to support the baseline risk assessment in evaluating potential exposures to future on- and off-property receptors residing in areas surrounding the FEMP. This approach will also be used during the FS to support the establishment of final cleanup goals and to evaluate viable remedial action alternatives. While additional RI investigations could be performed to verify the above-noted predictive estimates, these refinements would not alter the establishment of final cleanup goals for surface soil and perched groundwater and would not impact the overall remedy selection. Additional data would reduce uncertainty in cost estimates for FS alternatives involving perched groundwater. The reduced uncertainty in estimating would not represent a significant cost consideration due to the extensive areas of affected perched groundwater at the FEMP site. Additional data may be required during remedial design, pending selection of remedial goals in the Operable Unit 5 ROD.

TABLE 7-10 (Continued)

Potential Data Limitation	Significance to Alternatives Evaluation	Significance to Baseline Risk Assessment	Recommended Action/Justification
Great Miami Aquifer - Sporadic/Isolated Detections of Various Contaminants			
Limited data are available to confirm the significance of sporadic/isolated detections of various CPCs in numerous wells outside of well-characterized (5 ppb total uranium) groundwater contaminant isopleths. With the exception of Well 2098, these isolated detections cannot be explained on the basis of laboratory uncertainties or by process/site knowledge.	Increased uncertainty regarding the definition of areas exhibiting elevated concentrations of constituents which may potentially require remedial action.	Increased uncertainty in the derivation of risk estimates for potential receptors at these well locations. Because the presence or absence of the constituents cannot be confirmed, the risk assessment assumed that the suspect values were supportable and represented viable mechanisms for exposure and risk to receptors. Thus, this data limitation presents a potential for overestimating risk.	No additional sampling is necessary to support the RI/FS. The extensive GMA data set provides a reliable delineation of the nature and extent of CPCs in areas downgradient of known or suspected sources. This data set provides a sound foundation for a comparative analysis of the limited range of remedial action alternatives which may be considered for the GMA. Outside the delineated boundary of these areas (represented by the 5 ppb total U isopleth) there are wells which yield elevated concentrations of various CPCs which are unrelated to previously known source areas. The areas appear to be isolated and could be the result of: 1) anomalous laboratory data, 2) natural causes (e.g., localized concentrations of constituents due to infiltration of surface deposition which was the result of causes other than the FEMP), 3) FEMP constituents transported to the area via multiple pathways which are not connected to the primary GMA plumes (e.g., air deposition which is first concentrated through surface water runoff to drainage ditches which then infiltrate to the GMA as indicated by Well 2098, or 4) cross contamination of the wells during installation or sampling. Because these areas are isolated and will not impact the selection of overall remedial actions selected for primary regions of elevated concentration, the investigations to confirm the presence or absence of isolated areas of elevated concentration should occur independently of the assessment of remedial actions for the general GMA. While such data may reduce uncertainty in the areas potentially requiring action and the associated FS cost estimates, the data would not be a major factor in the comparative analysis of alternatives. The need for additional investigations will be dependent on final remediation goals selected for the Operable Unit 5 ROD. This, however, is a remedy implementation issue that does not require resolution for the FS to proceed. Sufficient information is available to establish risk-based remedial goals, develop and evaluate remedial alternatives, and select a remedy for presentation in the ROD.

TABLE 7-10 (Continued)

Potential Data Limitation	Significance to Alternatives Evaluation	Significance to Baseline Risk Assessment	Recommended Action/Justification
Great Miami Aquifer - Sporadic/Isolated Uranium Detections			
Limited data are available to confirm the significance of sporadic/isolated detections of uranium in wells outside of well-characterized (5 ppb total uranium) GMA groundwater isopleths. With the exception of Well 2098, these isolated detections cannot be explained on the basis of laboratory uncertainties or by process/site knowledge. The occurrences include Well Locations 2092, 2098, 2733, and 2555.	Increased uncertainty regarding the definition of areas exhibiting elevated concentrations of constituents which may potentially require remedial action.	Increased uncertainty in the derivation of risk estimates for potential receptors at these well locations. Since the presence or absence of the constituents cannot be confirmed, the risk assessment assumed that the suspect values were supportable and represented viable mechanisms for exposure and risk to receptors. Thus, this data limitation presents a potential for overestimating risk.	No additional sampling is necessary to support the RI/FS. The extensive GMA data set provides a reliable delineation of the nature and extent of constituents of potential concern in areas down gradient of known or suspected sources. This data set provides a sound foundation for a comparative analysis of the limited range of remedial action alternatives which may be considered for the GMA. Outside the delineated boundary of these areas (typically represented by the 5 ppb total U isopleth) there are wells which yield elevated concentrations of uranium which are unrelated to previously known source areas. The areas appear to be isolated and could be the result of: 1) anomalous laboratory data, 2) natural causes (e.g., localized concentrations of constituents due to infiltration of surface deposition which was the result of causes other than the FEMP), 3) FEMP constituents transported to the area via multiple pathways which are not connected to the primary GMA plumes (e.g., air deposition which is first concentrated through surface water runoff to drainage ditches which then infiltrate to the GMA), or 4) cross contamination of the wells during installation or sampling. Because these areas are isolated and will not impact the selection of overall remedial actions selected for primary regions of elevated concentration, the investigations to confirm the presence or absence of isolated areas of elevated concentration should occur independent of the assessment of remedial actions for the general GMA. While such data may reduce uncertainty in the areas potentially requiring action and the associated FS cost estimates, the data would not be a major factor in the comparative analysis of alternatives. The need for additional investigations will be dependent on final remediation goals selected for the Operable Unit 5 Record of Decision (ROD). This, however, is a remedy implementation issue that does not require resolution for the FS to proceed. Sufficient information is available to establish risk-based remedial goals, develop and evaluate remedial alternatives, and select a remedy for presentation in the ROD.

TABLE 7-10 (Continued)

Potential Data Limitation	Significance to Alternatives Evaluation	Significance to Baseline Risk Assessment	Recommended Action/Justification
Great Miami Aquifer Near Confluence of Paddys Run and Great Miami River			
Limited groundwater characterization data are available in the region near the confluence of Paddys Run and the Great Miami River.	Increased uncertainty in the specific areas and volumes of groundwater potentially requiring remedial action. This increases uncertainty in the cost estimates associated with all alternatives considered for remediation of off-property groundwater.	Increased uncertainty in the baseline risk assessment due to reliance upon a limited data set to estimate risk to off-property personnel resulting from elevated concentrations of CPCs which exist in the groundwater today.	No additional sampling is required to support the RI/FS process. As part of the RI/FS, the FEMP completed the systematic installation of monitoring wells along the entire length of Paddys Run from north of the FEMP production area to the confluence of Paddys Run with the Great Miami River. Samples were analyzed for a full suite of radiological, HSL inorganic and general water quality analyses. In addition, home owners wells along Paddys Run and in the vicinity of the confluence of Paddys Run with the Great Miami River were sampled and analyzed for total uranium. Alternate water supplies have been offered to people whose wells yield a uranium concentration in excess of 2.7 μg/L. Existing sampling data in the vicinity of the confluence of Paddys Run with the Great Miami River is sufficient to estimate the volume of impacted groundwater, thereby supporting the evaluation and selection of remedial action alternatives from among a limited list of alternatives which may be considered as part of the FS. Verification data may be collected as part of remedial design activities, as necessary, to ensure the adequacy of proposed actions, and during the implementation phase of remedial actions to guide groundwater recovery and treatment activities and to certify that cleanup objectives have been met. Available characterization data coupled with an estimate of the extent of the affected groundwater provide the basis upon which to complete the baseline risk assessment.

TABLE 7-10 (Continued)

Potential Data Limitation	Significance to Alternatives Evaluation	Significance to Baseline Risk Assessment	Recommended Action/Justification
Fate and Transport Modeling			
Limited information is available regarding K_l for uranium contaminated soil in the glacial overburden outside of the former production area and other operable units. The RI assumes the uranium is less soluble (K_l value of 222) in these areas.	Increased uncertainty in the specific areas and volumes of surface soil potentially requiring remedial action because of potential impacts to the Great Miami Aquifer. This increases uncertainty in the cost estimates associated with all alternatives considered for remediation of on-property soil.	Increased uncertainty in the baseline risk assessment due to the assumption of less soluble uranium in these areas. Uncertainty analysis was conducted to bound the range of potential future impacts to receptors by using lower K_l and K_d values.	Additional sampling and batch leaching tests of samples collected outside the former production area (in areas where air deposition is the only known source) are required to support the FS. A work plan is being prepared to address the collection and analysis of samples to fulfill this need. The results of this program will be incorporated into the Operable Unit 5 FS. EPA and OEPA have been provided an opportunity to comment on the sampling and analytical protocols incorporated in the work plan.

TABLE 7-10 (Continued)

Potential Data Limitation	Significance to Alternatives Evaluation	Significance to Baseline Risk Assessment	Recommended Action/Justification
Modeling - Colloidal Transport			
Specific investigations regarding the role of colloidal migration mechanisms in the transport of site contaminants in groundwater have not been conducted.	If colloidal transport is actually occurring but is not accounted for in the fate and transport models, migration rates could be underestimated. The clean-up levels necessary to develop alternatives could therefore be underestimated, increasing the uncertainty in the cost estimates associated with the alternatives.	Increased uncertainty in the baseline risk assessment due to uncertainty in the fate and transport models.	Additional information concerning colloidal transport is not needed to support the RI/FS for the following reasons: The nature and extent of uranium in both the perched zones and the Great Miami Aquifer (i.e., plume definition) are defined by groundwater monitoring data. Filtered and unfiltered analyses of groundwater were performed for radiological and inorganic contaminants. The extent of groundwater contamination associated with colloidal uranium, if present, would be bounded by these analyses. Furthermore, the higher of filtered/unfiltered analyses for a particular well are used for decision making and fate and transport modeling. There is no well-developed and verified approach for modeling the rate of transport of colloidal particles. The presence or absence of colloidal transport, which might or might not be faster than the transport of soluble species, is one of numerous parameters with a degree of uncertainty that must be factored into any transport model. The transport model accommodates these uncertainties by conservatively estimating input parameters such as K_d. Based on the above and other conservative assumptions used during the risk assessment process, it is unlikely that the Operable Unit 5 baseline risk assessment will underestimate the exposure risk without specifically quantifying colloidal transport. For the purpose of the FS, all groundwater treatment systems will be capable of addressing colloidal uranium, if present. An ion exchange system is the preferred alternative for uranium removal at the FEMP. A filtration system is typically placed ahead of ion exchange columns for protection against plugging. The combination of filtration followed by ion exchange has proven to be more than adequate to remove all forms of uranium. Also, colloidal uranium, if present, should not affect the performance of groundwater extraction and conveyance systems. Therefore, additional information regarding colloidal transport is not required for the evaluation of groundwater remedial alternatives in the FS.

TABLE 7-10 (Continued)

Potential Data Limitation	Significance to Alternatives Evaluation	Significance to Baseline Risk Assessment	Recommended Action/Justification
Hazardous Waste Management Units			
Limited characterization data is available surrounding select RCRA-regulated units and non-clean-closed underground petroleum product storage tanks.	Increased uncertainty in the quantity of surface and subsurface soil containing RCRA-listed constituents and petroleum derivatives. This increases uncertainty in the cost estimates associated with all alternatives considered for remediation of on-property soil.	Increased uncertainty in the baseline risk assessment due to the limited availability of data to identify the CPCs and establish source term concentrations.	No additional sampling is required to support the RI/FS process. Each of the regulated units with limited data sets lie within the study area defined by the Production and Additional Suspect Area (PASA) Investigation. This investigation employed process knowledge regarding the types and volumes of material handled to guide intrusive sampling activities to areas suspected of unmonitored releases to the glacial overburden adjacent to or beneath the production facilities. The program involved completion of approximately 300 borings and installation of more than 200 wells across the former production area. Initial samples were collected under the PASA program during the period 1988 to 1992. A subsequent program was implemented in 1993 to fulfill the complete data needs of the RI/FS. Placement of the borings and constituents evaluated in samples collected during the PASA and 1993 investigations were sufficiently broad to characterize FEMP production area source terms to the extent necessary to support the baseline risk assessment and alternatives assessment under the FS. To ensure continued visibility of those media potentially containing listed hazardous wastes or petroleum derivatives, care will be taken to ensure that these constituents are not screened from consideration in the FS. Contamination from these units is contained within the limits of the 20 mg/kg uranium envelope discussed in Section 4. However, estimates of media volumes containing listed constituents or petroleum products will be presented in the FS based upon the results of the previously mentioned investigation and unit-specific process knowledge. Appropriate alternatives will be developed and evaluated to ensure that media containing listed constituents and petroleum products are adequately addressed. Following remedy selection and identification of cleanup goals, additional sampling may be required during remedial design and remedial actions to validate the FS estimates of effected media.

TABLE 7-10 (Continued)

Potential Data Limitation	Significance to Alternatives Evaluation	Significance to Baseline Risk Assessment	Recommended Action/Justification
Threatened and Endangered Species			
The Site-Wide Characterization Report (DOE 1993) identified habitat potential for several state/federal threatened and endangered species at the FEMP. However, much of this data is inconclusive.	This limits the ability to assess impacts of remedial action alternatives upon sensitive biological receptors.	None.	No additional surveys are necessary to support the RI. Additional surveys are necessary to support the FS. Available information provides a relative indication of the presence/absence of both threatened and endangered species which may be present in the region of the FEMP. Additional threatened and endangered species surveys are being conducted during 1994 to confirm the presence/absence of these species. This will provide additional information regarding potential impacts various remedial action alternatives may have on these species to support the FS and RD/RA. These surveys and their projected completion dates are: Spring Coral Root - Complete Slender Finger Grass - Fall 1994 Indiana Bat - Summer 1994 Cobblestone Tiger Beetle - Summer 1994 Cave Salamander - Complete Running Buffalo Clover - Complete Mountain Bindweed - Summer 1994 Sloan's Crayfish - Complete The results of those studies completed by August 1994 will be included in the next version of the RI.

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TABLE 7-10 (Continued)

Potential Data Limitation	Significance to Alternatives Evaluation	Significance to Ecological Risk Assessment	Recommended Action/Justification
Ecological Risk			
Site-specific data regarding the occurrence and impact of contaminants on biological resources are limited.	Increased uncertainty regarding the potential relationship between elevated concentrations of contaminants and the possible adverse impacts to biological communities.	Increased uncertainty in the ecological risk assessment due to limited data. Conservative assumptions have been used to ascertain risk to biological resources. This could potentially result in an over-estimation of risk to ecological receptors.	No additional sampling is necessary to support the RI/FS process. During the course of RI sampling related to ecological receptors, the focus was on the media that potentially affects the receptors rather than the receptors themselves. Therefore, limited data are available regarding concentrations of contaminants in the receptors. The ecological risk assessment has relied on conservative uptake factors for both flora and fauna to determine conservative estimates of risk to these receptors. Following selection of remedial actions and identification of clean-up goals, additional sampling or site-specific tests/studies may be necessary during RD/RA to verify that biological resources are being adequately protected. A management plan will be developed to protect natural resources, including ecological receptors, to the extent practicable during remediation of the site.

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TABLE 7-11

OPERABLE UNIT 5 CONSTITUENTS OF CONCERN

Constituents	Air	Soil	Perched Water	Groundwater
Cs_{137+1d}		X		
Np_{237+1d}		X	X	X
Pu_{238}	X	X	X	
Pu_{239}	X			
$Pu_{239/240}$		X	X	
Ra_{226+8d}	X	X	X	X
Ra_{228}		X		X
Ru_{106}		X		
Sr_{90+1d}		X	X	X
Tc_{99}		X	X	X
Th_{228}		X		X
Th_{230}	X	X	X	X
$Th_{232+10d}$	X	X	X	X
U_{234}	X	X	X	X
U_{235}		X		X
$U_{235/236}$	X	X	X	X
U_{238+2d}	X	X	X	X
Rn_{222+4d}	X			
1,1-dichloroethene				X
1,1-dichloroethene		X		X
1,1,2-trichloroethane			X	
1,2-dichloroethane			X	X
1,2-dichloroethene			X	X
1,2-dichloroethene				X
2-chlorophenol			X	
4-methylphenol				X
4-methylphenol				X
antimony		X	X	X
aroclor-1254	X	X		
aroclor-1260		X		
arsenic		X	X	X
arsenic	X	X	X	X
barium		X	X	X
benzene			X	
benzo(a)anthracene		X		
benzo(a)pyrene		X		

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TABLE 7-11 (Continued)

Constituents	Air	Soil	Perched Water	Groundwater
benzo(b)fluoranthene		X		
benzo(k)fluroanthene		X		
beryllium		X	X	X
beryllium		X	X	X
bis(2-chloroisopropyl)ether				X
bis(2-ethylhexyl)phthalate		X	X	X
bis(2-ethylhexyl)phthalate		X	X	X
boron		X	X	
bromoform			X	
cadmium		X	X	X
carbazole		X		
carbon tetrachloride			X	
carbon disulfide			X	
carbon tetrachloride			X	
chloride				
chloroform			X	X
chloroform			X	X
chromium		X	X	X
chromium	X			
chrysene		X		
cobalt		X		X
copper		X	X	X
cyanide		X	X	X
dibenzo(a,h)anthracene		X		
fluoride			X	X
heptachlorodibenzofuran		X		
indeno(1,2,3-cd)pyrene		X		
magnesium		X	X	X
manganese		X	X	X
mercury		X		X
methylene chloride		X	X	X
methylene chloride		X	X	X
molybdenum		X	X	X
n-nitrosodiphenylamine		X		
n-nitrosodipropylamine			X	
nickel		X		X
nitrate			X	X
octachlorodibenzo-p-dioxin		X		
octachlorodibenzofuran		X		

TABLE 7-11 (Continued)

Constituents	Air	Soil	Perched Water	Groundwater
pentachlorophenol			X	
pentachlorophenol			X	
selenium				X
silver		X	X	X
tetrachloroethene		X	X	X
tetrachloroethene	X	X	X	
thallium		X	X	
tributyl phosphate			X	
trichloroethene	X	X	X	X
uranium - total		X	X	X
vanadium		X	X	X
vinyl chloride			X	
zinc		X		X

TABLE 7-12

PRELIMINARY REMEDIATION GOALS FOR URANIUM BY MEDIA[f]

	Carcinogenic Risk[a]			Toxicological Risk[b]
Media	10^{-6}	10^{-5}	10^{-4}	HI=0.2
Surface Soil (mg/kg)[c]	5.2E-01	5.2E+00	5.2E+01	8.7E+00
Great Miami Aquifer (mg/L)[c]	6.2E-01	6.2E+00	6.2E+01	6.5E-3
Perched Groundwater (mg/L)[c]	7.3E-01	7.3E+00	7.3E+01	9.0E-03
Paddys Run (mg/L)[d]	1.3E+02	1.3E+03	1.3E+04	3.8E+00
Paddys Run (mg/L)[e]	1.6E+03	1.6E+04	1.6E+05	7.7E+00
Great Miami River (mg/L)	6.0E-01	6.0E+00	6.0E+01	1.7E-02
Sediment (mg/kg)[e]	3.7E+02	3.7E+03	3.7E+04	2.1E+02

[a]For uranium-238
[b]For total uranium
[c]Based on exposures to on-property RME farmer (U-238) and child (total uranium)
[d]Based on exposures to a consumer of meat and milk products
[e]Based on exposures to an explorign youth.
[f]See Appendix A.7 for a complete list of PRGs by media

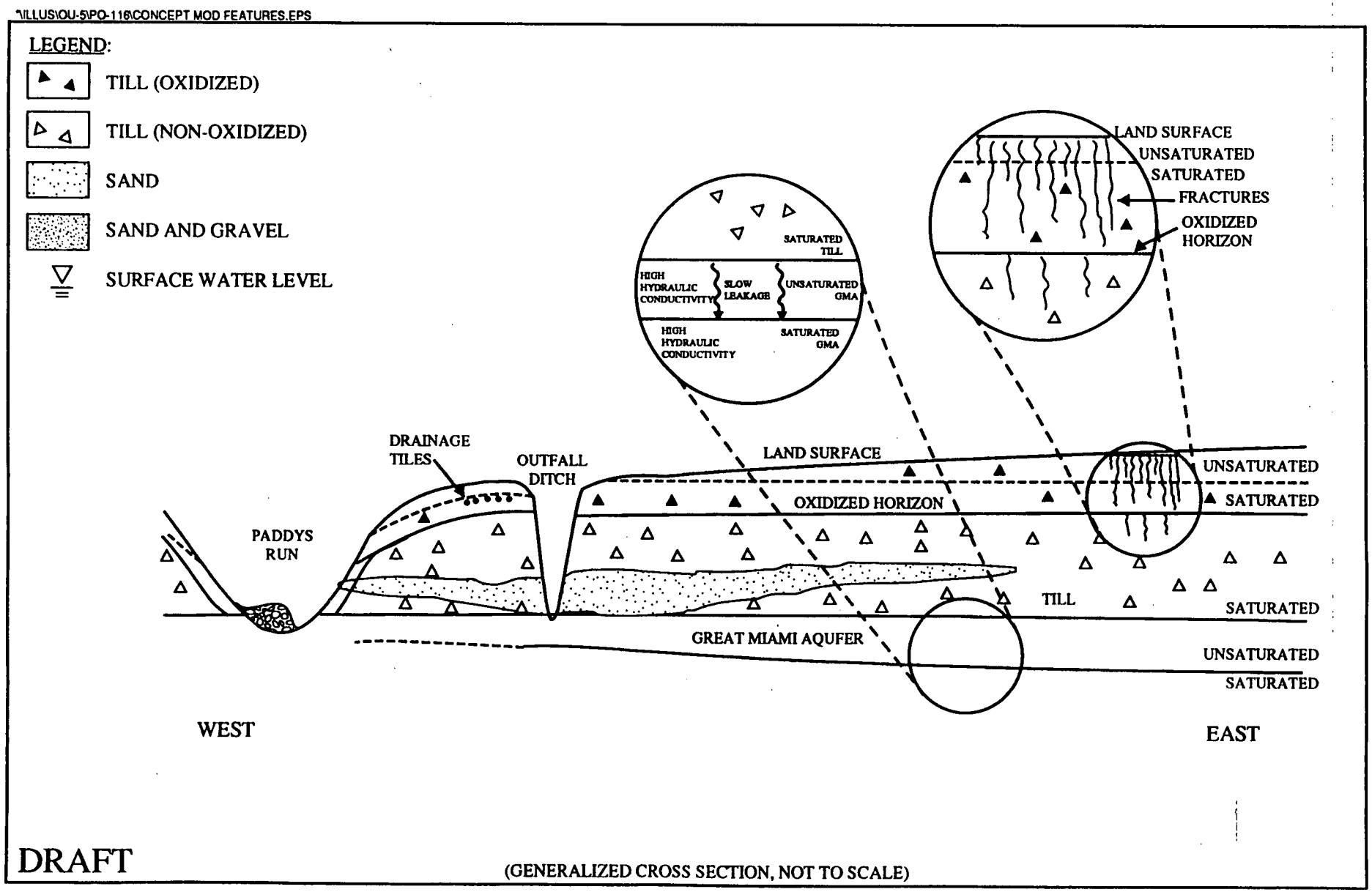


FIGURE 7-1. MAJOR FEATURES OF THE CONCEPTUAL MODEL OF THE HYDROLOGY OF THE FEMP AREA

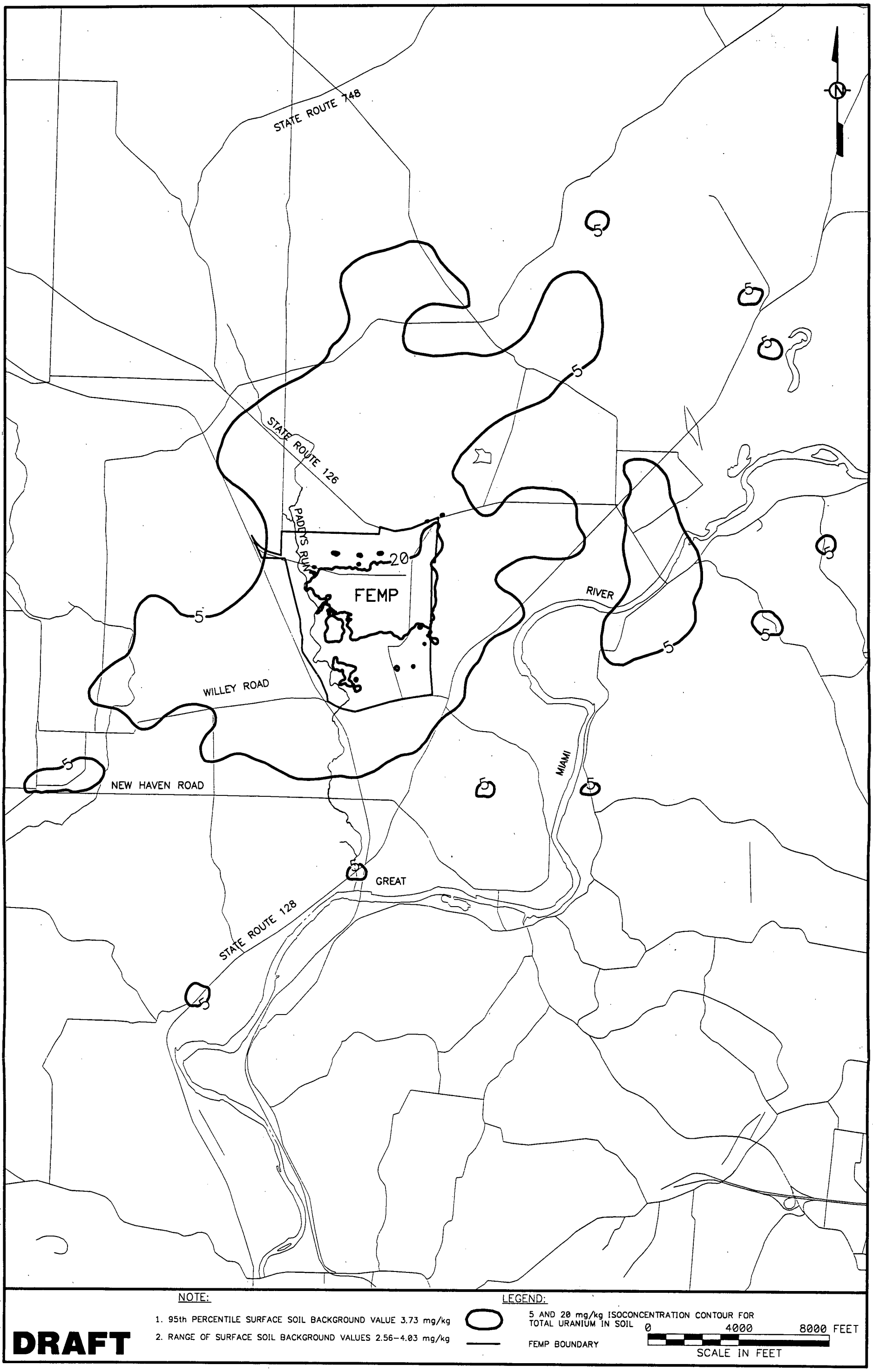


FIGURE 7–2. 5 AND 20 mg/kg ISOCONCENTRATION CONTOUR FOR TOTAL URANIUM IN SOIL, OU5, FEMP

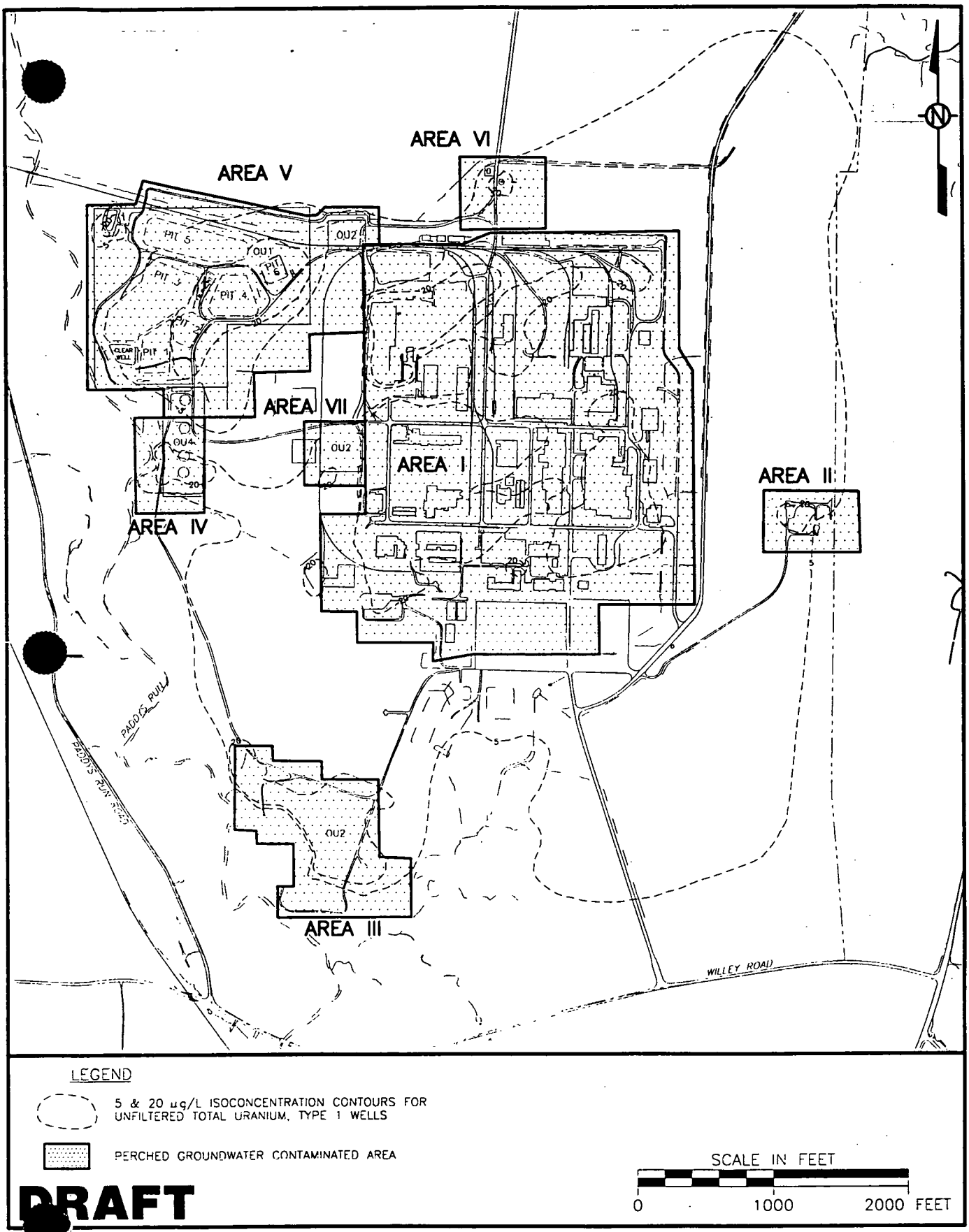


FIGURE 7-3. LOCATIONS OF PERCHED GROUNDWATER CONTAMINATED AREAS

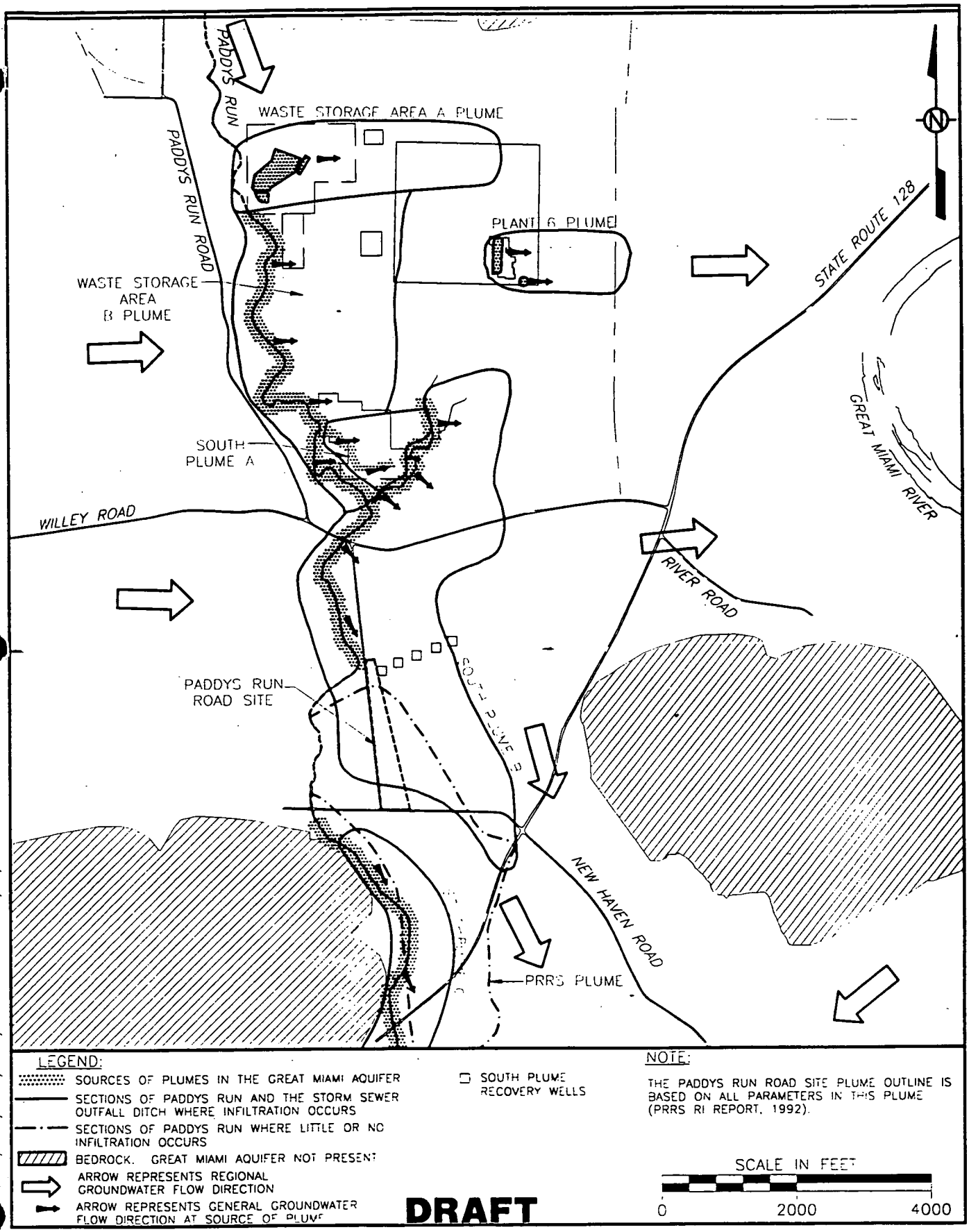
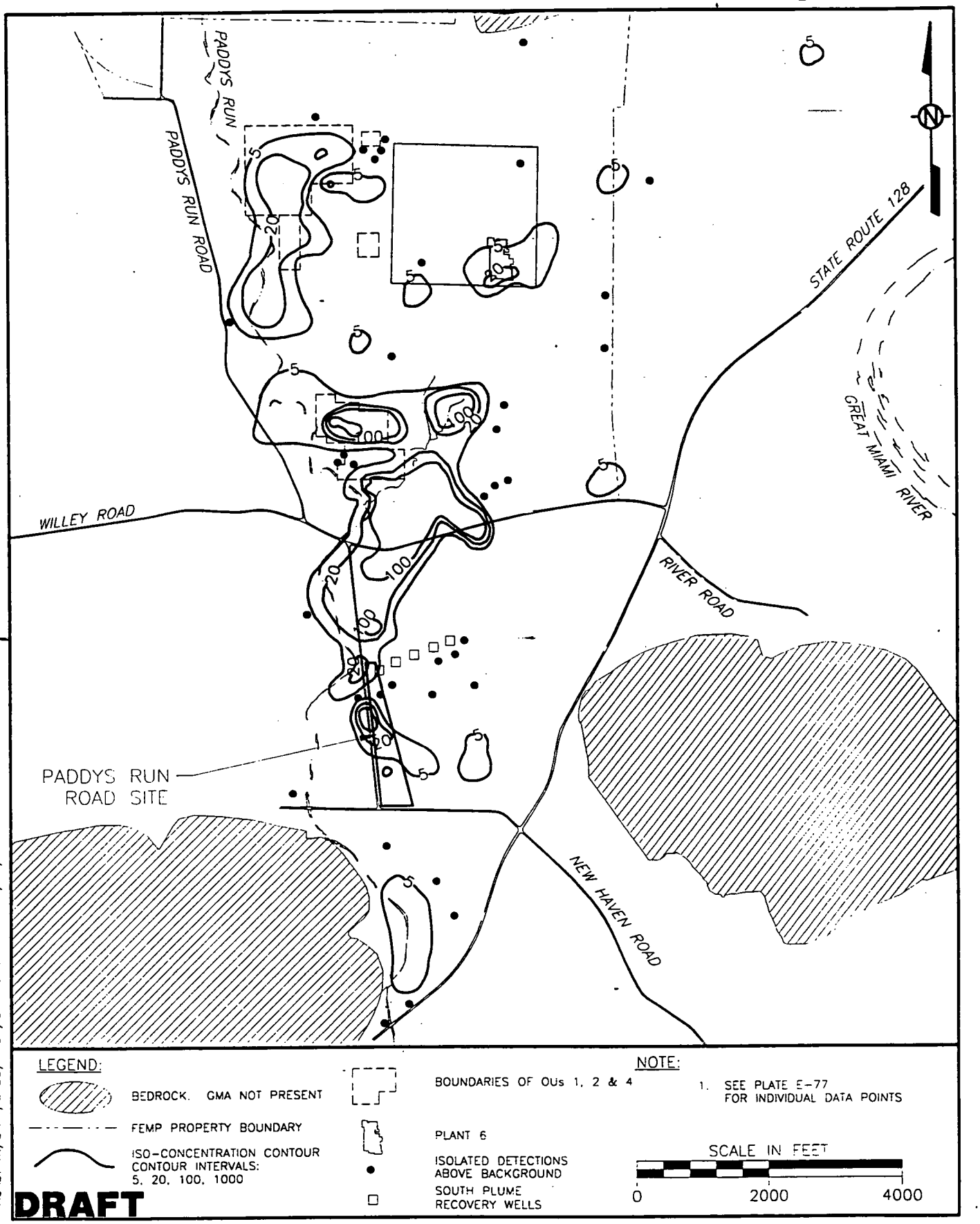


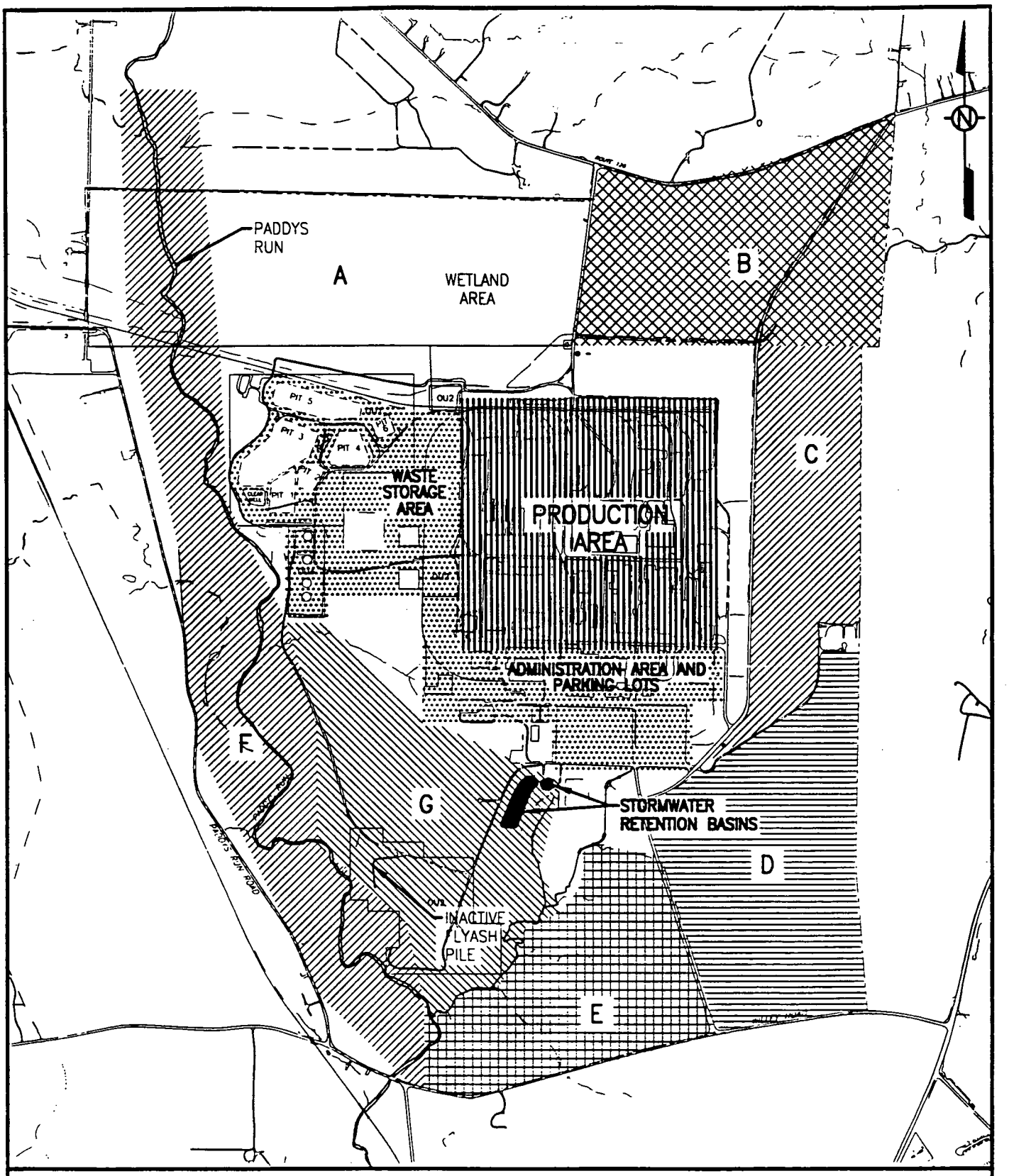
FIGURE 7-4 SCHEMATIC DEPICTION OF THE MAJOR FEMP AND PRRS PLUMES IN THE GREAT MIAMI AQUIFER



STATE PLANAR COORDINATE SYSTEM 1927

ACAD: W:/DATA/CADD/4P94/SM102U2.DWG 06/18/94 MB

FIGURE 7-5 TOTAL URANIUM CONTAMINATION IN FEMP TYPE 2 WELLS – UNFILTERED SAMPLES, 1993 DATA SET



LEGEND :

A WOODLOT / WETLAND
B PINE PLANTATION
C GRASSLAND
D GRASSLAND
E GRASSLAND
F PADDYS RUN
G PINE PLANTATION

SCALE IN FEET
0 1200 2,400

DRAFT

C:\1001.DWG 6/12/94 MRM STATE PLANAR COORDINATE SYSTEM 1927

FIGURE 7-6 STUDY AREAS FOR THE SITE-WIDE ECOLOGICAL RISK ASSESSMENT

BIBLIOGRAPHY

Anderson, D. M., 1982, "Plant Communities of Ohio," Unpublished manuscript, Ohio Dept. of Natural Resources, Division of Natural Areas and Preserves, Columbus, OH.

ATEC Associates, Inc., 1982, "Topographic Survey and Geotechnical Investigation, FMPC Water Pollution Control," n.p.

Ball, D., U.S. Army Corps of Engineers, Oct. 1991, Personal communication.

Bassarab, D. R. and W. D. Huff, 1969, "Clay Mineralogy of Kope and Fairview Formations (Cincinnatian) in the Cincinnati Area," J. of Sedimentary Petrology, Vol. 39, No. 3, pp. 1014-1022.

Battelle Laboratories, Inc., 1981, "Environmental Report of the Feed Materials Production Center," Final Report to NLO, Battelle Laboratories, Columbus, OH.

Battelle Laboratories, Inc., National Lead Co. of Ohio, and the U.S. Dept. of Energy, 1977, "Environmental Impact Assessment - Feed Materials Production Center, Fernald, Ohio," DOE, Oak Ridge Operations Office, Oak Ridge, TN.

Bauer, B. H., B. A. Branson and S. T. Colwell, 1978, "The Fishes of Paddys Run Creek and the Dry Fork of the Whitewater River, Southwestern Ohio," Ohio J. of Science, Vol. 78(3), pp. 144-148.

Berner, R. A., 1971, Principles of Chemical Sedimentology, McGraw-Hill, New York, NY.

Blaney, H. F. and W. D. Criddle, 1950, Determining Water Requirements in Irrigated Areas from Climatological and Irrigation Data, U.S. Dept. of Agriculture, SCS-TP-96, Washington, DC.

Boback, M. W., T. A. Dugan, D. A. Fleming, R. B. Grant and R. W. Keys, 1985, "History of FMPC Radionuclide Discharges," NLCO-2039, National Lead Co. of Ohio, Cincinnati, OH, prepared for U.S. Dept. of Energy, Oak Ridge Operations Office, Oak Ridge, TN.

Boback, M. W., T. A. Dugan, D. A. Fleming, R. B. Grant and R. W. Keys, 1987, "History of FMPC Radiological Discharges," FMPC-2082, revision to NLCO-2058, Westinghouse Materials Co. of Ohio, Cincinnati, OH, prepared for U.S. Dept. of Energy, Oak Ridge Operations Office, Oak Ridge, TN.

Booth, J. S. and R. H. Osborne, 1971, American Upper Ordovician Standard XV, Clay Mineralogy of Insoluble Residues from Cincinnatian Limestones, Hamilton County, Ohio, University of Southern California, Los Angeles, CA.

Brockman, C. S., 1988, "Report of Progress on the Final Phase of Glacial Geologic Mapping in Hamilton County, Ohio," Ohio Dept. of Natural Resources, Division of Geological Survey, Columbus, Ohio.

Brown, G. J. and D. J. Carr, 1989, "Offsite Soils Removal," FMPC-2184, Westinghouse Materials Co. of Ohio, prepared for U.S. Dept. of Energy, Oak Ridge Operations Office, Oak Ridge, TN.

Butler, J. C. and D. M. Scotford, 1973, "Re-examination of Upper Cincinnatian Shale Petrology," Geological Soc. of America Bulletin, Vol. 84, pp. 2431-2434.

Clark, T. R., L. Elikan, C. A. Hill and B. L. Speicher, 1989, "History of FMPC Radionuclide Discharges-Revised Estimates of Uranium and Thorium Air Emissions from 1951-1987," Addendum to FMPC-2082, Westinghouse Materials Co. of Ohio, Cincinnati, OH, prepared for U.S. Dept. of Energy, Oak Ridge Operations Office, Oak Ridge, TN.

Cowan, C. W., 1987, First Farmers of the Middle Ohio Valley, Cincinnati Museum of Natural History, Cincinnati, OH.

Cross, W. P. and R. E. Hedges, 1959, "Flow Duration of Ohio Streams," Bulletin 31, Ohio Dept. of Natural Resources, Division of Water, Columbus, OH.

Dames and Moore, 1985, "Dept. of Energy Feed Materials Production Center, Groundwater Study - Task C Report," Dames & Moore, White Plains, NY, prepared for National Lead of Ohio, Inc., Cincinnati, OH.

Davis, J. G., 1994, "Report on the Status of the Cave Salamander (*Eurycea lucifuga*) at the Fernald Environmental Management Project," FERMCO, Cincinnati, OH.

Dove, G. D. and S. E. Norris, 1951, "Conditions Governing the Occurrence of Groundwater in the Fernald Area, Ohio, with Reference to the Possibilities of Contamination by Disposal of Chemical Wastes," U.S. Geological Survey, Groundwater Branch, Columbus, OH.

Dove, G. D., 1961, "A Hydrologic Study of the Valley-Fill Deposits in the Venice Area, Ohio," Technical Report No. 4, Ohio Dept. of Natural Resources, Division of Water, Columbus, Ohio.

Dragun, J., 1988, The Soil Chemistry of Hazardous Materials, Hazardous Materials Control Research Institute, Silver Spring, MD.

Durrell, R. H., 1961, "The Pleistocene Geology of the Cincinnati Area," Geological Soc. of America Guidebook Series, Cincinnati Meeting, pp. 47-57.

Durrell, R. H., 1982, "A Recycled Landscape," Cincinnati Museum of Natural History, Popular Publication Series, Number 9, Cincinnati, OH.

EG&G Energy Measurements, 1985, "An Aerial Radiological Survey of the Feed Materials Production Center and Surrounding Area," EGG-10282-1084, UC-41, prepared for U.S. Dept. of Energy, Office of Nuclear Safety, Washington, DC.

ERM-Midwest, Inc., 1992, "Remedial Investigation and Risk Assessment Report, Paddys Run Road Site, Crosby Township, Hamilton, Ohio," ERM-Midwest, Inc., Worthington, OH.

Facemire, C. F., S. I. Guttman, D. R. Osborne, and R. H. Sperger, 1990, "Biological and Ecological Site Characterization of the Feed Materials Production Center," FMPC-SUB 018, Prepared for Westinghouse Materials Co. of Ohio, Cincinnati, OH.

Federal Emergency Management Agency, 1982, "Flood Insurance Rate Map, County of Hamilton County, Ohio (Unincorporated Areas)," Panel 10 of 105, National Flood Insurance Program, FEMA, n.p.

Federal Interagency Committee for Wetland Delineation, 1989, Federal Manual for Identifying and Delineating Jurisdictional Wetlands, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and U.S. Soil Conservation Service, Washington, DC.

Feed Materials Production Center (FMPC), March 1988, "A Closer Look at Uranium Metal Production: A Technical Overview," Fernald, OH.

Fenneman, N. M., 1916, "The Geology of Cincinnati and Vicinity," Geological Survey of Ohio, Bulletin 19, Ohio Division of Geological Survey, Columbus, OH.

Fernald Environmental Restoration Management Corp., 1993, "1992 Fernald Site Environmental Report," FEMP-2290, prepared for U.S. Dept. of Energy, Fernald Field Office, Cincinnati, OH.

Fetter, C. W., Jr., 1980, Applied Hydrogeology, Charles E. Merrill Publ. Co., Columbus, OH.

Fleming, D. A. and K. N. Ross, 1984, "FMPC Environmental Monitoring Annual Report for 1983," NLCO-2018, National Lead Co. of Ohio, Cincinnati, OH, prepared for U.S. Dept. of Energy, Oak Ridge Operations Office, Oak Ridge, TN.

Folk, R. L., 1980, Petrology of Sedimentary Rocks, Hemphill Publ. Co., Austin, TX.

Ford, J. P., 1974, "Bedrock Geology of the Cincinnati West Quadrangle and Part of the Covington Quadrangle, Hamilton County, Ohio," Report of Investigations No. 93, Ohio Dept. of Natural Resources, Division of Geological Survey, Columbus, OH.

Freeze, R. A. and J. A. Cherry, 1979, Groundwater, Prentice-Hall, Englewood, Cliffs, NJ.

GeoTrans, Inc., 1985, "Preliminary Characterization of the Groundwater Flow System Near the Feed Materials Production Center, Great Miami River Valley-Fill Aquifer, Fernald, Ohio," prepared for the Ohio Environmental Protection Agency, Southwest District Office, Dayton, OH.

Guttman, S. I., 1990, "Characterization of the Tree Frog Null Allele," FMPC-SUB 032, prepared for Westinghouse Materials Co. of Ohio, Cincinnati, OH.

Guttman, S. I., 1992, "Characterization of the Tree Frog Null Allele 1991," FEMP-SUB046 UC702, prepared for Westinghouse Materials Co. of Ohio, Cincinnati, OH.

Hansen, M. C., 1988, "Earthquakes in Ohio," Educational Leaflet Number 9, State of Ohio, Dept. of Natural Resources, Division of Geological Resources, Columbus, OH.

Harrington, C. D. and A. E. Ruehle, 1959, Uranium Production Technology, D. Van Nostrand Co., Inc., Princeton, NJ.

Harstine, L. J., 1991, "Hydrologic Atlas of Ohio," Water Inventory Report, Number 28, Ohio Dept. of Natural Resources, Columbus, OH.

Henderson, F. M., 1966, Open Channel Flow, McMillan Publishing Co., Inc., New York, NY.

Houck, I. E., 1921, "Rainfall and Runoff in the Miami Valley," Technical Reports Part VIII, The Miami Conservancy District, Dayton, OH.

Humphrey, S. R., A. R. Richter, and J. B. Cope, 1977, "Summer Habitat and Ecology of the Endangered Indiana Bat, *Myotis Sodalis*," J. of Mammology, Vol. 58, pp. 334-346.

International Agency for Research on Cancer (IARC), 1987, IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Overall Evaluations of Carcinogenicity: An Updating of IARC Monographs, Vols. 1 to 42, Preamble, Supplement 7, WHO: Lyon, France, pp. 17-34.

IT Corp., 1986, "Final Interim Report - Air, Soil, Water, and Health Risk Assessment in the Vicinity of the FMPC, Fernald, Ohio," report and data package prepared for the U.S. Dept. of Energy in support of the Fernald litigation, Oak Ridge Operations Office, Oak Ridge, TN.

IT Corp., 1988, "Hydrogeologic Study of the FMPC Discharge to the Great Miami River (Zone of Influence Report)," prepared for the U.S. Dept. of Energy, Oak Ridge Operations Office, Oak Ridge, TN.

Kitchen, J., Ohio Historical Soc., 1990, [Letter to B. Shroff, Subject: Review of Remedial Activities at the FMPC].

Klaer, F. H., Jr., 1967, "Well and Well Field Operations," J. of the American Water Works Assn., Vol. 60, No. 3, pp.273-280.

Lee, S. Y. and J. D. Marsh, 1992, "Characterization of Uranium Contaminated Soils from DOE Fernald Environmental Management Project Site: Results of Phase I Characterization," Oak Ridge National Laboratory, ORNL/TM-11980, Oak Ridge, TN.

Lee, S. Y., M. Elless, and F. Hoffman, 1993, "Solubility Measurement of Uranium in Uranium Contaminated Soils," Oak Ridge National Laboratory, ORNL/TM-12401, Oak Ridge, TN.

Leow, J. A., 1985, "Top of Rock Map of Butler County, Ohio," Open File Map 224, Ohio Dept. of Natural Resources, Division of Geological Survey, Columbus, OH.

Lewis, R. C., 1968, "An Investigation of the Potential Yield of the Big Bend Wellfield," unpublished thesis, Univ. of Cincinnati, OH.

Luce, W. R., Ohio Historical Soc., 1987, [Letter to J. Reafsnyder, Subject: Review of Archaeological Properties at the FEMP].

Lyman, W. J., W. F. Reehl and D. H. Rosenblatt, 1982, Handbook of Chemical Property Estimation Methods, McGraw-Hill Book Co., New York, NY.

Mason, W. T., Jr., 1973, "An Introduction to Identification of Chironomid Larvae," MERC/EPA, Cincinnati, OH.

Merritt, R.W. and K.W. Cummins, eds., 1984, An Introduction to the Aquatic Insects, 2nd ed., Kendall/Hunt Publishing Co., Dubuque, IA.

Miami Conservancy District, 1993, "Hydrologic Data for the Hamilton-New Baltimore Area 1992," the Water Conservation Subdistrict of the Miami Conservancy District, Dayton, OH.

Miller, M. C. et al., 1985-1993, "Electrofishing Survey of the Great Miami River," annual reports, Fernald Environmental Management Co., Cincinnati, OH.

Nash, Granger and Adams, 1981, "Geology in Concepts of Genesis of Important Types of Uranium Deposits," in Economic Geology, special 75th anniversary volume, pp. 63-116.

National Lead Co. of Ohio, Inc., 1965-1985, "Aquifer Contamination Control Reports," various authors: C. F. Facemire, R. B. Weidener, M. W. Boback, and R. H. Starkey, NLO, Cincinnati, OH.

Oak Ridge Associated Universities, 1985, "Environmental Program Review of the Feed Materials Production Center, Fernald, Ohio," prepared for U.S. Dept. of Energy, Oak Ridge Operations Office, Oak Ridge, TN.

Ohio Dept. of Health, 1988, "Study of Radioactivity in Drinking Water and Other Environmental Media in the Vicinity of the U.S. Dept. of Energy's Feed Materials Production Center and Portsmouth Gaseous Diffusion Plant," prepared for U.S. Dept. of Energy, Oak Ridge Operations Office, Oak Ridge, TN.

Ohio Dept. of Natural Resources, 1992, Species of Animals That Are Considered to be Endangered, Threatened, of Special Interest, Extirpated, or Extinct in Ohio, ODNR, Division of Wildlife, Division of Natural Areas and Preserves, Columbus, OH.

Ohio Environmental Protection Agency, 1982, Comprehensive Water Quality Report for the Lower Mainstem of the Great Miami River, OEPA, Southwest District Office, Dayton, OH.

Ohio Environmental Protection Agency, 1988, "Biological Criteria for the Protection of Aquatic Life: Vol. II: User's Manual for Biological Field Assessment of Ohio Surface Waters," OEPA, Div. of Water Quality Planning and Assessment, Columbus, OH.

Ohio Environmental Protection Agency, 1989, Great Miami River Intensive Stream Survey, OEPA, Southwest District Office, Dayton, OH.

Osborne, D. R. and F. A. Jones, 1991, "Reproduction and Growth in American Robins at the Feed Materials Production Center," FMPC SUB-031, prepared for Westinghouse Materials Co. of Ohio, Cincinnati, OH.

Osborne, D. R., D. M. Ambrose and J. C. Simpson, 1992, "Characterization of Reproduction and Growth of American Robins at the Fernald Environmental Management Project, 1991," FEMP/SUB-059 UC-702, prepared for Westinghouse Environmental Management Co. of Ohio, Cincinnati, OH.

Parrish, F. K., 1975, "Keys to Water Quality Indicative Oganisms of the Southeastern United States," 2nd ed., EMSL/EPA, Cincinnati, OH.

Pennak, R. W., 1978, Freshwater Invertebrates of the United States, 2nd ed., Wiley-Interscience, New York, NY.

001342

Plummer, Paul, Miami Conservancy District, Dayton, OH, July 24, 1990, Personal communication.

Radiological Assessments Corporation, 1994, "The Fernald Dosimetry Reconstruction Project, Tasks 2 and 3, Radionuclide Source Terms and Uncertainities," RAC Report CDC-5, RAC, Neeses, SC.

Reding, M. E. and S. I. Guttman, 1991, "Radionuclide Contamination as an Influence on the Morphology and Genetic Structure of Periodical Cicada (*Magicicada Cassini*) Populations," American Midland Naturalist, Vol. 126, pp. 332-337.

Reed, P. B., Jr., 1988, "National List of Plant Species that Occur in Wetlands: Region 1," Biological Report 88 (26.1), U.S. Fish and Wildlife Service, Washington, DC.

RUST Environmental and Infrastructure, Inc., 1994, "Field Survey for Spring Coral-root at the FEMP Site," Draft, FERMCO, Cincinnati, OH.

Schultz, E. F., 1980, Problems in Applied Hydrology, Water Resources Publication, Fort Collins, CO.

Schumacher, G. A., E. M. Swinford and D. L. Shrake, 1991, Lithostratigraphy of the Grant Lake Limestone and Grant Lake Formation (Upper Ordovician) in Southwestern Ohio, Ohio Dept. of Natural Resources, Division of Geological Survey, Columbus, OH.

Scotford, D. M., 1965, "Petrology of the Cincinnatian Series Shales and Environmental Implications," Geological Soc. of America Bulletin, Vol. 76, pp. 193-222.

Sedam, A. C., 1984, "Occurrence of Uranium in Groundwater in the Vicinity of the U.S. Dept. of Energy Feed Materials Production Center, Fernald, Ohio," U.S. Geological Survey Administrative Report, Columbus, OH.

Sitton, M. D., 1988, "Site Analysis, Feed Materials Production Center, Fernald, Ohio, Interim Report," TS-PIC-88088, The Bionetics Corp., Warrenton, Virginia, prepared for U.S. EPA, Environmental Photographic Interpretation Center, Warrenton, VA.

Smith, R. D., 1962, "Groundwater Development, Miami River Area," Consultant report to the City of Cincinnati, Ohio, Water Works Dept. (see GeoTrans, 1985).

Spenceley, R. M., National Lead Co. of Ohio, Inc., 1983, [letter to M. R. Theisen, DOE, Subject: Non-FMPC sources of radioactivity in environmental samples].

Spieker, A. M. and S. E. Norris, 1962, "Groundwater Movement and Contamination at the AEC Feed Materials Production Center Located Near Fernald, Ohio," U.S. Geological Survey Technical Report for the U.S. Atomic Energy Commission.

Spieker, A. M., 1968a, "Effect of Increased Pumping of the Groundwater in the Fairfield-New Baltimore Area, Ohio - A Prediction of Analog-Model Study," U.S. Geological Survey Professional Paper 605-C, U.S. Government Printing Office, Washington, DC.

Spieker, A. M., 1968b, "Future Development of the Groundwater Resource in the Lower Great Miami River, Ohio - Problems and Alternative Solutions," U.S. Geological Survey Professional Paper 605-D, available from U.S. Government Printing Office, Washington, DC.

Spieker, A. M., 1968c, "Groundwater Hydrology and Geology of the Lower Great Miami River Valley, Ohio," U.S. Geological Survey Professional Paper 605-A, available from U.S. Government Printing Office, Washington, DC.

St. John, F. L., 1993, "Report on the Status of the Sloan's Crayfish (*Orconectes sloanii* Bundy) at the Fernald Environmental Management Project," FERMCO, Cincinnati, OH.

St. John, F. L., 1994, "Addendum to the Report on the Sloan's Crayfish (*Orconectes sloanii* Bundy) at the Fernald Environmental Management Project," Draft, FERMCO, Cincinnati, OH.

Starkey, R. H., C. Watson, R. C. Coates, E. B. Riestenberg and J. W. Robinson, 1962, "Report of FMPC Ground Contamination Study Committee," FMPC-110, National Lead Co. of Ohio, Cincinnati, OH.

Swinford, E. M., 1990, "Bedrock Geology of the Shandon Quadrangle (Hamilton County Portion)," Open File Map BG-B5C6, Ohio Dept. of Natural Resources, Division of Geological Survey, Columbus, OH.

Todd, D. K., 1970, The Water Encyclopedia, Water Information Center, Port Washington, NY.

Trautman, M. B., 1981, The Fishes of Ohio, 2nd Edition, Ohio State University Press, Columbus, OH.

U.S. Dept. of Agriculture, Soil Conservation Service, Ohio Dept. of Natural Resources, Division of Lands and Soil, Cooperative Extension Service and Ohio Agricultural Research and Development Center, 1970, "Ohio Irrigation Guide," USDA, ODNR, Ohio Agricultural Research and Development Center, Ohio State University, and the U.S. Weather Bureau, n.p.

U.S. Dept. of Agriculture, Soil Conservation Service, Ohio Dept. of Natural Resources, Division of Lands and Soil, Cooperative Extension Service and Ohio Agricultural Research and Development Center, 1980, "Soil Survey of Butler County, Ohio," USDA, ODNR, and Ohio Agricultural Research and Development Center, n.p.

U.S. Dept. of Agriculture, Soil Conservation Service, Ohio Dept. of Natural Resources, Division of Lands and Soil, Cooperative Extension Service and Ohio Agricultural Research and Development Center, 1982, "Soil Survey of Hamilton County, Ohio," USDA, ODNR, and Ohio Agricultural Research and Development Center, n.p.

U.S. Dept. of Agriculture, Soil Conservation Service, 1987a, "Field Office Technical Guide for Butler County, Ohio," Section IId, USDA, SCS, Washington, DC.

U.S. Dept. of Agriculture, Soil Conservation Service, 1987b, "Hydric Soils of the United States (Ohio)," in cooperation with the National Technical Committee for Hydric Soils, USDA, SCS, Washington, DC.

U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, n.d., "1989 - Local Climatological Data; Annual Summary with Comparative Data," NOAA, Asheville, NC.

U.S. Dept. of Energy, 1985, "Report of Historic Uranium Releases from Current DOE Oak Ridge Operations Office Facilities," DOE, Oak Ridge Operations Office, Oak Ridge, TN.

U.S. Dept. of Energy, 1987, "Remedial Investigation and Feasibility Study, Feed Materials Production Center, Fernald, Ohio, Task 1 Report: Description of Current Situation," DOE, Oak Ridge Operations Office, Oak Ridge, TN.

U.S. Dept. of Energy, 1988, "Remedial Investigation and Feasibility Study, Feed Materials Production Center, Fernald, Ohio, Work Plan Requirements," Revision 3, DOE, Oak Ridge Operations Office, Oak Ridge, TN.

U.S. Dept. of Energy, 1990, "A Probabilistic Risk Assessment for the K-65 Silos at the FMPC," FMPC/SUB-029 UC-702.

U.S. Dept. of Energy, 1992, "Risk Assessment Work Plan Addendum," Final Draft, FEMP, Remedial Investigation and Feasibility Study, DOE, Fernald Office, Cincinnati, OH.

U.S. Dept. of Energy, 1993a, "CERCLA/RCRA Background Soil Study," Fernald Environmental Management Project, DOE, Fernald Field Office, Cincinnati, OH.

U.S. Dept. of Energy, 1993b, "Development and Application of the ECTran Model to Support the RI/FS at the FEMP," Fernald Environmental Management Project, DOE, Fernald Field Office, Cincinnati, OH.

U.S. Dept. of Energy, 1993c, "Groundwater Modeling Evaluation Report and Improvement Plan," Fernald Environmental Management Project, DOE, Fernald Field Office, Cincinnati, OH.

U.S. Dept. of Energy, 1993d, "Groundwater Modeling Report - Summary of Model Development," Fernald Environmental Management Project, DOE, Fernald Field Office, Cincinnati, OH.

U.S. Dept. of Energy, 1993e, "Remedial Investigation Report for Operable Unit 4," Fernald Environmental Management Project, Final, DOE, Fernald Field Office, Cincinnati, OH.

U.S. Dept. of Energy, 1993f, "Sitewide CERCLA Quality Assurance Project Plan," Fernald Environmental Management Project, DOE, Fernald Field Office, Cincinnati, OH.

U.S. Dept. of Energy, 1993g, "Site-Wide Characterization Report," Fernald Environmental Management Project, DOE, Cincinnati, OH.

U.S. Dept. of Energy, 1993h, "South Groundwater Contamination Plume Design Monitoring Evaluation Program Plan," Fernald Environmental Management Project, DOE, Fernald Field Office, Cincinnati, OH.

U.S. Dept. of Energy, 1993i, "South Plume Removal Action Pumping Test Report," Fernald Environmental Management Project, DOE, Fernald Field Office, Cincinnati, OH.

001345

U.S. Dept. of Energy, 1994a, "Characterization of Background Water Quality for Streams and Groundwater," Fernald Environmental Management Project, Draft, DOE, Fernald Field Office, Cincinnati, OH.

U.S. Dept. of Energy, 1994b, "Feasibility Study Report for Operable Unit 4," Fernald Environmental Management Project, Final, DOE, Fernald Field Office, Cincinnati, OH.

U.S. Dept. of Energy, 1994c, "Feasibility Study Report for Operable Unit 1," Fernald Environmental Management Project, Draft, DOE, Fernald Field Office, Cincinnati, OH.

U.S. Dept. of Energy, 1994d, "Feasibility Study Report for Operable Unit 2," Fernald Environmental Management Project, Draft, DOE, Fernald Field Office, Cincinnati, OH.

U.S. Dept. of Energy, 1994e, "FEMP Glacial Till/Vadose Zone Hydraulic Investigations Report," Fernald Environmental Management Project, DOE, Fernald Field Office, Cincinnati, OH.

U.S. Dept. of Energy, 1994f, "Glacial Overburden/Upper Great Miami Aquifer System Model Report," Fernald Environmental Management Project, DOE, Fernald Field Office, Cincinnati, OH.

U.S. Dept. of Energy, 1994g, "Remedial Investigation Report for Operable Unit 1," Fernald Environmental Management Project, Draft, DOE, Fernald Field Office, Cincinnati, OH.

U.S. Dept. of Energy, 1994h, "Remedial Investigation Report for Operable Unit 2," Fernald Environmental Management Project, Draft, DOE, Fernald Field Office, Cincinnati, OH.

U.S. Dept. of Energy, 1994i, "Surface Water Flow and Infiltration Model Summary Report," Fernald Environmental Management Project, DOE, Fernald Field Office, Cincinnati, OH.

U.S. Dept. of Energy, 1994j, "SWIFT Great Miami Aquifer Model - Summary of Improvements Report," Fernald Environmental Management Project, DOE, Fernald Field Office, Cincinnati, OH.

U.S. Environmental Protection Agency, 1982, "Aquatic Fate Process Data for Organic Priority Pollutants," EPA 440/4-81-014, EPA, Washington, DC.

U.S. Environmental Protection Agency, 1983, "Guidelines and Specifications for Preparing Quality Assurance Project Plans," QAMS-005/80, EPA, Office of Monitoring Systems and Quality Assurance, Washington, DC.

U.S. Environmental Protection Agency, 1985, "Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites," EPA/600/8-85/002, EPA, Washington, DC.

U.S. Environmental Protection Agency, 1986, "Guidelines for Carcinogen Risk Assessment," Federal Register 51 (185), pp. 33992-34003.

U.S. Environmental Protection Agency, 1988a, "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA," EPA/540/G-89/004, EPA, Office of Emergency and Remedial Response, Washington, DC.

U.S. Environmental Protection Agency, 1988b, "Superfund Exposure Assessment Manual," EPA/540/1-88/001, EPA, Office of Remedial Response, Washington, DC.

U.S. Environmental Protection Agency, 1989a, "Bioremediation of Hazardous Waste Sites Workshop," CERI 89-11, Cincinnati, OH.

U.S. Environmental Protection Agency, 1989b, "Risk Assessment Guidance for Superfund, Vol. I, Human Health Evaluation Manual (Part A), Interim Final," EPA/540/1-89/002, EPA, Office of Emergency and Remedial Response, Washington, DC.

U.S. Environmental Protection Agency, 1989c, "Risk Assessment Guidance for Superfund, Vol. II: Environmental Evaluation Manual," EPA/540/1-89/0014, EPA, Office of Emergency and Remedial Response, Washington, DC.

U.S. Environmental Protection Agency (EPA), 1989d, "General Quantitative Risk Assessment Guidelines for Noncancer Health Effects," prepared by the Office of Health and Environmental Assessment for the Risk Assessment Forum, ECAO-CIN-538, Cincinnati, OH.

U.S. Environmental Protection Agency, 1991, "National Primary Drinking Water Regulations; Radionuclides; Proposed Rule," 58 Federal Register 138, pp. 33050-33127, July 18.

U.S. Environmental Protection Agency, 1992, U.S. Dept. of Health and Human Services, and U.S. Public Health Service, "A Citizen's Guide to Radon," 2nd ed., EPA, HHS, and CDC, Washington, DC.

U.S. Environmental Protection Agency, 1993, "Standards for Management of Uranium Byproduct Materials Pusruant to Section 84 of the Atomic Energy Act of 1954," as amended at 58 FR 60355, November 15.

U.S. Fish and Wildlife Service, 1991, Endangered and Threatened Wildlife and Plants, 50 CFR 17.11 and 17.12, U.S. Dept. of the Interior, Washington, DC.

U.S. Geological Survey, 1965, "Shandon, Ohio Quadrangle Map," photorevised 1981, USGS, Reston, VA.

U.S. Geological Survey, 1992, "Water Quality Data Collected for National Stream Quality Accounting Network," Data Printout, Great Miami River at New Baltimore, Ohio, for 1974 to 1982, USGS, Columbus, OH.

Vormelker, J., 1985, "Top of Rock Map of Hamilton County, Ohio," Open File Map 229, State of Ohio, Dept. of Natural Resources, Division of Geological Survey, Columbus, OH.

Walker, A. C., 1986, "Groundwater Resources of Hamilton County," map available from the Ohio Dept. of Natural Resources, Division of Water, Columbus, OH.

Walton, W. C. and E. J. Schaefer, 1956, "Report to the Southwestern Ohio Water Co. on Evaluation of the Potential Yield of the Aquifer in the Big Bend Area, Ohio," Mimeographed report, available from the Ohio Dept. of Natural Resources, Division of Water, Columbus, OH.

Watkins, J. S. and A. M. Spieker, 1971, "Seismic Refraction Survey of Pleistocene Drainage Channels in the Lower Great Miami River Valley, Ohio," U.S. Geological Survey, Professional Paper 605-B, U.S. Government Printing Office, Washington, DC.

001347

Weber, C. I., ed., 1973, "Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents," NERC/EPA, Cincinnati, OH.

Westinghouse Environmental Management Co. of Ohio, 1992, "Annual Site Environmental Report for Calendar Year 1991," FEMP-2275, prepared for U.S. Dept. of Energy, Fernald Field Office, Cincinnati, OH.

Westinghouse Materials Co. of Ohio, 1986, "Feed Materials Production Center Environmental Monitoring Annual Report for 1985," FMPC-2047, prepared for the U.S. Dept. of Energy, Oak Ridge Operations Office, Oak Ridge, TN.

Westinghouse Materials Co. of Ohio, 1987, "Feed Materials Production Center Environmental Monitoring Annual Report for 1986," FMPC-2076, prepared for U.S. Dept. of Energy, Oak Ridge Operations Office, Oak Ridge, TN.

Westinghouse Materials Co. of Ohio, 1988, "Feed Materials Production Center Environmental Monitoring Annual Report for 1987," FMPC-2135, prepared for the U.S. Dept. of Energy, Oak Ridge Operations Office, Oak Ridge, TN.

Westinghouse Materials Co. of Ohio, 1989, "Feed Materials Production Center Environmental Monitoring Annual Report for 1988," FMPC-2173, prepared for the U.S. Dept. of Energy, Oak Ridge Operations Office, Oak Ridge, TN.

Westinghouse Materials Co. of Ohio, 1990, "Feed Materials Production Center Annual Environmental Monitoring Report for 1989," prepared for the U.S. Dept. of Energy, Fernald Office, Cincinnati, OH.

Westinghouse Materials Co. of Ohio, 1991, "Feed Materials Production Center Annual Environmental Monitoring Report for 1990," FMPC-2245, prepared for the U.S. Dept. of Energy, Fernald Field Office, Oak Ridge, TN.

Weston, Inc., Roy F., 1986, "Dept. of Energy Feed Materials Production Center, Fernald, Ohio - Site Characterization of the Waste Storage Areas, Part 1: Evaluation of Current Situation," Weston, Inc., West Chester, PA, prepared for Westinghouse Materials Co. of Ohio, Cincinnati, OH.

Weston, Inc., Roy F., 1987, "Characterization Investigation Study, Vol. 3: Radiological Survey of Surface Soils," Weston, Inc., West Chester, PA, prepared for Westinghouse Materials Co. of Ohio, Cincinnati, OH.

Williams, G. M. and J. H. Weisburger, 1991, "Chemical Carcinogenesis," M. O. Amdur, J. Doull, and C. D. Klaassen, eds., Casarett and Doull's Toxicology, the Basic Science of Poisons, 4th ed., Pergamon Press, New York, pp. 127-200.

Wolery, T. J., 1992, "EQ3NR, A Computer Program for Geochemical Aqueous Speciation-Solubility Calculations: Theoretical Manual, User's Guide, and Related Documentation (Version 7.0)," Lawrence Livermore National Laboratory, UCRL-MA-110662 PT III, Berkeley, CA.

Wolery, T. J. and S. A. Daveler, 1992, "EQ6, A Computer Program for Reaction Path Modeling of Geochemical Systems: Theoretical Manual, User's Guide, and Related Documentation (Version 7.0)," Lawrence Livermore National Laboratory, UCRL-MA-110662 PT IV, Berkeley, CA.