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REMEDIAL INVESTIGATION REPORT OPERABLE UNIT 2 VOLUME 1 OF 3 OCTOBER 1992

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FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

REMEDIAL INVESTIGATION and FEASIBILITY STUDY

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LIST OF ACRONYMS

AEC	Atomic Energy Commission
ANL	Argonne National Laboratory
ASL	analytical support level
ASTM	American Society of Testing and Materials
BGL	below ground level
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CIS	Characterization Investigation Study
CLP	Contract Laboratory Program
COA	Certificate of Analysis
COC	chain of custody
CMS	Consolidated Metropolitan Statistical Area
DCE	dichloroethylene
DDT	dichlorodiphenyltrichloroethane
DOE	U.S. Department of Energy
DQO	data quality objectives
EIS	environmental impact statement
EP	extraction procedure
EPA	U.S. Environmental Protection Agency
FEMP	Fernald Environmental Management Project
FFCA	Federal Facility Compliance Agreement
FIDLER	field instrument for detecting low-energy radiation
FMPC	Feed Materials Production Center
FS	feasibility study
GC/MS	gas chromatograph/mass spectrometer
GPR	ground-penetrating radar
HELP	Hydrogeologic Evaluation of Landfill Performance (model)
HI	hazard index
HSL	Hazardous Substance List
ILCR	incremental lifetime cancer risk
IT	International Technology Corporation
MSL	mean sea level
MUSLE	modified Universal Soil Loss Equation
NEPA	National Environmental Policy Act [of 1969]
NLO	National Lead Company of Ohio
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission

LIST OF ACRONYMS (continued)

NRHP	National Register of Historic Places
ODH	Ohio Department of Health
OEPA	Ohio Environmental Protection Agency
ORAU	Oak Ridge Associated Universities
PAH	polynuclear aromatic hydrocarbon
PEIS	programmatic environmental impact statement
PCB	polychlorinated biphenyl
QAPP	Quality Assurance Project Plan
QA	quality assurance
QC	quality control
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RFA	request for analysis
RI/FS	remedial investigation/feasibility study
RM	river mile
RME	reasonable maximum exposure
SARA	Superfund Amendment and Reauthorization Act
SHPO	State Historic Preservation Office
SOW	statement of work
SOWC	Southwestern Ohio Water Company
SQL	sample quantitation limit
SRLP	simulated rainwater leaching procedure
SVOC	semivolatile organic compound
SWCR	Site-Wide Characterization Report
TCLP	toxicity characteristic leaching procedure
TCA	trichloroethane
TEF	toxicity equivalency factor
TOC	total organic carbon
UCL	upper confidence level
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation
UTL	upper tolerance limit
VOC	volatile organic compound
WEMCO	Westinghouse Environmental Management Company of Ohio
WMCO	Westinghouse Materials Company of Ohio

DISTRIBUTION LIST

Project Director - John Wood, Fernald
Deputy Project Director - John Razor, Fernald
Site Characterization Director - Douglas Harmel, Fernald
Technical Integration Director - Ed Hopson, Fernald
Operable Unit/Task Managers - Mike Higgins, Knoxville
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EXECUTIVE SUMMARY

23A

EXECUTIVE SUMMARY

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The Feed Materials Production Center, renamed on August 23, 1991 and hereinafter called the Fernald Environmental Management Project (FEMP), is a contractor-operated federal facility where pure uranium metals were produced for the U.S. Department of Energy (DOE) between 1951 and 1989. The FEMP site is located on 1050 acres in a rural area of Hamilton and Butler counties, approximately 18 miles northwest of Cincinnati, Ohio.

In July 1986, a Federal Facility Compliance Agreement (FFCA) pertaining to environmental impacts associated with the FEMP was signed by DOE and U.S. Environmental Protection Agency. The FFCA was intended to ensure that environmental impacts associated with past and present activities at the FEMP are thoroughly and adequately investigated so that appropriate remedial response actions can be formulated, assessed, and implemented. In response to the FFCA, a Remedial Investigation/ Feasibility Study (RI/FS) was initiated pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act, as amended by the Superfund Amendment and Reauthorization Act.

The RI/FS Work Plan ultimately addressed 39 separate units at the FEMP that required investigation. These units were categorized and grouped into five operable units to expedite remedial planning and implementation. Separate schedules were generated for each operable unit. The five operable units established at the FEMP are:

- Operable Unit 1 - Waste Pit Area
- Operable Unit 2 - Other Waste Units
- Operable Unit 3 - Production Area
- Operable Unit 4 - Silos 1 – 4
- Operable Unit 5 - Environmental Media

Operable Unit 2 includes the Solid Waste Landfill, the North and South Lime Sludge Ponds, the Active Flyash Pile, the Inactive Flyash Pile, and the South Field. These waste areas were used for the storage/disposal of sanitary waste, spent lime sludge, flyash, and construction rubble. The primary characteristic of these waste areas is that they contain large volumes of waste with relatively low concentrations of hazardous chemicals and/or radionuclides.

The objectives of the RI are to:

- Identify and characterize any sources of potential radiological and chemical contamination
- Determine the nature and extent of waste-related radiological and chemical substances found in soils, sediments, surface water, and groundwater
- Identify the migration pathways and mechanisms for transport of waste-related radiological and chemical substances

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- Characterize the occurrence of chemical or radiological substances in aquatic and terrestrial organisms both on and adjacent to the FEMP
- Conduct health risk assessment and environmental impact studies to assess the risk associated with any confirmed contamination at or emanating from the site
- Develop, validate, and apply various site models to augment the current understanding of the site environment
- Provide the data necessary to perform the screening and detailed analysis of remedial alternatives during the FS

An additional purpose of the RI is to provide, in combination with the Site-Wide Characterization Report, data required for National Environmental Protection Act (NEPA) analyses of environmental impacts of proposed remedial actions. The NEPA analyses will be included in the Operable Unit 2 RI and FS reports.

RI/FS environmental sampling and analyses programs were designed to address the data needs of the RI. Data previously published for the FEMP were also considered, particularly those gathered as a part of (1) the Environmental Survey in 1985 and 1986 and (2) the Characterization Investigation Study conducted in 1986 and 1987. Data from all of these sources are evaluated in this RI. Samples were collected from surface media (including soils, lime sludge residue, and/or flyash), subsurface soils, surface water, drainage sediments, groundwater, and biota.

The radionuclides encountered most frequently and at the highest concentrations included uranium, thorium, and radium. Other radionuclides were encountered, but with less frequency and at lower concentrations. Organic compounds detected in the waste included polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), chlorinated dioxins and furans, phthalate esters, and chlorinated volatile compounds. In general, these organic compounds were detected infrequently and at low concentrations. Beryllium, cadmium, and molybdenum were detected with frequencies greater than 50 percent in at least three of the Operable Unit 2 waste areas. Elevated uranium levels were measured in sediments of streams and ditches that drain the Solid Waste Landfill and the Active and Inactive Flyash Piles. Elevated levels of uranium were measured in wells near all of the Operable Unit 2 waste areas, but it is unclear whether the source of this uranium is Operable Unit 2 waste or some other upgradient source(s).

Fate and transport models were used to predict the migration of contaminants from the waste areas to potential human and environmental receptors via air, surface water, and groundwater pathways. These models were used to estimate contaminant concentrations at potential human exposure locations so that the risk to human health could be evaluated.

The Baseline Risk Assessment for Operable Unit 2 is a supplement to this RI report and addresses potential pathways for the exposure to soils and migration of contaminants from Operable Unit 2. Baseline risk assessment has two major objectives: (1) to determine whether "no action" is an acceptable alternative from a public health and environmental perspective as required by 40CFR1508.-25[b][1], and (2) to provide the public health and environmental baseline conditions for comparing the impacts of remedial action alternatives identified and evaluated in the FS. The Operable Unit 2 Baseline Risk Assessment focuses on human receptors. Non-human receptors are addressed in the Site-Wide Characterization Report and will be evaluated as part of the Operable Unit 5 RI/FS.

The risk assessment presents estimated risks associated with five potential land-use scenarios: current land use with and without access controls and future land use with and without access controls (the latter for the both a "typical average" and a "reasonable maximum" exposure scenario). For the scenarios without access controls, it is assumed that the government will not maintain control over the use of the FEMP property.

Risks associated with contaminant migration from the waste areas to the groundwater were calculated for the future land-use scenarios. Uranium was the major contaminant estimated to reach the aquifer. For each waste area, risks associated with estimated uranium concentrations in groundwater are within or lower than the acceptable risk range of 10^{-6} to 10^{-4}.

The important risks associated with Operable Unit 2 waste areas are associated with soil pathways. For land use scenarios that assume access controls will remain in place, no elevated risks are projected except for the slightly elevated risk from radium in the South Field. For land use scenarios that assume loss of access controls, the risks are not within acceptable ranges. For these scenarios, potential receptors are assumed to have frequent direct access to the wastes, which leads to conservative estimates on the true risk. Chemicals that contribute to the elevated risks include uranium, thorium, radium, technetium, lead-210, PCBs, PAHs, dioxins/furans, 1,4-dioxane, chlordane, 2-butanone, antimony, arsenic, beryllium, cadmium, copper, lead, mercury, silver, and zinc. The elevated risks associated with the metals results in part from conservative estimates of chemical transfer into vegetables, meat, and milk.

The results suggest that there is great variation in estimated risks based on the assumption of future control of the property. If the government retains control of the property, risks associated with Operable Unit 2 are in the acceptable range. If the government loses control of the property, future exposures to the Operable Unit 2 waste areas may lead to unacceptable risks.

1.0

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1.0 INTRODUCTION

The Feed Materials Production Center (FMPC), renamed on August 23, 1991 and hereinafter called the Fernald Environmental Management Project (FEMP), is a contractor-operated federal facility where pure uranium metals were produced for the U.S. Department of Energy (DOE) between 1951 and 1989. The FEMP site is located on 1050 acres in a rural area of Hamilton and Butler counties approximately 18 miles northwest of Cincinnati, Ohio. The production area is limited to an approximate 136-acre tract near the center of the FEMP site. The villages of Fernald, New Baltimore, Ross, New Haven, and Shandon are all located within a few miles of the site (Figure 1-1).

On March 9, 1985, the U.S. Environmental Protection Agency (EPA) issued a Notice of Noncompliance to DOE, identifying EPA's major concerns over potential environmental impacts associated with the FEMP's past and present operations. Between April 1985 and July 1986, conferences were held between DOE and EPA representatives to discuss the issues and identify the steps DOE proposed to take to achieve and maintain environmental compliance.

On July 18, 1986, a Federal Facility Compliance Agreement (FFCA) pertaining to environmental impacts associated with the FEMP was signed by DOE and EPA. The FFCA was entered into pursuant to Executive Order 12088 (43FR47707) to ensure compliance with existing environmental statutes and implementing regulations such as the Clean Air Act, the Resource Conservation and Recovery Act (RCRA), and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). In particular, the FFCA was intended to ensure that environmental impacts associated with past and present activities at the FEMP are thoroughly and adequately investigated so that appropriate remedial response actions can be formulated, assessed, and implemented. In response to the FFCA, a Remedial Investigation/Feasibility Study (RI/FS) was initiated pursuant to CERCLA, as amended by the Superfund Amendment and Reauthorization Act (SARA). All RI/FS activities are being conducted in conformance with EPA's "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA 1988a).

The 1986 FFCA was amended by a Consent Agreement under Sections 120 and 106(a) of CERCLA (Consent Agreement) in order to achieve consistency with the operable unit concept and the commitments of the RI/FS program without modifying the underlying objectives. The Consent Agreement was signed on April 9, 1990 and became effective on June 29, 1990.

The Consent Agreement was itself amended the next year to revise the schedules for completing the RI/FS for the five operable units. This Amended Consent Agreement was signed on September 20 and became effective on December 19, 1991.

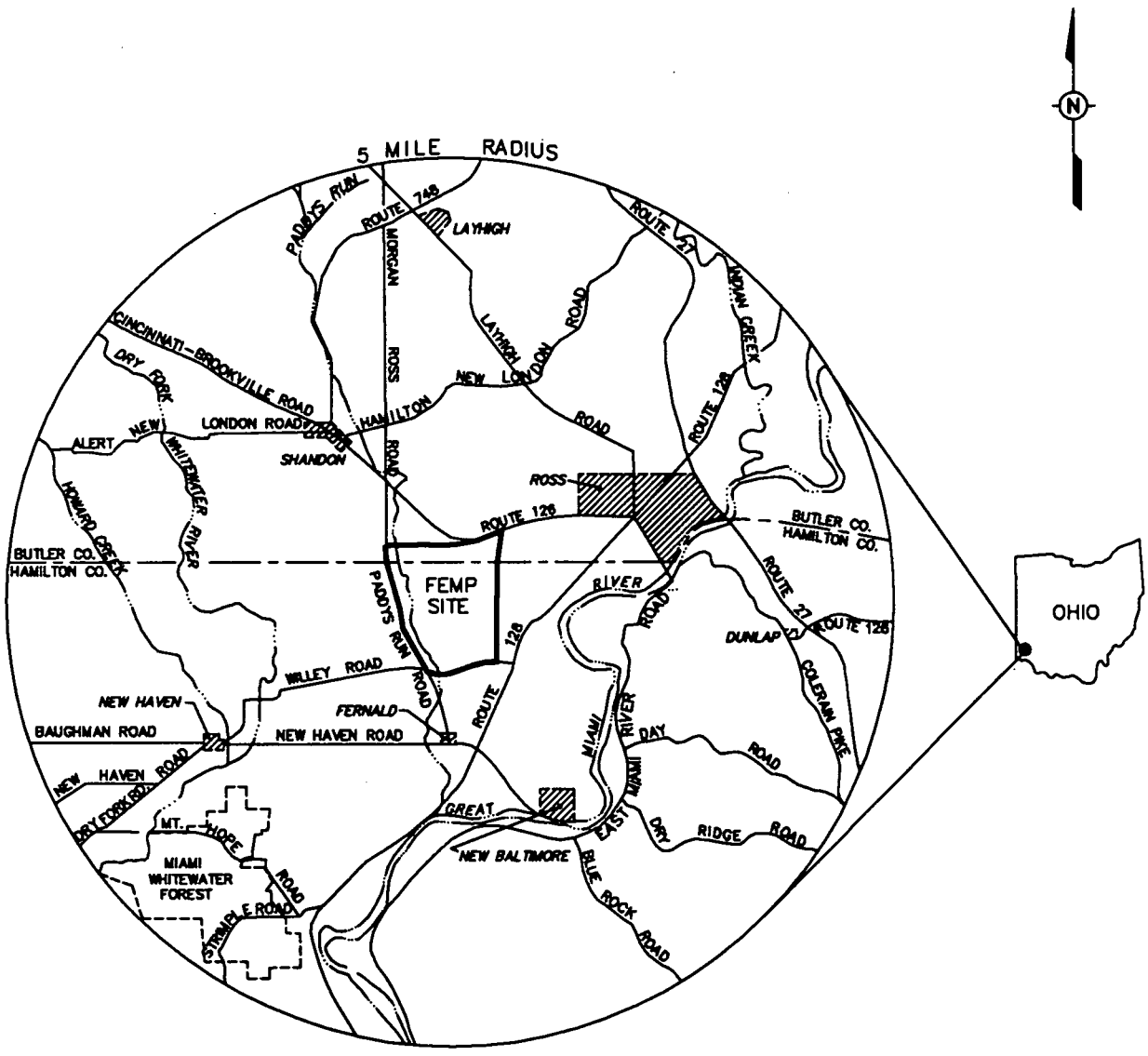

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FIGURE 1-1. FIVE-MILE RADIUS MAP, FERNALD ENVIRONMENTAL MANAGEMENT PROJECT

1.1 APPROACH AND OBJECTIVES

The RI/FS for the FEMP was initially designed to address the entire site and to focus on various environmental media that could be impacted by past and present operations at the FEMP. The purpose of the RI is to determine the nature and extent of any release, or threat thereof, of hazardous or radioactive substances and to gather the necessary data to support the evaluation of remedial action alternatives in the FS.

1.1.1 Site Characterization

A Work Plan for the site-wide RI/FS, based on the requirements of the FFCA, was originally submitted to EPA in December 1986. After a series of technical discussions, the Work Plan was modified and resubmitted in March 1988. It received EPA approval in May 1988.

The Work Plan provided the overall technical approach, identified a number of investigative areas, developed objectives for each of the specified investigations, and established overall objectives for the evaluation of data collected during the RI activities. The Work Plan included 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 contained objectives, sampling locations, and sampling procedures for the following:

- Radiation measurements
- Surface soils
- Groundwater
- Subsurface soils
- Surface water and sediment
- Biological resources

The Work Plan identified 27 units of the FEMP to be investigated in the RI/FS. Several modifications to the list eventually increased this total to 39 units. In the course of the investigation, it became apparent that, for technical and program management purposes, these 39 units needed to be categorized and grouped together. 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 or problematic units, while data collection and analysis continued for other operable units.

There are five operable units:

- Operable Unit 1 - Waste Pit Area
- Operable Unit 2 - Other Waste Units
- Operable Unit 3 - Production Area
- Operable Unit 4 - Silos 1 - 4
- Operable Unit 5 - Environmental Media

The Amended Consent Agreement adds a Comprehensive Site-Wide Operable Unit that will evaluate the remedies selected for the five operable units on a site-wide basis.

Since the Work Plan, and more specifically the Sampling Plan, was developed before the formulation of the operable units for the FEMP, there were no specific operable unit sampling plans prepared. Areas covered by Operable Units 1 through 4 are considered sources for possible contamination of the underlying aquifer (Figure 1-2). Although an RI report for one operable unit may indicate the presence of an adjacent operable unit as a potential contributing source, the focus of the RI report will be to present data identifying that source and define the vertical and lateral extent of contamination within the boundary of that operable unit.

The RI report for Operable Unit 5 will address (1) the Great Miami Aquifer which underlies the source operable units, (2) surface water drainages that may carry contamination from those operable units, and (3) any remaining soil contamination not included in the other operable unit RI reports. The net effect of the five RI reports will be to provide a complete description of the extent of contamination and a detailed analyses of its various sources.

The Amended Consent Agreement authorizes a Site-Wide Characterization Report (SWCR) (DOE 1992b) to provide a one-time summary of all site data available as of December 1, 1991. The SWCR is to include the leading remedial alternatives for Operable Units 1-5 and a preliminary baseline risk assessment which characterizes the current and potential threats to human health and the environment from the entire site.

The scope of work for the RI at the FEMP was prepared to satisfy the following specific objectives:

- Identify and characterize any sources of potential radiological and chemical contamination
- Determine the nature and extent of any radiological and chemical substances found in soils, sediments, surface water, and groundwater
- Identify the migration pathways and mechanisms for transport of radiological and chemical substances found in soils, sediments, surface water, and groundwater

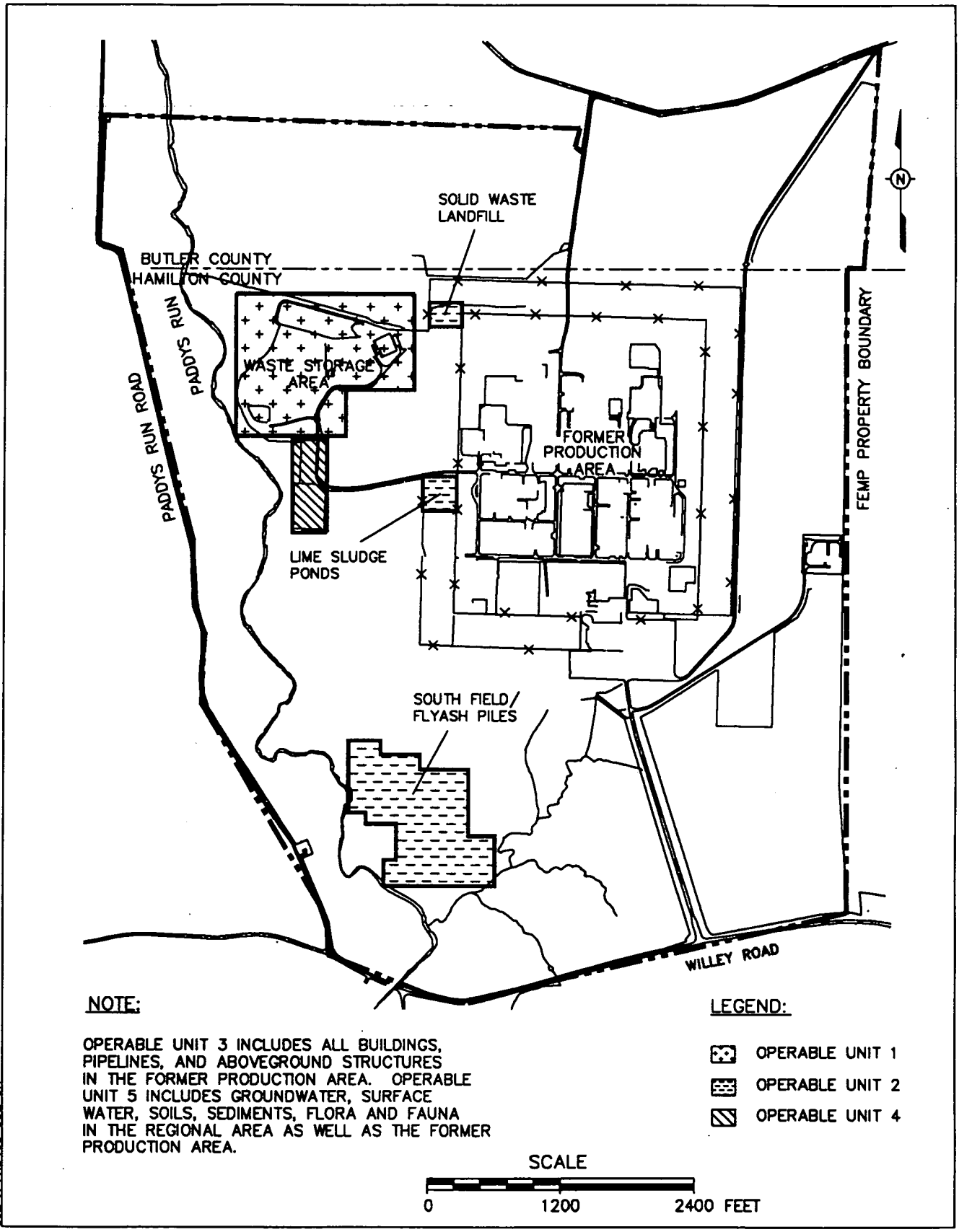

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FIGURE 1–2. RI/FS OPERABLE UNITS

- Characterize the occurrence of chemical or radiological substances in aquatic and terrestrial organisms both on and adjacent to the FEMP

- Conduct health risk assessments and environmental impact studies to assess the risk associated with any confirmed contamination at or emanating from the site

- Develop, validate, and apply various site models to augment the current understanding of the site environment

- Provide the data necessary to perform the screening and detailed analysis of remedial alternatives during the FS

This RI report serves to document the data collection and analysis phase of the RI/FS for Operable Unit 2. A brief description of Operable Unit 2 waste areas is presented in Section 1.3. The FS for Operable Unit 2 will subsequently utilize the RI data to select, screen, and analyze remedial action alternatives. Criteria for selection of remedial alternatives will be effectiveness, implementability, and cost.

1.1.2 NEPA Compliance

An additional purpose of the RI is to provide, in combination with the SWCR, data required for National Environmental Protection Act (NEPA) analyses of environmental impacts of proposed remedial actions. The NEPA analyses will be included in the Operable Unit 2 RI and FS reports.

Section 3.0, Description of the Physical Characteristics of the Study Area, meets the NEPA requirement to describe the affected environment. It includes discussions of floodplains and wetlands, threatened and endangered species, and population and land use. The site-wide database required for analysis of potential impacts of site-wide remedial activities is contained in the SWCR (DOE 1992b), which is incorporated herein by reference.

This approach is in accord with DOE's intent to integrate the requirements of NEPA and CERCLA as set forth in DOE Order 5400.4. The specific NEPA/CERCLA integration approach for the FEMP was published in the Notice of Intent (55 Federal Register 20183, May 15, 1990), which concluded that:

- A RI/FS - Environmental Impact Statement (EIS) is the appropriate level of NEPA documentation for the lead operable unit

- NEPA/CERCLA integration will also be provided in the remaining operable unit RI/FS - NEPA documents. These documents will be "tiered to" (or reference) the lead RI/FS - EIS and will present impacts specific to the operable units and update site-wide and cumulative impacts, as necessary.

DOE's intent to integrate NEPA and CERCLA requirements for the FEMP is reiterated and further detailed in the Implementation Plan for the RI/FS-EIS for Remedial Activities at Operable Unit 2 and Other Operable Units (DOE 1992d).

DOE is also preparing a Programmatic Environmental Impact Statement (PEIS) to assess broad issues and integrated approaches to DOE's nationwide environmental restoration and waste management activities. The FEMP will be considered within the PEIS, because the site requires environmental restoration that will generate large volumes of radioactive, hazardous, and mixed waste. Thus, the PEIS may have an impact on disposal alternatives and planning for potential interim storage of these wastes at the FEMP.

1.2 SITE BACKGROUND

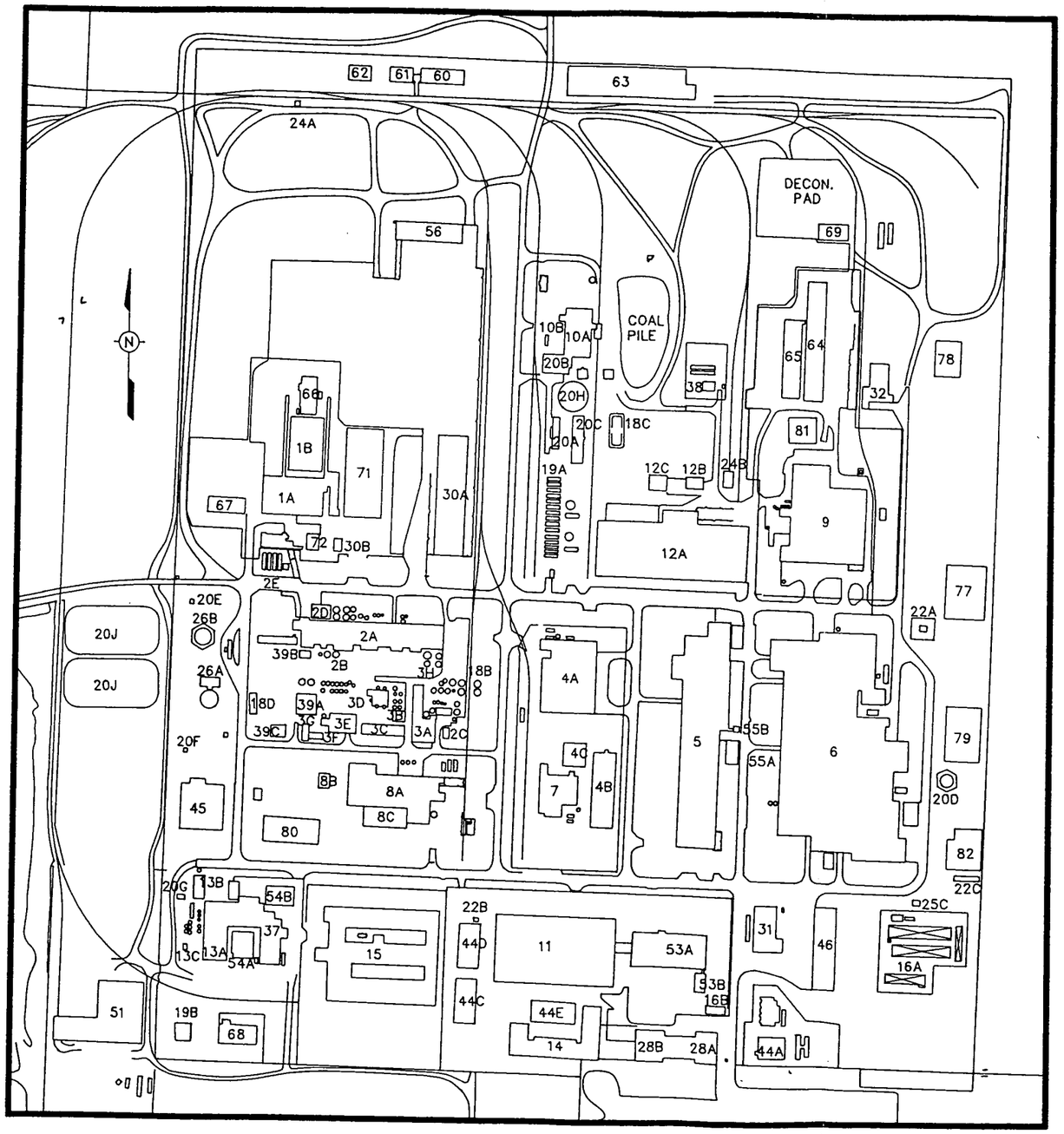
This section provides general site-wide background information on the FEMP and the surrounding area. It includes a description of the FEMP, a site history, and a discussion of previous site investigations. More specific information for Operable Unit 2 is supplied in Sections 1.3 and 2.0.

1.2.1 Site Description and History

The U.S. Atomic Energy Commission (AEC), predecessor to DOE, established the FEMP for processing uranium and its compounds from natural uranium ore concentrates and recycled recoverable residues for government needs. This integrated production complex began operations in conformance with AEC Orders in the early 1950s. In 1951, National Lead Company of Ohio (now NLO Inc.) entered into contract with the AEC as Operations and Management Contractor. This contractual relationship continued with AEC, and subsequently with DOE, until January 1, 1986. Westinghouse Materials Company of Ohio (WMCO), a wholly owned subsidiary of Westinghouse Electric Corporation, then assumed management responsibilities of the site operations and facilities for a minimum of five years. In 1991 Westinghouse renamed this subsidiary the Westinghouse Environmental Management Company of Ohio (WEMCO).

A pilot plant, completed in 1951, was the first operational facility at the FEMP; a metals fabrication plant (Plant 6) began operations in 1952. Another metals production plant (Plant 5), the green salt plant (Plant 4), the recovery plant (Plant 8), the sampling plant (Plant 1), and the refinery (Plants 2 and 3) began operations in 1953. Plant 7, where uranium hexafluoride (UF_6) was processed, and Plant 9, the special products plant, became operational in 1954. A diagram of the existing FEMP layout is provided in Figure 1-3.

Production peaked in 1960 at approximately 10,000 metric tons of uranium (mtu) per year. A product decline began in 1964, to a low in 1975 of about 1230 mtu. During the 1970s, consideration was given to closing the FEMP, so capital improvements and staffing were minimized. The staffing level,



1A PREPARATION PLANT
1B PLANT 1 STORAGE BLDG.
2A ORE REFINERY PLANT
2B LIME HANDLING BLDG.
2C BULK LIME HANDLING BLDG.
2D METAL DISSOLVER BLDG.
2E MFS STORAGE AND PUMP HOUSE
3A MAINTENANCE BLDG.
3B OZONE BLDG.
3C CONTROL HOUSE
3D NAR TOWERS
3E HOT RAFFINATE BLDG.
3F DIGESTION FUME RECOVERY
3G REFRIGERATION BLDG.
3H REFINERY SUMP
4A GREEN SALT PLANT
4B PLANT 4 WHSE.
4C PLANT 4 MAINTENANCE BLDG.
5 METALS PRODUCTION PLANT
6 METALS FABRICATION PLANT
7 PLANT 7
8A RECOVERY PLANT
8B MAINTENANCE BLDG.
8C ROTARY KILN/DRUM RECOND. BLDG.
9 SPECIAL PRODUCTS PLANT
10A BOILER PLANT
10B BOILER PLANT MAINTENANCE BLDG.
11 SERVICE BLDG.
12A MAIN MAINTENANCE BLDG.
12B CYLINDER STORAGE BLDG.
12C LUMBER STORAGE BLDG.
13A PILOT PLANT WET SIDE
13B PILOT PLANT MAINTENANCE BLDG.
13C SUMP PUMP HOUSE
14 ADMINISTRATION BLDG.

15 LABORATORIES
16A MAIN ELECTRICAL STATION
16B ELECTRICAL SUBSTATION
18B GENERAL SUMP
18C COAL PILE RUNOFF BASIN
18D BIODENITRIFICATION TOWERS
19A MAIN METAL TANK FARM
19B PILOT PLANT AMMONIA TANK FARM
20A VALVE/CONTROL BLDG
20B FILTER/CHEMICAL BLDG.
20C COOLING TOWERS
20D ELEVATED POTABLE STORAGE TANK
20E WELL HOUSE #1
20F WELL HOUSE #2
20G WELL HOUSE #3
20H PROGESS WATER STORAGE TANK
20J LIME SLURRY PITS
22A GAS METER BLDG.
22B SEWER LIFT STATION
22C TRUCK SCALE
24A RAILROAD SCALE HOUSE
24B RAILROAD ENGINE HOUSE
25C SEWAGE LIFT STATION BLDG.
25D U.V. DISINFECTION BLDG.
25E DIGESTER CONTROL BLDG.
26A PUMP HOUSE-HP FIRE PROTECTION
26B ELEVATED WATER STORAGE TANK
28A SECURITY BLDG.
28B HUMAN RESOURCES BLDG.
30A CHEMICAL WHSE.
30B DRUM STORAGE WHSE.
31 ENGINE HOUSE/GARAGE
32 MAGNESIUM STORAGE BLDG.
37 PILOT PLANT ANNEX
38 PROPANE STORAGE

39A INCINERATOR BLDG.
39B SHELTER STORAGE BLDG.
39C INCIN. BLDG. SPRINKLER RISER HOUSE
44A TRAILER COMPLEX (6-PLEX)
44C TRAILER COMPLEX (7 PLEX S)
44D TRAILER COMPLEX (7 PLEX N)
44E TRAILER COMPLEX (NO PLEX)
45 RUST ENG. BLDG.
46 HEAVY EQUIPMENT BLDG.
51 6 TO 4 REDUCTION FACILTY #2
53A O.S. & H. BLDG.
53B IN-VIVO BLDG.
54A 6 TO 4 REDUCTION FACILITY #1
54B PILOT PLANT WHSE.
55A SLAG RECYCLING BLDG.
55B SLAG RECYCLING PIT/ELEVATOR
56 CP STORAGE WHSE.
60 QUONSET HUT #1
61 QUONSET HUT #2
62 QUONSET HUT #3
63 KC-2 WHSE.
64 THORIUM WHSE.
65 (OLD) PLANT 5 WHSE.
66 DRUM RECONDITIONING BLDG.
67 PLANT 1 THORIUM WHSE.
68 PILOT PLANT WHSE.
69 DECONTAMINATION BLDG.
71 GENERAL IN-PROCESS STORAGE WHSE.
72 DRUM STORAGE BLDG.
77 FINISHED PRODUCT WHSE.
78 D & D BLDG. (NOT CONSTR.)
79 PLANT 6 WHSE.
80 PLANT 8 WHSE.
81 PLANT 9 WHSE.
82 RECEIVING/INCOMING MTRLS. INSP. BLDG.

SCALE
0 250 500 FEET

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FIGURE 1-3. FORMER PRODUCTION AREA LAYOUT

which peaked at 2891 in 1956, slowly declined from 662 in 1972 to 538 in 1979. In 1981, the FEMP began planning to accommodate increased production requirements. Production levels significantly increased and there was a rapid staff buildup in many areas for several years. Implementation of a major facilities restoration program followed. Then production ceased in the summer of 1989 and plant resources were focused on a cleanup program. In June 1991, the FEMP was officially closed as a federal production facility; however, the environmental studies and cleanup activities continue.

A variety of chemical and metallurgical processes were used at the FEMP for the manufacture of uranium products. During the manufacturing process, high-quality uranium compounds were introduced into the FEMP processes at several points. Impure starting materials were dissolved in nitric acid, and the uranium was purified through solvent extraction to yield a solution of uranyl nitrate. Evaporation and heating converted the nitrate solution to uranium trioxide (UO_3) powder. This compound was reduced with hydrogen to uranium dioxide (UO_2) and then converted to uranium tetrafluoride (UF_4) by reaction with anhydrous hydrogen fluoride. Uranium metal was produced by reacting UF_4 and magnesium metal in a refractory-lined vessel. This primary uranium metal was then remelted with scrap uranium metal to yield a purified uranium ingot. Various uranium metalworking processes were also housed on the FEMP.

From 1953 through 1955, the FEMP refinery processed pitchblende ore from the Belgian Congo. Pitchblende ore contains all progeny products of uranium decay and is particularly high in radium content. No chemical separation or purification was performed on the ore before its arrival at the FEMP. Beginning in 1956, the refinery feedstock consisted of uranium concentrates (yellowcake) from Canada and the United States. Canadian concentrates were not processed after 1960. In the production of these concentrates, most of the uranium progeny had been removed. However, radium-226 (Ra-226) remained in the yellowcake in amounts that varied with the process.

Small amounts of thorium were produced at the FEMP on several occasions from 1954 through 1975. Thorium operations were performed in the metals fabrication plant, the recovery plant, the special projects plant, and the pilot plant. The FEMP currently serves as the thorium repository for DOE and maintains long-term storage facilities for a variety of thorium materials.

Large quantities of liquid and solid wastes were generated by the various operations at the FEMP. 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 1-4), includes six low-level radioactive waste storage pits; two earthen-bermed concrete silos containing K-65 residues, which are high-specific activity, radium-bearing residues resulting from the pitchblende refining process; one

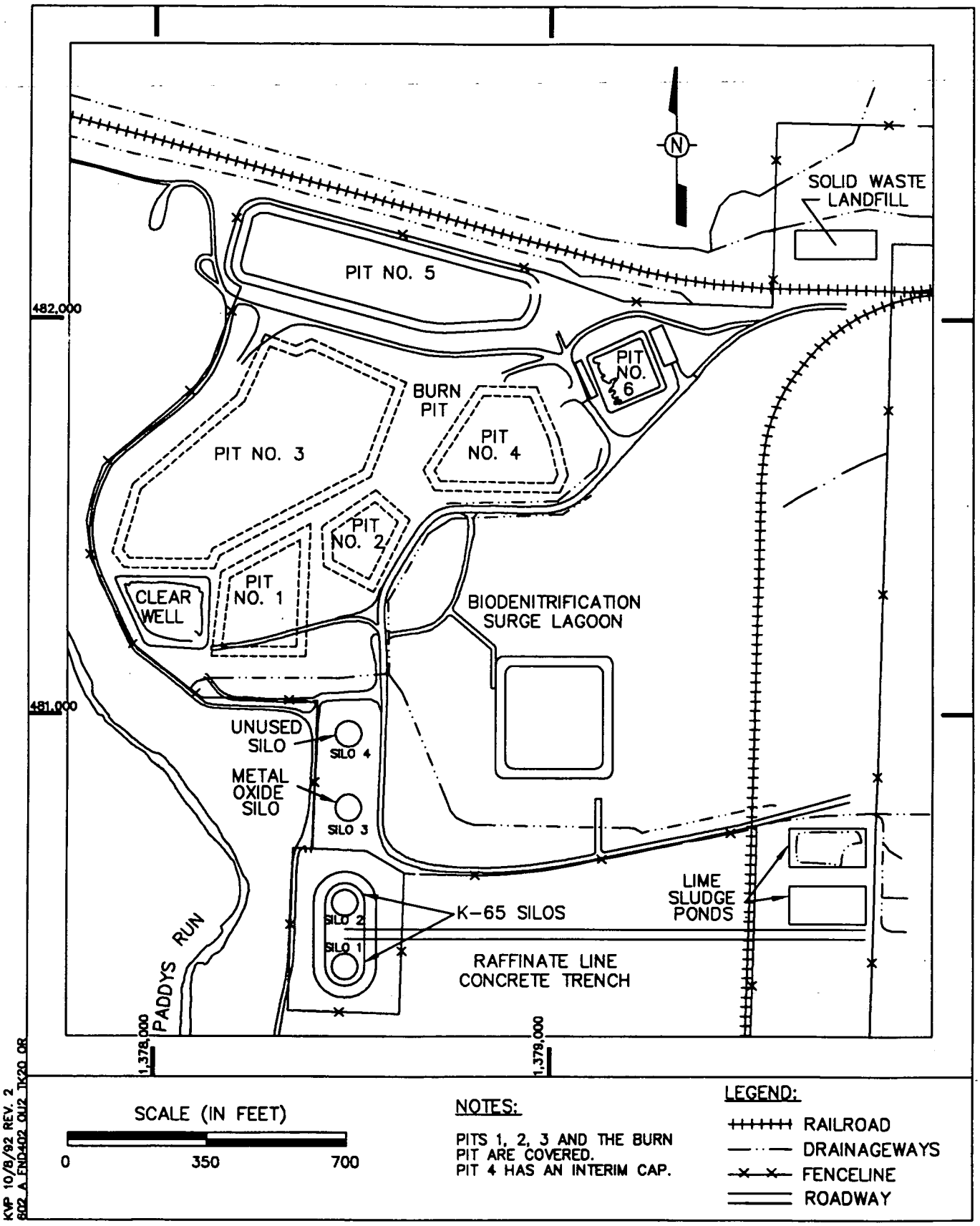

FIGURE 1-4. WASTE STORAGE AREA

concrete silo containing metal oxides and one unused concrete silo; two lime sludge ponds; and a solid waste landfill. The waste storage area is addressed under Operable Units 1, 2, and 4.

Additional waste materials associated with uranium metals production are presently stored on the property in steel drums, awaiting further processing or off-site disposal at approved facilities. These wastes include oils, sludges, contaminated combustibles, filter cake, off-specification UF_4 or thorium-tetrafluoride (ThF_4), and reject UO_3. The drums sit on various pads and in warehouses and are inspected weekly. Contents of deteriorated drums are repackaged. Other wastes, stored in drums on contained surfaces, include spent degreasing solvents and material contaminated with polychlorinated biphenyls (PCBs).

The Active and Inactive Flyash Piles, addressed under Operable Unit 2, are located approximately 3000 feet south-southeast of the waste storage area. One pile remains active for the disposal of flyash, bottom ash, and precipitator ash (all of which are hereinafter referred to as flyash) from the FEMP coal-fired boiler plant. An area between and adjacent to the flyash areas, known as the South Field, is believed to have been the disposal site for construction and demolition debris and possibly other types of solid waste from FEMP operations. The South Field is also being addressed as a waste area, under Operable Unit 2.

Surface water runoff from the waste storage area, flyash piles, and other affected areas within the western portion of the FEMP enters Paddys Run, a tributary of the Great Miami River. Paddys Run is an intermittent stream that originates north of FEMP and flows south-southeast along the western edge of the site.

Leachate from these same areas has the potential to migrate vertically through a till layer of varying thickness to the regionally important Great Miami Aquifer which underlies the site. This aquifer serves as a principal source of domestic, municipal, and industrial water throughout the region. A portion of the flow in Paddys Run is also known to enter this aquifer as a result of leakage through the stream bottom. Leakage occurs over the length of Paddys Run, beginning at a point west of the waste storage area and extending to the Great Miami River.

Liquid waste effluent generated by FEMP process operations is sent to the general sump for treatment and analysis prior to release to the Great Miami River through the main effluent line. The main effluent line to the Great Miami River is the permitted discharge point for wastewater from the FEMP. The discharge is regulated by a National Pollutant Discharge Elimination System (NPDES) permit and DOE Orders, with compliance monitoring performed at Manhole 175 before the effluent leaves the FEMP boundary.

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Storm water runoff from the production area is collected in storm water retention basins, located on the south side of the production area, to allow for solids to settle out before the water is analyzed and released to the Great Miami River through the same effluent line. During extreme storm events, if the storm water retention basins overflow, storm water is discharged through the storm sewer outfall ditch to Paddys Run.

1.2.2 Previous Site Investigations

1.2.2.1 Geologic Investigations

Geologic investigations of the area that surrounds and includes the FEMP have contributed substantial information to the RI/FS investigation. Fenneman (1916) performed an extensive survey of the geology in the Cincinnati area. This report describes in detail the interbedded limestone and shale bedrock and its mantle of glaciofluvial and alluvial sediments that comprise the buried channel aquifers in southwestern Ohio. Later investigators such as Durrell (1961) supported the earlier observations of Fenneman. 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, in preparation). Maps showing the extent and age of glacial overburden in the study area have also been produced (Brockman 1986). The Soil Conservation Service (USDA 1980, 1982) performed soil surveys of Butler and Hamilton counties, Ohio.

1.2.2.2 Surface Water Investigations

The Miami Conservancy District has kept precipitation and runoff records for the Miami River Valley since the early 1900s (Houck 1921). Precipitation records have also been kept at the Cincinnati 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; Ohio EPA 1982).

Flow from the drainage basin is monitored by the U.S. Geological Survey (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 (1985a). Realignments and other modifications of Paddys Run and its tributaries on the FEMP have been documented by Dove (1961) and WMCO (1987). Surface water quality data for the FEMP area are available from NLO for the period 1979 through 1985 and the Ohio Environmental Protection Agency (OEPA) for the period 1977 through 1983. WEMCO has maintained surface water quality data since 1986.

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1.2.2.3 Hydrogeologic Investigations

Dove (1961) and Spieker (1968a) extensively described the hydrology and hydrogeology of the Great Miami Aquifer in the lower Great Miami River Valley. These studies documented recharge rates, permeabilities of various lithologies, and other aquifer characteristics. Both 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 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 1985a; 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.

1.2.2.4 Contamination 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 of the Great Miami Aquifer. Publications released in the last five years document radionuclide releases from the FEMP into the environment. These studies are from either the Report of Historic Uranium Releases from Current DOE Oak Ridge Operations Office Facilities (DOE 1985b) or are internal NLO/WEMCO documents (Boback et al. 1985, 1986; WMCO 1987, 1989; Clark et al. 1989). Spieker and Norris (1962) investigated radionuclide contamination of the groundwater and the transport of the contaminated water through the Fernald, Ohio area. Additionally, the Ohio Department of Health (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 for DOE. Starkey et al. (1962) and NLO (Spenceley 1983) performed internal investigations to distinguish between FEMP contamination and non-FEMP contamination. International Technology Corporation (IT) also conducted hydrogeologic studies of contaminant discharge to the Great Miami River (IT 1988).

1.2.2.5 Environmental Surveys

For more than 10 years, the environment in and around the FEMP has been closely monitored by DOE (Battelle et al. 1977; DOE 1985b, 1987), Oak Ridge Associated Universities (ORAU 1985), various FEMP-related committees (WMCO 1986, 1987; Fleming and Ross 1984), and various contracted groups (IT 1986; Weston 1986a and 1986b; Battelle 1981). The DOE and ORAU documents include environmental impact assessments, RI/FS studies, and environmental surveys. Internal reports of studies by NLO and WMCO include the annual Environmental Monitoring Reports and the Aquifer Contamination Control Reports (various authors, 1965-present). These documents are available through DOE. The contracted studies represent more comprehensive environmental sampling and analysis programs. These reports document the analytical results from a large number of groundwater, surface water, sediment, soil, and air samples. The analytical constituents include radionuclides,

organic compounds, metals, and general water quality parameters. A sampling and analysis program is ongoing at the FEMP to comply with environmental monitoring provisions of RCRA.

1.2.2.6 Vegetation and Wildlife Studies

Battelle Columbus Laboratories studied and characterized vegetation and wildlife at the FEMP (Battelle 1981). Similar studies and characterizations were also conducted by WEMCO, NLO, and the 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 (WMCO 1986, 1987). The OEPA study (OEPA 1982) was a more comprehensive study of the aquatic environment in the Great Miami River. A recent study by Facemire et al. (1990), under contract to WEMCO, describes the general terrestrial and aquatic environments of the FEMP and surrounding areas. The RI/FS biological sampling program is described in the SWCR (DOE 1992b). The database compiled in this study is the most complete characterization of the environmental resources available.

1.3 OPERABLE UNIT 2, OTHER WASTE UNITS

This section provides background information on the waste areas that comprise Operable Unit 2. It includes a brief description and history of each waste area and a discussion of previous investigations pertaining to that area; more detailed information is provided in Sections 2, 3, and 4. The waste areas that comprise Operable Unit 2 are:

- Solid Waste Landfill
- Lime Sludge Ponds
- Active Flyash Pile
- Inactive Flyash Pile
- South Field

The use of the term "study area" along with the name of a waste area indicates that sampling locations outside the waste area boundaries (but in appropriate proximity) are included in the discussion.

1.3.1 Description and History

1.3.1.1 Solid Waste Landfill

The Solid Waste Landfill is located in the northeast corner of what is termed the waste storage area. This facility, which covers approximately one acre, is organized into the original disposal area, five individual cells, and an evaporation pond (Figure 1-5). The original disposal area is inactive and the five cells are filled to capacity and are no longer in service; a soil cover has been placed over the cells and the original disposal area. The evaporation pond, which was used for collecting storm water runoff, has been backfilled with soil.

The Solid Waste Landfill was used for the disposal of cafeteria waste, rubbish, and other types of wastes from FEMP nonprocess areas and on-site construction/demolition activities. Materials

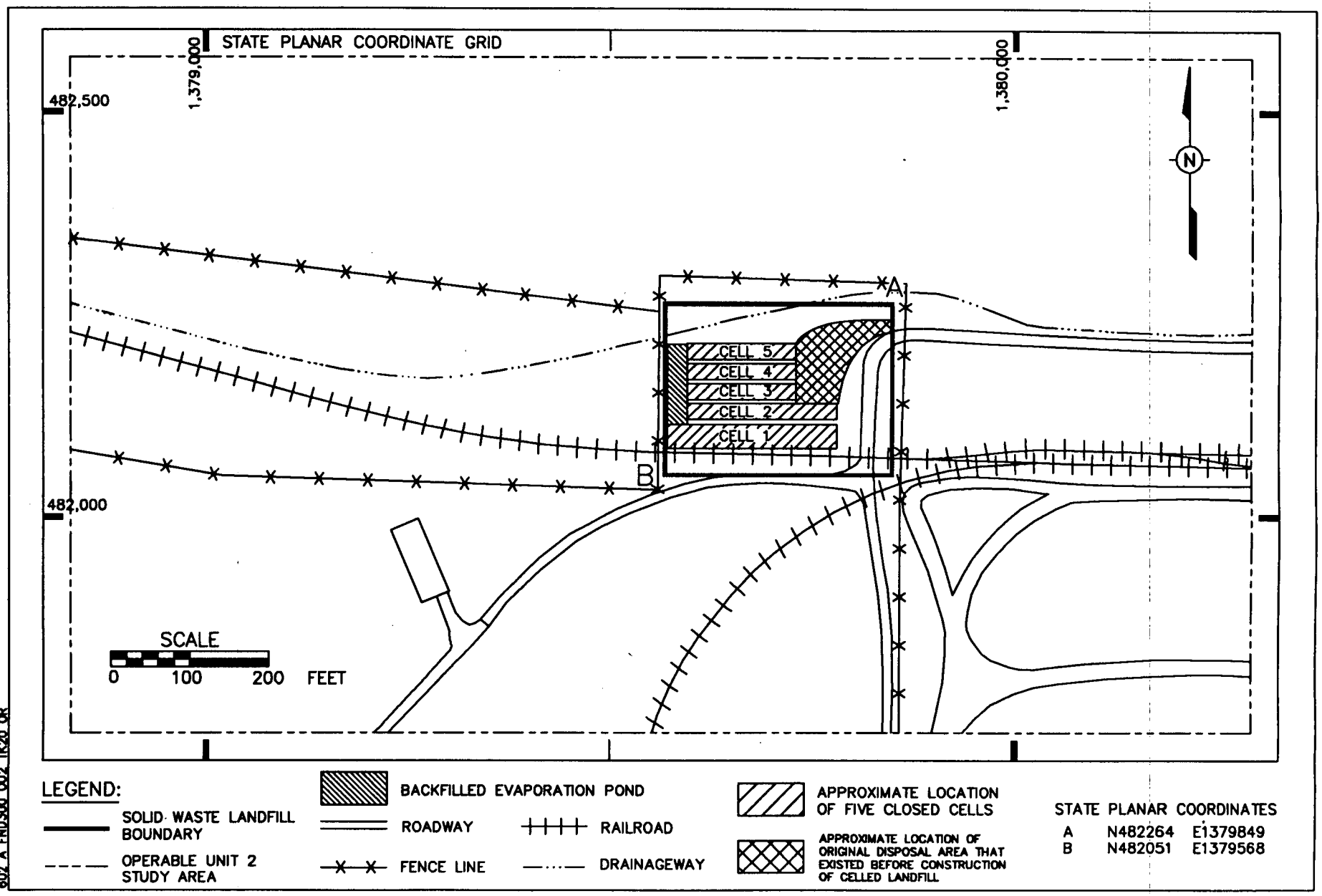

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FIGURE 1-5. SOLID WASTE LANDFILL STUDY AREA

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reportedly accepted include nonburnable and nonradioactive solid wastes generated on FEMP property, nonradioactive construction-related rubble, and double-bagged and bulk quantities of nonradioactive asbestos (DOE 1988a; Weston 1987b). Construction rubble placed in the landfill and the soil used to cover exposed wastes may be contaminated with radionuclides (DOE 1988a). According to the Sanitary Landfill Soil Trenching/Characterization Report (WEMCO 1992), the following wastes were encountered:

- Burnable – bagged trash and wood
- Possible burnable – respirator cartridges, asphalt roofing materials, medical wastes, firehoses, and rubber hoses/belts
- Nonburnable – medicine vials, bagged asbestos, ceramic tiles, magnesium fluoride, glass acid bottles, steel cables/cans, paint cans, and copper tubing

A review of historical site photos (EPA 1988b) indicates that activity at the Solid Waste Landfill occurred as early as 1954. Use of the landfill was halted in early 1986. Cafeteria waste and nonhazardous general refuse are currently collected for shipment and disposal at approved off-site locations. Descriptions of Solid Waste Landfill waste volume (including cover soils) and characteristics are presented in Section 4.2.2.

1.3.1.2 North Lime Sludge Pond

The North Lime Sludge Pond is an unlined pond of approximately 125 by 225 feet (Figure 1-6) that receives spent lime sludges from the FEMP water treatment operations, sludges from the neutralization of boiler plant blowdown, and coal pile storm water runoff (WMCO 1989). The sludges and runoff are pumped into this pond and allowed to settle. This pond is usually covered with 2 to 3 feet of water, but the water cover has been observed, on occasion, to be up to 7 feet deep (DOE 1991), depending on plant operations and precipitation. Descriptions of North Lime Sludge Pond waste volume and characteristics are presented in Section 4.3.2.

1.3.1.3 South Lime Sludge Pond

The South Lime Sludge Pond (inactive since the mid-1960s) is a dry, unlined pond of approximately 125 by 225 feet (Figure 1-6) that received spent lime sludges from FEMP water treatment operations, sludges from the neutralization of boiler plant blowdown, and coal pile storm water runoff (WMCO 1989). The South Lime Sludge Pond is now overgrown with grass and shrubs. Descriptions of South Lime Sludge Pond waste volume and waste characteristics are presented in Section 4.3.2.

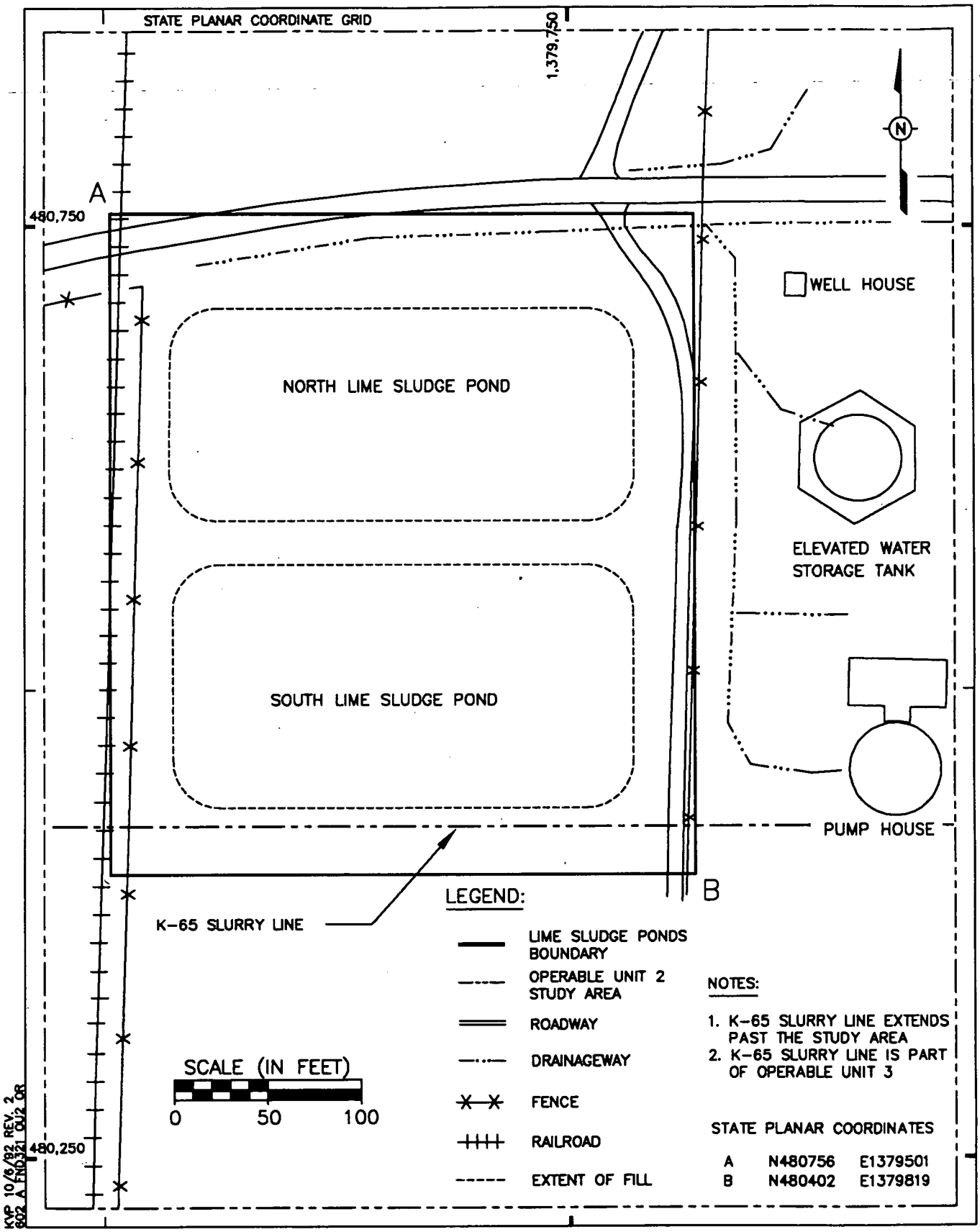


FIGURE 1-6. LIME SLUDGE PONDS STUDY AREA

1.3.1.4 Active Flyash Pile

This uncovered waste area is located just east of the South Field, on the opposite side of the south construction road. The storm sewer outfall ditch is located to the east and south of the Active Flyash Pile (Figure 1-7).

In past and current operations, flyash (mechanical and electrostatic precipitator ash combined with bottom ash) from the coal-fired boiler plant transported to the flyash pile site by dump trucks. It has been reported that, in the past, PCB- and uranium-contaminated waste oils were sprayed, periodically, onto the flyash pile as a means of dust control (DOE 1988a; Weston 1987b). Attempts to document this have been unsuccessful, and it has not been possible to determine whether the uranium detected in the pile is a result of this practice. Descriptions of Active Flyash Pile waste volume and characteristics are presented in Section 4.4.2.

1.3.1.5 Inactive Flyash Pile

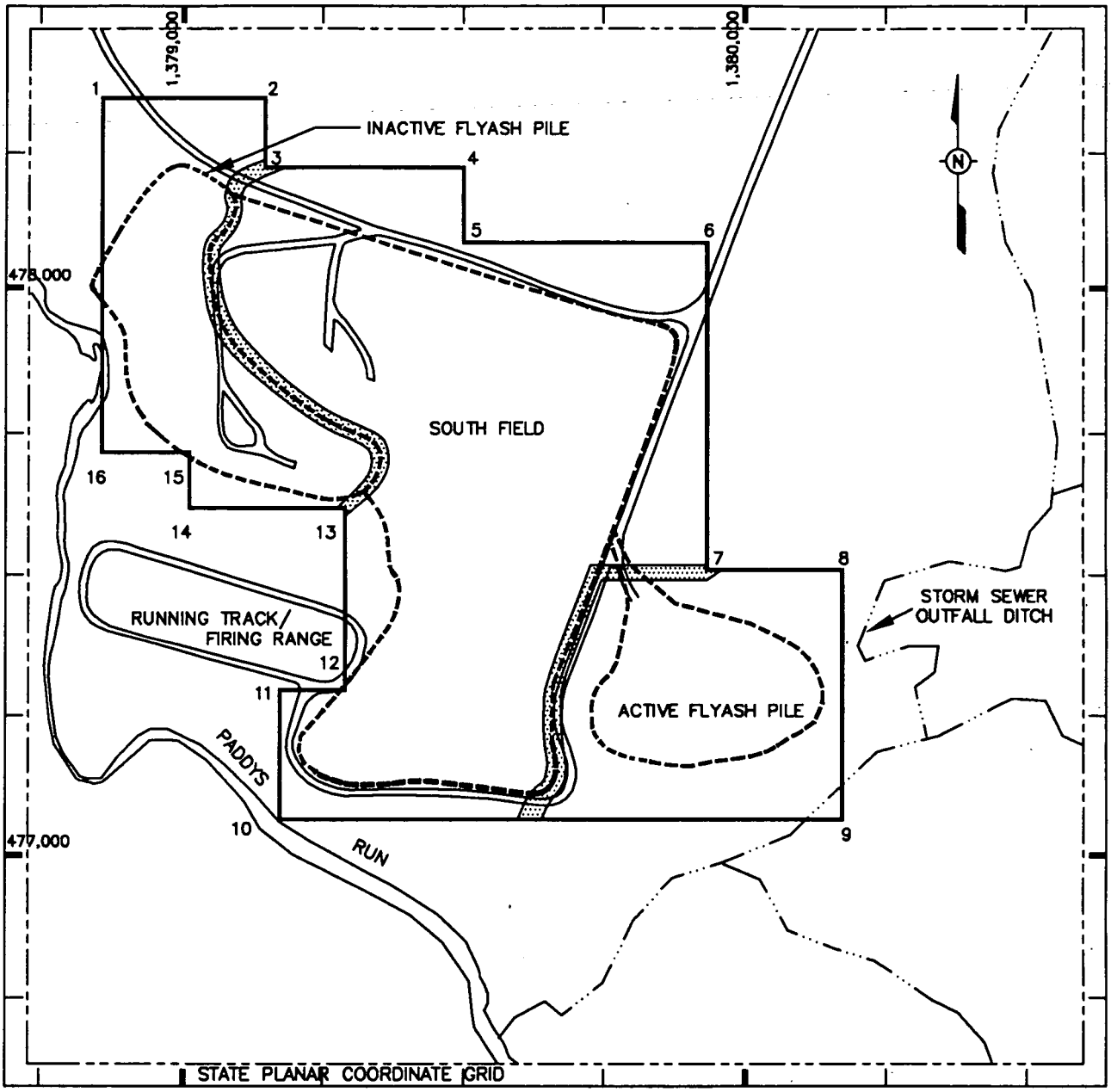
The Inactive flyash pile is located approximately 2000 feet southwest of the production area (Figure 1-7). Based on a review of historical photos (EPA 1988b) and borehole logs (Weston 1988), the northern portion of this waste area is located on an old drainage leading to Paddys Run. The photographs indicate that disposal activity at this location ceased between 1964 and 1968.

Flyash from the coal-fired boiler plant was disposed of in the Inactive Flyash Pile starting in 1951. Based on information provided by WEMCO, 1500 to 2000 tons per year of flyash were generated during the period of disposal. Some of the flyash was disposed of in the Burn Pit and Pit 3 (part of Operable Unit 1) (Weston 1988) in addition to the Inactive Flyash Pile. The Inactive Flyash Pile is currently covered with soil and vegetation.

Previous investigations have included mention of waste oils (containing uranium and PCBs) having been spread on the flyash in this waste area to control dust (DOE 1988a; Weston 1987b). Attempts to document this have been unsuccessful, and it has not been possible to determine whether the uranium detected in the pile is a result of this practice. Nonprocess wastes from the FEMP and building rubble (such as concrete, gravel, asphalt, masonry, and steel rebar from on-site construction/demolition activities) was also discarded at the Inactive Flyash Pile (DOE 1988a; Weston 1987b), and are visible along its southern edge. Transite, which contains asbestos, was also deposited in the Inactive Flyash Pile. Descriptions of Inactive Flyash Pile waste volume and characteristics are presented in Section 4.5.2.

1.3.1.6 South Field

The South Field, a large heterogeneous area, lies between the Active Flyash Pile and the Inactive Flyash Pile (Figure 1-7). It was reportedly used as a burial site for FEMP nonprocess wastes such as



LEGEND:

- FLYASH/SOUTH FIELD BOUNDARY
- BOUNDARY BETWEEN FLYASH PILES AND SOUTH FIELD
- OPERABLE UNIT 2 STUDY AREA
- ROADWAY
- DRAINAGEWAY
- EXTENT OF FILL

SCALE

0 125 250 FEET

STATE PLANAR COORDINATES

1	N478348	E1378859
2	N478348	E1379148
3	N478225	E1379148
4	N478225	E1379500
5	N478091	E1379500
6	N478091	E1379933
7	N477509	E1379933
8	N477509	E1380172
9	N477064	E1380172
10	N477064	E1379174
11	N477295	E1379174
12	N477295	E1379289
13	N477617	E1379289
14	N477617	E1379014
15	N477715	E1379014
16	N477715	E1378859

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FIGURE 1-7. FLYASH/SOUTH FIELD STUDY AREA

on-site construction/demolition rubble and soils that may have contained low levels of radioactivity, including debris from the razing of the old administration building (DOE 1988a; Weston 1987b). The southwest edge of the South Field is a slope, the edge of which has been built up over time by the addition of fill materials. This slope has long been used as the backdrop for a firing range.

Previous reports have not defined the boundaries of the South Field (DOE 1988b). A review of historical photos, topographical maps, and borehole logs (Weston 1988) were used to estimate boundaries and fill areas. For example, aerial photographs from 1954 and 1957 indicate where fill activity occurred (EPA 1988b). Currently, the South Field is covered with soil and vegetation. Descriptions of South Field waste volume and characteristics are presented in Section 4.6.2.

1.3.2 Past and Present Investigations

Various studies and field investigations covering the Operable Unit 2 waste areas have been performed at the FEMP. These studies have been used to establish the RI information base. The major relevant studies, in progress or completed, are:

- DOE's draft FMPC Sampling and Analysis Data Document (Environmental Survey) (DOE 1988a)
- Weston Characterization Investigation Study (CIS) (Weston 1987a, b, and c; Weston 1988)
- RI/FS, in progress (DOE multiple documents and dates)

A DOE environmental survey team conducted a survey of the FEMP as part of the larger environmental survey of all DOE facilities, nationwide, and produced a draft report entitled "Sampling and Analysis Data Document," commonly referred to as the Environmental Survey Report. The purpose of the environmental survey program was to identify existing environmental problems and areas of environmental risk at DOE facilities and to prioritize them throughout DOE, using a consistent risk-based ranking method.

During the CIS (before the site-wide RI/FS was initiated), the Operable Unit 2 waste areas were examined. Field activities of the CIS were subdivided into these three phases: geophysical studies, chemical and radiological characterization of stored wastes, and radiological survey of surface soils. A series of reports detailing the results of each CIS phase were developed in 1987.

Additional investigative activities have been conducted to confirm the results of previous investigations and to fill in informational gaps in support of subsequent remedial planning and implementation. More specifically, these activities were intended to provide additional information to (1) characterize the level of contamination in waste materials, (2) estimate waste volumes, (3) define the vertical extent

of contamination in native soils underlying the waste, (4) develop source terms and model parameters for fate and transport modeling, and (5) characterize the risk to human health and the environment associated with the existing contamination.

1.3.3 Removal Actions To Date

Three removal actions and one removal site evaluation that directly impact Operable Unit 2 are completed or ongoing at the FEMP.

1.3.3.1 The Active Flyash Pile Control Removal Action

The objective of the Active Flyash Pile Control Removal Action, a time-critical removal action was to significantly mitigate the wind and water erosion of the existing Active Flyash Pile at the FEMP site. This was accomplished by implementing the following controls: (1) installation of a silt trap made from permeable geotextile fabric around the entire perimeter of the pile at the toe of the slope; (2) installation of a wind barrier made from high-density polyethylene around the top perimeter of the flyash pile; (3) alteration of the active working surface to minimize the noncompacted area and to prevent an increase in the maximum height of the existing pile; (4) minor regrading of the outer berm and compacting the nonworking top surfaces of the flyash pile; (5) application of water and foam and binding-type dust-control agents on side slopes and top; and (6) providing periodic routine inspection and necessary maintenance identified during inspection. Planning and design of the removal action began in December 1991. This removal action was completed in June 1992 (almost sixteen months ahead of schedule).

1.3.3.2 The Inactive Flyash Pile/South Field Disposal Area Control Removal Action

The Inactive Flyash Pile/South Field Disposal Area Control Removal Action consisted of the installation of ropes, fences, and warning signs around the perimeter of the waste areas to control and limit access. During the course of the removal action, walk-over radiation surveys were conducted over the entire area to define those locations that should be delineated as regulated areas. Implementation activities began in September 1991. Phase I of the activities, which included fencing and roping the areas to be controlled, was completed in December 1991. Phase II, which included surveying the area for additional hot spots, was completed on June 30, 1992.

1.3.3.3 The Waste Pit Area Storm Water Runoff Control Removal Action

The Waste Pit Area Storm Water Runoff Control Removal Action, a non-time-critical removal action, is a sequence of engineering controls that are being implemented to control, capture, and treat contaminated storm water runoff from the waste pit area. The waste pit area encompasses the Operable Units 1 and 4 and a portion of Operable Unit 2 (the Solid Waste Landfill and the Lime Sludge Ponds). The control measures will halt the runoff of surface water to Paddys Run. Construction for the removal action began in 1991 and was completed in July 1992.

1.3.3.4 Removal Site Evaluation to Investigate Lead Contamination in the South Field Due to Spent Ammunition Bullets in the Firing Range

A removal site evaluation is currently being conducted to (1) assess lead contamination in the South Field from past use of the firing range, and (2) determine whether the nature and extent of contamination warrants further action (i.e., a removal action). In January and February 1992, vertical and horizontal borings were completed in the western embankment of the South Field, just east of the FEMP running track/firing range. Soil samples were analyzed for organic, inorganic, and radiological contaminants. This evaluation was initiated due to concerns that the long-term use of the firing range may have resulted in significant lead contamination in the South Field. The evaluation is scheduled to be completed by September 30, 1992.

1.4 REPORT ORGANIZATION

This RI report is formatted in accordance with the latest EPA guidance (EPA 1988a). Section 1 discusses the approach and objectives for the RI, the site background, and previous investigations. Section 2 briefly describes the investigative procedures employed in the RI. A description of the site-wide environment and the physical characteristics of the waste areas in Operable Unit 2 are discussed in Section 3. A presentation of results and a discussion of the nature and extent of contamination appear in Section 4. Section 5 is a discussion of fate and transport modeling. Excerpts from the Operable Unit 2 Baseline Risk Assessment appear in Section 6. Section 7 presents a summary of the results of the data evaluations, modeling, and risk assessment. All sections address elements common to all of the Operable Unit 2 waste areas and each waste area separately.

Appendix A is the Operable Unit 2 Baseline Risk Assessment, and Appendix B discusses details of fate and transport modeling.

Appendices C through G consist of raw data tables specific to each of the Operable Unit 2 waste areas. Each appendix contains surface media (soils, flyash, or lime sludge residue), subsurface media (soils, flyash, or lime sludge residue), surface water, sediments, and groundwater data from the three investigations described in Section 1.3.2. Also included in each of these appendices are borings logs, monitoring well construction records, biological resources data, geotechnical data, and water elevation data.

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2.0 OPERABLE UNIT 2 INVESTIGATION

Data from three investigations are used to characterize the Operable Unit 2 waste areas: the Environmental Survey, the CIS, and the RI/FS. The Environmental Survey (DOE 1988a), conducted in 1985 and 1986, was a cursory investigation of the site that intended only to identify existing or potential human health and environmental concerns. The CIS, (Weston 1987a, b, c; Weston 1988) conducted in 1986 and 1987, was more detailed in scope than the Environmental Survey. When the FEMP RI/FS sampling began in 1987, it was believed that existing data from the Environmental Survey and the CIS were sufficient to meet the needs of the RI/FS for Operable Unit 2 waste areas. In 1990, however, it became apparent that additional chemical, radiological, and geotechnical data would be required to complete the Operable Unit 2 RI/FS, so an investigation of the Operable Unit 2 waste areas was undertaken in 1991 to complete gaps in the existing data.

This section will present the objectives and methods of the three field investigations. Because the objectives, sampling methods, and analytical procedures differed among them, the first subsection, Section 2.1, is devoted to a general description of the Environmental Survey, CIS, and RI/FS investigations. A description of the data validation process is also included in Section 2.1. Sections 2.2 through 2.6 describe in greater detail the sampling frequencies and types of samples collected for each Operable Unit 2 waste area.

Throughout the RI/FS, the terms "surface media" and "subsurface media" are used to describe samples taken from the Operable Unit 2 waste areas. "Surface media" includes surface soil, lime sludge residue, flyash, and other fill at the surface of the waste areas down to 1.5 feet deep. "Subsurface media" includes subsurface soil, shallow fill, deep fill, and underlying native soil taken from depths exceeding 1.5 feet.

This section presents individual sampling program goals, analytical methods, and the specific field methods used to collect analytical samples. Quality control samples (including rinsates, field blanks, trip blanks, and duplicate samples) were collected according to requirements in the respective work plans of the three investigations. Procedures used for sample preservation, maintenance of chain of custody, and documentation of the samples are outlined in the respective sampling and analysis plans under which the field programs were conducted.

2.1 GENERAL DESCRIPTION OF INVESTIGATIVE METHODS

2.1.1 Environmental Survey

The Environmental Survey of the FEMP was part of a larger DOE-wide environmental survey announced by the U.S. Secretary of Energy on September 18, 1985. The purpose of the survey at

each DOE facility, including the FEMP, was to identify existing environmental concerns and areas of environmental risk. Environmental concerns at that time were defined as:

- Concerns resulting from DOE operations where pollutants or hazardous materials exist in the air, surface water, groundwater, or soil in concentrations that pose or may pose a hazard to human health or the environment

- Conditions at a DOE facility that pose or may pose a hazard to human health or the environment

Levels of contaminants that constituted an environmental concern were generally those that exceeded federal, state, or local statutes and regulations for release of, contamination by, or exposure to such materials. The survey also evaluated the potential for some unregulated materials, if present, to create an environmental concern.

2.1.1.1 Environmental Survey Objectives

The Environmental Survey sampling and analysis program was intended only to confirm the presence of contamination in selected locations. It was not intended to characterize extent of contamination or rate of contaminant movement, identify specific isolated incidents of noncompliance, or to analyze environmental management practices.

2.1.1.2 Environmental Survey Methods

The FEMP Environmental Survey was conducted by a multidisciplinary team of environmental specialists, led and managed by DOE's Environment, Safety and Health Office of Environmental Audit. This team conducted a preliminary survey from June 16 through June 27, 1986 that yielded a preliminary report describing the existing and potential environmental problems. This preliminary report became the basis for the sampling and analysis program developed for the FEMP (DOE 1988a). The sampling and analysis requests supplied by the survey team specified the types of samples to be collected and the analyses to be performed, but did not define environmental problems or sampling objectives.

At the time of this sampling and analysis at the FEMP, no comprehensive requirements and guidelines for ensuring the comparability and quality of data were in place; so the field sampling protocols were based on guidance provided by the May 1986 draft Environmental Survey Manual, which was largely a compilation of EPA protocols and EPA guidance documents.

Support for the Environmental Survey at the FEMP was provided by the sampling and analysis teams from Argonne National Laboratory (ANL). ANL teams collected samples between September 1986 and June 1987.

Standard operating procedures for analysis of radiological samples from the FEMP were developed by the ANL Analytical Chemistry Laboratory. Chemical analyses were conducted by the standard procedures summarized in Table 2-1.

Environmental Survey Surface Media Sampling

Composite and grab samples were used for sampling surface media from the various waste areas. Composite samples were collected with precleaned stainless steel scoops and hand trowels. Any vegetation present was cleared, and a 1-meter square was measured on the ground. Individual aliquots were collected from the four corners and from the center. Grab samples were collected with precleaned stainless steel scoops and/or hand trowels, and transferred directly to the sample container. Composited samples of the individual aliquots from the sampled area were prepared by mixing in a precleaned aluminum pan. Samples were not screened to eliminate large material (i.e., gravel) in the field.

Surface media samples from the Solid Waste Landfill, South Lime Sludge Pond, Inactive Flyash Pile, Active Flyash Pile, and South Field were analyzed for radionuclides, total uranium, toxicity characteristic leaching procedure (TCLP) RCRA metals (the eight metals regulated under RCRA), and volatile organic compounds (VOCs). Samples from the Solid Waste Landfill, Inactive Flyash Pile, Active Flyash Pile, and South Field were also analyzed for asbestos.

Environmental Survey Subsurface Media Sampling

Subsurface media samples were collected from hand augers and from open trenches that were excavated by backhoe. Samples collected from an open trench were obtained by removing grab samples taken from the appropriate depth and brought to the surface in a backhoe bucket. Augured samples were collected directly from the hand-auger bucket by transferring the material from the auger into individual sample containers using precleaned stainless steel scoops or trowels.

Subsurface media samples taken from the Solid Waste Landfill, Inactive Flyash Pile, Active Flyash Pile, and South Field were analyzed for radionuclides, total uranium, TCLP RCRA metals, and VOCs. Samples from the Solid Waste Landfill, Active Flyash Pile, and Inactive Flyash Pile were analyzed for asbestos, also.

Environmental Survey Groundwater Sampling

When groundwater was encountered during the excavation of trenches, a sample was collected with a precleaned stainless steel dipper and poured into the appropriate sample container. Groundwater samples were analyzed for radionuclides, total uranium, VOCs, and RCRA metals.

TABLE 2-1

SUMMARY OF THE ANALYTICAL METHODS USED FOR THE THREE SITE STUDIES

Analyte	Methods Used in Analyses[a]		
	Environmental Survey	CIS	RI/FS
Radiological			
On site	10	10	10
Off site	1	11	12
Volatile Organic Compounds	2, 3, 4	9	13
Semivolatile Organic Compounds	5, 6, 7	9	13
Metals and Inorganics		9	14
Pesticides/Polychlorinated Biphenyls		9	13
Dioxins/Furans		9	13
Organophosphorus Pesticides		9	13
Toxicity Characteristic Leaching Procedure (TCLP)	1		9
Extraction Procedure Toxicity (EP TOX)		8	8

[a]Key to Methods Used

1. Standard operating procedures developed by the Analytical Chemistry Laboratory of the Chemical Technology Division at Argonne National Laboratory
2. Methods for Organic Analysis of Municipal and Industrial Wastewater, EPA Publication No. 600/4-82-057, Method 624, U.S. EPA, Cincinnati, OH (revised October 1984).
3. U.S. EPA Method 624 (Federal Register, Vol. 49, No. 209, PG. 43373-43384, October 26, 1984).
4. Test Methods for Evaluating Solid Waste, EPA Publication No. SW-846, 2nd Ed., Method 8240, U.S. EPA, Washington, DC (Revised April 1984).
5. Methods for Organic Analysis of Municipal and Industrial Wastewater, EPA Publication No. 600/4-82-057, Method 625, U.S. EPA, Cincinnati, OH (revised October 1984)
6. U.S. EPA Method 625 (Federal Register, Vol. 49, No. 209, pp 43385-43406, October 26, 1984).
7. Test Methods for Evaluating Solid Waste, EPA Publication No. SW-846, 2nd Ed., Method 8270, U.S. EPA, Washington, DC (revised April 1984).
8. U.S. EPA, SW-846, September 1986.
9. U.S. EPA Statement of Work "Organic Analysis Multimedia, Multi-Concentration," SOW 785, July 1985.
10. Analyzed by gamma spectrometry by techniques developed by the on-site laboratory.
11. Radiochemical procedures and analytical methods were those developed by the TMA/Eberline Laboratory.
12. IT Methods.
13. U.S. EPA Contract Laboratory Program (CLP) Statement of Work (SOW) February 1988.
14. U.S. EPA CLP SOW March 1990.

2.1.2. Characterization Investigation Study

Selected investigations of the waste storage areas were performed to provide additional data to characterize the nature and extent of contamination. The site characterizations are collectively referred to as the CIS. The investigations pertinent to Operable Unit 2 are the Geophysical Survey (Weston 1987a), Chemical and Radiological Analysis of Waste Storage Pits (Weston 1987b), Radiological Survey of Surface Soils (Weston 1987c) and the Geotechnical Evaluation of Material Properties of Waste Pit Materials (Weston 1988). Descriptions of these investigations follow.

2.1.2.1 CIS Geophysical Survey

Objectives

The geophysical survey was conducted to provide information on waste volumes and shallow stratigraphy for optimizing the placement of soil borings and groundwater monitoring wells at the FEMP. An additional objective of the geophysical survey was to identify locations that were potentially hazardous for drilling because of buried steel drums and tanks.

Methods

Geophysical surveys were conducted in the Operable Unit 2 waste areas using the following three techniques:

- Magnetic surveys, to identify areas containing relatively large concentrations of buried ferrous metal
- Electromagnetic terrain conductivity, to locate areas of anomalous electrical conductivity produced by buried metal debris or groundwater plumes
- Ground-penetrating radar (GPR), to locate excavation boundaries and to verify possible locations of buried metal objects and pipelines

Magnetic surveys were performed in the Solid Waste Landfill and South Lime Sludge Pond using an EG&G Geometrics Model G-856 portable proton precession magnetometer. The surveys were conducted at 25-foot intervals with the sensor at a height of 8 feet above the ground surface.

Electromagnetic terrain conductivity surveys were performed in all Operable Unit 2 waste areas using Geonics, Ltd. EM 31 and EM 34-3 terrain conductivity meters. The EM 31 survey was performed using a 50- by 25-foot grid, with 50 feet separating the north-to-south trending profiles and 25 feet between the measurement stations along each profile. Additional measurements were taken in the 25-foot intervals between the stations when anomalous readings occurred at the primary nodes. North-to-south orientation of the instrument was maintained during the entire survey. For the EM 34-3 survey, a 50- by 50-foot grid was used at the Active Flyash Pile, the Inactive Flyash Pile, and the South Field.

Cultural features with potential to affect conductivity data were present in the vicinity of the Active Flyash Pile, the Inactive Flyash Pile, and the South Field. Most notable were the rubble piles in the South Field, directly east of the Inactive Flyash Pile. Metal strapping material, rebar, and metal drums were observed in the rubble.

GPR surveys were performed at the Solid Waste Landfill and the South Lime Sludge Pond using the Geophysical Survey Systems, Inc., S/R System 8. Profiling was performed in both north-to-south and east-to-west directions over the 25- by 25-foot grid used for the GPR survey.

2.1.2.2 CIS Chemical and Radiological Analyses of Waste Areas

Objectives

Vertical borings were completed in the waste areas to determine the vertical distribution of chemical and radiological constituents (Weston 1987b). To provide additional data to support FS and potential remedial design activities, selected samples were processed on site for standard engineering properties such as moisture content, density, Atterberg limits, and particle size (Weston 1988).

Methods

Soil borings were drilled in the fill material of each Operable Unit 2 waste area except for the Active Flyash Pile. The original intent was to distribute the borings evenly within each waste area, but boring locations were adjusted, based on the results of the geophysical surveys, to avoid areas with high potential for buried metal objects. Borings were advanced until native soil was encountered.

In waste areas other than the North Lime Sludge Pond, each boring location was sampled continuously by split-spoon sampler, several discrete analytical samples being taken at intervals of 1 to 2 feet to yield a vertical profile of the waste area. Sampling was continued until native soil was encountered. Each time the split-spoon sampler was opened, the core from that interval was split lengthwise and a section of it was immediately placed in a sample bottle and sealed for shipment to Weston Analytics for VOC analysis. Half of the core was placed directly into a sample jar for radiological analysis by an on-site laboratory, for the purpose of developing a profile of radiological activity with depth. The remainder of each core was placed in a large stainless steel bowl and covered for compositing with the remaining cores taken from the boring. After sampling was completed at a boring location, the material in the stainless steel bowls was thoroughly mixed. The resulting composite sample was placed in appropriate containers for shipment to TMA/Eberline Laboratory in Albuquerque, New Mexico, for radiological and nonvolatile chemical analyses. The purpose of analyzing a composite sample was to evaluate the overall level of contamination in the corresponding waste area.

Residues in the North Lime Sludge Pond were sampled from a floating sampling platform using a 3-inch-diameter stainless steel, piston-type sampler (Weston 1987b). This device was used to obtain 20-inch incremental samples for the entire depth of the pit residue or until equipment refusal was

encountered. After the piston sampler was removed, a portion of the residue from each 20-inch sampling interval was immediately placed into VOC-analysis sample containers and sealed for analysis the Western Analytics laboratory. The remainder of each sample interval was composited in a large stainless steel bowl. The composite sample was placed in appropriate containers for shipment to TMA/Eberline Laboratory in Albuquerque, New Mexico, for radiological and nonvolatile chemical analyses.

Analyses

Each borehole sample interval (with the exception of composited samples) was processed through the on-site gamma spectroscopy laboratory to provide data for developing the vertical distribution of radium-226, thorium-232, and uranium-238. Borehole composite samples were analyzed at off-site laboratories for radionuclides, semivolatile organic compounds (SVOCs), pesticides (PCBs), total metals, the extraction procedure (EP) toxicity analysis for the eight RCRA metals, and the additional RCRA characteristics of reactivity, ignitability, and corrosivity. Individual interval samples collected for VOC analyses were composited at the off-site laboratory to create a borehole composite. This borehole composite was analyzed for VOCs. All chemical analyses were performed in accordance with the EPA protocols listed in Table 2-1 (Weston 1987b).

2.1.2.3 CIS Radiological Survey of Surface Media and Stream Sediments

Objectives

The objective of the radiological characterization of surface media was to provide a systematic survey of surface media throughout the Solid Waste Landfill, Lime Sludge Ponds, Inactive Flyash Pile, South Field, and associated on-site drainages within the Operable Unit 2 study area to determine the locations(s) of areas with elevated radionuclide activity.

Methods

A Bicron Model G5 field instrument for detecting low-energy radiation (FIDLER) was used to perform systematic standing measurements on the ground surface on a 50-foot grid (FIDLER grid measurements). Following these measurements, each 50- by 50-foot grid block was subdivided into four quarters, each 25 by 25 feet. These subdivided blocks were scanned for anomalous radioactivity concentrations (FIDLER scan measurements). When subgrid blocks having these anomalies were noted, they were further divided into 6.25-foot subgrids and additional measurements were taken.

The surface media sampling procedures used for the CIS followed the techniques outlined in Procedures for Sampling Radium-Contaminated Soils (DOE 1985a). These techniques included the use of "ring" samplers and stainless steel trowels to obtain surface samples to a depth of 6 inches. Below this depth, the technicians used trowels and post-hole samplers to sample to a depth of 18 inches. Before surface samples were collected, a gamma radiation measurement was made on the surface using a FIDLER. An Eberline SPA-3 scintillation probe was used in both the Inactive Flyash

Pile and South Field because of the steep slopes encountered there. If elevated radioactivity (above background level) was detected, a 0- to 2-inch sample and a 2- to 6-inch sample were taken. The 0- to 2-inch analytical sample was collected so that correlations of uranium-238 activity concentrations and FIDLER count rates could be established. The 0- to 2-inch interval was used because the thorium-234 63 keV photon is attenuated below 2 inches. After the samples were collected to 6 inches, a probe was placed in the cavity and another measurement was made. Where a change in detector-soil geometry resulted in a radiation level higher than expected, an intermediate depth sample (6 to 12 inches) was collected. This was repeated, as needed, to a depth of 18 inches.

Analyses

Surface media samples were sent to the on-site gamma spectroscopy laboratory where radionuclide activity concentrations were estimated for uranium-238, radium-226, thorium-232, cesium-137, and ruthenium-106. Samples showing the highest activity were sent to an off-site laboratory for (1) determination of the isotopic activity of uranium and thorium and (2) identification of radionuclides such as strontium-90, technetium-99, lead-210, neptunium-237, and isotopes of plutonium that are not readily detectable by gamma spectral techniques.

CIS Geotechnical Evaluation of Material Properties of Waste Area Materials

Objectives

The objective of the geotechnical evaluation was to measure the physical properties of the waste areas to support potential FS and remedial design activities.

Methods

From March 1987 through April 1987, samples from the Solid Waste Landfill and the Lime Sludge Ponds were collected for a geotechnical evaluation of their material properties. The samples, collected with a split-spoon sampler, were analyzed for:

- Grain size - American Society of Testing and Materials (ASTM) Method D422 (procedure modified for samples that showed signs of organic saturation to include pretreatment to remove organic material)
- Specific gravity - ASTM Method D854
- Atterberg limits - ASTM D4318-83, Procedure A. (Atterberg limits: liquid limit, plastic limit, and plastic index)
- Moisture content - modified ASTM Method D2216-80

2.1.3 RI/FS Investigations

The RI/FS investigative activities that apply to Operable Unit 2 were conducted in phases, according to objectives and procedures outlined in the following documents:

- RI/FS Sampling Plan, Volume 1, and the Quality Assurance Project Plan, Volume 4, of the "Remedial Investigation and Feasibility Study Work Plan," Revision 3, March 1988
- "Remedial Investigation Work Plan Addendum - Production and Additional Suspect Areas Work Plan," Revision 1 (Document Change Request No. 33, October 1989)
- "Operable Unit 2 Sampling and Analysis Plan Addendum" (Document Change Request No. 41, Rev. D, July 1991)
- Other miscellaneous addenda to Volume 1 of the RI/FS Work Plan

At the start of the RI/FS sampling in 1987, it was believed that the work outlined in the Sampling Plan (Volume 1 of the RI/FS Work Plan) would be sufficient to augment existing data and fulfill the data requirements for the project. As newly generated data and regulatory requirements were reviewed, however, it became apparent that additional data would be required to complete the RI/FS. Consequently, a number of sampling and analysis plans were added to the RI/FS Work Plan to meet newly identified data requirements, including the need to (1) improve the spatial coverage of each of the waste areas, (2) analyze samples for a wider range of analytes, and (3) collect samples from native soils underlying fill. Work plan addenda generally proposed only additional borings, monitoring wells, sample locations, etc.; generally, new procedures for collecting samples or analyzing data were not proposed, so as to maintain consistency of methods and thereby ensure comparability of data.

Work plan addenda that apply to Operable Unit 2 are (1) the Production and Additional Suspect Areas Work Plan that covered trenching and sampling of the South Field, (2) a number of miscellaneous addenda that covered the installation and sampling of monitoring wells adjacent to the Operable Unit 2 waste areas, and (3) the Operable Unit 2 Sampling and Analysis Plan addendum that covered drilling and sampling of the contents of the waste areas. The latter work plan, the only addendum that focused specifically on Operable Unit 2, outlined samples to be collected to fill specific data gaps in the Operable Unit 2 investigation.

The objectives and methods of sample collection are described in the sections below. Additional details on sample collection and sample management protocols may be found in the RI/FS Quality Assurance Project Plan (QAPP) and the RI/FS Sampling Plan.

For some waste areas, the term "study area" is attached to the name of the waste area, indicating that some sample locations outside the boundary of the waste area are being considered because of their proximity to that waste area.

2.1.3.1 RI/FS Surface Media Sampling

A major task completed under the Operable Unit 5 RI was the Surface Soil Characterization Task. Under this task, as outlined in the RI/FS Work Plan, Revision 3, (DOE 1988b), two separate programs were conducted: the radiation measurements program and the surface soil sampling program. The radiation measurements program did not generate data that is directly applicable to Operable Unit 2, but it did provide input to the surface soil sampling program. Under this program, which was not intended to specifically address any of the Operable Unit 2 waste areas since their surface media had been extensively sampled for the CIS, only seven media samples were collected for Operable Unit 2. The analyses of these samples, however, did provide supplemental data to characterize the nature and extent of Operable Unit 2 contamination.

Objectives

The primary objectives for the site-wide RI/FS surface soil sampling program were to:

- Characterize the nature and extent of contamination in the surface media
- Provide data to evaluate the potential for the migration of contaminants via the surface water pathway
- Provide data to evaluate the potential for exposure via the direct contact pathway
- Provide data to evaluate the potential for exposure via the air migration pathway

Methods

A radiation survey was conducted prior to the surface media sampling. As a part of this radiation survey, 100-foot spacings were established inside the perimeter of the waste storage areas and the Flyash/South Field area. Where appropriate, these spacings were further divided into smaller spacings of 25 feet to delineate contamination boundaries. A FIDLER Low-Energy Scintillation Detector was used to detect isotopes of uranium, thorium, and radium. Surface radiation measurements were made within each of the 25-foot subgrids with the FIDLER. The technician walked a serpentine pattern within the subgrid and swept the probe over the media surface. A total of 16 measurements were made, within each 100-square-foot grid, and documented on field survey forms.

Samples from a 6-inch depth were collected at locations where results of the radiation survey and/or site history indicated the possibility of elevated radionuclides. At these biased sampling locations, three samples were collected at 2-inch intervals, using a precleaned stainless steel hand auger. At other locations where elevated radionuclide levels were not suspected, nonbiased samples were collected. At these nonbiased sampling locations, three samples were collected with a decontaminated stainless steel trowel at 2-inch-depth intervals.

Analytical Parameters

Surface media samples were analyzed at the IT laboratory in Oak Ridge, Tennessee, for the radiological parameters listed in Table 2-2 by methods outlined in the RI/FS QAPP.

2.1.3.2 RI/FS Subsurface Media Sampling

Subsurface media samples were collected during execution of each of the work plans described in Section 2.1.3. Subsurface media samples were collected during the drilling of monitoring wells, from trenches excavated in the South Field, and from all borings completed in the waste areas.

Objectives

All sampling completed under the RI/FS was required to fill gaps in data previously collected during previous investigations and to meet the following objectives:

- Characterize the physical nature of buried waste materials
- Characterize the stratigraphy of media underlying the site
- Determine the volumes and depths of waste areas
- Determine the nature and extent of contamination
- Determine whether contaminants have migrated from the waste into the underlying native soils
- Provide physical and chemical data to support the modeling of contaminant migration
- Provide geotechnical data of the subsurface media in the Active and Inactive Flyash Piles for use in evaluating the feasibility of remedial alternatives and for the treatability study

Methods

A number of monitoring wells were installed adjacent to Operable Unit 2 waste areas. Data from the wells are being used to document whether contaminants have been released from waste areas into perched water bodies or the Great Miami Aquifer. The 1000-series wells monitor perched groundwater within the glacial overburden. The 2000-series wells are intermediate-depth wells in the top of the Upper Great Miami Aquifer. The 3000-series wells monitor the bottom of the Upper Great Miami Aquifer by providing data on the potential downward transport of contaminants from the top of the aquifer. These wells are screened immediately above a regionally extensive clay layer that divides the Upper and Lower Great Miami aquifers. The 4000-series wells were screened in the Lower Great Miami Aquifer immediately above the shale bedrock. Most of the 2000-, 3000-, and 4000-series monitoring wells adjacent to Operable Unit 2 waste areas were installed primarily to monitor the Great Miami Aquifer and secondarily to monitor for any releases from Operable Unit 2 waste areas.

TABLE 2-2

THE FEMP RI/FS FULL LIST OF RADIOLOGICAL PARAMETERS

Parameters	
Cesium-137	Thorium-228
Lead-210	Thorium-230
Neptunium-237	Thorium-232
Plutonium-238	Total Thorium
Plutonium-239/240	Uranium-234
Radium-224	Uranium-235
Radium-226	Uranium-235/236
Radium-228	Uranium-238
Ruthenium-106	Total Uranium
Strontium-90	Gross Alpha
Technetium-99	Gross Beta

On-site monitoring wells were installed between 1988 and 1991 using cable-tool drilling techniques, with the exception of the 1000-series wells which were typically drilled using a hollow-stem continuous flight auger. During the drilling program to install these wells, standard penetration tests were conducted and subsurface media samples were collected using a split-spoon sampler (ASTM Method D1586-84). The glacial overburden was sampled and described continuously. The Great Miami Aquifer was sampled and described at intervals of 5 feet, or at changes in lithology. Immediately upon opening each split-spoon sampler, the samples were screened for VOCs using a portable HNu photoionizing organic vapor detector. Split-spoon samples were then screened with a Geiger-Mueller pancake beta/gamma radiation detector and an alpha scintillation probe. The sample with the highest radiological reading within each geologic horizon (glacial overburden, unsaturated sand and gravel, saturated sand and gravel above the regionally extensive blue clay layer [Upper Great Miami Aquifer], and the saturated sand and gravel below the blue clay layer [Lower Great Miami Aquifer]) for each boring location was selected for off-site radiological analysis (Table 2-2). Samples were described and classified by the field geologist based on color (Munsell Soil Color Charts), texture (modified Unified Soil Classification System), water content, and depth from the land surface. Sample boring logs for each Operable Unit 2 waste area are included in Volume 3, Appendices C through G, of this report. More detailed discussions of techniques used to drill and sample borings can be found in the RI/FS Work Plan.

A series of six trenches were excavated in the South Field in 1990 to evaluate areas that had not been previously sampled but were suspected of high elevations of radionuclides. Trenches were approximately 50 feet long and spaced throughout the northern and eastern portions of the South Field, at an approximate north-south orientation, where building rubble was thought to be buried. This part of the South Field was not extensively characterized by the CIS. Using a track-mounted backhoe with an 18- to 24-inch bucket, the trenches were excavated until native soil was encountered. The depths of the trenches ranged from 3.75 to 5.75 feet. Samples for radionuclide analysis were collected from the bottom of the fill material and from the native soil immediately below the South Field material at the north, south, and middle locations of each trench. Samples were screened in the field for VOCs using a portable photoionizer HNu and placed in appropriate sample containers. After the trenches were inspected, sampled, and described, they were backfilled with the excavated material.

In 1991, additional borings were drilled in each of the Operable Unit 2 waste areas. Deep borings (i.e., deeper than 2 feet) were drilled with continuous flight hollow-stem augers. Continuous samples were collected in 1.5- to 2-foot increments with a split-spoon sampler, according to ASTM Method D1586-84. A hand auger was used to collect samples from depths less than 2 feet. Samples were transferred from the stainless steel auger bucket to a stainless steel bowl before being placed in appropriate sample containers. The subsurface soil samples were examined and described by the field geologist who classified the samples on the basis of their color (Munsell Soil Color Charts), texture (modified Unified Soil Classification System), estimated water content, and depth from the land

surface. Immediately upon opening each split-spoon sample, the samples were screened with a photoionizing HNu organic vapor detector. The samples were also screened for gross alpha radiation using an alpha scintillation probe and for beta and gamma radiation using a Geiger-Mueller meter. HNu and radiological readings were entered into the boring logs. When a VOC-analysis sample was required, it was collected immediately in sample jars. Depth-specific samples, such as VOCs, metals, and radiological samples, were transferred directly from the split-spoon into sample bottles using stainless steel scoops or spoons. Composite samples were prepared by placing each split-spoon sample in a stainless steel bowl (using stainless steel spoons or scoops) and mixing it with a stainless steel sampling tool until it was observed to be of uniform color and texture. Nonmixable materials (e.g., concrete, wood chips, paper, plastic, glass, and rock fragments) were removed before compositing took place. Each composite was then quartered and equal portions were taken from each quarter to provide the necessary volume for analysis.

Analytical Parameters

Samples from monitoring well borings were tested for radionuclides listed in Table 2-2. Table 2-3 lists the approximate sample depths and analytical parameters for samples collected and borings drilled during the 1991 drilling program and from trenches excavated during the 1989 South Field Trenching Program.

2.1.3.3 RI/FS Surface Water and Sediment Sampling

Surface water and sediments of the Great Miami River have been sampled for the past 30 years (WMCO 1989). Paddys Run was recently included in the monitoring program. The RI/FS surface water and sediment sampling program included Paddys Run, seepage from the eastern embankment of Paddys Run, the Great Miami River, and a number of drainages across the FEMP. Surface water and sediment samples were collected from various seeps and trenches within Operable Unit 2. This section addresses only those samples collected in or immediately downstream of Operable Unit 2 waste areas.

Objective

The objective of surface water and sediment sampling for Operable Unit 2 waste areas was to determine if contaminants are migrating from these areas via the surface water pathway.

Methods

The mouth of a clean grab bottle was placed into the stream upgradient from where the sampling technician stood, thereby preventing contamination of the sample by disturbance of bottom sediments by the technician. Samples were taken at approximately 6 inches below the water's surface and transferred to individual sample containers. The sampling crew estimated water flow at each sampling location (at the time of sampling) in accordance with the Sampling Plan. Sediment samples from flowing water courses were collected below the water surface using a stainless steel scoop or Ponar dredge. Before the sampling of sediments in a stream, the sampling device was rinsed with stream

TABLE 2-3

SUMMARY OF THE 1991 OPERABLE UNIT 2 SUBSURFACE MEDIA SAMPLING AND ANALYSIS PROGRAM AND 1989 SOUTHFIELD TRENCHING PROGRAM

Waste Unit	Number of Borings	Sample Depth	Analytical Parameters
Solid Waste Landfill	Six	25% of fill depth	Radionuclides VOCs[a] SVOCs[b] Pesticides/PCBs[c] Dioxins/Furans Organophosphorus Pesticides Metals Total Organic Carbon
		50% of fill depth or highest HNu reading	TCLP[d] VOCs/SVOCs
		75% of fill depth	Radionuclides VOCs SVOCs Pesticides/PCBs Dioxins/Furans Organophosphorus Pesticides Metals Additional RCRA[f] Appendix IX Parameters[g] EP Toxicity Herbicides/Pesticides/ Metals Total Organic Carbon
		Immediately below fill/soil interface	Radionuclides VOCs SVOCs Pesticides/PCBs Dioxins/Furans Organophosphorus Pesticides Metals Total Organic Carbon
		Boring Composite	TCLP Metals/Pesticides/Herbicides RCRA Characteristics of Corrosivity/Igntability/Reactivity
Lime Sludge Ponds	1 each pond	2 feet	Radionuclides VOCs SVOCs Pesticides/PCBs Dioxins/Furans Organophosphorus Pesticides Metals Additional RCRA Appendix IX Parameters TCLP Full List

TABLE 2-3
(continued)

Waste Unit	Number of Borings	Sample Depth	Analytical Parameters
	North Pond	Water Sample	Radionuclides VOCs SVOCs Pesticides/PCBs Dioxins/Furans Organophosphorus Pesticides Metals General Groundwater Quality Parameters (Table 2-4) Additional RCRA Appendix IX Parameters
Active Flyash Pile	Four	25% of fill depth	Radionuclides VOCs SVOCs Pesticides/PCBs Metals Total Organic Carbon
		50% of fill depth or highest HNu reading	TCLP VOCs/SVOCs
		75% of fill depth	Radionuclides VOCs SVOCs Pesticides/PCBs Metals EP Toxicity Herbicides/Pesticides/Metals Total Organic Carbon
		Immediately below the fill/soil interface	Radionuclides VOCs SVOCs Pesticides/PCBs Metals Total Organic Carbon
		Boring Composite	TCLP Herbicides/Pesticides/Metals RCRA Characteristics of Corrosivity/ Ignitability/Reactivity

TABLE 2-3
(continued)

Waste Unit	Number of Borings	Sample Depth	Analytical Parameters
Inactive Flyash Pile	Four	25% of fill depth	Radionuclides VOCs SVOCs Pesticides/PCBs Metals Total Organic Carbon
		50% of fill depth or highest HNu reading	TCLP VOCs/SVOCs
		75% of fill depth	Radionuclides VOCs SVOCs Pesticides/PCBs Metals EP Toxicity Herbicides/Pesticides/Metals Total Organic Carbon
		Immediately below the fill/soil interface	Radionuclides VOCs SVOCs Pesticides/PCBs Metals Total Organic Carbon
		Boring Composite	TCLP Herbicides/Pesticides/Metals RCRA Characteristics of Corrosivity/ Ignitability/Reactivity

TABLE 2-3
(continued)

Waste Unit	Number of Borings	Sample Depth	Analytical Parameters
South Field	Four	1.5-2 feet	TCLP full list RCRA Characteristics of Corrosivity/Ignitability/Reactivity TCLP VOC/SVOCs
	Four	1.5-2 feet	TCLP VOC/SVOCs
	Two	1-2 feet or highest HNu reading	VOCs SVOCs Pesticides/PCBs Dioxins/Furans Organophosphorus Pesticides Metals
		2-3 feet	TCLP Full List
		4-5 feet or from fill/soil interface	VOCs SVOCs Pesticides/PCBs Dioxins/Furans Organophosphorus Pesticides Metals
	Two	One couple from each successive 5-feet interval. Sample from midpoint of interval or at highest HNu reading	VOCs SVOCs Pesticides/PCBs Dioxins/Furans Organophosphorus Pesticides Metals
		Immediately above the fill/soil interface	TCLP Full List
	[h]Six	Fill Sample 2.5 to 5.0 feet depending on fill depth (middle of trench)	VOCs SVOCs Pesticides/PCBs Metals
	[h]Six	Fill Sample 2.5 to 5.0 feet depending on fill depth (both ends and middle of trench)	Radionuclides
	[h]Six	Immediately below fill/native soil interface (at 3.5 to 6.0 feet depending on fill depth) (both ends and middle of trench)	Radionuclides

[a] VOC = Volatile organic compound
[b] SVOC = Semivolatile organic compound
[c] PCB = Polychlorinated biphenyls
[d] TCLP = Toxicity characteristic leaching procedure
[e] EP = Extraction procedure
[f] RCRA = Resource Conservation and Recovery Act
[g] Appendix IX of 40 CFR 264 is the RCRA Groundwater Monitoring List
[h] Six trenches were excavated; three boring numbers were assigned to each trench

water, downstream from the sampling location. Surface sediment samples from dry stream channels or drainages were collected by using a stainless steel scoop to scrape away and collect the uppermost inch of sediment. For stream channels and principal drainageways, sediment samples were collected, at quarter-points across the channel, and composited. For traverse sampling, a clamshell or dredge was used to collect bottom samples. Sediment samples were collected to a depth of approximately 6 inches below the sediment/water interface. The vertical pipe core sampler and/or dredge were decontaminated between each sample collection (cleaned with surface water and a brush).

Analytical Parameters

The field analyses performed on the water samples included pH, temperature, conductivity, and dissolved oxygen. Sediment samples were screened in the field for radionuclides using a Geiger-Mueller beta/gamma detector and an alpha scintillation detector. The sample with the highest reading at each location was selected for further laboratory analysis.

The surface water samples were analyzed for radionuclides listed in Table 2-2 and general water quality parameters listed in Table 2-4. Samples from selected locations were also analyzed for VOCs, SVOCs, pesticides/PCBs, dioxins/furans, organophosphorus pesticides, and metals in accordance with the Work Plan. Sediment samples were analyzed for radionuclides, VOCs, SVOCs, pesticides/PCBs, dioxins/furans, organophosphorus pesticides, metals, and grain size distribution.

During the 1991 Operable Unit 2 sampling program, a surface water sample from the North Lime Sludge Pond was analyzed for the parameters listed in Table 2-4, as well as the RCRA Groundwater Monitoring List (40CFR264, Appendix IX; henceforth referred to as the additional Appendix IX parameters).

2.1.3.4 RI/FS Groundwater Investigation

Because an extensive groundwater monitoring program for the FEMP will be presented in the RI/FS for Operable Unit 5, the groundwater sampling discussed here in the RI/FS for Operable Unit 2 only focuses on the Operable Unit 2 waste areas. For the purposes of the Operable Unit 2 groundwater investigation, the release of contaminants into the groundwater from only the Solid Waste Landfill, Lime Sludge Ponds, Active Flyash Pile, Inactive Flyash Pile, and South Field are examined. Releases from other operable unit study areas are not considered. The site-wide groundwater investigation which will be presented in the Operable Unit 5 RI/FS, will contain the examination of contaminant releases into the groundwater from all Operable Units, including Operable Unit 2.

Objectives

The objectives of groundwater sampling in the Operable Unit 2 area were to:

- Determine if contaminants from the waste have migrated to groundwater

TABLE 2-4

THE FEMP RI/FS LIST OF GENERAL GROUNDWATER AND SURFACE WATER QUALITY PARAMETERS

Parameters	
Aluminum	Nitrates
Ammonia	Phenols
Antimony	Potassium
Arsenic	Selenium
Barium	Silicon
Beryllium	Silver
Cadmium	Sodium
Calcium	Sulfate
Chloride	Thallium
Chromium	Vanadium
Cobalt	Uranium
Copper	Zinc
Cyanide	Total organic carbon
Fluoride	Total organic halides
Iron	Total organic nitrogen
Lead	Alkalinity as $CaCO_3$
Magnesium	pH
Manganese	Specific conductance
Mercury	Biological Oxygen Demand
Molybdenum	Total Suspended Solids
Nickel	Oil and grease

- Characterize any perched groundwater that may be encountered during remediation of Operable Unit 2

Methods

A total of 27 monitoring wells were installed within the Operable Unit 2 study area during the RI, as described below. Monitoring Wells 2014, 2016, 3014, and 3016, however, were installed prior to the RI/FS by Dames & Moore (1985a). Four different water-bearing zones were monitored by the wells, as described below. The locations were selected on the basis of data gaps identified from previous groundwater studies and on sampling results from the existing wells.

The 1000-series wells monitor perched water within the glacial overburden. The 2000-series wells are intermediate-depth wells at top of the Upper Great Miami Aquifer. They monitor the top of this regional aquifer. The 3000-series wells were installed near the bottom of the Upper Great Miami Aquifer to investigate the potential downward transport of contaminants from the Upper portion of the aquifer. They are screened immediately above a regionally extensive clay layer that divides the Upper and Lower Great Miami aquifers. The 4000-series wells installed within the study areas of Operable Unit 2 were screened in the Lower Great Miami Aquifer immediately above the shale bedrock.

All 2000-, 3000-, and 4000-series RI/FS wells were drilled using cable-tool drilling techniques. The cable-tool technique advances a temporary steel casing that seals the Upper borehole and minimizes the potential migration of contamination to the deeper units. This temporary casing also maintains an open borehole without the use of drilling fluids that could introduce foreign materials into the subsurface environment. The temporary steel casing was a nominal 10-inch diameter to allow for construction of the well. The temporary casings in the 3000- and 4000-series wells deeper than 150 feet were in some cases telescoped from a nominal 10-inch to a nominal 8-inch diameter.

After each boring reached the designated depth, a well was constructed of 4-inch inside diameter 316 stainless steel casing and stainless steel well screens. Sand packs around the screens are well sorted medium- or coarse-grained quartz sand. During well installation, field measurements and information such as the depth to the bottom of the boring, screen location, granular backfill interval, type of seals, grout, and height of riser above ground surface were recorded on the Piezometer Installation Sheet and Monitoring Well Installation Detail sketch. After completion, the well was surveyed for horizontal and vertical control.

After the RI/FS wells were completed, they were all developed (to remove fines from the area around the sensing zone) according to the general guidelines described in the approved Work Plan. The methods used to develop each well depended upon its type of construction and the type of subsurface material in which it was completed. Generally, all 2000-, 3000-, and 4000-series wells were developed by using a surge block and purging five times the volume of water added during drilling

plus five times the well volume. Each well was developed until its water was nonturbid and sediment free, to the fullest extent practical.

Although the 1000-series wells were drilled using a hollow-stem continuous-flight auger and constructed according to the specifications described in the previous paragraph, they were developed differently because they are located in the fine-grained glacial overburden. They were surged with a surge block and then five times the volume of the well was purged from the well. In 1000-series wells, it was not always possible to develop the wells sufficiently to obtain nonturbid groundwater.

All equipment and materials used for well development were decontaminated in the same manner as the drilling equipment, before and after each use. The development equipment was also cleaned if it became visibly contaminated during the development phase. Water samples were collected using a stainless steel submersible pump, a teflon bailer, and/or a stainless steel and teflon positive displacement pump. Groundwater samples collected for radiological and metal analysis were filtered.

Analytical Parameters

Groundwater samples for each well were taken quarterly for a period of one year, beginning in May 1988 for those wells installed as of that date. All groundwater samples were analyzed for the radiological and general groundwater quality parameters listed in Tables 2-2 and 2-3.

RI/FS Wells 1016, 2014, 2016, 2027, 2037, 2042, and 2065 were selected to be analyzed for additional chemical parameters to augment the quarterly RCRA monitoring program. These parameters include VOCs, SVOCs, pesticides/PCBs, organics of concern under the Federal Drinking Water Standards, organophosphorus pesticides, and the general groundwater parameters listed in Table 2-4. These analyses of well water samples were done on a limited basis to meet the needs of the site RCRA program.

2.1.3.5 RI/FS Biological Resources Investigation

Vegetation and wildlife at the FEMP were studied and characterized by Battelle Columbus Laboratories (Battelle 1981) and C. F. Facemire, under contract to WEMCO (Facemire et al. 1990). WEMCO performed two studies of fish that are indigenous to Paddys Run and the Great Miami River in the vicinity of the FEMP (WMCO 1986, 1987). In 1982, OEPA conducted a study of the aquatic environment in the Great Miami River (OEPA 1982). The studies were not focused on Operable Unit 2 specifically, but on the site as a whole.

A site-wide study under the SWCR has also been conducted specifically to support the RI/FS; details are provided in the draft SWCR (DOE 1992b). The study is a site-wide analysis of the radionuclide and chemical uptake by flora and fauna at the FEMP. The radionuclide and chemical uptake study was designed in 1987 to examine site-wide contamination of terrestrial, wetland, and aquatic

organisms. Because the plan was designed for the whole site and was not operable-unit specific, only six biota sample locations fell within in the Operable Unit 2 study area. Site-wide objectives, methods, and analytical parameters are discussed below. A separate discussion of the general site-wide ecological study is presented in Section 3.0.

Objectives

The main objectives for the site-wide biological resources investigation were to determine:

- Whether any radiological or hazardous substance releases to the FEMP environment by surface water, sediments, or adjacent wetlands had resulted in significant uptake, assimilation, and transfer through ecological habitats within the FEMP boundaries
- Whether such releases and uptakes represent significant pathways to human receptors
- Whether federal or state threatened or endangered species exist within the FEMP environment and the potential risk that is posed to such species through contaminant releases from the FEMP

Methods

For purposes of the site-wide biological resources study, a 1000-foot grid was established over the FEMP (Figure 2-1). Six sampling locations fell within the Operable Unit 2 study area. The general flora sampled from sample points located within Operable Unit 2 included grasses and forbs and were sampled at each location by placing a 0.5-meter by 0.5-meter (0.25-square-meter) quadrat over the vegetation at the appropriate grid point. The sampling quadrat is divided into four 0.25 meter by 0.25 meter quadrants. Vegetation samples were taken from one of the four quadrants (chosen by random selection). Terrestrial vegetation samples were collected from just south of the Active Flyash Pile, from the center of the Inactive Flyash Pile, and near the northeast corner of the South Field Figure 2-1. Vegetation samples were collected by cutting shoots at ground level with decontaminated shears and dividing the material into major groups (e.g., grass or forb). Vegetation samples were not classified further (for example, as to species). Root samples were collected to a depth of approximately 15 centimeters at each sample site. To the extent possible, earth was removed from root samples before they were packaged. Proper measures to prevent sample cross-contamination were taken at each sampling location. Individual samples of plant material were wrapped in an aluminum foil sheet and placed in a zipper-locked bag for shipment to the off-site analytical laboratory for radiological and chemical analysis. One wetland vegetation site was also sampled near the Solid Waste Landfill (Figure 2-1). Wetland vegetation samples consisting of cattail leaves and roots were collected using the previously described methods. A soil sample was also collected along with the vegetation samples. Soil samples were taken from soil from the quadrant diagonally opposite the vegetation-sampling quadrant. Each soil sample was collected within 0.5 meter of the vegetation sample to discount the possibility of spatial variations occurring between the precise soil and vegetation sampling locations.

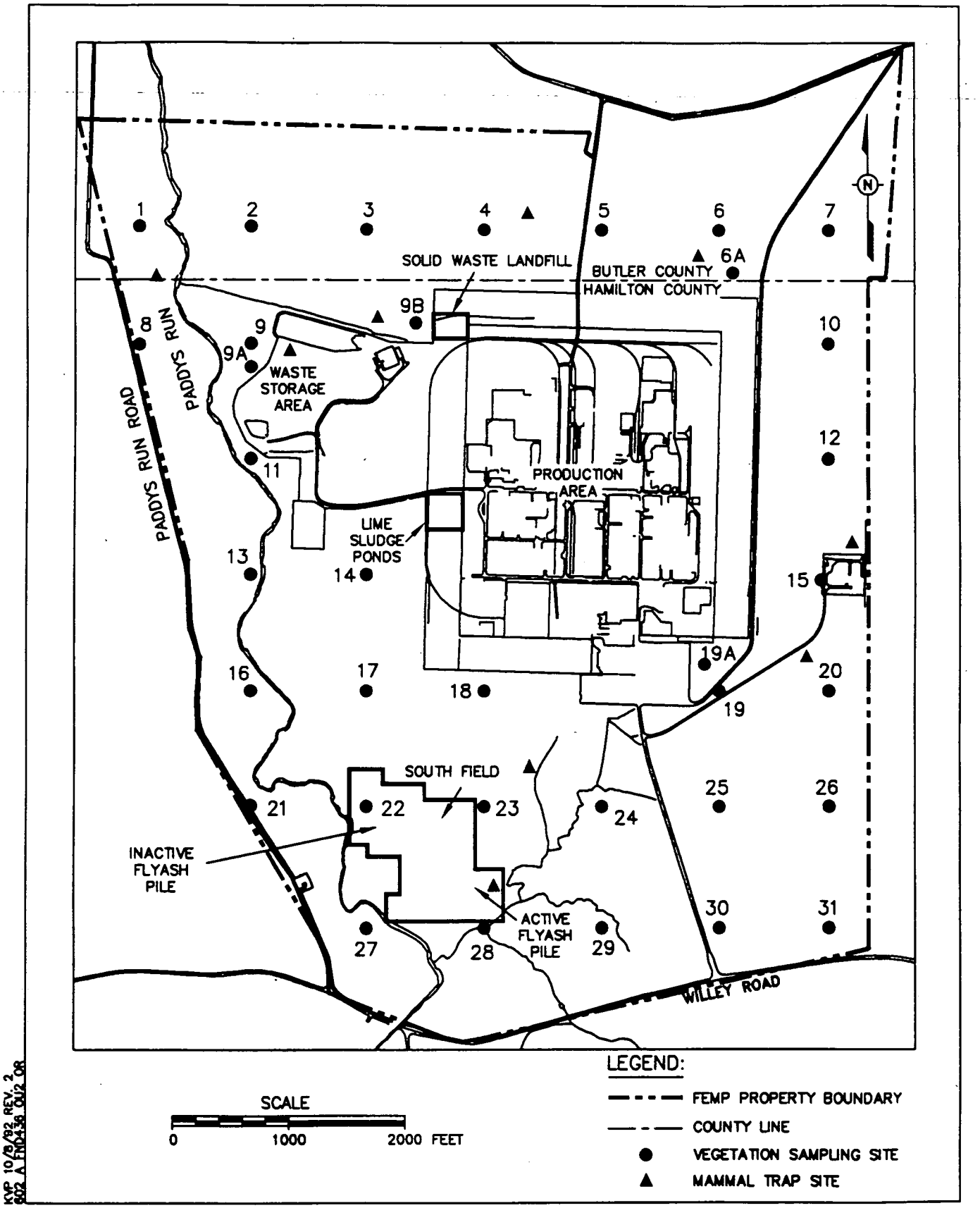

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FIGURE 2-1. LOCATION OF RI/FS VEGETATION/SOILS AND MAMMAL SAMPLING SITES ON THE FEMP

Fauna samples taken from the Operable Unit 2 study area included only small mammals. Sample locations for the site-wide biological study were selected in areas where the potential for contamination was high. Two such locations fell within Operable Unit 2—one just south of the Active Flyash Pile and one in a drainage pond just below the Solid Waste Landfill. Small mammals were captured at these locations using snap traps. Traps were appropriately baited and set in likely habitats. Tissues from the small mammals captured at these locations were composited from each trap set. Only small mammals were captured at these locations and composited. Following capture, all samples were placed in appropriately labeled zipper-locked bags and stored in a locked, dedicated freezer until dissection at the on-site laboratory. All dissection of mammal tissue was performed in the on-site laboratory to minimize the potential for cross-contamination. During dissection, samples of muscle, internal organs (liver, kidney, and gonads), and/or bone were excised using decontaminated scalpel, forceps, and shears. These samples were then wrapped in foil and placed in a zipper-locked bag for shipment to the off-site analytical laboratory for radionuclide and chemical testing .

Analytical Parameters

Terrestrial vegetation and small mammal samples were tested for isotopic uranium (uranium-234, uranium-235, and uranium-238 activities), cesium-137, and strontium-90. As part of the site-wide sampling plan, eight percent of all locations were analyzed for technetium-99, SVOCs, pesticides/PCBs, and/or metals. A few biota samples from the Solid Waste Landfill and the Active Flyash Pile fell into this eight percent and were tested for some or all of these chemical constituents.

2.1.3.6 RI/FS Geotechnical Analyses

In 1991, RI/FS sampling technicians conducted in-place density measurements on the wastes in each of the five waste areas of Operable Unit 2. An expanded suite of geotechnical analyses, required to support the FS, was performed on subsurface samples from the Active and Inactive Flyash piles.

Methods

In situ density measurements were performed under ASTM Method D-2922, Density of Soil and Soil-Aggregate In Place by Nuclear Methods (Shallow Depth). Data from these tests will be used to calculate bulk densities for use in the FS.

Shelby tube samples were collected at a depth of 10 feet from one boring in the Inactive Flyash Pile and one boring in the Active Flyash Pile. The boring and sampling interval was selected in the field based on the geologist's estimation that the sample properties were typical of the waste area. All geotechnical testing was conducted as specified by the appropriate ASTM standards and laboratory procedures according to ASTM D3740-0.

Analytical Parameters

Shelby tube samples were tested for the following parameters using their respective testing methods.

- Grain size, ASTM D-422
- Atterberg limits, ASTM D-4318
- Moisture content, ASTM D-2216
- Specific gravity, ASTM D-854
- Standard Proctor, ASTM D-698
- Relative density, ASTM D-2049
- 1-D consolidation, ASTM D-2435
- Permeability, EPA METHOD 9100 (SW 846)
- In-place density, ASTM D-2922, D-2167, or D-1556

2.1.4 Data Validation

RI/FS data, which is used as the basis for remedial action decision-making has been validated. This section presents discussions of the data validation process for the RI/FS and also an evaluation of the data collected and analyzed during the CIS and Environmental Survey.

Data validation is an after-the-fact, independent, systematic process of (1) evaluating data, (2) comparing it to pre-established criteria, (3) providing confirmation that the data is of the technical quality necessary to meet its intended use, and (4) assuring that a legally defendable "road map" can be established to trace each sample from the time it is collected in the field to its ultimate end use. Data quality objectives (DQOs) address five principal parameters: precision, accuracy, completeness, comparability, and representativeness. To verify that these objectives are met and to determine compliance with appropriate and applicable procedures, the validation process examines (1) field measurements, (2) sampling and handling procedures, (3) laboratory analysis and reporting, and (4) any nonconformances and discrepancies in the data. Data qualifiers are assigned to the analytical data to alert the user of any nonconformances to quality assurance/quality control (QA/QC) requirements.

The level of quality required depends on the intended use of the data, which in turn dictates the appropriate level or extent of validation. The FEMP RI/FS Data Validation Plan classifies data into one of five analytical support levels (ASLs):

- ASL I (qualitative) - Applies to field screening or analysis using portable instruments. Results are often not compound-specific and not quantitative but are available in real time.

- ASL II (semi-quantitative) - Includes both field and laboratory analyses using either more sophisticated portable analytical field instruments or controlled laboratory procedures. Results are defendable as approximations of the true value of measured analytes.

- ASL III (quantitative) - Includes all analyses performed in an off-site laboratory which may or may not use EPA Contract Laboratory Program (CLP) procedures, providing quantitative results within the limits of the laboratory quality assurance plan. Actual defendability of data is uncertain due to the absence of supporting raw data to determine actual compliance with established QA/QC requirements.

- ASL IV (quantitative) - EPA CLP routine analytical services. All analyses are performed at an off-site analytical laboratory approved to perform analyses under the EPA CLP using specified CLP protocols. This level is characterized by rigorous QA/QC procedures and documentation. The majority of the organic and inorganic chemical analyses were performed under the 1988 EPA CLP Statement of Work.

- ASL V (quantitative) - Analysis by non-standard methods. All analyses are performed at an off-site laboratory that may or may not be a CLP laboratory. Standard methods are those that have been accepted and/or published by EPA. Radiological and dioxin/furan analyses fall into this category. Data collected for ASL III or IV are sometimes assigned to ASL V instead, because of method modifications or departures noted during reviews. Data derived from non-standard methods are subject to the same QA/QC requirements as ASL III data and require additional internal validation of the method by the laboratory.

The validation program is divided into two phases. The first phase considers field data, which is collected at ASL I or II. The second phase deals with analytical data, which is collected at ASL III, IV, or V. For most of the organic and inorganic data, reviews are performed under the CLP Statement of Work, corresponding to data collected at ASL IV. Data reported under a Certificate of Analysis (COA) are reviewed and qualified as ASL III. Radiological data are normally qualified based on deliverables provided for ASL V. Separate evaluations are conducted for radiological, organic, and inorganic analytes.

2.1.4.1 Review of Environmental Survey Data

Samples collected as part of the Environmental Survey sampling program in 1986 have been included in the characterization of Operable Unit 2 but not in the quantification of the risks. Documentation of procedures, operator training, equipment calibration, and QA/QC steps are incomplete. Additionally, although radiological and chemical analyses conformed to EPA methods (Table 2-1), CLP protocols were not followed.

2.1.4.2 Review of CIS Data

CIS samples were collected before the FEMP RI/FS QAPP was adopted in March 1988, and CIS data has not been validated according to the RI/FS Data Validation Plan.

A review of CIS data, however, indicates that organic and inorganic analyses were performed in accordance with CLP protocols in effect at that time. There is no CLP for radiological data. Based on the review of CIS data, it appears likely that the documentation will support validation to ASL III or V, but not to ASL IV; consequently, the CIS data have been used both in the characterization of nature and extent of contamination and in the quantification of risk. The use of CIS data as a basis for site characterization and risk assessment is supported by the Risk Assessment Work Plan Addendum. Furthermore, the RI/FS sampling effort was designed to supplement existing data, including CIS data.

2.1.4.3 RI/FS Data Validation

Data validation was performed on analytical results for all the RI/FS surface and subsurface media samples (i.e., soil, lime sludge residue, and flyash samples) used in site characterization and risk assessment. The data validation process includes a review of field data records, as well as laboratory data packages, as prescribed in the FEMP RI/FS QAPP.

RI/FS Field Data Validation

Validation checklists were used to trace specific samples from one document to another and relate information contained on boring logs, sample collection logs, chain of custody (COC), request for analysis (RFA) forms, field activity data logs, and geologist field logs. Information was checked to determine if all requirements of the FEMP RI/FS QAPP were implemented as the documents were prepared. Field forms were checked for completeness, and calibration documentation was verified for each field instrument used or analysis performed. Training records were checked to ensure that all field personnel had current and complete training as required by appropriate work plans.

RI/FS Radiological Data Validation

Project-specific methods for radiological analyses were used. Neither the EPA, DOE, nor the Nuclear Regulatory Commission have issued guidelines for radiological data validation. Furthermore, the RI/FS QAPP contains no specific methods and requirements for radiological analyses and data documentation. Consequently, the radiological analyses were performed according to the standard operating procedures and QA plan of the laboratory.

The radiological data packages consisted of the sample traffic reports (COC and RFA), sample results, supporting raw data, and QC data. The packages did not contain information on sample preparation or instrument calibration and, until mid-1991, did not contain COAs. The validation process consisted of reviewing the documentation for completeness, consistency, and compliance with QC criteria established under the RI/FS QAPP. The methods of analysis were examined, and data were evaluated based on specific parameters such as radiometric or gravimetric yields. Also, instrument calibration information was obtained and applied to the sample data.

RI/FS Organic and Inorganic Data

Separate reviews were performed for organic and inorganic analyses reported under the EPA CLP format. Analyses for compounds tested under certain parameters (e.g., general chemistry, TCLP, and groundwater monitoring) were performed under Certificates of Analyses. Samples were reviewed based on QC results reported with the data. Some analytes, such as dioxins/furans, were reported in a CLP-equivalent format and were reviewed based on the information provided. Data packages included sample results, a summary QC data, calibration data, and supporting raw data.

The organic data review consisted of documenting compliance with (or deviation from) expected QC limits established for sample holding times, gas chromatograph/mass spectrometer (GC/MS) performance (i.e., tuning), GC/MS calibration, surrogate spike recoveries, matrix spike recoveries, matrix spike duplicates, blank contaminants, and internal standard performance. In addition, system performance for pesticides/PCBs analysis was verified by checking (1) linearity of analyte response, (2) absolute retention times for dichlorodiphenyltrichloroethane (DDT), (3) potential for breakdown of DDT and endrin on the GC column, (4) retention time shifts relating to identification, and (5) observed retention times for standards and samples.

The inorganic data review consisted of: (1) documenting compliance with (or deviation from) expected QC limits established for sample holding times, Inductivity Coupled Plasma, Gas Furnace Atomic Absorbtion, and other instrument performance criteria; (2) initial and continuing calibrations; (3) matrix spike recoveries; (4) matrix spike duplicates; (5) blank contaminants; (6) detection limit determinations; and (7) serial dilution studies.

2.1.4.4 Data Validation Qualifiers

Review checklists were completed, and data deficiency summaries indicating data qualifiers were completed for all chemical and radiological sample data sets that have been validated. These identified the problems observed and described the potential effects on data. Non-flagged data appear to be scientifically defendable as required by the FEMP RI/FS QAPP and thus may be used for any purpose. Data flagged with a "J" qualifier may be assumed to be present but are not within "quantitative" limits anticipated by the QA plan. Data qualified as "J" may be biased either high or low or may be imprecise and should be considered as estimated values. 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 normally assigned to data by the laboratory, but it was also used as a validation qualifier when common contaminants were detected in field blanks, trip blanks, and laboratory blanks. If a common laboratory contaminant (i.e., acetone, methylene chloride, 2-butanone, or one of the pthalate esthers) was detected in a site-related sample at a level less than ten times the highest associated blank sample, the site-related result was adjusted and was qualified with a "U" (undetected at the reported level), as prescribed by the 5X/10X rule. If another chemical was detected in a site-related sample at a level less than five times the highest associated blank, the site-related result was adjusted and was qualified with a "U." Some of the early data was flagged with a "JB" qualifier, indicating potential bias from blank contamination. This qualifier is no longer used and has been replaced with either the "J" or "U" qualifier. In instances where the limit of quantitation is uncertain, data flagged by the laboratory as "U" (not detected) are qualified as estimated or "UJ."

Additional qualifiers for radiological data are "D," "M," "C," "E," and "F." A "D" qualifier indicates a possible false negative which is a reported non-positive result greater than the detection limit for that radionuclide. An "M" qualifier indicates the matrix spike recovery was outside the control limits,

suggesting possible matrix interference. The qualifiers "C," "E," and "F" refer to the uranium results. A "C" qualifier, assigned to uranium-238, indicates that the calculated total uranium value from the measured uranium isotope results does not agree within 20 percent of the measured total uranium result. An "E" qualifier, assigned to uranium-235, indicates that the calculated percent enrichment of uranium-235 is outside the acceptance limits of 0.2–1.3 percent. An "F" qualifier, assigned to uranium-234, indicates that the ratio of the uranium-234/uranium-238 results is outside of the acceptance limits of 0.4-1.3 percent. It is possible for multiple qualifiers to be assigned to one analyte. For example, uranium-238 can be assigned a "CJ" or a "DCJ."

Data was flagged as "R" (unusable) whenever holding times were grossly exceeded or when severe QC deficiencies were observed. These data were considered unsuitable for the intended purposes and were not used to support this report.

2.2 SOLID WASTE LANDFILL

The Solid Waste Landfill is located at the northwest corner of the former production facility. It is composed of the original disposal area, the five excavated cells, and an evaporation pond. The evaporation pond was used to temporarily retain storm water runoff that would eventually evaporate or percolate into the soils (Figure 1-5). The five cells and the adjacent disposal area have been covered with on-site soils and the evaporation pond has been backfilled. The landfill has not been used since 1986.

2.2.1 Waste Description

The Solid Waste Landfill, which was operational from about 1954 to 1986, was used to dispose of cafeteria waste (e.g., food, paper products, and styrofoam containers), rubbish, and other wastes from FEMP nonprocess areas and on-site construction/demolition activities. Materials reported to have been accepted include nonburnable, nonradioactive solid waste generated on site and nonradioactive, construction-related rubble (Weston 1987b). In addition, double-bagged and bulk quantities of nonradioactive asbestos were placed in the landfill (DOE 1988a). Radionuclide-contaminated materials, including construction rubble and soil previously used to cover exposed wastes, may also have been disposed of in the landfill (DOE 1988a). A September 1992 letter report on characterization trenching performed during July and August 1992 at the Solid Waste Landfill and the South Field (DOE 1992e) reported that the following wastes were detected in the Solid Waste Landfill:

- burnable - bagged trash and wood
- possible burnable - respirator cartridges, asphalt roofing materials, medical wastes, fire-hoses and rubber hoses/belts
- nonburnable - medicine vials, bagged asbestos, ceramic tiles, magnesium fluoride, glass acid bottles, steel cables/cans, paint cans, and copper tubing

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2.2.2 Surface Media Sampling in the Solid Waste Landfill

The objectives of surface media (soil) sampling in the Solid Waste Landfill were to

- Characterize the nature and extent of contamination in the cover soils
- Provide data to evaluate the potential for migration off of the waste area via the surface water pathway
- Provide data to evaluate the potential for exposure via the direct contact pathway
- Provide data to evaluate the potential for exposure via the air migration pathway

As part of the Environmental Survey (DOE 1988a), four surface media samples were composited from the Solid Waste Landfill (Figure 2-2) as described in Section 2.1.1.2. These samples were analyzed for radionuclides, PCBs, and asbestos.

During the CIS (Weston 1987c), a number of surface media samples were collected for on-site gamma spectroscopy analysis for cesium-137, radium-226, ruthenium-106, thorium-232, and uranium-238. Based on this initial screening, four surface media samples were selected for more extensive radiological analysis at an off-site laboratory (Figure 2-2).

During the RI/FS, three surface media samples were collected at a single location just outside the northwest corner of the landfill (Figure 2-2). Samples were collected from 0 to 2 inches, 2 to 4 inches and 4 to 6 inches, and were analyzed for radionuclides listed in Table 2-2.

2.2.3 Subsurface Media Sampling in the Solid Waste Landfill

The objectives of subsurface media (soil) sampling in the Solid Waste Landfill were to:

- Characterize the physical nature of buried waste materials in the landfill
- Characterize the nature and extent of contamination
- Determine fill depths and volumes
- Determine whether contaminants have migrated from fill into underlying native soils
- Provide data to support the modeling of contaminant migration from the Solid Waste Landfill

During the Environmental Survey, Test Pit No. 8 was excavated west of the Solid Waste Landfill, on the northern side of the drainage ditch (Figure 2-2). Samples collected in the pit from depths of 3.5 and 6.5 feet were analyzed for radionuclides.

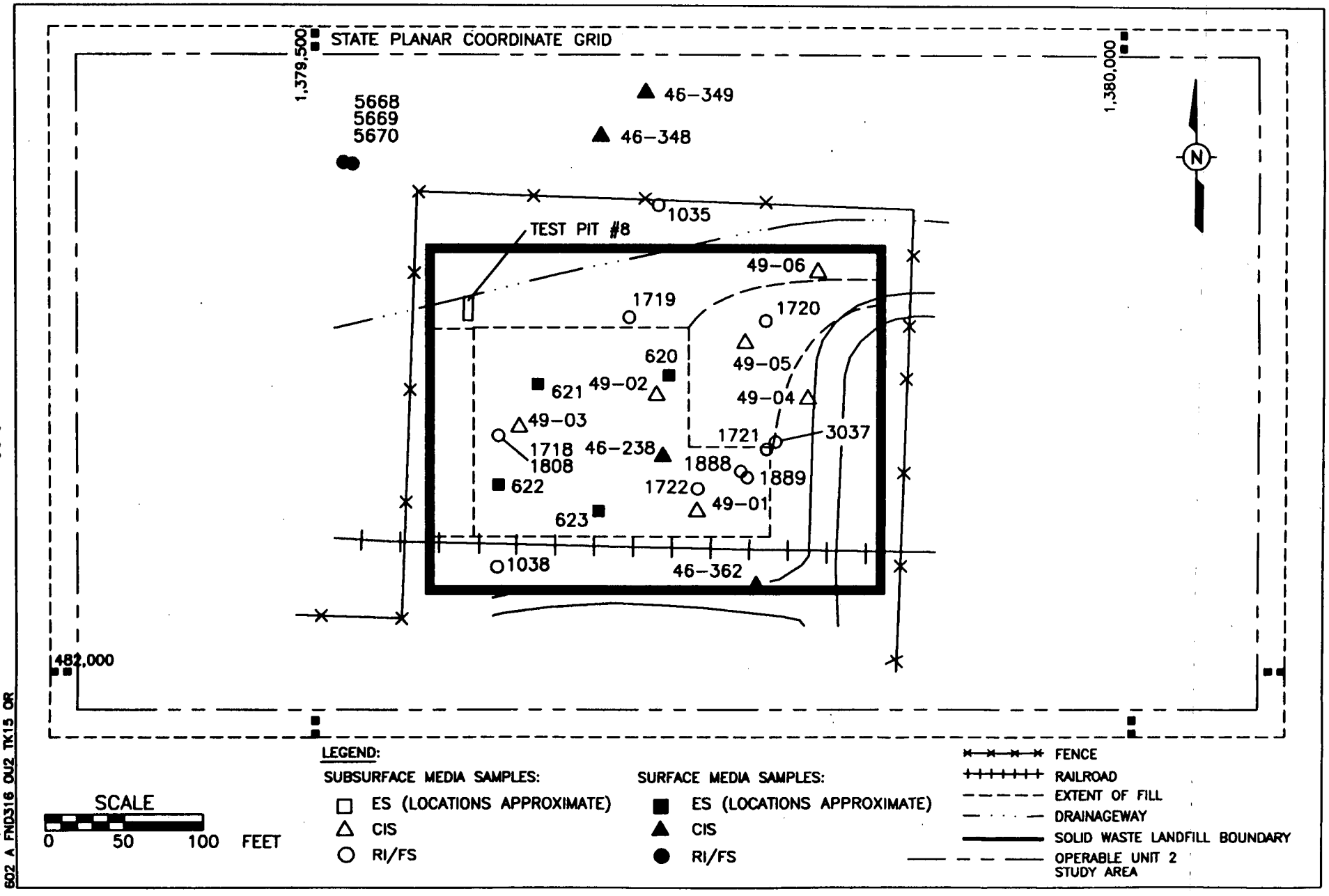

FIGURE 2-2. SURFACE AND SUBSURFACE MEDIA SAMPLE LOCATIONS IN THE SOLID WASTE LANDFILL STUDY AREA

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During March and April 1987, six borings were completed in the Solid Waste Landfill for the CIS (Weston 1987b). Split-spoon samples were collected at 1- to 2-foot intervals and were analyzed for radium-226, thorium-232, and uranium-238 at the on-site gamma spectroscopy laboratory. The purpose of this sampling was to develop activity profiles for these three radionuclides. Samples were also collected from each boring, composited into a single sample, and sent to off-site laboratories for chemical and radiological analyses. Chemical analyses included VOCs, SVOCs, pesticide/PCBs, metals, and the four RCRA characteristics—EP toxicity, reactivity, ignitability, and corrosivity.

During 1988, the RI/FS sampling team drilled three borings (1035, 1038, and 3037) as a part of the site-wide monitoring well installation program. Borings 1035 and 1038 appear to be outside the known fill area. A total of four subsurface media (soil) samples were collected from these borings and were analyzed for radionuclides.

During July and August 1991, six RI/FS borings were drilled to obtain samples to further characterize the nature of the fill and the underlying native soil, because previous sampling had not quantified the vertical distribution of contaminants sufficiently to meet the study objectives. Samples were collected from the shallow fill, deep fill, and underlying native soils (Table 2-3). Boring 1718/1809 was placed within the abandoned evaporation pond near CIS Borehole 49-03, where elevated concentrations of radionuclides had been detected in the CIS composite. Because previous investigations provided insufficient areal coverage, these additional borings were distributed throughout the waste area. Table 2-3 describes the depth of these specific samples and the particular analyses for each sample. Note that the TCLP VOC/SVOC samples were collected from the portion of the boring that displayed the highest HNu reading during screening. If no HNu readings occurred, the sample was collected from the mid-point of the boring. A composite sample from each boring was analyzed for the remainder of the TCLP RCRA analytes. The purpose of TCLP analysis was to determine whether the waste met criteria for regulation under RCRA and to determine leaching and transport potentials for groundwater modeling. EP toxicity and the additional Appendix IX parameters were analyzed for deep fill samples.

2.2.4 Surface Water and Sediment Sampling in the Solid Waste Landfill Study Area

The objective of surface water and sediment sampling in the Solid Waste Landfill study area was to determine whether contaminants from the landfill have migrated from the area via the surface water pathway. Storm water runoff and seepage from the landfill eventually reaches the drainage ditch just north of the landfill (Figure 2-3). This drainage flows westerly toward Paddys Run.

Sediments were sampled for the CIS (Weston 1987b) at five locations in the drainageway and analyzed for cesium-137, radium-226, ruthenium-106, thorium-232, and uranium-238 at the on-site gamma spectroscopy laboratory. Sample Location 21-009 was selected for more extensive laboratory analysis because it showed the highest radionuclide results from the on-site analysis.

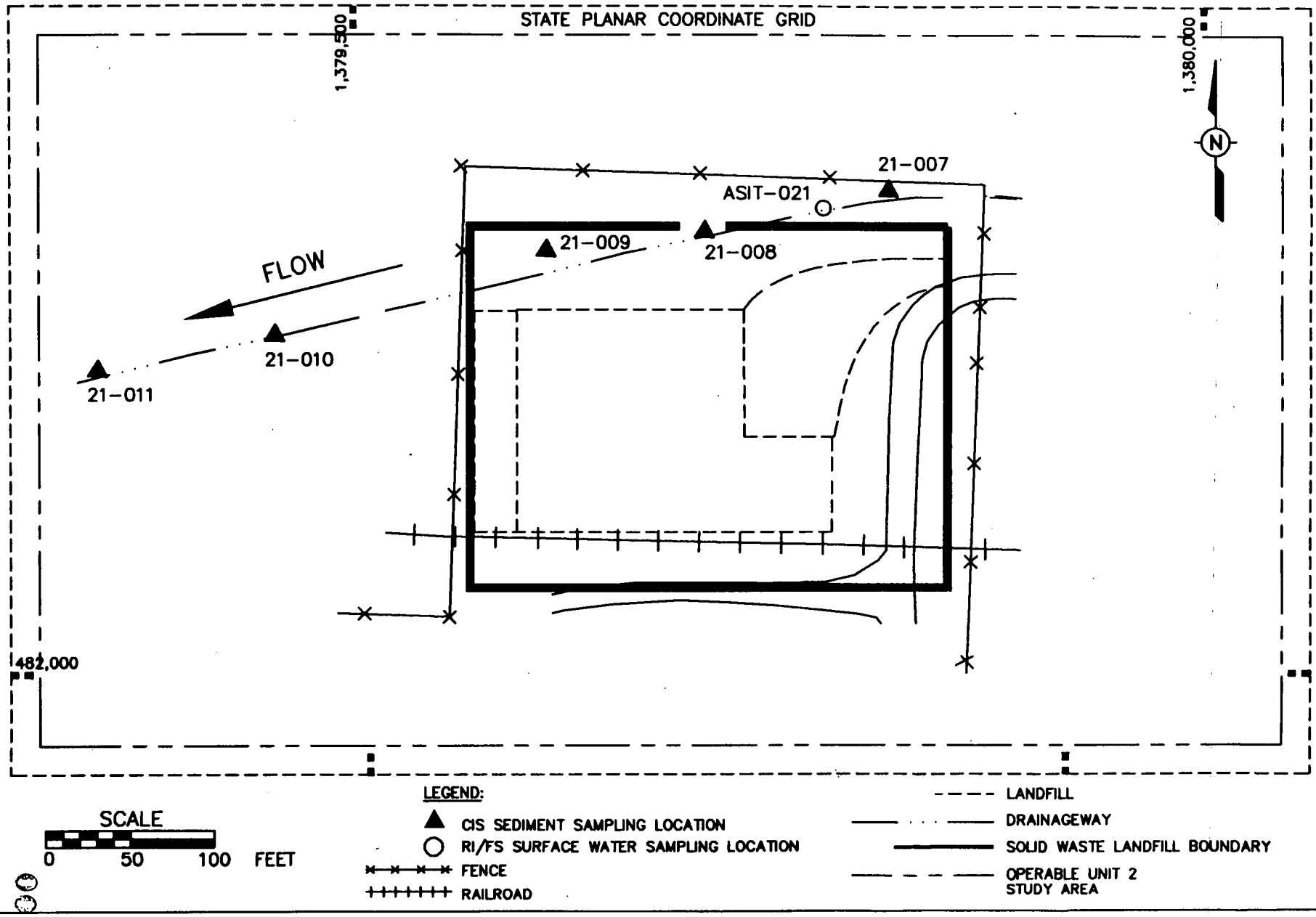

FIGURE 2-3. SURFACE WATER AND SEDIMENT SAMPLE LOCATIONS IN THE SOLID WASTE LANDFILL STUDY AREA

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The RI/FS sampling team collected a single sample of water from that same stream as it enters the boundary of the landfill (ASI/IT-021). This sample was analyzed for radionuclides (Table 2-2) and general water quality parameters (Table 2-4).

2.2.5 Groundwater Sampling in the Solid Waste Landfill Study Area

The objectives of groundwater sampling in the Solid Waste Landfill study area were to:

- Determine if contaminants from the landfill have migrated to groundwater
- Characterize perched groundwater which could be encountered during remediation of the landfill.

Seven RI/FS monitoring wells have been installed in the vicinity of the Solid Waste Landfill (Figure 2-4). These were screened in the perched water and in the top and bottom of the Upper Great Miami Aquifer (Table 2-5). These wells were sampled quarterly during 1988 and 1989 and analyzed for radionuclides, VOCs, SVOCs, pesticides/PCBs, metals, and the general water quality parameters.

Boring 1719, which was drilled in May 1992, was converted to a perched groundwater monitoring well. This well was sampled and analyzed for total uranium, VOCs, metals, and the general groundwater quality parameters. During July 1992, three trenches were excavated in the Solid Waste Landfill to visually inspect the buried materials (DOE 1992e). A total of four perched groundwater samples were collected from the three trenches and were analyzed for radionuclides, VOCs, SVOCs, pesticides/PCBs, metals, and the general water quality parameters. The analytical results for Well 1719 and the trench groundwater sampling were not available for consideration in this RI, but will be considered in the FS for characterizing leachate for the no-treatment alternatives.

2.2.6 Biota Sampling in the Solid Waste Landfill Study Area

The objective of biota sampling in the Solid Waste Landfill study area was to determine whether any radiological substance release into the adjacent wetlands resulted in significant uptake of radionuclides by wetland vegetation or in significant uptake of radionuclides by small mammals. In 1987, the RI/FS technicians collected and analyzed one set of wetland vegetation samples (cattail leaves and roots) at Vegetation Sampling Location 9B, a pond and wetland system occupying the drainage ditch downstream of the Solid Waste Landfill (Figure 2-5). Small mammal composite samples (white-footed mice and short-tailed shrews) were taken from Small Mammal Sampling Location 9B near the Solid Waste Landfill and Waste Pit 5 (Figure 2-5). Biota samples from both sampling locations were analyzed for uranium, strontium-90, and cesium-137.

2.2.7 Geotechnical Sampling in the Solid Waste Landfill

During the Weston CIS Boring Program (Weston 1988), a composite sample was collected from Boring 49-03 from a depth of 0 to 18 feet (Figure 2-6). This sample was analyzed for specific gravity, liquid limit, plasticity index, natural moisture content, particle size distribution, maximum dry

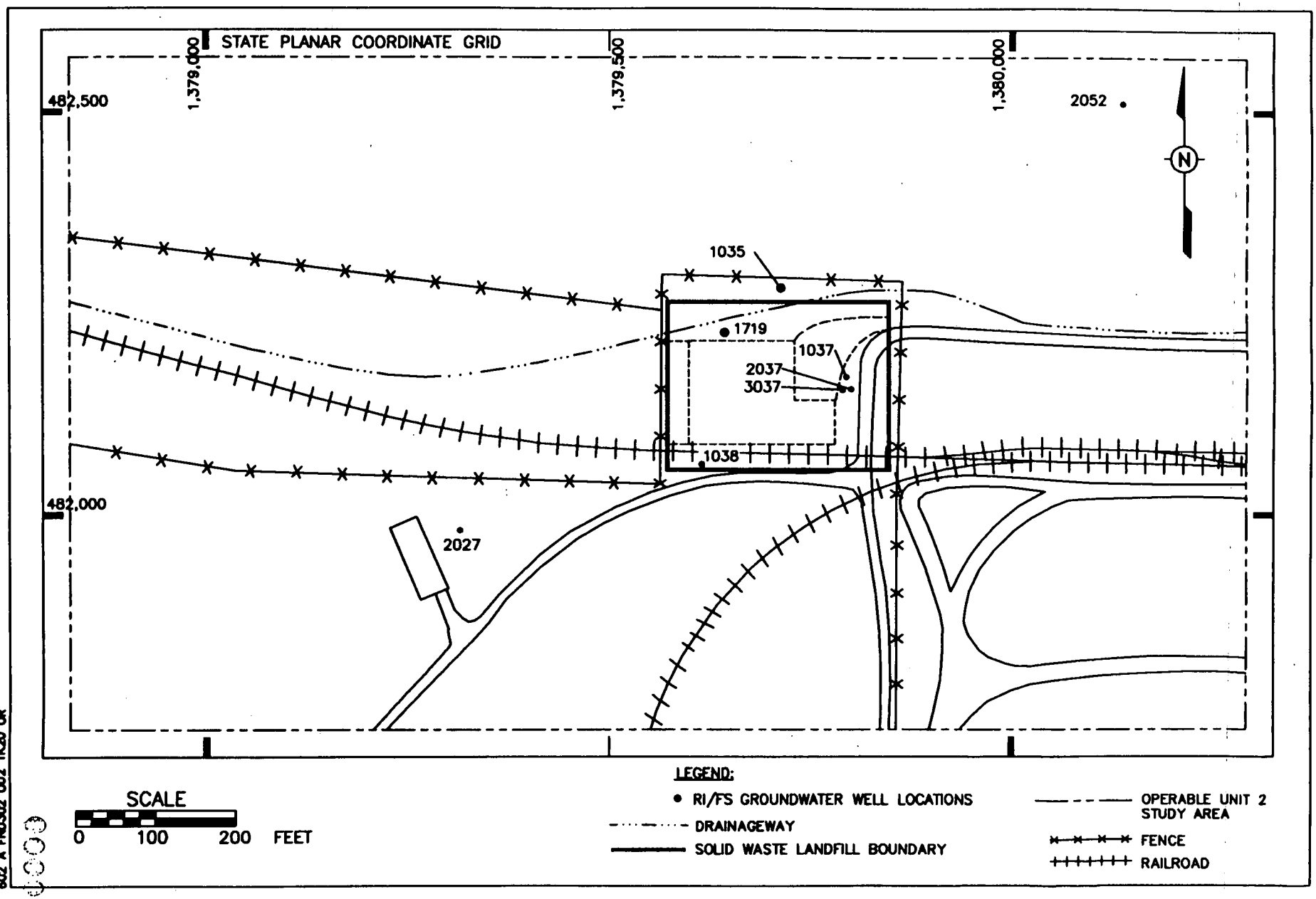

FIGURE 2-4. GROUNDWATER MONITORING WELLS IN THE SOLID WASTE LANDFILL STUDY AREA

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TABLE 2-5

SCREENED INTERVALS OF MONITORING WELLS
SOLID WASTE LANDFILL STUDY AREA

Well	Ground Elevation (feet MSL[a])	Screened Interval (feet MSL[a])	Depth to Mid-Screen (feet)	Screened Lithologic Member
1035	584.8[b]	571.19-560.19	20	Glacial Overburden
1037	588.6	560.60-549.60	35	Glacial Overburden
1719	590.1	577.30-572.30	15	Glacial Overburden
1038	582.4[b]	566.09-556.09	20	Glacial Overburden
2027	583.2	521.80-509.50	70	Upper Great Miami Aquifer
2037	588.5	523.50-508.50	70	Upper Great Miami Aquifer
2052	584.5	524.50-509.50	70	Upper Great Miami Aquifer
3037	588.5	464.50-454.50	130	Bottom of Upper Great Miami Aquifer

[a] MSL = above mean sea level
[b] Elevation of concrete pad

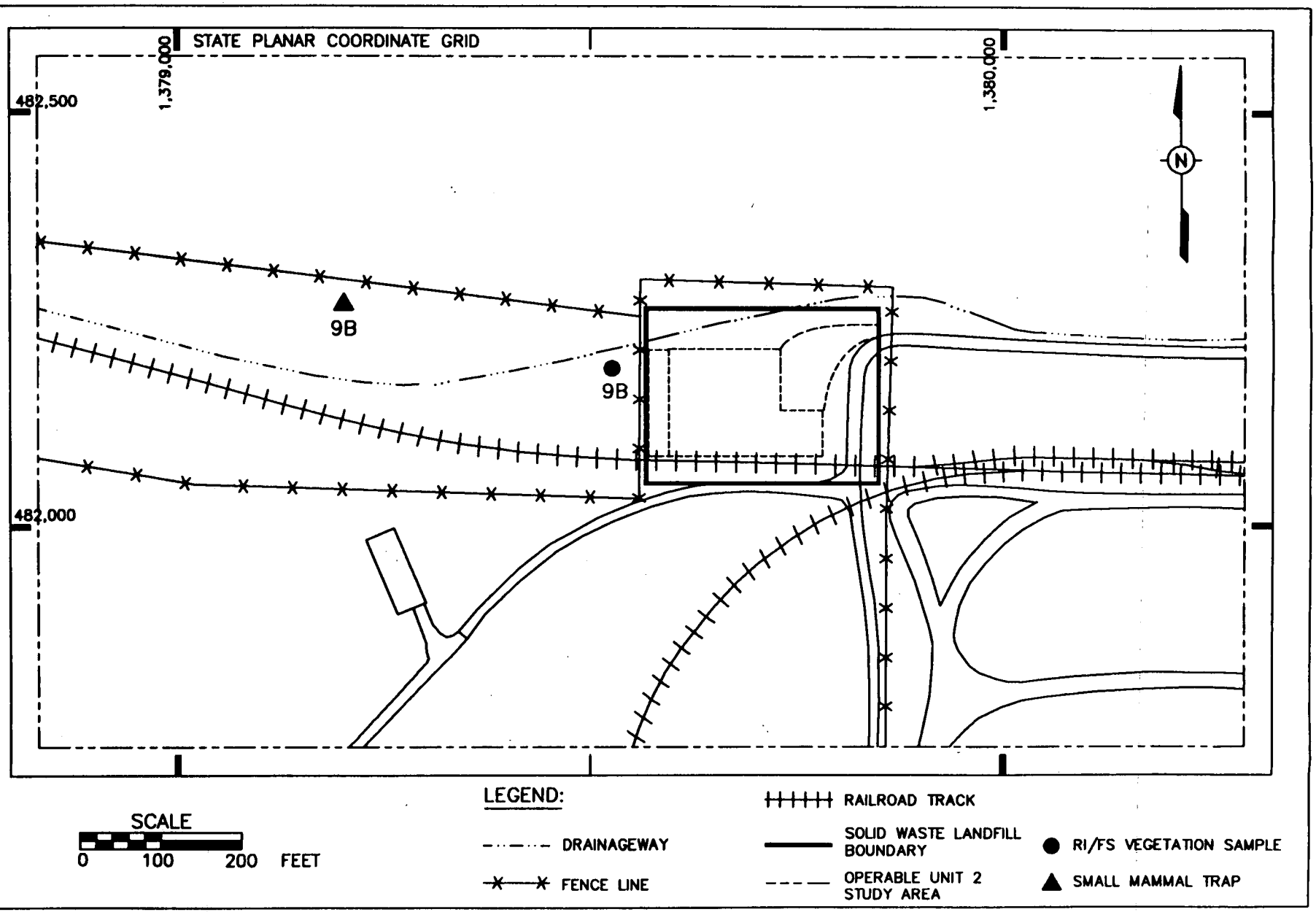

FIGURE 2-5. BIOTA SAMPLING LOCATIONS IN THE VICINITY OF THE SOLID WASTE LANDFILL

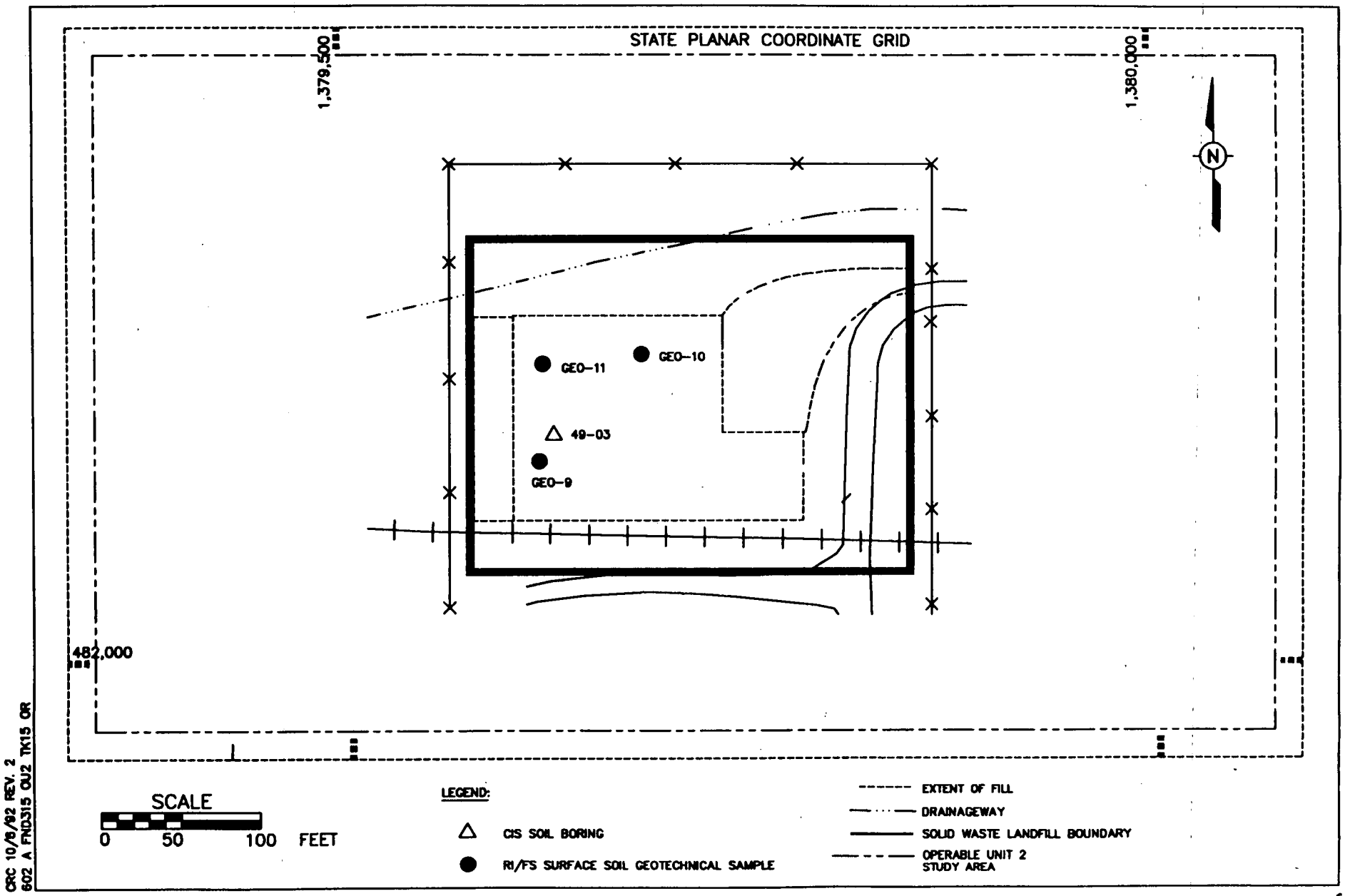

FIGURE 2-6. GEOTECHNICAL SAMPLE AND MEASUREMENT LOCATIONS IN THE SOLID WASTE LANDFILL

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density, optimum moisture content, color, and physical state. An additional CIS composite sample was collected from a depth of 0 to 12 feet, but the CIS report did not specify the exact location.

In 1991, the RI/FS sampling team measured in-place density at three locations by ASTM Method D-2922 (Figure 2-6). Wet density, dry density, and moisture content were measured at each sampling location.

2.3 NORTH AND SOUTH LIME SLUDGE PONDS

The Lime Sludge Ponds are located within the waste storage area, approximately 1500 feet south of the Solid Waste Landfill (Figure 1-6). The South Pond has been inactive since the mid-1960s, but the North Lime Sludge Pond is currently receiving spent lime sludge.

2.3.1 Waste Description

An historical aerial photograph dated April 6, 1954 (EPA 1988b) shows evidence of lime disposal activity in the Lime Sludge Ponds. Wastes currently routed to the North Lime Sludge Pond are spent lime sludges from FEMP water treatment plant operations, sludges resulting from neutralized boiler plant blowdown, and coal pile storm water runoff (WMCO 1989). The sludges and runoff are pumped into this pond and allowed to settle. Typical sludge constituents are aluminum, calcium, iron, magnesium, manganese, and potassium (Weston 1987b). Due to the presence of 1,1,1-trichloroethane in the FEMP process waters, it is also a possible constituent of sludge.

2.3.2 Surface Media Sampling in the Lime Sludge Ponds

The objectives of surface media (including soil and lime sludge residue) sampling at the Lime Sludge Ponds were to:

- Characterize the nature and extent of radionuclides in the ponds
- Provide data to evaluate the potential for exposure via the direct contact pathway
- Provide data to evaluate the potential for exposure via the air migration pathway

During the Environmental Survey, four composite surface media samples were collected from the South Lime Sludge Pond (Figure 2-7). These samples were analyzed for radionuclides, VOCs, and TCLP RCRA metals.

A large number of samples were collected along the route of the K-65 slurry line (part of Operable Unit 3) as a part of the CIS radiological survey of surface soils (Weston 1987c). This slurry line, which lies in a 2.5-foot-deep concrete trench, was used to pump the waste raffinate slurries or residues resulting from the processing of pitchblende ores from the production area to the K-65 silos (also part of Operable Unit 3). Many of these samples were located within the boundary of the Lime Sludge Ponds (Figure 2-7). Surface media samples were analyzed for cesium-137, radium-226, ruthenium-

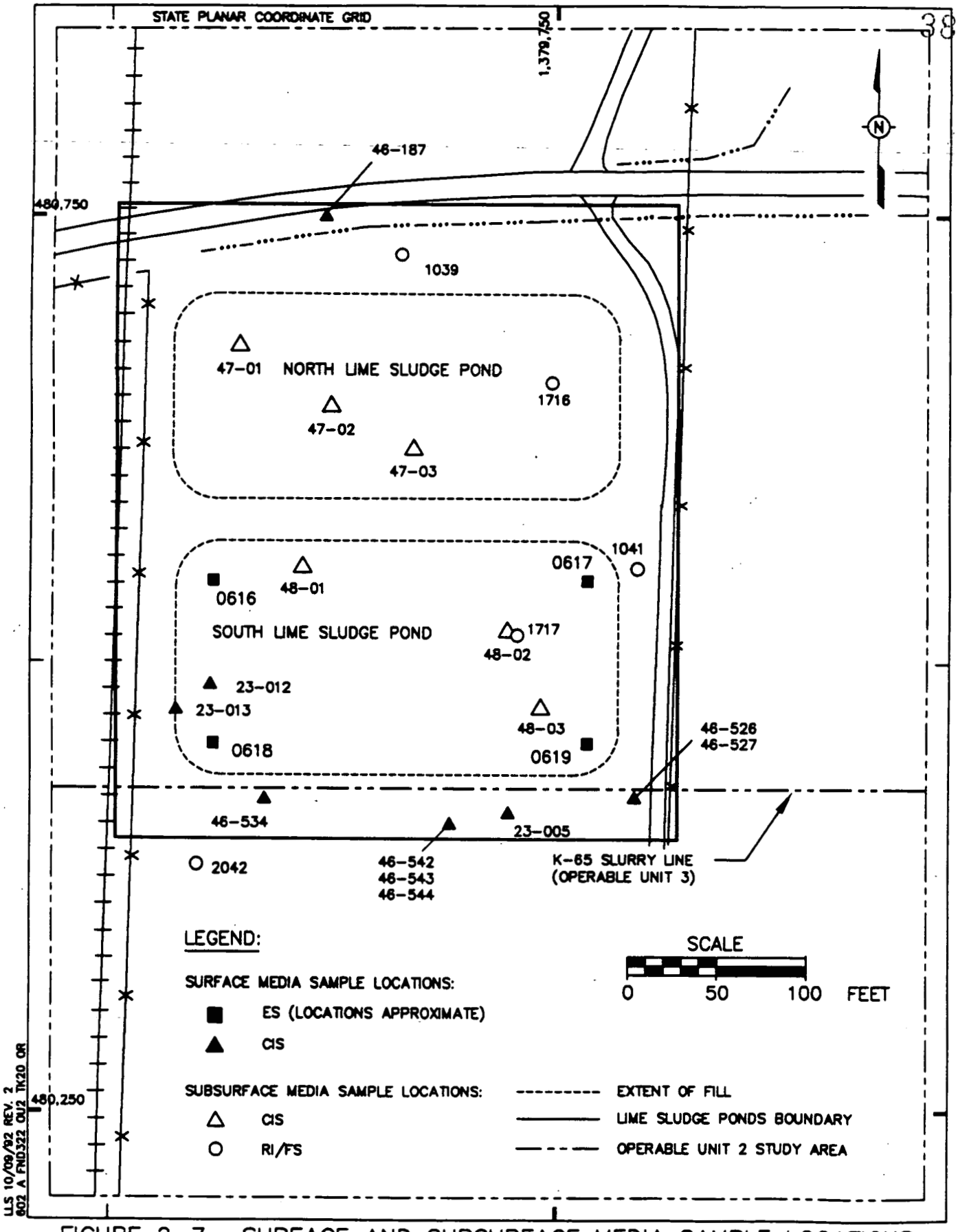

FIGURE 2-7. SURFACE AND SUBSURFACE MEDIA SAMPLE LOCATIONS IN THE LIME SLUDGE PONDS STUDY AREA

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106, thorium-232, and uranium-238 at the on-site gamma spectros collected from the north-central vicinity of the North Lime Sludge Pond for the more extensive radiochemical analysis (Figure 2-7).

2.3.3 Subsurface Media Sampling in the Lime Sludge Ponds

Objectives for subsurface media (including soil and lime sludge residue) sampling at the Lime Sludge Ponds were to:

- Characterize the physical nature of sludge residuals in the ponds
- Characterize the nature and extent of contamination
- Determine fill depths and volumes
- Provide data to support the modeling of contaminant migration from the Lime Sludge Ponds

During the CIS boring program (Weston 1987b), three borings were drilled in the North Lime Sludge Pond and another three borings were drilled in the South Lime Sludge Pond (Figure 2-7). Profile samples were collected from the North Pond at 6- to 20-inch-depth increments and from the South Pond at 1-foot-depth increments. These were analyzed for radium-226, thorium-232, and uranium-238 at the on-site gamma spectroscopy laboratory to evaluate the vertical distribution of radionuclides.

One composite sample from each of the six borings was also collected and shipped to an off-site laboratory for analyses of radionuclides, VOCs, SVOCs, pesticides/PCBs, metals, EP toxicity metals, and the RCRA characteristics of reactivity, ignitability, and corrosivity.

In 1990, the RI/FS sampling team drilled three borings (1039, 1041, and 2042) adjacent to the Lime Sludge Ponds (Figure 2-7) as a part of the site-wide monitoring well installation program. One sample was collected from the glacial overburden sequence in each of these borings for radiological analysis. In addition, a soil sample was collected from the underlying sand and gravel in Boring 2042 for radiological analysis.

In 1991, as part of the RI/FS, samples were collected from one hand-augured boring in each pond for characterization of pond contents pursuant to current regulatory requirements that mandate TCLP analysis of this waste location. Boring 1716 in the North Pond and Boring 1717 in the South Pond (Figure 2-7) were located arbitrarily, since sediments deposited in each pond were assumed to be evenly distributed across the bottom. In each boring, a grab sample was taken at approximately 2 feet below the surface of each pond and analyzed for radionuclides, VOCs, SVOCs, pesticides/PCBs, dioxins/furans, organophosphorus pesticides, metals, and TCLP metals/organics.

In March 1992, WEMCO conducted a RCRA Facility assessment of the North Lime Sludge Pond. As part of this assessment, samples of lime sludge residue were taken at 14 locations in the pond (Figure 2-8). At 8 of these, a single sample was collected, typically from the top 1 to 3 feet of residue. At 6 locations, samples were collected at multiple depths. (Depth is measured from the pond water/residue

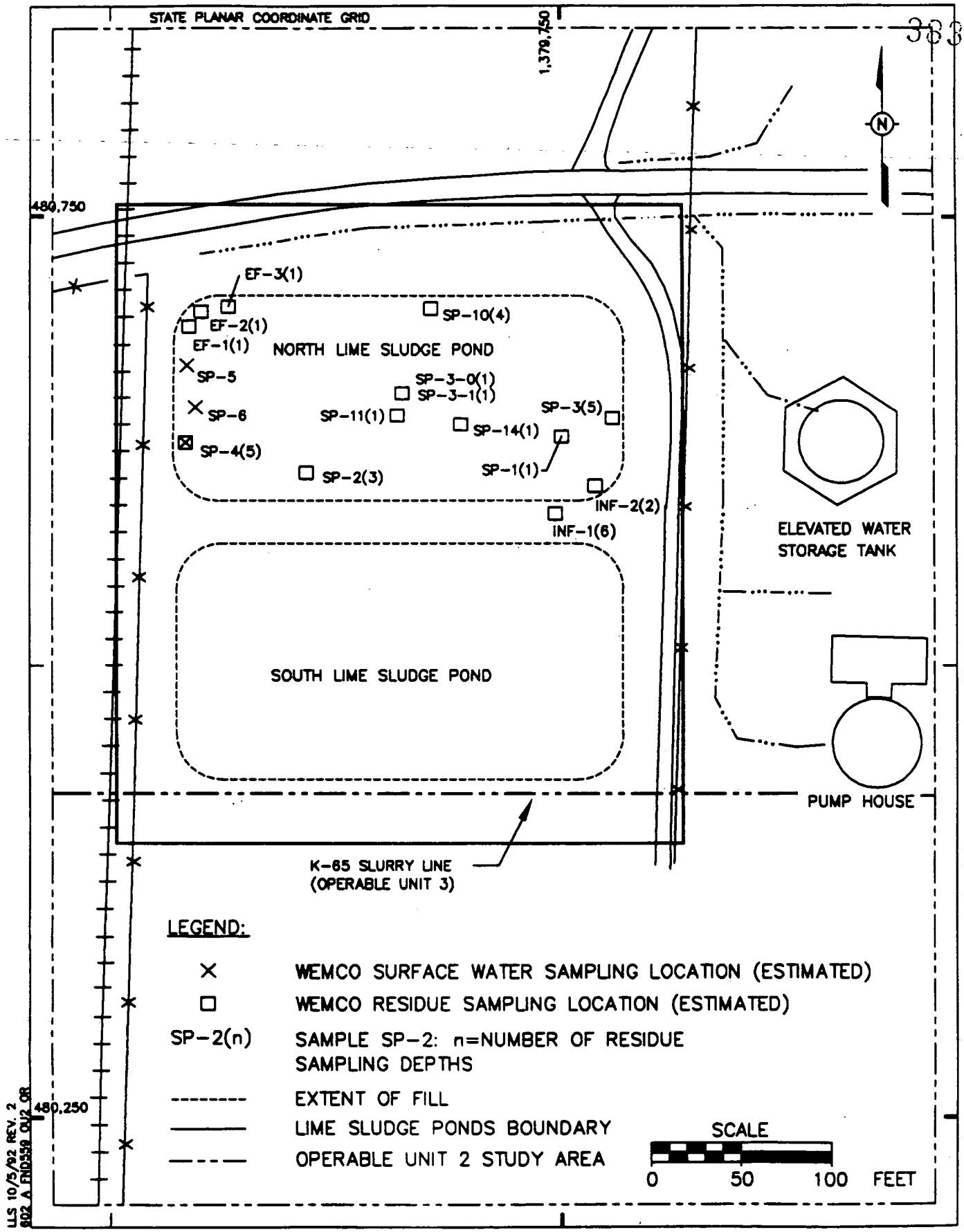

FIGURE 2-8. SURFACE WATER AND SUBSURFACE MEDIA SAMPLING LOCATIONS FOR THE RCRA FACILITY ASSESSMENT IN THE NORTH LIME SLUDGE POND

interface). In addition, three surface water samples were collected. Samples were analyzed for VOCs and the full list of TCLP analytes.

2.3.4 Surface Water Sampling in the North Lime Sludge Pond

The objectives of surface water sampling in the North Lime Sludge Pond were to:

- Characterize the nature of the contamination in the ponds
- Provide data to evaluate the potential for contaminants to leach into underlying soils and groundwater from the ponds

Because the ponds are bermed, the possibility of impacts to surface water are remote.

In 1991, the RI/FS sampling team collected surface water samples from the North Lime Sludge Pond and analyzed them for radionuclides, VOCs, SVOCs, pesticides/PCBs, dioxins/furans, organophosphorus pesticides, metals, general groundwater chemistry parameters, and the additional Appendix IX parameters. The South Pond does not contain standing water.

2.3.5 Groundwater Sampling in the Lime Sludge Pond Study Area

The objectives of groundwater sampling in the Lime Sludge Pond study area were to:

- Determine if contaminants from the ponds have migrated to groundwater
- Characterize perched groundwater that could be encountered during remediation of the ponds

Seven RI/FS monitoring wells were completed in the vicinity of the Lime Sludge Ponds (Figure 2-9). These were screened in the perched water, the Upper Great Miami Aquifer, and the Lower great Miami Aquifer (Table 2-6). These wells were sampled quarterly during 1988 and 1989 and analyzed for radionuclides, VOCs, SVOCs, pesticides/PCBs, metals, and the general water quality parameters.

2.3.6 Biota Sampling in the Lime Sludge Pond Study Area

No biota samples were taken from the Lime Sludge Pond study area.

2.3.7 Geotechnical Sampling in the Lime Sludge Ponds

During the CIS boring program (Weston 1988), one sample from the North Lime Sludge Pond and two samples from the South Lime Sludge Pond were collected for geotechnical evaluation. Samples from the North Lime Sludge Pond were collected from the 0- to 5.5-foot depth interval and those from the South Pond were collected from the 0- to 12-foot and the 2- to 11.2-foot depth intervals. The exact location of these samples was not specified in the CIS report. The testing parameters included specific gravity, liquid limit, plasticity index, natural moisture content, particle size distribution, maximum dry density, optimum moisture content, color, and physical state. In October 1991, the

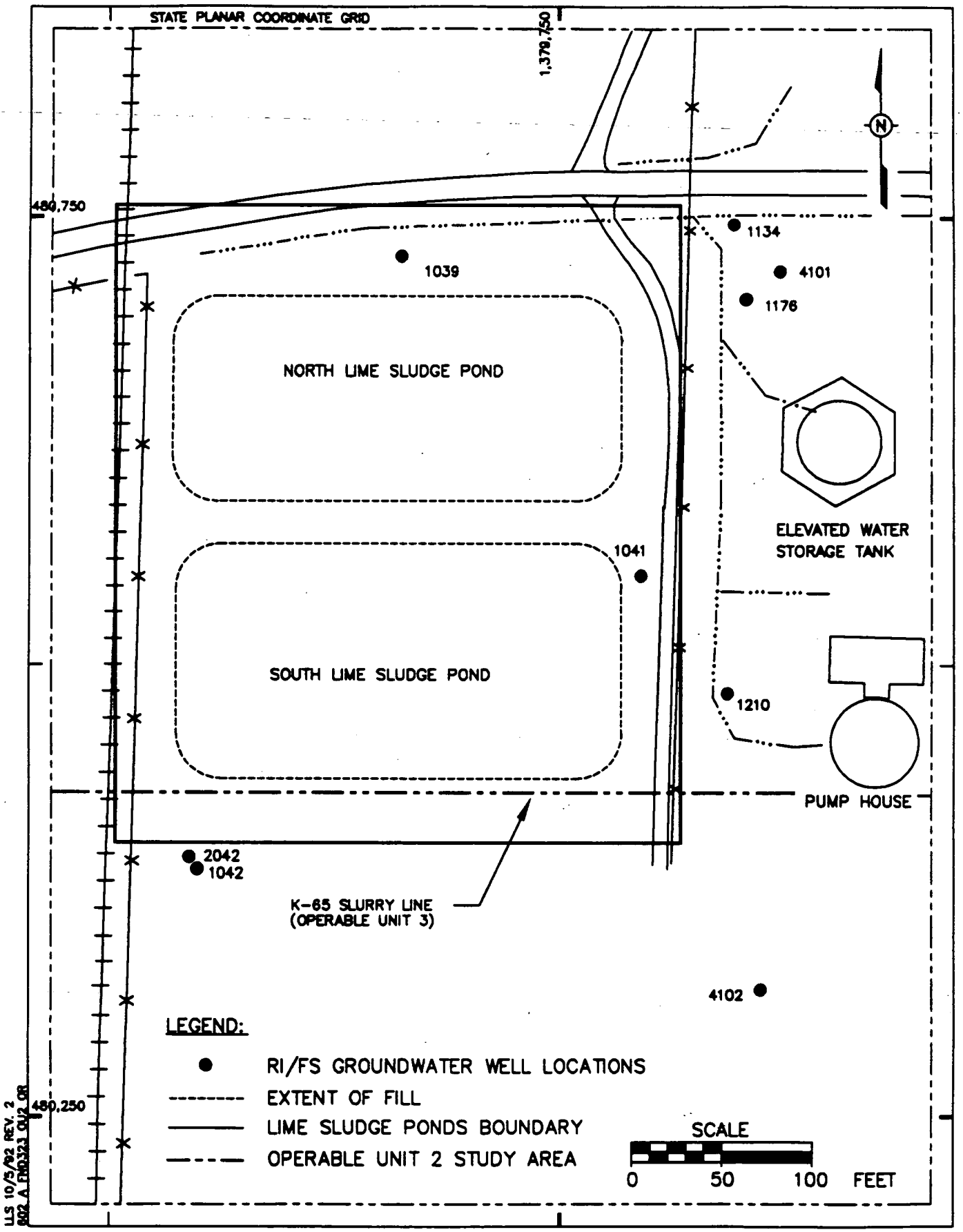

FIGURE 2-9. GROUNDWATER MONITORING WELLS IN THE LIME SLUDGE PONDS STUDY AREA

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TABLE 2-6

SCREENED INTERVALS OF MONITORING WELLS
LIME SLUDGE PONDS STUDY AREA

Well	Ground Elevation (feet MSL[a])	Screened Interval (feet MSL[a])	Depth to Mid-Screen (feet)	Screened Lithologic Member
1039	577.4	564.40 - 553.40	20	Clay, Sand Lens
1041	581.3	571.13 - 561.13	15	Clay
1042	575.4[b]	565.46 - 555.46	15	Clay, Sand Lens
1134	579.8	569.80 - 564.00	15	Clay
1176	579.7	572.70 - 567.70	10	Clay, Sand Lens
1210	579.4[b]	573.91 - 568.91	10	Clay
2042	575.3[b]	525.20 - 509.20	60	Upper Sand and Gravel Aquifer
4101	577.3[c]	ND[d]	ND	Lower Great Miami Aquifer
4102	577.6[c]	ND	ND	Lower Great Miami Aquider

[a] MSL = above mean sea level
[b] Elevation of concrete pad
[c] Elevation of top well
[d] No data available; old production well

RI/FS sampling team measured in-place density at two locations in each pond by ASTM Method D-2922 (Figure 2-10), Wet density, dry density, and moisture content were measured at each sampling location.

2.4 ACTIVE FLYASH PILE

The Active Flyash Pile is located east of the South Field, approximately 2250 feet south of the former production area (Figure 1-7).

2.4.1 Waste Description

The Active Flyash Pile has served continuously as the disposal area for bituminous flyash and bottom ash from the coal-fired boiler plant since the mid-1960s. The flyash is transported to the Active Flyash Pile by dump trucks. Spectrochemical analysis indicated that the major constituents in the bottom ash/flyash disposed at the Inactive Flyash Pile are aluminum, calcium, iron, magnesium, silicon, and titanium (Bogar 1987). Bogar also reported that uranium is a constituent of FEMP flyash. A study performed by the United Nations Scientific Committee on the effects of atomic radiation (UN 1982) indicates that concentrations of natural uranium-238 in bottom ash and flyash from Illinois and Kentucky coal (the type burned at the FEMP) are approximately 1.5 mg/kg and 1.0 mg/kg, respectively. PCB- and uranium-contaminated waste oils reportedly were used to control dust at the Active Flyash Pile (DOE 1988a, Weston 1987b). Attempts to document this practice, however, have been unsuccessful, and it is not possible to verify that the uranium present in the pile is a result of this practice.

2.4.2 Surface Media Sampling in the Active Flyash Pile

The overall objectives of surface media sampling (including flyash) in the Active Flyash Pile were to:

- Characterize the nature of contamination in surface media and flyash
- Provide data to evaluate the potential for contaminant migration from the Active Flyash Pile via the surface water pathway
- Provide data to evaluate the potential for exposure via the direct contact pathway
- Provide data to evaluate the potential for migration via the air pathway

During the Environmental Survey, surface media from eight locations widely dispersed across this waste area (Figure 2-11) were sampled. These samples were analyzed for radionuclides, VOCs, TCLP RCRA metals, and asbestos. Surface media from the Active Flyash Pile were not sampled for either the CIS or the RI/FS.

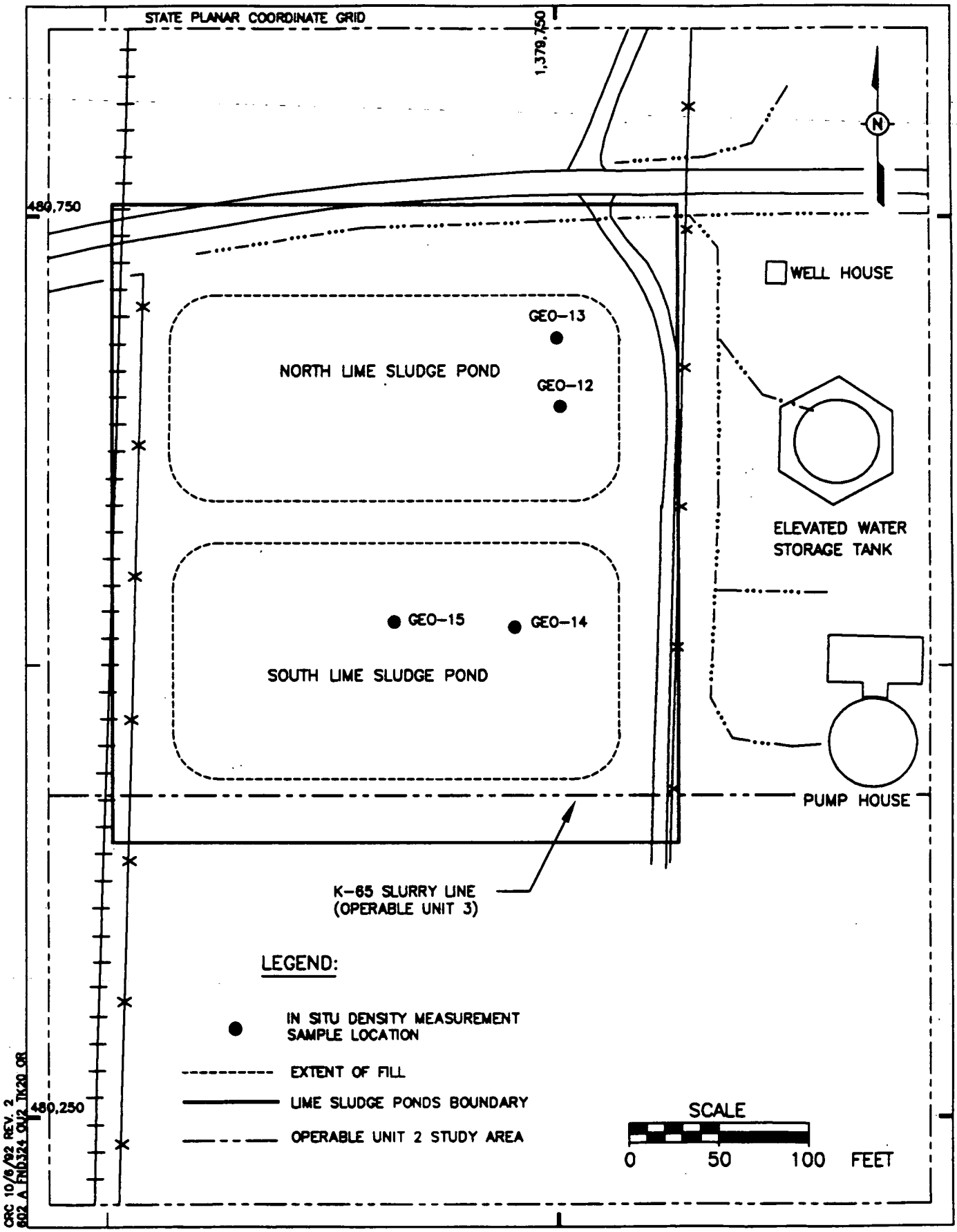
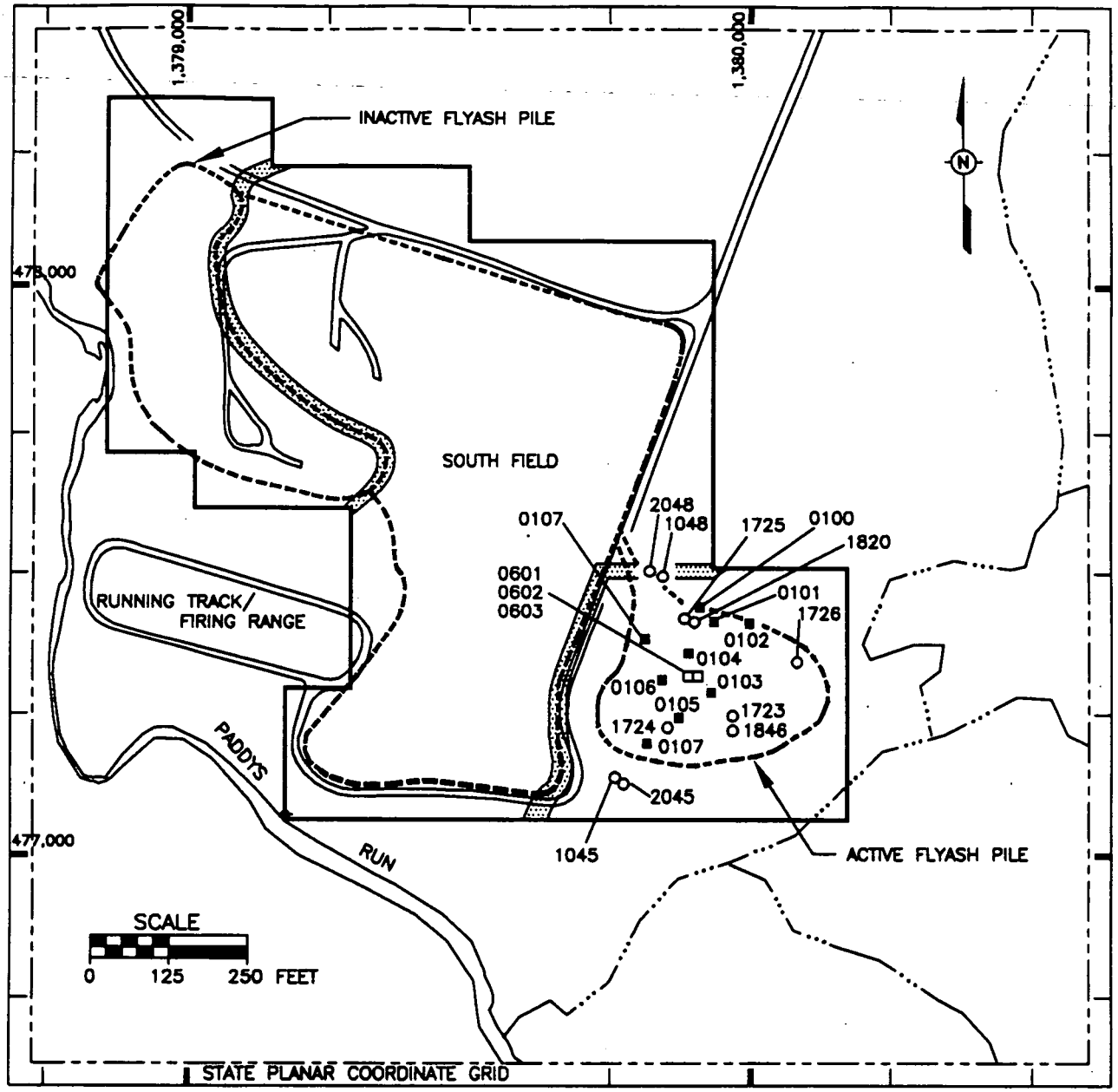


FIGURE 2-10. GEOTECHNICAL SAMPLE AND MEASUREMENT LOCATIONS IN THE LIME SLUDGE PONDS



LEGEND:

SURFACE MEDIA SAMPLING LOCATIONS:

■ ES (LOCATIONS APPROXIMATE)

SUBSURFACE MEDIA SAMPLING LOCATIONS:

□ ES BORING (LOCATIONS APPROXIMATE)

○ RI/FS BORING

------ EXTENT OF FILL

——— FLYASH/SOUTH FIELD BOUNDARY

▒ BOUNDARY BETWEEN FLYASH PILES AND SOUTH FIELD

— - - — OPERABLE UNIT 2 STUDY AREA

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FIGURE 2-11. SURFACE AND SUBSURFACE MEDIA SAMPLE LOCATION IN THE ACTIVE FLYASH PILE STUDY AREA

2.4.3 Subsurface Media Sampling in the Active Flyash Pile

The objectives of subsurface media sampling (including flyash and underlying native soil) in the Active Flyash Pile were to:

- Characterize the physical nature of buried waste materials in the Active Flyash Pile
- Characterize the nature and extent of contamination
- Determine fill depths and volumes
- Determine whether contaminants have migrated from fill into the underlying native soils
- Provide data to support the modeling of contaminant migration from the Active Flyash Pile

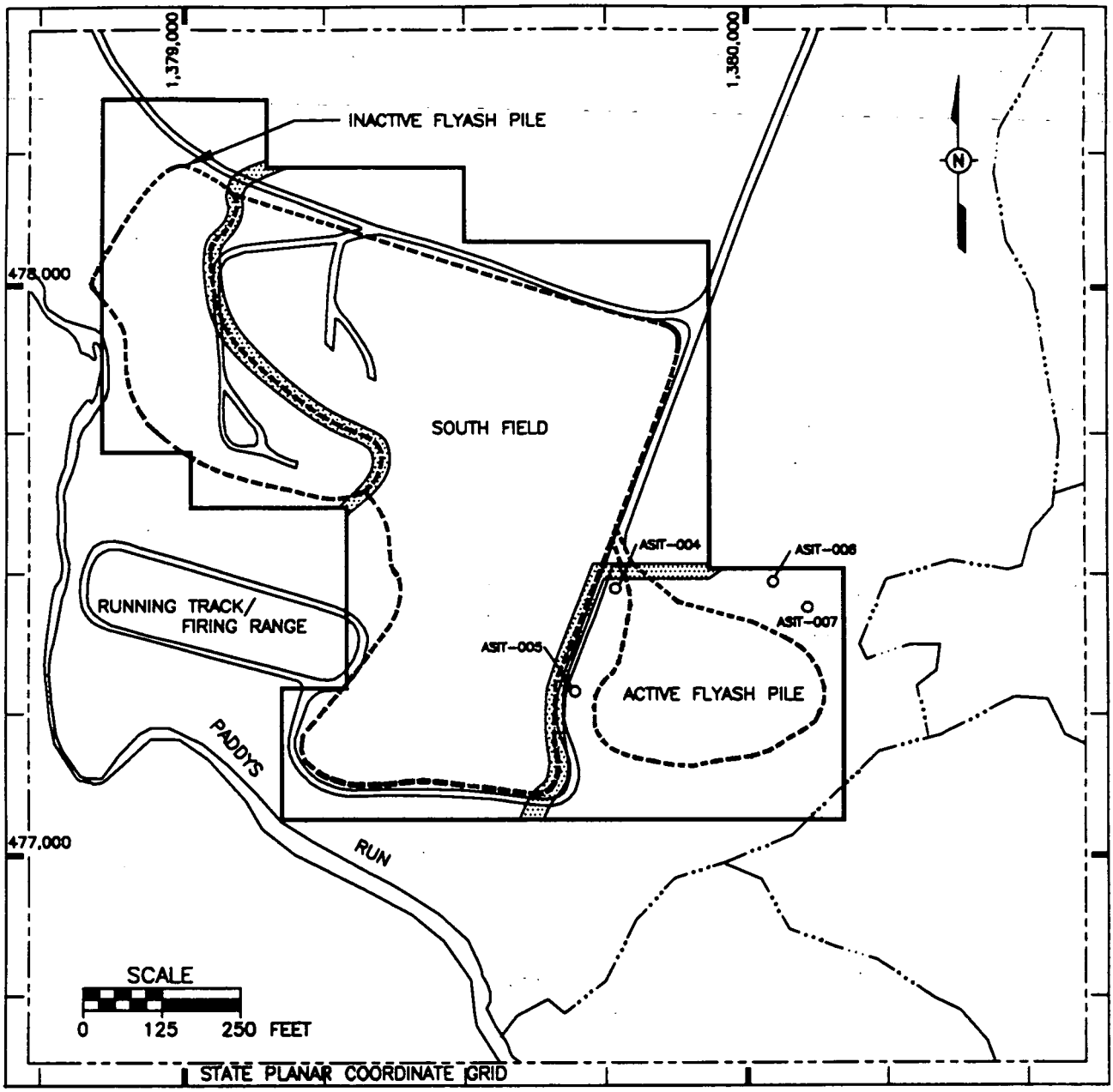
As part of the Environmental Survey, three subsurface media samples were collected from a boring at one location in the Active Flyash Pile (Figure 2-11). Samples 601, 602, and 603 were taken from the center of this boring at depths of 0 to 5 feet, 5 to 11 feet, and 11 to 13.5 feet, respectively. These samples were analyzed for radionuclides and TCLP metals.

During 1987 and 1988, the RI/FS sampling team drilled five borings (1048, 2048, 1045, 2045 and 3045) (Figure 2-11) as part of the sitewide groundwater installation program. A total of six subsurface samples were collected from these borings and were analyzed for radionuclides.

In 1991, the RI/FS sampling team drilled five borings to further characterize the nature of the fill and the underlying native soil, because previous sampling had not sufficiently quantified the vertical distribution of contaminants to meet the study objectives. Samples were collected from the shallow fill, deep fill, and the underlying native soils (Table 2-3). Table 2-3 describes the depth of specific samples and the particular analyses for each sample. Note that the TCLP VOC/SVOC sample was collected from the portion of the boring that displayed the highest HNu reading during screening. Samples from borings for which there were no HNu readings were collected from the midpoint of the boring. A composite sample from each boring was analyzed for the remainder of the TCLP RCRA analytes. The purpose of TCLP analysis was to determine whether the waste met criteria for regulation under RCRA and to determine leaching and transport potentials for waste transport modeling.

2.4.4 Surface Water and Sediment Sampling in the Active Flyash Pile Study Area

The objective of surface water and sediment sampling in the Active Flyash Pile study area was to determine if contaminants from the Active Flyash Pile have migrated via the surface water pathway. The topography of Active Flyash Pile is such that surface runoff is radial, so surface water and sediments were sampled during the RI/FS at four locations around it: two to the west and two to the northeast (Figure 2-12). Samples were analyzed for radionuclides, VOCs, SVOCs, pesticides/PCBs and the general water quality parameters.



LEGEND:

O RI/FS – SURFACE WATER AND SEDIMENT SAMPLE LOCATION

EXTENT OF FILL

FLYASH/SOUTH FIELD BOUNDARY

BOUNDARY BETWEEN FLYASH PILES AND SOUTH FIELD

OPERABLE UNIT 2 STUDY AREA

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FIGURE 2-12. SURFACE WATER AND SEDIMENT SAMPLE LOCATIONS IN THE ACTIVE FLYASH PILE STUDY AREA

2.4.5 Groundwater Sampling in the Active Flyash Pile Study Area

Although a number of groundwater monitoring wells exist within the boundaries of (or downgradient from) the Active Flyash Pile, these wells are also downgradient from (and, consequently, could be adversely affected by) the South Field. Therefore, all of these wells will be addressed in Section 2.6.5, which addresses South Field groundwater sampling.

2.4.6 Biota Sampling in the Active Flyash Study Area

The objective for biota sampling in the Active Flyash Pile study area was to determine whether any radiological and/or chemical substance release into the adjacent terrestrial habitats has resulted in significant uptake of analytes by terrestrial vegetation or in significant uptake of analytes by small mammals. In 1987, the RI/FS sampling team collected two sets of surface soil and terrestrial vegetation samples (forbs and grasses) in the Active Flyash Pile study area at biota Sampling Location 28, just south of the Active Flyash Pile (Figure 2-13). Small mammal composite samples (composites of white-footed mice, short-tailed shrews, and eastern cottontail rabbits) were also taken at Location 28.

All biota samples were analyzed for uranium, strontium-90, and cesium-137. The small mammal composite samples and the terrestrial vegetation samples for grass leaves and grass roots were also analyzed for SVOCs, pesticides/PCBs, and metals. Small mammal composite samples also were analyzed for technetium-99.

2.4.7 Geotechnical Sampling in the Active Flyash Pile

In October 1991, the RI/FS sampling team measured in-place density at three locations by ASTM Method D-2922 (Figure 2-14). Wet density, dry density, and moisture content were measured at each location. A Shelby tube sample for geotechnical analysis was also collected from boring 1724. These samples were collected from the 12- to 14.5-foot depth interval and were analyzed for moisture content, specific gravity, and grain size distribution.

2.5 INACTIVE FLYASH PILE

The Inactive Flyash Pile is located approximately 2000 feet southwest of the former production area and is currently covered with vegetation (Figure 1-7).

2.5.1 Waste Description

Bituminous flyash and bottom ash from the coal-fired boiler plant were dumped in this waste area from approximately 1952 until the mid-1960s. Spectrochemical analysis of FEMP flyash disposed at the Inactive Flyash Pile indicated that the major constituents in the bottom ash/flyash disposed at the FEMP are aluminum, calcium, iron, magnesium, silicon, and titanium (Bogar 1987). Bogar also reported that uranium is a constituent of the flyash. The United Nations Scientific Committee on the effects of atomic radiation (UN 1982) indicates that concentrations of natural uranium-238 in bottom

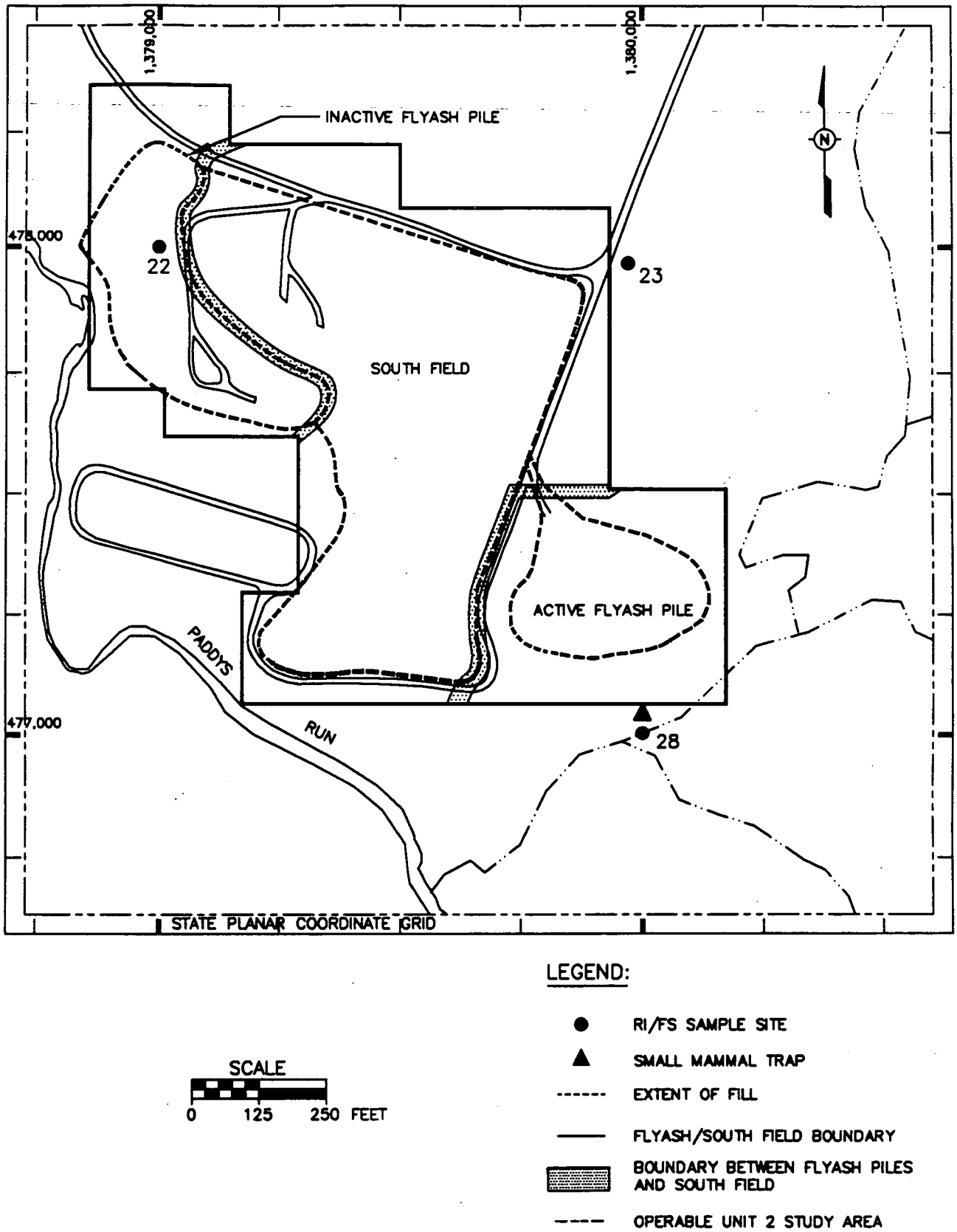

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FIGURE 2-13. BIOTA SAMPLE LOCATIONS IN THE FLYASH/SOUTH FIELD STUDY AREA

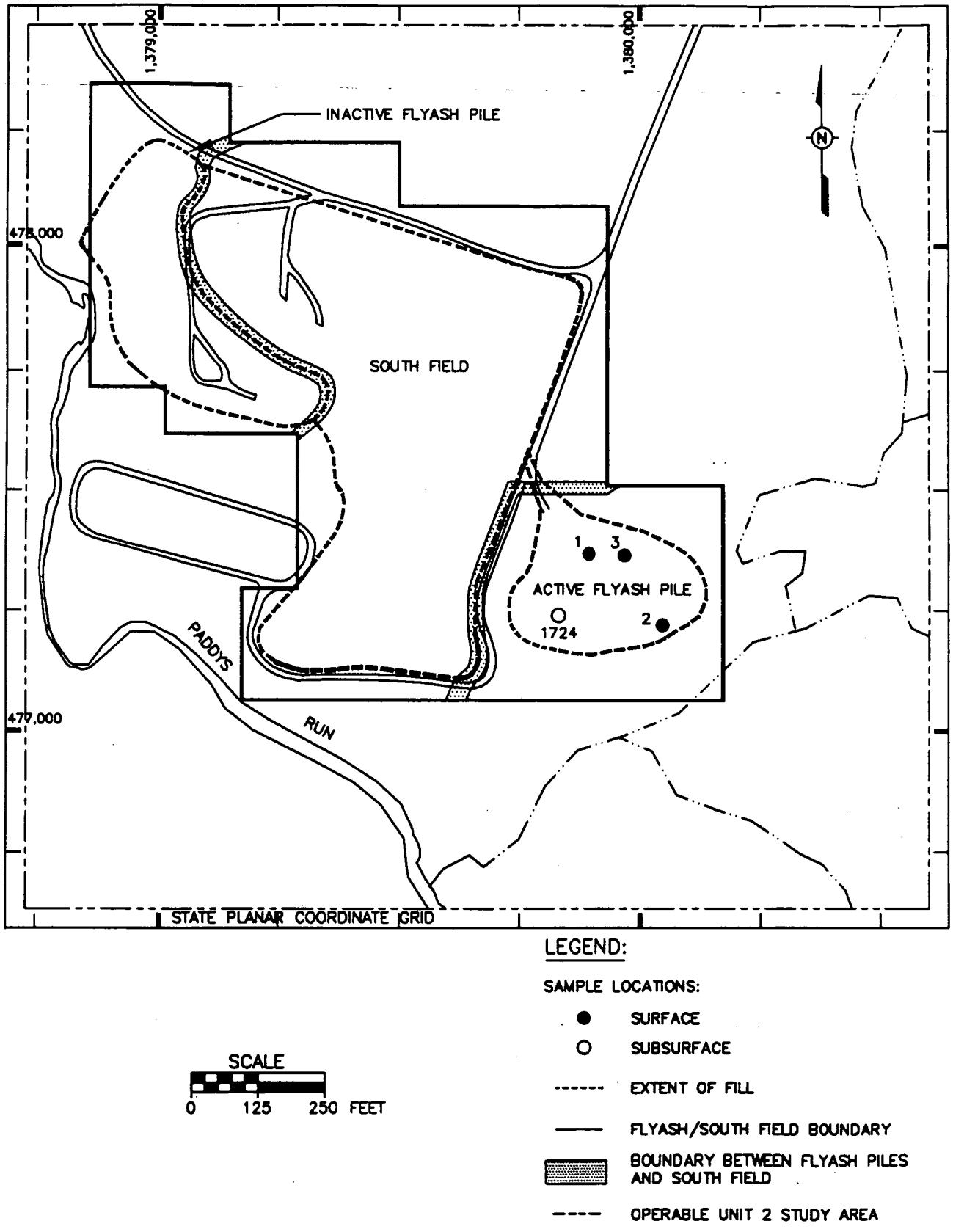

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FIGURE 2-14. GEOTECHNICAL SAMPLE AND MEASUREMENT LOCATIONS IN THE ACTIVE FLYASH PILE

ash and flyash from Illinois and Kentucky coal (the type burned at the FEMP) are approximately 1.5 mg/kg and 1.0 mg/kg, respectively.

Nonprocess wastes from the FEMP and building rubble such as concrete, gravel, asphalt, masonry, and steel rebar from on-site construction/demolition activities also were discarded in the Inactive Flyash Pile (Weston 1987b). PCB- and uranium-contaminated waste oils reportedly were used to control dust at the Inactive Flyash Pile (DOE 1988a, Weston 1987b). Attempts to document this practice, however, have been unsuccessful, and it is not possible to verify that the uranium present in the pile is a result of this practice.

2.5.2 Surface Media Sampling in the Inactive Flyash Pile

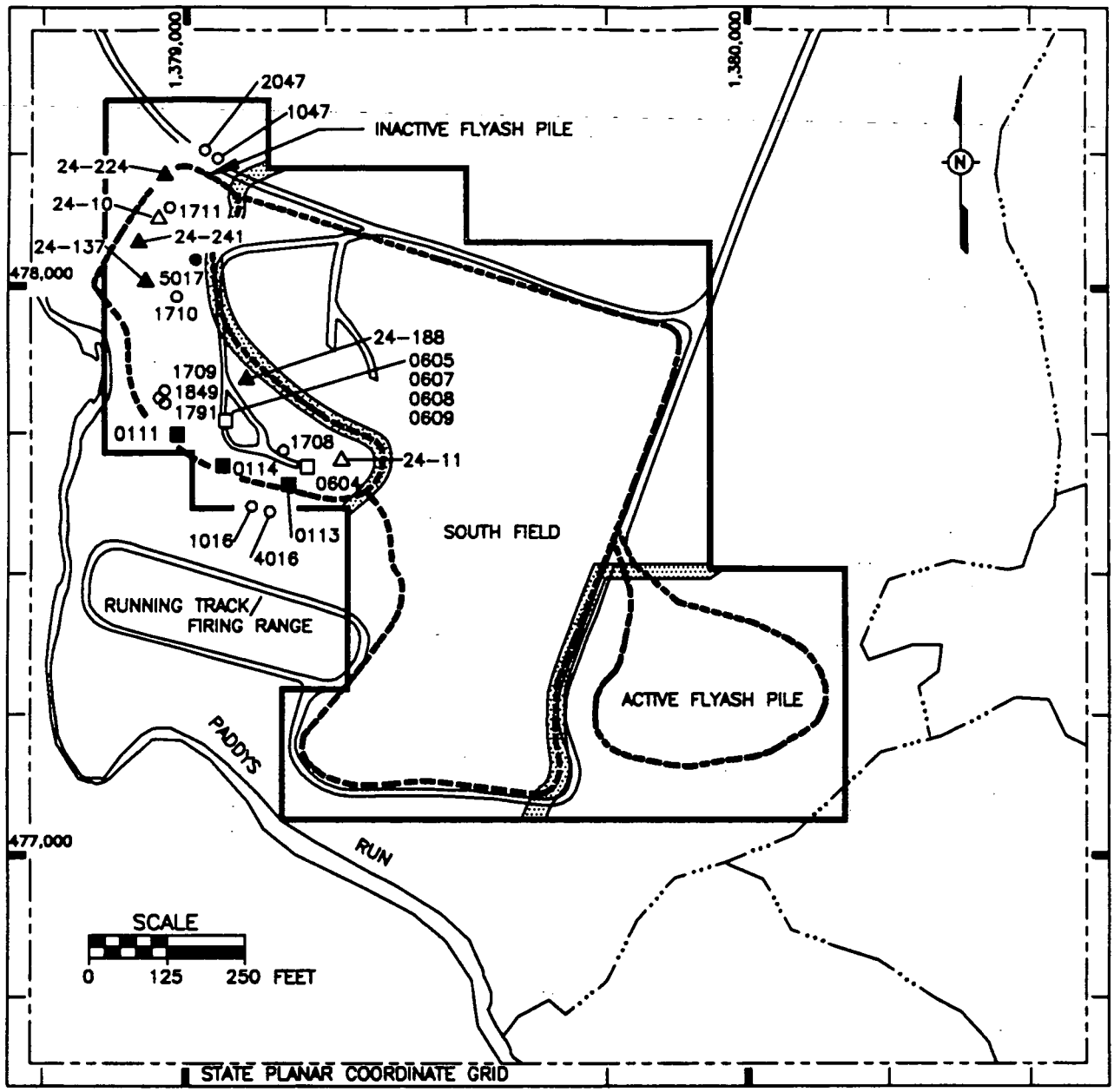
The objectives of surface media (including flyash) sampling at the Inactive Flyash Pile were to:

- Characterize the nature of contamination in surface media and flyash
- Provide data to evaluate the potential for migration from the Inactive Flyash Pile via the surface water pathway
- Provide data to evaluate the potential for exposure via the direct contact pathway
- Provide data to evaluate the potential for migration via the air pathway

During the Environmental Survey (DOE 1988a), a radiological survey in the Inactive Flyash Pile was conducted using an Eberline PG-2 and PRM-5-3. Based on elevated radiation levels measured at ground surface, two surface media samples were collected from the Inactive Flyash Pile (Figure 2-15). These samples were analyzed for radionuclides, VOCs, and TCLP RCRA metals.

During the CIS, a FIDLER was used to conduct a radiological survey to estimate uranium-238 activities in surface media. Based on these estimates, over 50 surface media samples were collected at depth intervals from 0- to 0.16 feet, 0.16- to 0.5-feet, 0.5- to 1- feet, and 1- to 1.5-feet (Weston 1987c). Samples also were taken along the steep berm on the Northwestern perimeter of the South Field adjacent to the Inactive Flyash Pile where gamma-ray measurements, taken with a scintillometer (SPA-3) indicated measurements statistically greater than background, i.e., greater than three standard deviations above background. The on-site gamma spectrometry laboratory was used to analyze all samples for cesium-137, radium-226, ruthenium-106, thorium-232, and uranium-238. Based on this initial screening, four samples were selected for more extensive analysis at an off-site laboratory (Figure 2-15).

During the RI/FS, one surface media sample for radionuclide analysis was collected from 0- to 0.16-feet (Figure 2-14).



LEGEND:

SURFACE MEDIA SAMPLING LOCATIONS:

- ■ ES (LOCATION APPROXIMATE)
- ▲ CIS
- ● RI/FS

SUBSURFACE SOIL SAMPLING LOCATIONS:

- □ ES MEDIA BORING (LOCATION APPROXIMATE)
- △ CIS MEDIA BORING
- ○ RI/FS MEDIA BORING

- EXTENT OF FILL
- FLYASH/SOUTH FIELD BOUNDARY
- BOUNDARY BETWEEN FLYASH PILES AND SOUTH FIELD
- OPERABLE UNIT 2 STUDY AREA

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FIGURE 2-15. SURFACE AND SUBSURFACE MEDIA SAMPLE LOCATIONS IN THE INACTIVE FLYASH PILE STUDY AREA

2.5.3 Subsurface Media Sampling in the Inactive Flyash Pile

The objectives of subsurface media sampling (including flyash and underlying native soil) in the Inactive Flyash Pile were to:

- Characterize the physical nature of buried waste materials in the Inactive Flyash Pile
- Determine the nature and extent of contamination
- Determine fill depths and volumes
- Determine whether contaminants have migrated from the fill into the underlying native soils
- Provide data to support the modeling of contaminant migration from the Inactive Flyash Pile

During the Environmental Survey (DOE 1988a), subsurface media samples from two hand-auger borings were collected (Figure 2-15). Samples 605, 607, 608, and 609 were collected from one of these borings located near the center of the Inactive Flyash Pile. These samples were collected at 5 foot intervals, with Sample 605 at 0- to 5-feet, Sample 607 at 5- to 10-feet, Sample 608 at 10- to 15-feet, and Sample 609 at 15- to 20-feet. Sample 604 was collected from the other boring located in the southeastern part of the Inactive Flyash Pile from the depth interval of 0- to 2-feet. The above samples were analyzed for radionuclides, VOCs, and TCLP metals.

Two borings were completed in the Inactive Flyash Pile for the CIS (Weston 1987b) (Figure 2-15), and split samples were collected at 1-foot intervals to depths of 25-feet (Borehole 24-10) and 34-feet (Borehole 24-11). Samples were analyzed at the on-site gamma spectrometry laboratory for radium-226, thorium-232, and uranium-238 to evaluate the vertical distribution of these radionuclides. A composite sample from each boring was analyzed for radionuclides, VOCs, SVOCs, pesticides/PCBs, and EP toxicity metals. The boring locations were selected based upon radiological surveys indicating elevated levels of radionuclides at the surface location. Geophysical survey data was reviewed to avoid areas with a high potential for buried metal objects. Otherwise an attempt was made to space the borings throughout the South Field and Inactive Flyash Pile.

During 1988, the RI/FS sampling team drilled four borings (1016, 4016, 1047, and 2047) near the northern and southern boundaries of the Inactive Flyash Pile (Figure 2-15) as part of the site-wide monitoring well installation program. These borings are located outside of the fill areas. Seven subsurface media (soil) samples were collected from these borings and were analyzed for radionuclides. During the installation of piezometer wells 1516, 1517, and 1518 (just south of the South Field), samples were collected at 1- to 2-foot intervals to a depth of 20 feet. These samples were analyzed for radionuclides.

In 1991, because previous sampling had not quantified the vertical distribution of contaminants sufficiently to meet the study objectives, the RI/FS sampling team drilled five borings to further characterize the nature of the fill and the underlying native soil. Samples were collected from the shallow fill, the deep fill, and the underlying native soils (Table 2-3). Table 2-3 describes the depth of

specific samples and the particular analyses for each sample. Note that the TCLP VOC/SVOC sample was collected from the portion of the boring that displayed the highest HNu reading during screening. Samples from borings for which there were no HNu readings were collected from the midpoint of the boring. A composite sample from each boring was analyzed for the remainder of the TCLP RCRA analytes. The purpose of the TCLP analysis was to determine whether the waste met criteria for regulation under RCRA and to determine leaching and transport potentials for waste transport modeling.

2.5.4 Surface Water and Sediment Sampling in the Inactive Flyash Pile

The objective of surface water and sediment sampling in the Inactive Flyash Pile was to determine whether contaminants from the waste area are migrating across its boundaries via the surface water pathway. The topography of the Inactive Flyash Pile is such that runoff flows west, toward Paddys Run, east into the drainage ditch separating the Inactive Flyash Pile from the South Field, or south onto the running track.

Sediments were sampled at two locations west of the Inactive Flyash Pile as part of the CIS (Weston 1987b) (Figure 2-16). The two samples were analyzed for cesium-137, radium-226, ruthenium-106, thorium-232, and uranium-238 at the on-site gamma spectroscopy laboratory. Neither was selected for more extensive off-site laboratory analysis.

The RI/FS sampling team sampled surface water and sediments at two location west of the Inactive Flyash Pile (Figure 2-16). Surface water and sediment samples were analyzed for radionuclides, VOCs, SVOCs, pesticides/PCBs, metals, and the general water quality parameters.

2.5.5 Groundwater Sampling in the Inactive Flyash Pile Study Area

The objectives of groundwater sampling in the Inactive Flyash Pile study area were to:

- Determine if contaminants from Inactive Flyash Pile appear to have migrated to groundwater
- Characterize any perched groundwater that could be encountered during remediation of the Inactive Flyash Pile

Two RI/FS monitoring wells are located at the northern boundary of the Inactive Flyash Pile and four wells are at the southern boundary (Figure 2-17). These wells are screened in perched water of the glacial overburden, the Upper Great Miami Aquifer, and the Lower Great Miami Aquifer (Table 2-7). They were sampled quarterly during 1988 and 1989 and were analyzed for radionuclides, VOCs, SVOCs, pesticides/PCBs, dioxins/furans, metals, and general water quality parameters.

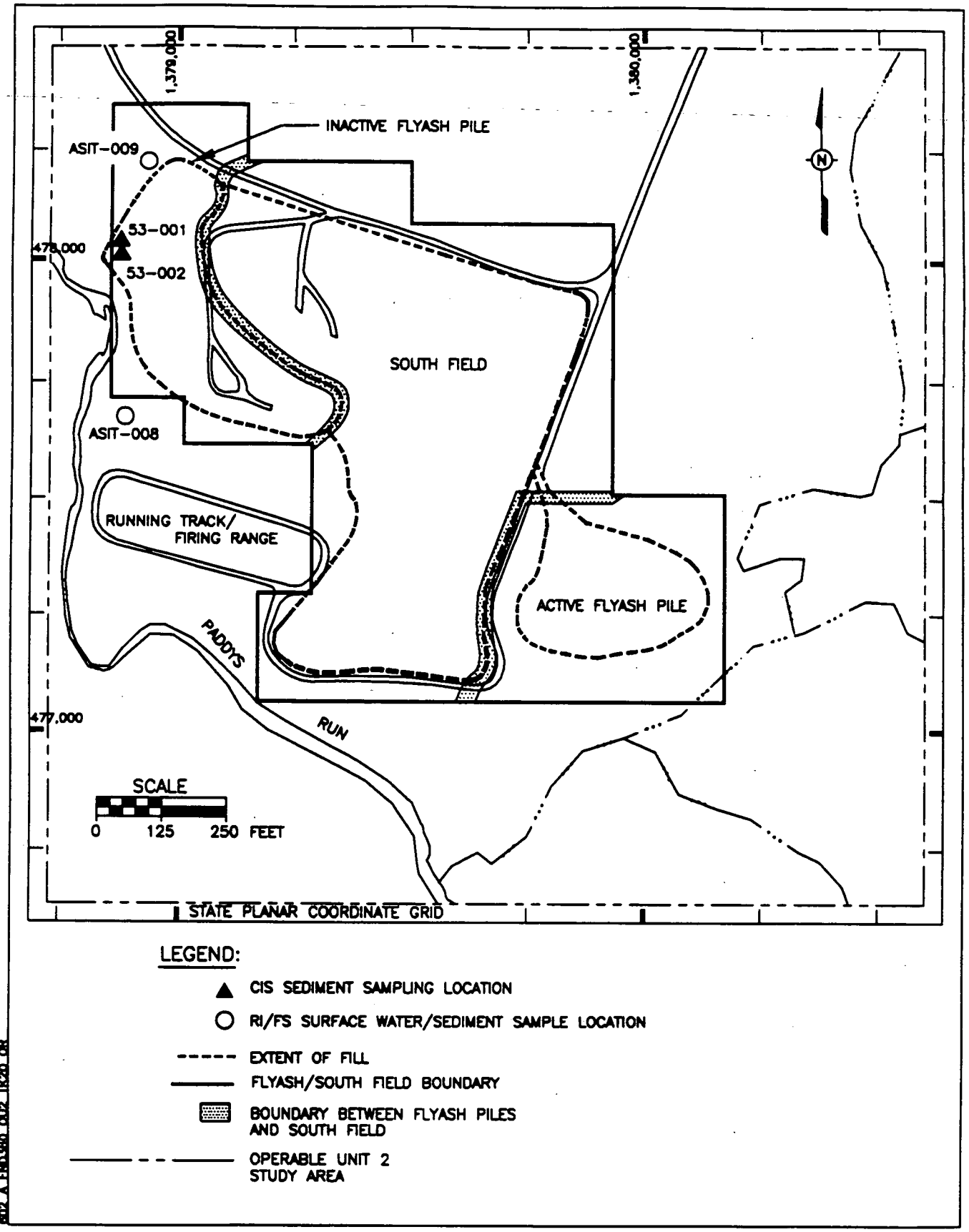

FIGURE 2-16. SURFACE WATER AND SEDIMENT SAMPLE LOCATIONS IN THE INACTIVE FLYASH PILE STUDY AREA

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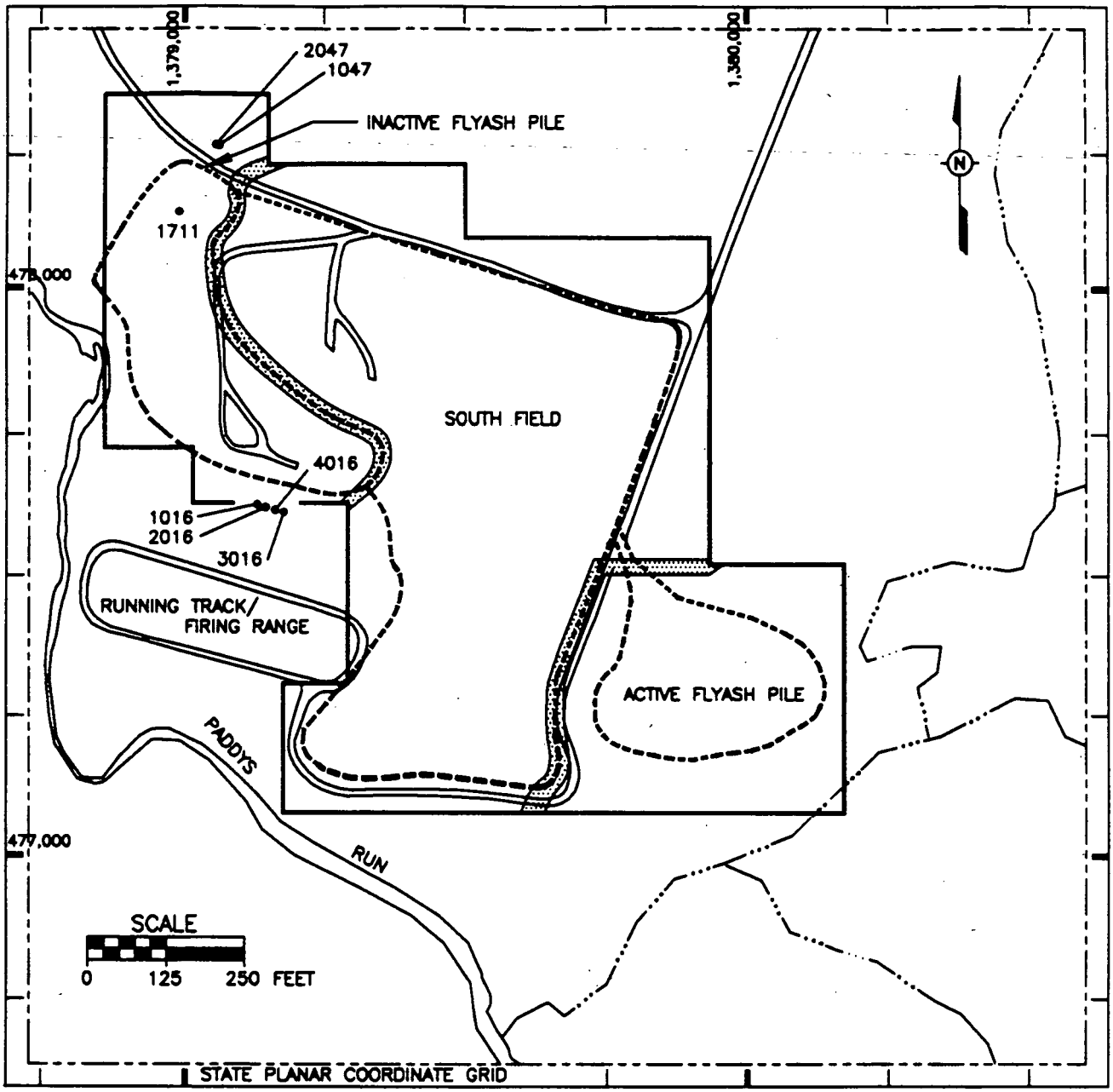

LEGEND:

- ● RI/FS GROUNDWATER WELL LOCATION
- ------ EXTENT OF FILL
- ——— FLYASH/SOUTHFIELD BOUNDARY
- ▒ BOUNDARY BETWEEN FLYASH PILES AND SOUTH FIELD
- —·—·— OPERABLE UNIT 2 STUDY AREA

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FIGURE 2-17. GROUNDWATER MONITORING WELLS IN THE INACTIVE FLYASH PILE STUDY AREA

TABLE 2-7

SCREENED INTERVALS OF MONITORING WELLS INACTIVE FLYASH PILE STUDY AREA

Well	Ground Elevation (feet MSL[a])	Screened Interval (feet MSL)	Depth to Mid-Screen (feet)	Screened Lithologic Member
1016	540.7[b]	529.95-519.95[c]	15	Top of Upper Great Miami Aquifer
1047	568.7	561.00-551.70	8	Glacial Overburden
1711	576.4	563.40–561.40	15	Glacial Overburden
2016	540.6[b]	510.70-506.50	30	Middle of Upper Great Miami Aquifer
2047	568.95[b]	522.73-507.73	55	Top of Upper Great Miami Aquifer
3016	540.6[b]	480.00-476.00	60	Bottom of Upper Great Miami Aquifer
4016	539.7	396.70-386.70	150	Lower Great Miami Aquifer

[a] MSL = above mean sea level
[b] Elevation of concrete pad
[c] Screened intervals approximated from Dames and Moore well schematics

Boring 1711, drilled in August 1991, was converted to a perched groundwater monitoring well. This well was sampled and analyzed for total uranium and metals. The analytical results were not available for consideration in this RI, but will be considered in the FS for characterizing leachate for the no-treatment alternatives.

2.5.6 Biota Sampling in the Inactive Flyash Pile Study Area

The objective for biota sampling in the Inactive Flyash Pile study area was to determine whether any radiological substance release into the adjacent terrestrial habitats resulted in significant uptake of radionuclides by terrestrial vegetation. In 1987, the RI/FS sampling team collected one set of surface soil and terrestrial vegetation samples (forb leaves and roots) at biota Sampling Location 22 in the center of the Inactive Flyash Pile (Figure 2-13). All biota samples were analyzed for uranium, strontium-90, and cesium-137.

2.5.7 Geotechnical Sampling in the Inactive Flyash Pile

In October 1991, the in-place density was measured at two locations by ASTM Method D-2922 (Figure 2-18). Wet density, dry density, and moisture content were measured at each location. Shelby tube samples for geotechnical analysis were collected from Boring 1708. These samples were collected from the 7.5- to 12-foot depth interval and were analyzed for moisture content, specific gravity, and particle size distribution.

2.6 SOUTH FIELD

The South Field lies approximately 2000 feet to the south of the former production area between the Active and Inactive Flyash piles. It is currently covered with soil and vegetation (Figure 1-7).

2.6.1 Waste Description

The South Field contains mostly fill material and was reportedly used as a burial site for construction and demolition rubble that may have contained low levels of radioactivity, including debris from the razing of the old administration building (Weston 1987b). Flyash was deposited on the northwest quadrant of the South Field, where it abuts the Inactive Flyash Pile. Other wastes also may have been deposited here, but records to support this are not available. Historical aerial photography (EPA 1988b) shows evidence of fill activity in the southeast section of the South Field as early as 1954. Flyash and the PCB- and uranium- contaminated oils (that reportedly were sprayed on flyash to control dust) may be present within the portions of the South Field that border the Active and Inactive Flyash Piles.

DOE (1988b) reported that contaminated soil from the South Field may have been removed and disposed of elsewhere within the FEMP during fill activities.

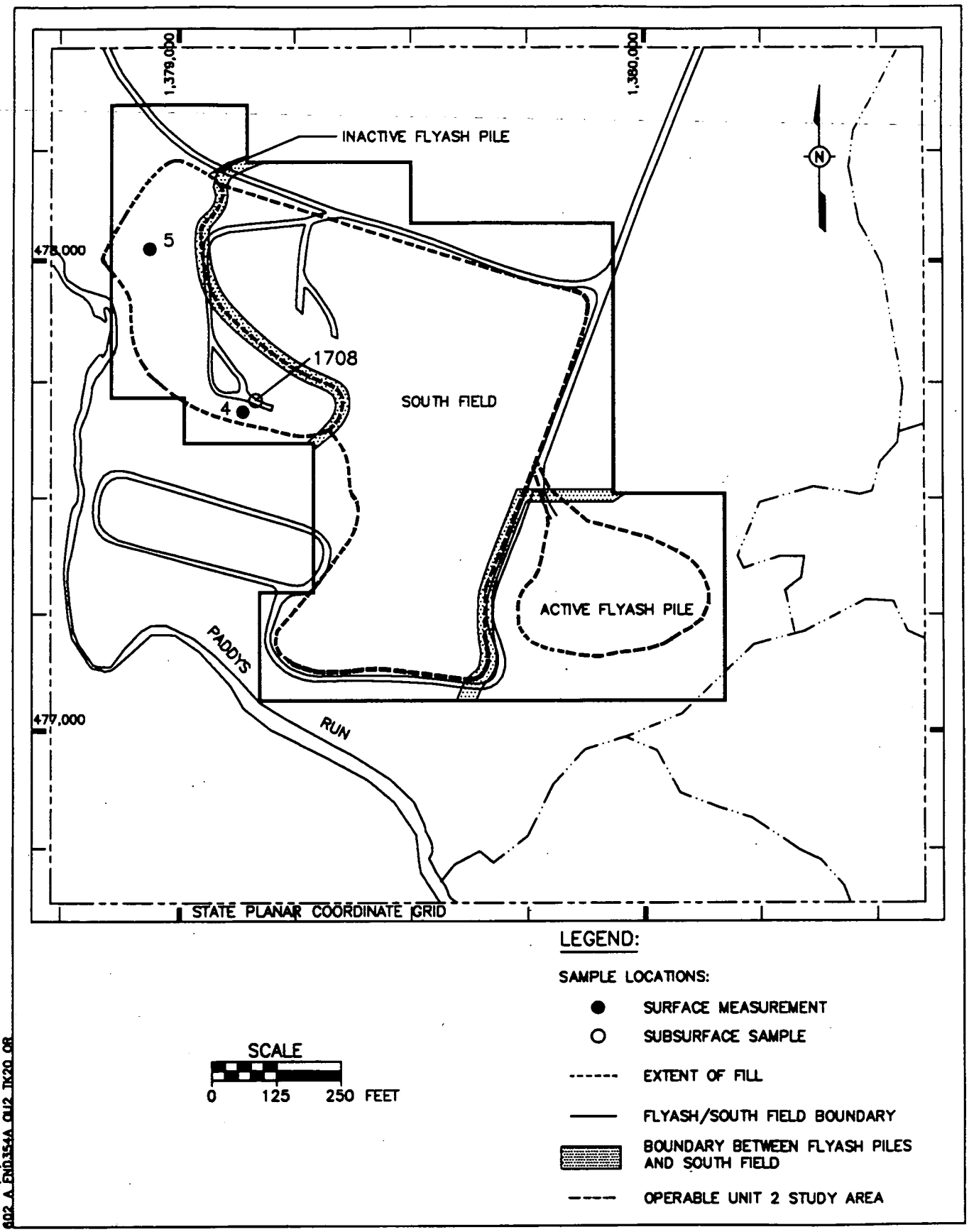

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FIGURE 2-18. GEOTECHNICAL SAMPLE AND MEASUREMENT LOCATIONS IN THE INACTIVE FLYASH PILE

The embankment along the southwest side of the South Field was used as the backdrop for the FEMP Firing Range (Figure 1-7) between 1955 and 1989. WEMCO estimates that 25,000 pounds of spent lead ammunition may have been entrapped within this soil embankment, based on the results of the firing range removal site evaluation (DOE 1992c). The amount of fill in the embankment has not been constant during the 1955 to 1989 period, but has been enlarged by the addition of soil and rubble to this part of the South Field. It is possible, therefore, that lead fragments extend further into the embankment than the penetration depth of fired ammunition.

2.6.2 Surface Media Sampling in the South Field

The objectives of surface media (soil) sampling at the South Field were to:

- Characterize the nature of contamination in the surface media
- Provide data to evaluate the potential for migration from the South Field via the surface water pathway
- Provide data to evaluate the potential for exposure via the direct contact pathway
- Provide data to evaluate the potential for migration via the air pathway

During the Environmental Survey (DOE 1988a), a radiological survey in the South Field was conducted using an Eberline PG-2 and PRM-5-3. Based on elevated radiation levels measured at ground surface, five surface media samples were collected in the South Field (Figure 2-19). These were analyzed for radionuclides, VOCs, TCLP RCRA metals and asbestos.

During the CIS, a FIDLER was used to conduct a radiological survey to estimate uranium-238 activities in surface media (Weston 1987c). Based on these estimates, several hundred surface media samples were collected at depth intervals from 0 to 0.16 feet, 0.16 to 0.5 feet, 0.5 to 1 feet, and 1 to 1.5 feet. Additionally, samples were taken along the steep berm on the northwestern perimeter of the South Field adjacent to the Inactive Flyash Pile where gamma-ray measurements, taken with a scintillometer (SPA-3), were statistically greater than background, i.e., greater than three standard deviations above background. The on-site gamma spectrometry laboratory was used to analyze all samples for cesium--137, radium-226, ruthenium-106, thorium-232, and uranium-238. Based on this initial screening, 27 samples were selected for more extensive analysis at an off-site laboratory (Figure 2-19).

2.6.3 Subsurface Media Sampling in the South Field

The objectives of subsurface media (soil) sampling in the South Field were to:

- Characterize the physical nature of buried waste materials in the South Field
- Characterize the nature and extent of contamination
- Determine fill depths and volumes

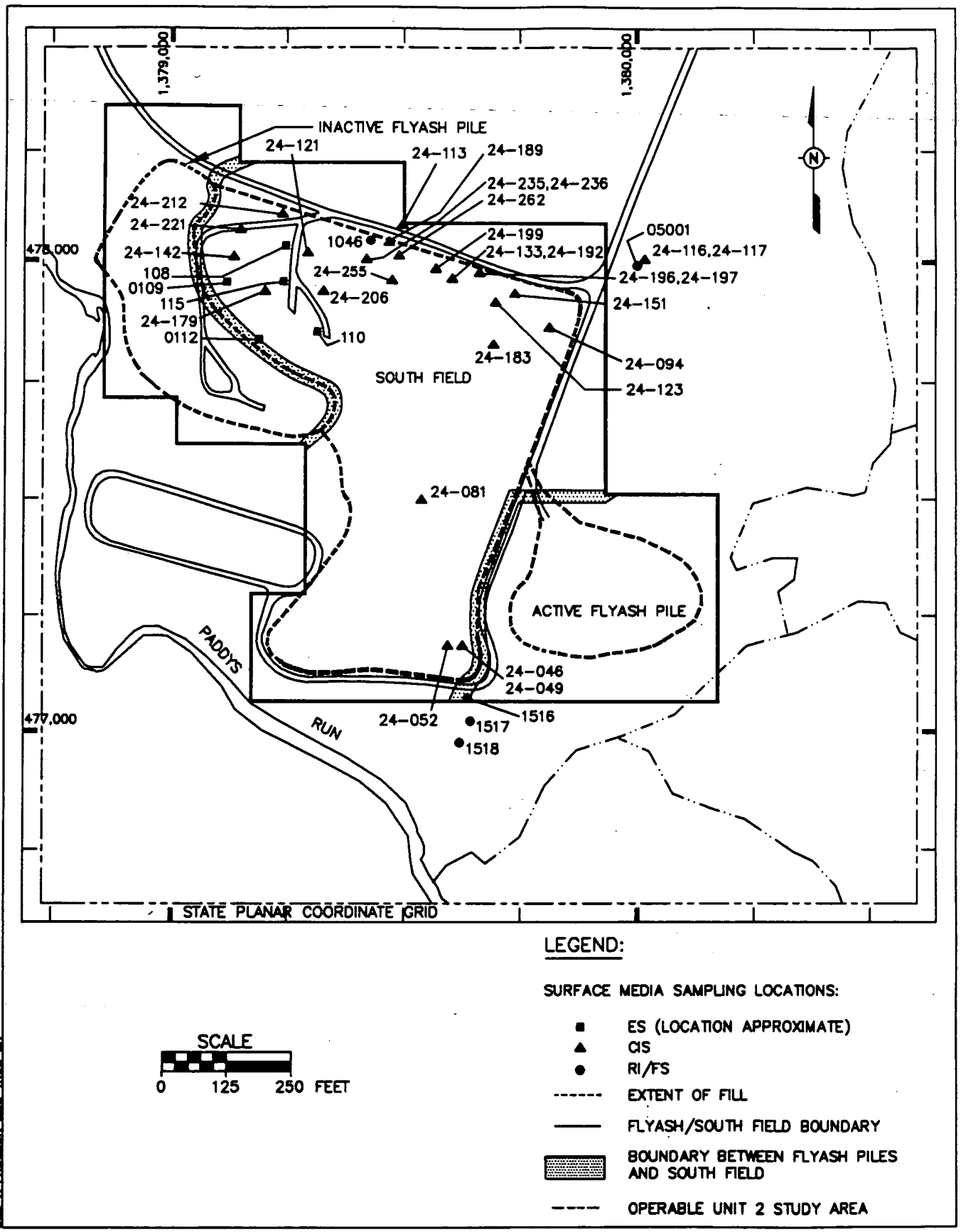

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FIGURE 2-19. SURFACE MEDIA SAMPLE LOCATIONS IN THE SOUTH FIELD

- Determine whether contaminants have migrated from the fill into the underlying native soils
- Provide data to support the modeling of contaminant migration from the South Field

During the Environmental Survey (DOE 1988a), nine grab samples were collected from four trenches (test pits) excavated in the South Field (Figure 2-20). The trench locations were selected based on prior radiological surveys. These trenches were oriented north-south and varied in depth from 2 to 10 feet. All samples were analyzed for radionuclides and TCLP RCRA metals. Only one sample was analyzed for VOCs.

Ten borings were completed in the South Field for the CIS (Weston 1987b) (Figure 2-20), and split-spoon samples were collected at 1-foot intervals to depths ranging from 4 feet (Borehole 24-04) to 20 feet (Borehole 24-12). Samples were analyzed at the on-site gamma spectrometry laboratory for radium-226, thorium-232, and uranium-238 to evaluate the vertical distribution of these radionuclides. A composite sample from each boring was analyzed for radionuclides, VOCs, SVOCs, pesticides/ PCBs, metals, and EP toxicity metals. The boring locations were selected based on radiological surveys indicating elevated levels of radionuclides at the surface location. Geophysical survey data was reviewed to avoid areas with a high potential for buried metal objects. Otherwise, an attempt was made to space the borings throughout the waste area South Field and Inactive Flyash Pile.

During 1988, the RI/FS sampling team drilled five borings (1046, 2046, 3046, 2385 and 3385) near the northern boundary of the South Field as part of the monitoring well installation program (Figure 2-20). These borings are located outside of the fill areas. A total of nine subsurface media (soil) samples were collected from these borings and analyzed for radionuclides. Subsurface media samples also were collected from Borings 1516, 1517, and 1518, which were drilled for wells, south of the South Field.

In 1989, the RI/FS sampling team excavated six trenches from the surface through the fill and into the underlying native soil (Figure 2-20). The trenches, with an approximate north-south orientation, were 50 feet long and their depths ranged from 3.75 to 5.75 feet. Samples from these trenches were collected from the bottom of the fill as well as from the native soil immediately below the fill. These samples were analyzed for radionuclides in order to characterize the nature of radionuclide contamination in both the fill and the underlying native soil. This procedure was repeated at the north, south, and middle locations of each trench. Fill samples were screened in the field for VOCs using a portable photoionizer HNu. Samples were analyzed for VOCs, SVOCs, pesticides/PCBs, and metals.

In 1991, the RI/FS sampling team completed eight borings in the South Field (Figure 2-20). For Borings 1712 through 1715, samples from the 1.5- to 2-foot-depth interval were analyzed for TCLP metals/organics and the RCRA characteristics of ignitability, corrosivity, and reactivity as described in Table 2-3. Samples from Borings 1792 and 1793 were sampled at 5-foot intervals until native soil

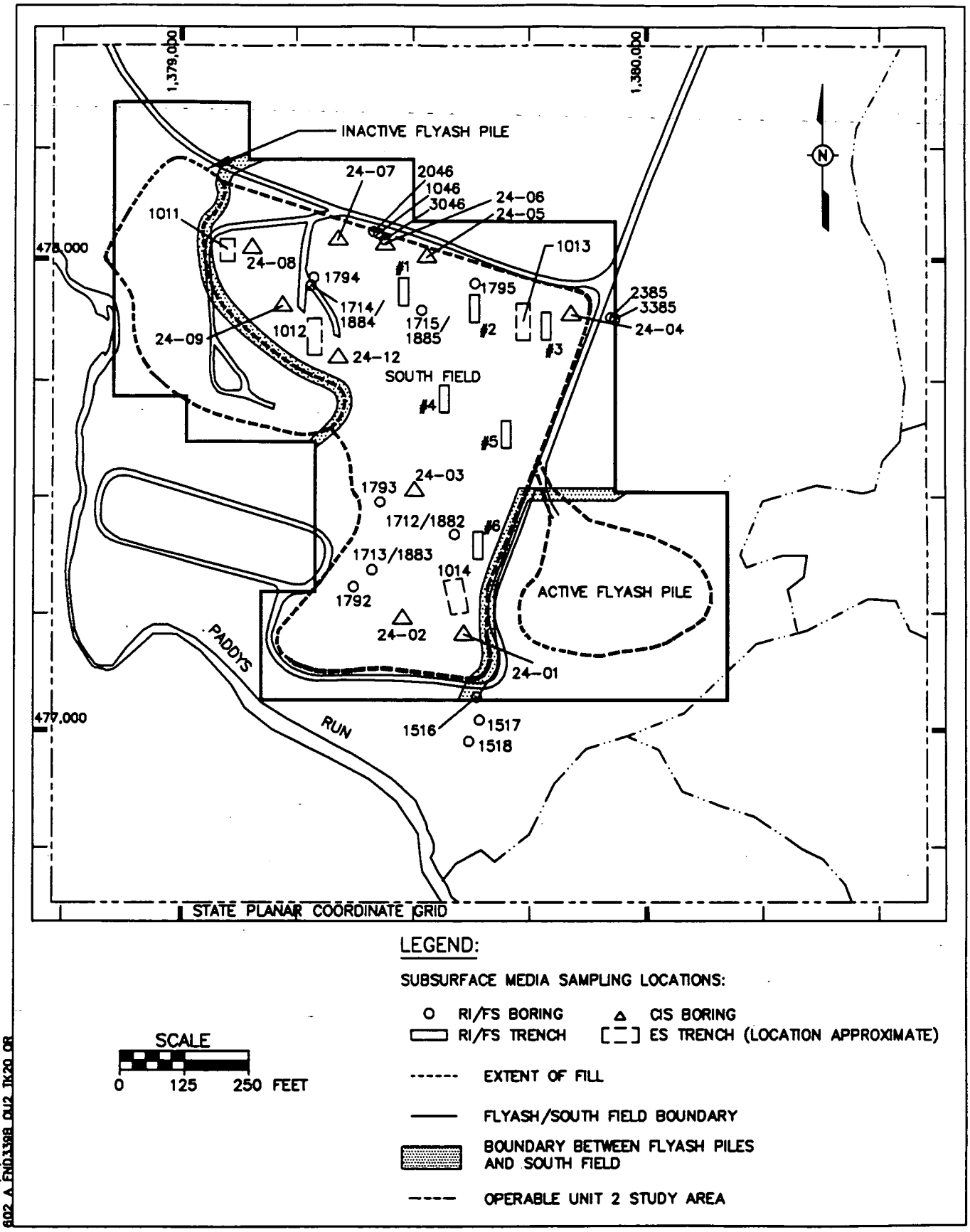

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FIGURE 2-20. SUBSURFACE MEDIA SAMPLE LOCATIONS IN THE SOUTH FIELD

was encountered. Samples were analyzed for VOCs, SVOCs, pesticides/PCBs, dioxins/furans and metals as outlined in Table 2-3. At the base of each of these two borings, above the native soil, a sample was collected for TCLP metals/organics analysis. At Borings 1794 and 1795, a subsurface media sample was collected from the 1- to 2-foot-depth interval and another from the 4- to 5-foot-depth interval (or from the base of fill if the fill was less than 5 feet thick). These samples were analyzed for VOCs, SVOCs, pesticides/PCBs, dioxins/furans, and metals as outlined in Table 2-3. One sample was collected from each of these two borings for TCLP metals/organics analysis.

In January and February 1992, six vertical borings (SP-1 through SP-6) (Figure 2-21) were completed in the FEMP Firing Range, each to a depth of 5 feet, as part of the removal site evaluation conducted by WEMCO. Samples were collected from consecutive 1-foot intervals, with an additional sample collected from the 0.0- to 0.5-foot interval. In the approximate center of the firing zone, a 50-foot horizontal boring (SP-7) (Figure 2-21) was drilled into the embankment; successive 5-foot intervals were sampled. In addition, two surface soil samples (SP-8 and SP-9) (Figure 2-21) were taken from the flat area between the firing line and the embankment. Each sample was sieved using a No. 10 sieve to capture spent lead ammunition fragments greater than 2 mm in diameter. Material that passed through the sieve was analyzed for TCLP lead. Because of the 20:1 dilution factor built into the TCLP test, soil samples that contain less than 100 mg/kg of lead cannot produce TCLP leachate with lead concentrations greater than 5.0 mg/ℓ, which is the RCRA hazardous waste characteristic threshold (DOE 1992c).

2.6.4 Sediment and Surface Water Sampling in the South Field Study Area

No sediment or surface water samples were taken in the South Field for the Environmental Survey, the CIS, or the RI/FS.

2.6.5 Groundwater Sampling in the South Field Study Area

The objectives of groundwater sampling in the South Field study area were to:

- Determine if contaminants from the South Field have migrated to groundwater
- Characterize perched groundwater that may be encountered during remediation of the South Field

Twenty-one RI/FS wells comprise the network that monitors the South Field (Figure 2-22). Three wells are located just within the northern boundary of the South Field, seven are just outside its eastern boundary, four are beyond the eastern boundary, and seven are outside the southern boundary. These wells are screened in the perched water of the glacial overburden, the Upper Great Miami Aquifer, and the Lower Great Miami Aquifer (Table 2-8). Groundwater was sampled quarterly during 1988 and 1989 for radionuclides, VOCs, SVOCs, metals, and general water quality parameters as outlined in Table 2-4.

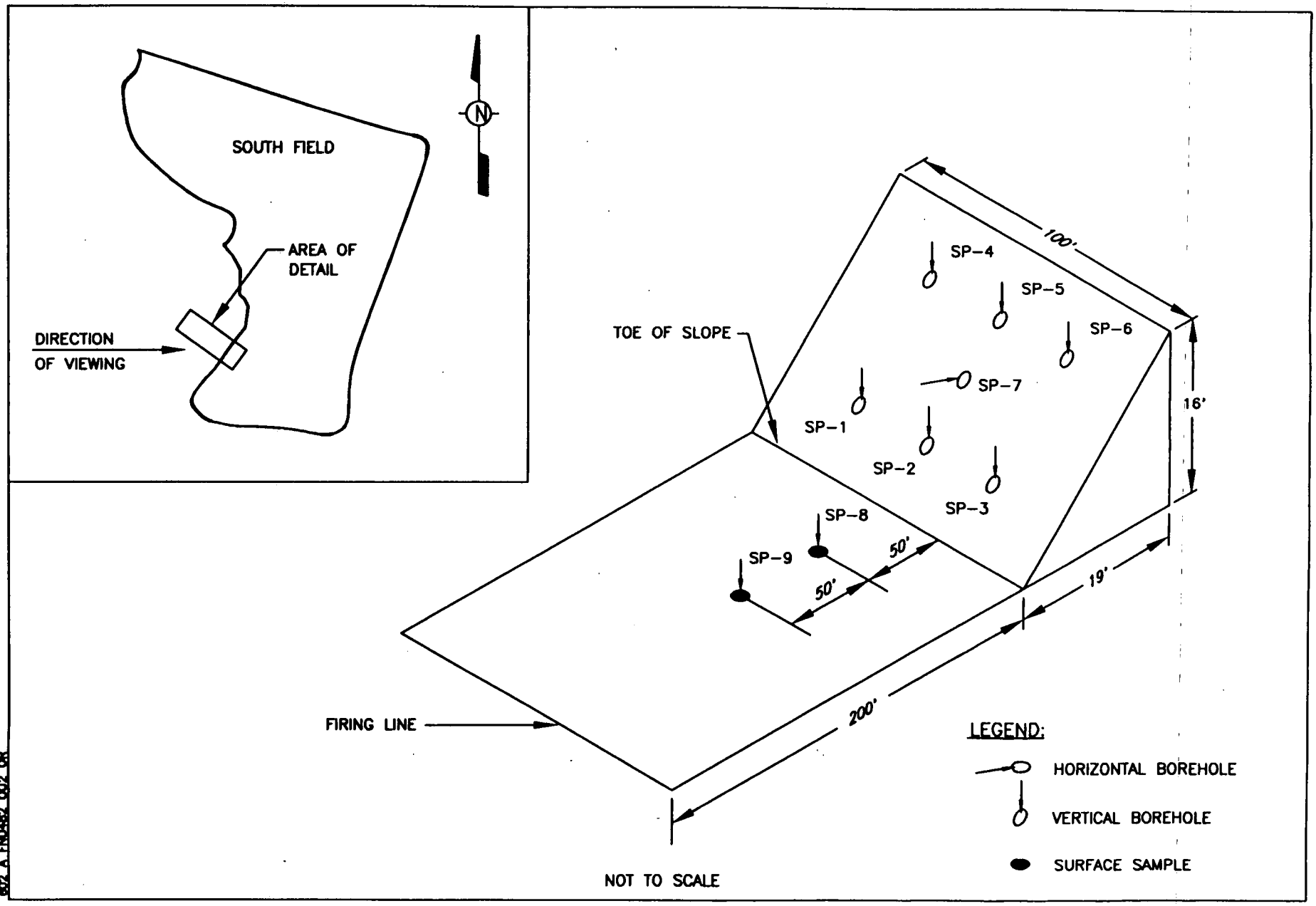

FIGURE 2-21. SUBSURFACE SAMPLING LOCATIONS FOR FIRING RANGE REMOVAL SITE EVALUATION

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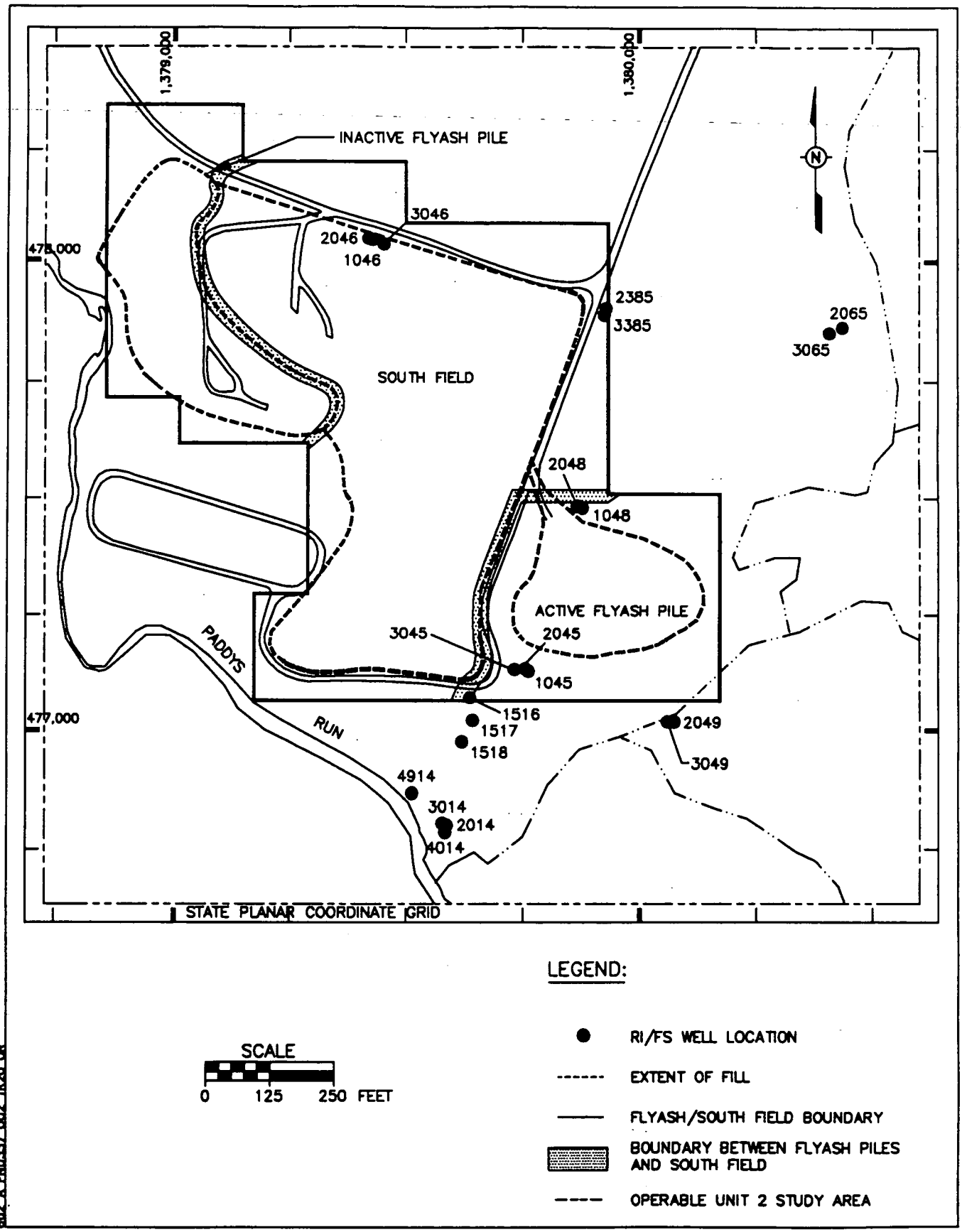

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FIGURE 2-22. GROUNDWATER MONITORING WELLS IN THE SOUTH FIELD/ ACTIVE FLYASH PILE

TABLE 2-8

SCREENED INTERVALS OF MONITORING WELLS ACTIVE FLYASH PILE/SOUTH FIELD STUDY AREA

Well	Ground Elevation (feet MSL[a])	Screened Interval (feet MSL)	Depth to Mid-Screen (feet)	Screened Lithologic Member
1045	546.2[b]	543.09-537.69	5	Glacial Overburden
1046	576.5	567.13-557.13	15	Glacial Overburden
1048	571.8[b]	565.67-555.67	10	Glacial Overburden
1516	539.3[b]	529.81-519.81	15	Glacial Overburden, Sand Lens
1517	538.6[b]	528.56-518.56	15	Glacial Overburden, Sand Lens
1518	537.3[b]	527.26-517.26	20	Glacial Overburden, Sand Lens
2014	533.9[b]	521.00-515.00[c]	15	Top of Upper Great Miami Aquifer
2045	545.4	522.40-507.40	30	Top of Upper Great Miami Aquifer
2046	575.9	522.50-507.50	60	Top of Upper Great Miami Aquifer
2048	571.5	521.56-511.56	55	Top of Upper Great Miami Aquifer
2049	541.2[b]	522.71-507.71	25	Top of Upper Great Miami Aquifer
2065	571.5	525.00-510.00	55	Top of Upper Great Miami Aquifer
2385	577.6	524.60-509.60	60	Top of Upper Great Miami Aquifer
3014	533.9[b]	491.00-486.00[c]	45	Bottom of Upper Great Miami Aquifer
3045	547.9[d]	464.86-454.86	90	Bottom of Upper Great Miami Aquifer
3046	578.6[d]	463.60-453.60	120	Bottom of Upper Great Miami Aquifer
3049	540.7	462.70-452.70	85	Bottom of Upper Great Miami Aquifer
3065	571.7	461.70-451.70	115	Bottom of Upper Great Miami Aquifer
3385	577.4	462.40-452.40	120	Bottom of Upper Great Miami Aquifer
4014	533.4	403.90-393.90	135	Lower Great Miami Aquifer
4914	535.95[d]	403.90-393.90	135	Lower Great Miami Aquifer

[a] MSL = above mean sea level
[b] Elevation of concrete pad
[c] Screened intervals approximated from Dames and Moore well schematics
[d] Elevation of top well

2.6.6 Biota Sampling in the South Field Study Area

The objective of biota sampling in the South Field study area was to determine if any radiological substance release into the adjacent terrestrial habitats resulted in significant uptake of radionuclides by terrestrial vegetation. In 1987, one set of surface soil and terrestrial vegetation samples (grasses) was collected in the South Field at biota Sampling Location 23, just outside the northeast corner boundary of the South Field (Figure 2-13). All biota samples were analyzed for uranium, strontium-90, and cesium-137.

2.6.7 Geotechnical Sampling in the South Field Study Area

In October 1991, the RI/FS sampling team measured in-place density at three locations by ASTM Method D-2922 (Figure 2-23). Wet density, dry density, and moisture content were measured at each sampling location.

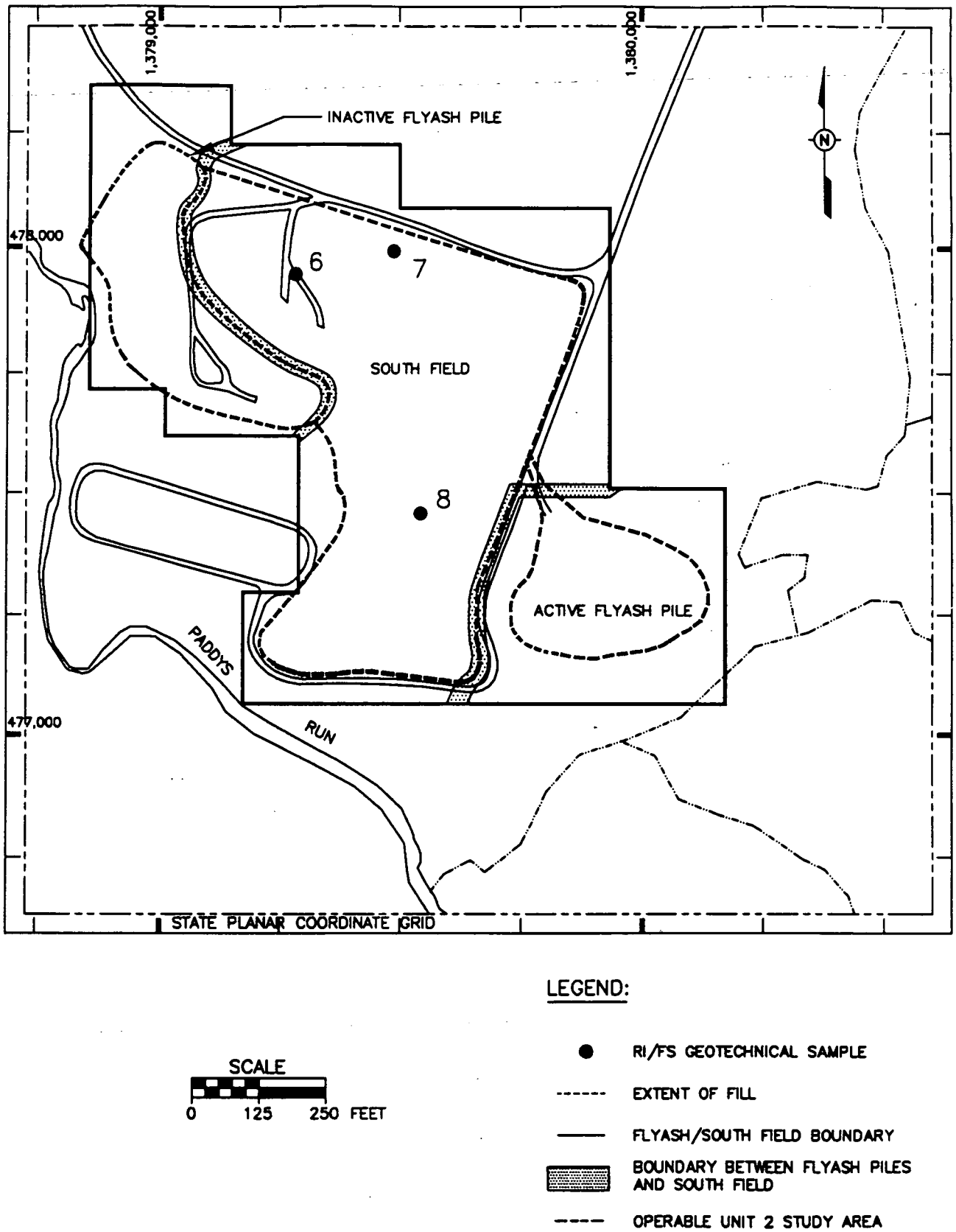

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FIGURE 2-23. GEOTECHNICAL SAMPLE AND MEASUREMENT LOCATIONS IN THE SOUTH FIELD

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3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

This section presents a description of the characteristics of the FEMP and its surrounding environment that may be affected by proposed remedial activities at the FEMP. Consistent with DOE's policy of integrating the requirements of NEPA with those of CERCLA, as set forth in DOE Order 5400.4, this section contains sufficient scope and depth to comply with NEPA requirements. Section 3.1 of this report describes the physical characteristics of the FEMP as a whole. Sections 3.2 through 3.6 describe the physical characteristics of each Operable Unit 2 waste area.

The site-wide data required for analysis of potential impacts of site-wide remedial activities is contained in the SWCR (DOE 1992b), which also includes detailed technical appendices reporting site-specific studies of wetlands, threatened and endangered species, and population estimates. The SWCR is incorporated herein by reference.

The DOE has announced its plan to integrate the procedural and documentation requirements of NEPA within the CERCLA documents being prepared for each operable unit at the FEMP. As stated in the "Notice of Intent to Prepare a Remedial Investigation/Feasibility Study Environmental Impact Statement (RI/FS-EIS) for the First of Five Remedial Actions at the FEMP (55 Federal Register 94, 20183-20188)," the first operable unit RI and FS-EIS will contain a complete discussion of common issues and potential cumulative impacts, referencing the SWCR as a site-wide database. The RI and SWCR will provide the baseline data. The FS-EIS will provide analysis of proposed remedial actions for all operable units. All subsequent operable unit RI reports will reference the material presented in this report and the SWCR. These subsequent RI reports will update available information, as appropriate, and contain adequate operable-unit-specific data to support the complete NEPA impact analyses to be contained in each operable unit FS. The NEPA analysis of the no action alternative for the entire site is included in the SWCR.

In summary, it is the intent of DOE to draft the RI/FS-EIS to support remedial action at the FEMP. The RI/FS-EIS will be integrated within the CERCLA-driven RI and FS reports prepared for each operable unit. The RI reports and SWCR will contain sufficient detail to facilitate environmental impact analysis of proposed remedial action alternatives to be discussed in the FS. Any additional data necessary for specific impact analyses will be included in the FS or compiled in an FS appendix.

3.1 SITE-WIDE CHARACTERISTICS

This section describes the regional and site-specific environment of the FEMP. A brief description of the physical, environmental, and demographic settings of the study area is provided in this section. Topics discussed include air quality, climate, topography, seismology, surface water hydrology,

geology, groundwater hydrology, soils, land use, population, vegetation, and wildlife. More detailed information on these subjects is available in the SWCR (DOE 1992b).

3.1.1 Meteorology

Information on the local climate was gathered from two primary sources—an on-property meteorological system installed at the FEMP in 1986 and the National Weather Service Office at the Cincinnati Northern Kentucky International Airport. Windflow data from the James A. Cox International Airport at Dayton, Ohio, were used as a secondary source.

3.1.1.1 Prevailing Winds

The FEMP meteorological system, installed to collect site-specific data for wind speed and direction, ambient air temperature, lapse rate, dew point, temperature, relative humidity, barometric pressure, and precipitation, was used by the National Oceanic and Atmospheric Administration to examine the complexity of the local wind field at the FEMP. The study showed that two major features, the Great Miami River Valley and the ridges surrounding the site, affect the wind patterns. A study by IT Corp. (1986) showed, however, that wind flow data from the Cincinnati Airport was sufficiently representative of local conditions to serve as a database for the years prior to the installation of the on-property meteorological system.

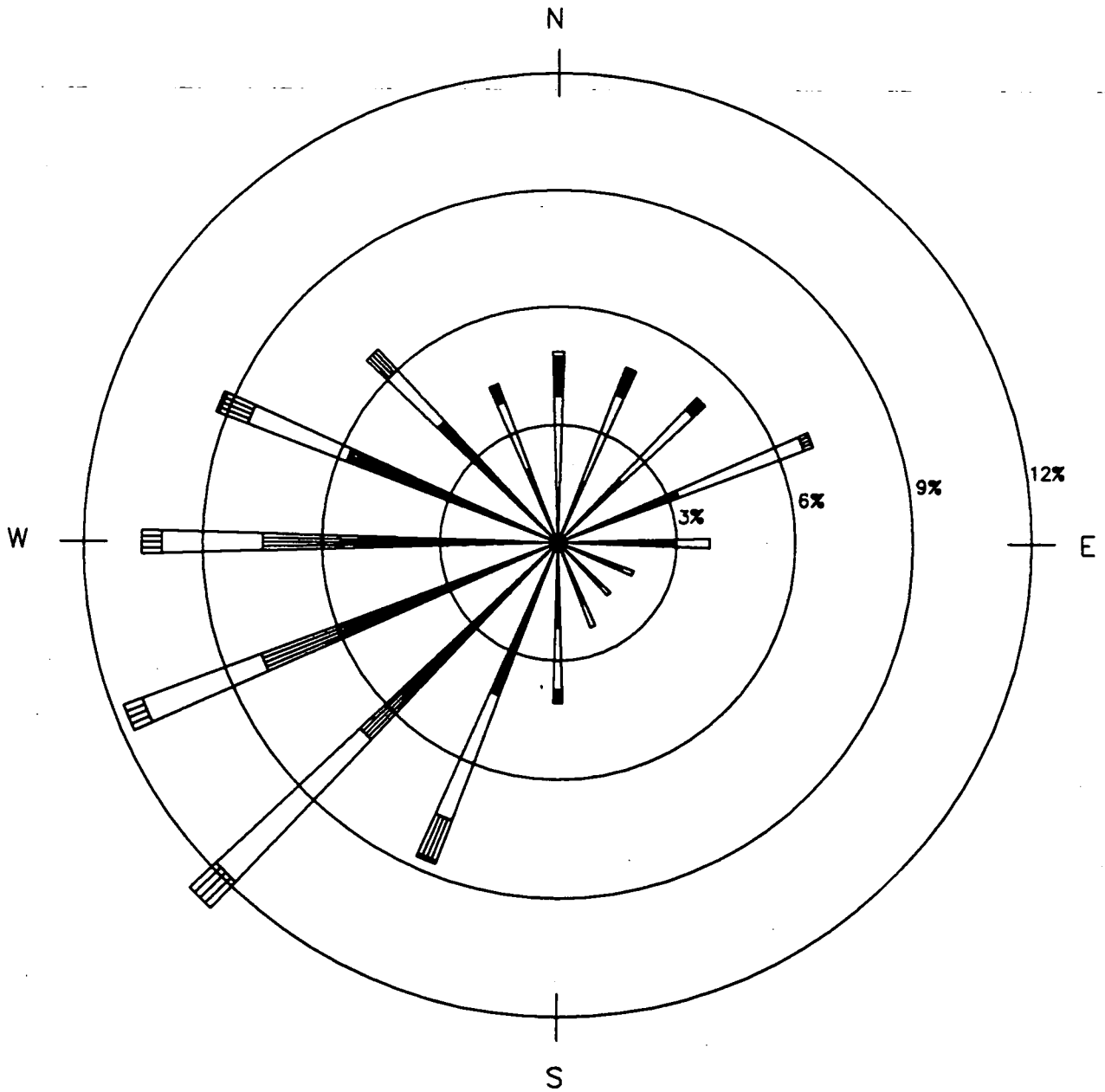
Figure 3-1 shows the typical wind pattern at the site recorded from a 10-meter tower. Prevailing winds are from the southwest and west-southwest. A frequency distribution summary of the wind speed and direction is presented in Table 3-1. This table presents the numerical data from which the FEMP wind rose was generated. The average monthly wind speeds, based on National Weather Service meteorological data, range from 3.1 meters/second (7 miles/hour) in August 1989 to 4.9 meters/second (11 miles/hour) in March 1989.

3.1.1.2 Precipitation

Average annual precipitation for the Cincinnati area for the period 1960 through 1989 was 40.56 inches and ranged from 27.99 inches in 1963 to 52.76 inches in 1979. The highest precipitation occurs during the spring and early summer; precipitation is typically lowest in late summer and fall.

The average annual snowfall for the 1960 to 1989 period was 23.5 inches, with the heaviest snowfall in January.

The total rainfall for this area in 1989 was 40.61 inches. Of this, more than 50 percent fell in April 1989 through September 1989, the growing season for most crops. The wettest months were March 1989 and July 1989, with 6.4 and 5.97 inches of rainfall, respectively. By contrast, the least precipitation was recorded in December 1989, when 1.96 inches of rain fell.



WIND SPEED CLASS BOUNDARIES
(METERS/SECOND)

-1989-
10-METER LEVEL
94.6 PERCENT DATA RECOVERY

NOTES:

DIAGRAM OF THE FREQUENCY OF OCCURRENCE FOR EACH WIND DIRECTION. WIND DIRECTION IS THE DIRECTION FROM WHICH THE WIND IS BLOWING. EXAMPLE – WIND IS BLOWING FROM THE NORTH 4.8 PERCENT OF THE TIME.

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FIGURE 3–1. WIND ROSE FOR 10–METER LEVEL

TABLE 3-1

FREQUENCY DISTRIBUTION OF WIND SPEED AND DIRECTION AT THE FEMP, 1989

Direction[a] (Degrees)	Wind-Speed Classes (meters/second) Class 1 (0-1.8)	Class 2 (1.8-3.3)	Class 3 (3.3-5.4)	Class 4 (5.4-8.5)	Class 5 (8.5-11.0)	Class 6 (>11)	Total
0.0	.01303	.02437	.00941	.00121	.00000	.00000	.04802
22.5	.01653	.02425	.00640	.00048	.00000	.00000	.04766
45.0	.02039	.02582	.00422	.00000	.00000	.00000	.05043
67.5	.03342	.03499	.00302	.00000	.00000	.00000	.07143
90.0	.02980	.00808	.00024	.00000	.00000	.00000	.03813
112.5	.01858	.00241	.00000	.00000	.00000	.00000	.02100
135.0	.01544	.00362	.00000	.00000	.00000	.00000	.01906
157.5	.01689	.00567	.00036	.00000	.00000	.00000	.02293
180.0	.02160	.01508	.00253	.00024	.00000	.00000	.03946
202.5	.04151	.03475	.01014	.00060	.00000	.00000	.08699
225.0	.07022	.04790	.00857	.00036	.00000	.00000	.12705
247.5	.08144	.02920	.00591	.00012	.00000	.00000	.11667
270.0	.07517	.02691	.00615	.00024	.00000	.00000	.10847
292.5	.05840	.02630	.00821	.00121	.00000	.00000	.09411
315.0	.04102	.01931	.00591	.00036	.00000	.00000	.06660
337.5	.02172	.01569	.00434	.00022	.00000	.00000	.04197
Total	.57518	.34436	.07542	.00504	.00000	.00000	1.00000

[a] Direction is the direction from which the wind is blowing. Zero degrees is due north, 90° is due east, etc.

SOURCE: FEMP On Site Meteorological Records, 1989.

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3.1.1.3 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 1960 through 1989 was 103°F in July 1988, and the lowest was -25°F in January 1977. 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 above is 20 days. Frost depth ranges from 30 to 36 inches.

3.1.2 Topography and Surface Water Hydrology

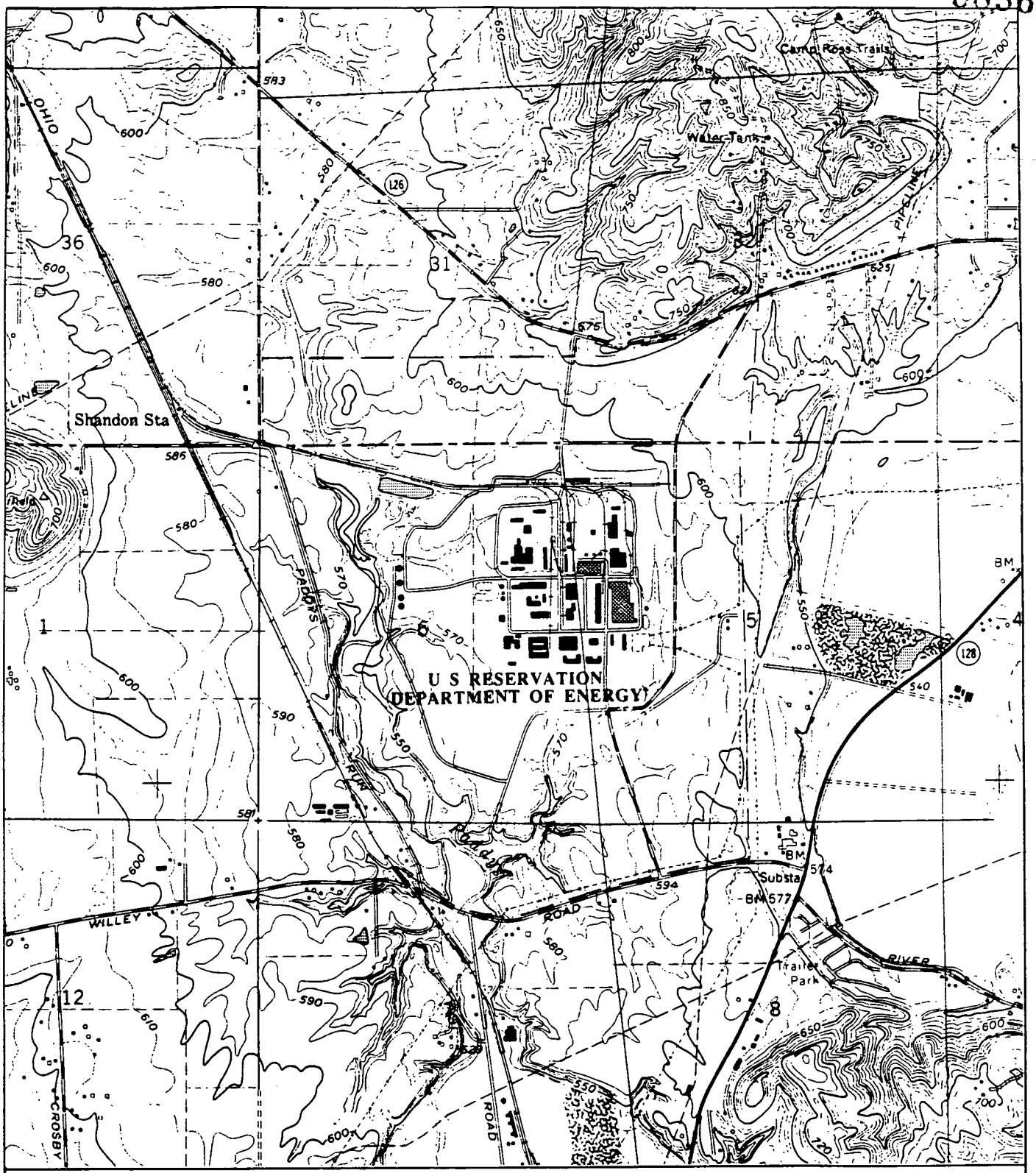
Maximum elevation along the northern boundary of the FEMP property is a little more than 700 feet above mean sea level (MSL). The former production area and waste storage area rest on a relatively level plain at about 580 feet above MSL. The plain slopes from 600 feet above MSL along the eastern boundary of the FEMP to 570 feet above MSL at the K-65 silos, and then drops off towards Paddys Run at an elevation of 550 feet above MSL. All drainage, including surface water, on the FEMP is generally from east to west into Paddys Run, with the exception of the extreme northeast corner, which drains east toward the Great Miami River (Figure 3-2).

The FEMP is located within the Great Miami River Basin drainage but above the river's present day floodplain. The Great Miami River flows within 0.75 miles of the facility's eastern boundary and discharges into the Ohio River approximately 24 river miles from the FEMP effluent line, which is located at river mile (RM) 24.1 (Figure 3-3). Tributaries to the Great Miami River in the FEMP region include Four Mile Creek at RM 38.4, approximately 14 RMs above the FEMP; Indian Creek at RM 27, just east of Ross, Ohio; Dry Run, approximately 1 mile above the FEMP; Owl Creek at RM 22; and Blue Rock Creek, which enters the river at RM 21. Paddys Run, which flows along the FEMP's western boundary, joins the Great Miami River at approximately RM 19.5, and Taylor Creek enters the river at approximately RM 14.4. The Whitewater River discharges into the Great Miami River at RM 6.

Surface waters on and adjacent to the FEMP are the storm sewer outfall ditch, Paddys Run, and the Great Miami River. The storm sewer outfall ditch originates within the FEMP and flows toward the southwest where it enters Paddys Run, which flows southward along the western boundary of the facility. Paddys Run, in turn, is a tributary of the Great Miami River, which flows generally toward the southwest, and lies to the east of the FEMP. These waters are described in detail in the following paragraphs and shown in Figure 3-4.

3.1.2.1 Storm Sewer Outfall Ditch

The storm sewer outfall ditch originates southeast 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. Much of the stream bottom of this drainage course, which also collects runoff from an area east of the former production area, is composed of sand and gravel and is highly permeable. Loss of



SOURCE: USGS 7.5 MINUTE QUADRANGLE, SHANDON, OHIO (1981)

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FIGURE 3-2. TOPOGRAPHIC MAP OF THE FEMP

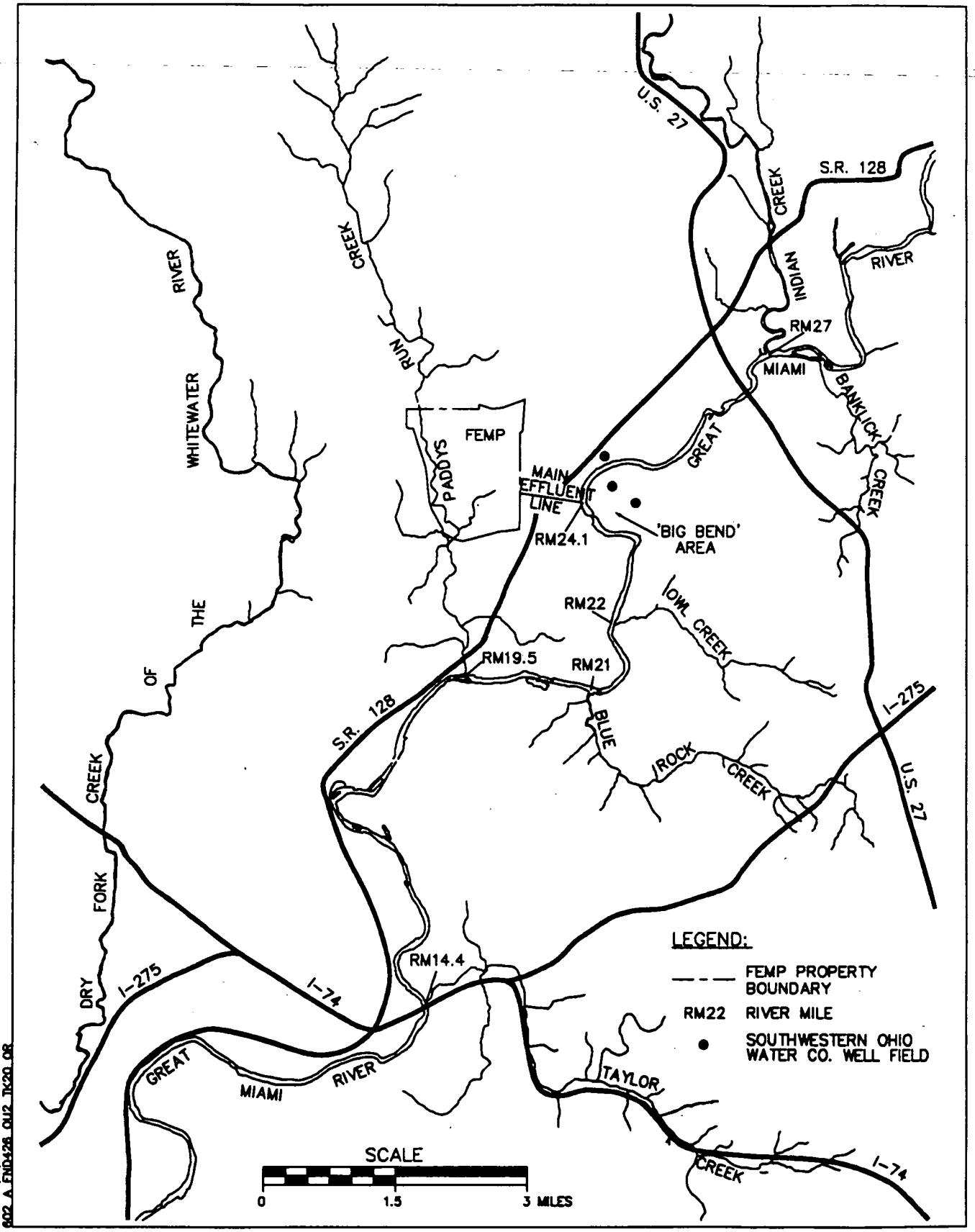

FIGURE 3-3. REGIONAL SURFACE WATERS

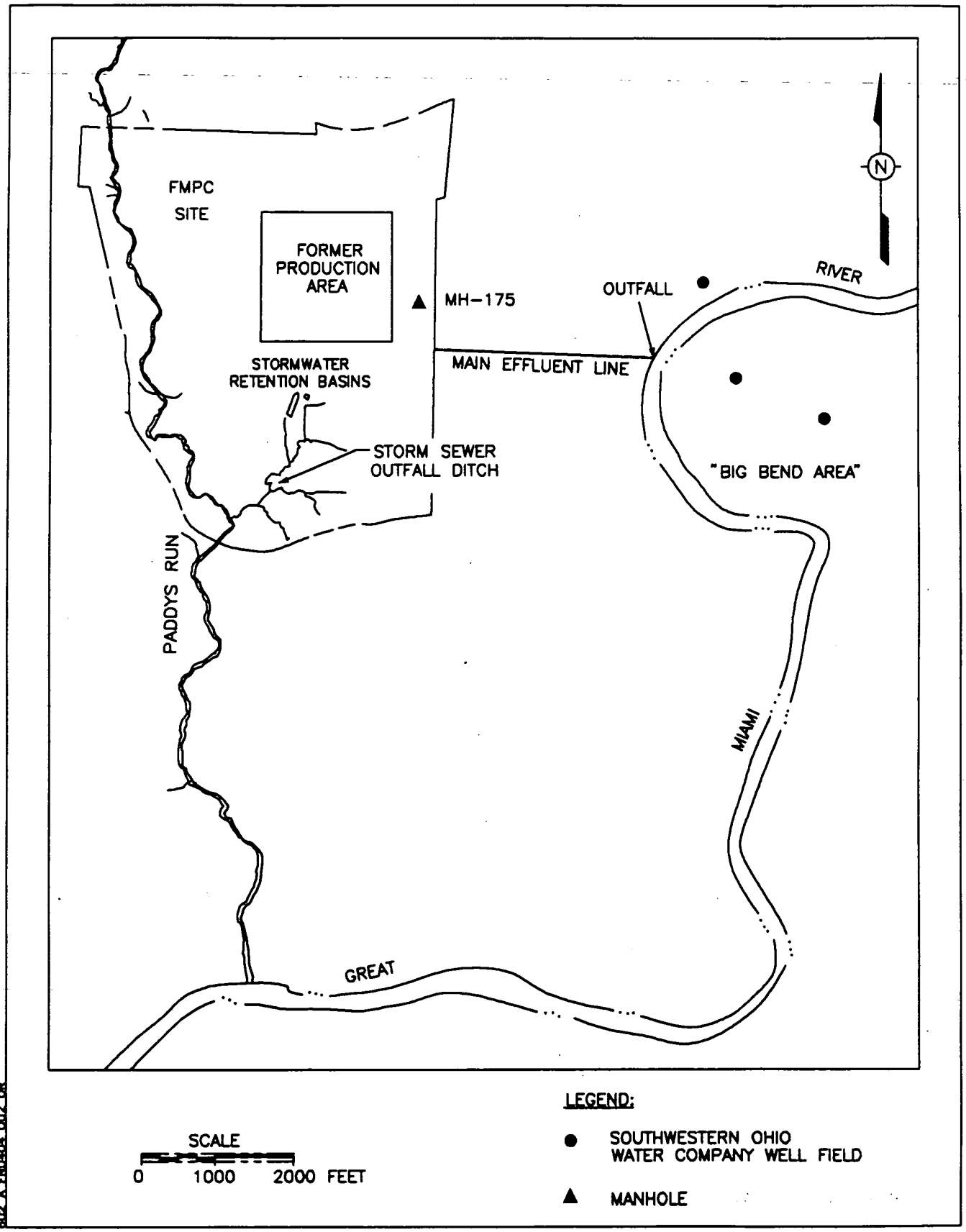

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FIGURE 3-4. SURFACE WATER HYDROLOGY

flow to the underlying Great Miami Aquifer is therefore significant. Throughout the year this drainage course is generally dry, with flows occurring only during and immediately after precipitation.

The storm sewer outfall ditch historically has conveyed surface water runoff from the former production area directly into Paddys Run during periods of heavy precipitation when the capacity of the storm sewer lift station (which diverts low-flow storm water to Manhole 175) has been exceeded. Two storm water retention basins were constructed, one in October 1986 and one in December 1989, at the head of the storm sewer outfall ditch (Figure 3-4). Storm water runoff from the former production area is now conveyed to these retention basins. After a minimum retention period of 24 hours to allow for settling of suspended solids, the water is pumped out of the basins into the Great Miami River through the main effluent line of the FEMP. The basins are 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 former production area enter the storm sewer outfall ditch.

3.1.2.2 Paddys Run

Paddys Run originates north of the FEMP, 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.

Natural surface drainage from the FEMP is towards Paddys Run, which has cut 6 feet or more through the geological deposits upon which the facility is built. Due to the highly permeable channel bottom, the stream loses water to the underlying Great Miami Aquifer. This characteristic contributes to the intermittent nature of the stream, which is sometimes dry but usually flows throughout its entire length between January and May.

Paddys Run is a steep-sided stream, and its banks erode severely during high flow periods. In 1961 and 1962, the course of the stream was altered to prevent it from eroding into the waste pit area (WMCO 1987). In 1970, a reach of the stream south of the K-65 silos was straightened to prevent erosion of Paddys Run Road. The stream is ungauged, but typical flows for the January through May period range from 0.2 to 4.0 cubic feet/second (ft^3/s). Channel overflow resulting from 25-year, 24-hour and 100-year, 24-hour storm events is possible, but peak flows occurring during storm events have not been measured.

3.1.2.3 Great Miami River

The Great Miami River is the main surface water feature in the vicinity of the FEMP, and is the receiving water from an NPDES-permitted discharge from 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 outfall. The three Southwestern Ohio

Water Company (SOWC) wells shown on Figure 3-4 have a significant influence on the infiltration rate from the Great Miami River.

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 site-wide RI/FS study area, the river passes through a 180-degree curve known as the Big Bend (Figure 3-4). A 90-degree bend in the river also occurs near New Baltimore, approximately two miles downstream from the FEMP point of discharge.

The average discharge of the Great Miami River at Hamilton, based on 55 years of records, is 3305 ft^3/s. Using drainage area scaling, the corresponding average flow at the FEMP point of discharge has been estimated at 3460 ft^3/s. The maximum discharge ever recorded for the Great Miami River at Hamilton occurred on March 26, 1913 and was estimated at 352,000 ft^3/s. The maximum discharge since the construction in 1922 of five retarding basins, located approximately 7 miles upstream of Ross, was 108,000 ft^3/s and occurred on January 21, 1959. The 10-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 ($Q_{7\text{-}10}$) of 267 ft^3/s, as computed by the USGS for the Hamilton gauge. This corresponds to 280 ft^3/s along the portion of the river shown in Figure 3-4.

3.1.3 Geology and Groundwater Hydrology

The following section provides a summary of the physiography, geological history, and hydrogeological setting of the area surrounding the FEMP.

3.1.3.1 Physiography

The FEMP lies in the Till Plains section of the Central Lowland physiographic province, characterized by structural and sedimentary basins and domes. Among these features, the Cincinnati Geoanticline is structurally significant in this region. The underlying bedrock is shale and fossiliferous limestone of Middle and Late Ordovician age (Fenneman 1916). It outcrops on steep valley walls in numerous waterfalls. In some areas, it is overlain by glacial deposits that range in thickness to as much as 400 feet.

The main physiographic features in the area are gently rolling uplands, steep hillsides along the major streams, and the Great Miami River Valley. This valley is 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.

3.1.3.2 Geologic History

The FEMP overlies a two- to three-mile-wide subterranean valley known as the New Haven Trough. This valley formed as a result of Pleistocene glaciation and subsequently filled with glacial outwash

materials and glacial overburden. The geologic history of the FEMP area, as presented by Fenneman (1916), is summarized in the following paragraphs.

In Late Ordovician time (approximately 450 million years ago), sediments that would become a predominantly flat-lying shale with thin interbedded limestone were deposited in a shallow sea. This shale is the relatively impermeable bedrock that now underlies the FEMP area and forms the adjacent highlands. The advance of Nebraskan and Kansan glaciation to the north of the Cincinnati area created a drainage system known as the Deep Stage Drainage System (Figure 3-5A). This drainage system was composed of three major rivers—the Miami River, the East Fork of the Little Miami River, and the Licking River. 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 area from the northeast. The Licking River came in from the south in essentially 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, which entered the 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.

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 main stream 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 turned eastward to Shandon and then flowed south through what is now the Paddys Run Valley.

During the time of Deep Stage Drainage and the early stages of Illinoisan Glaciation (300,000 to 400,000 years ago), the river valleys cut deeply into the shale bedrock to depths up to 200 feet below current land elevations. As the Illinoisan ice sheet advanced into the area, ice began to block the Great Miami River and its confluence with the ancestral Ohio River. For a time, water still flowed westward along the front of the advancing ice sheet and carved the present-day Great Miami River Valley along the tributary system near Miamitown.

When the confluence of the Great Miami River and the ancestral Ohio River was completely blocked, 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 3-5B).

The Great Miami River was forced out of the Deep Stage Valley during a subsequent ice advance, carving a new narrow deep stage valley from just north of New Baltimore to a location about 1 mile west of Cleves, where it returned to the original Deep Stage Valley. Because only water from the

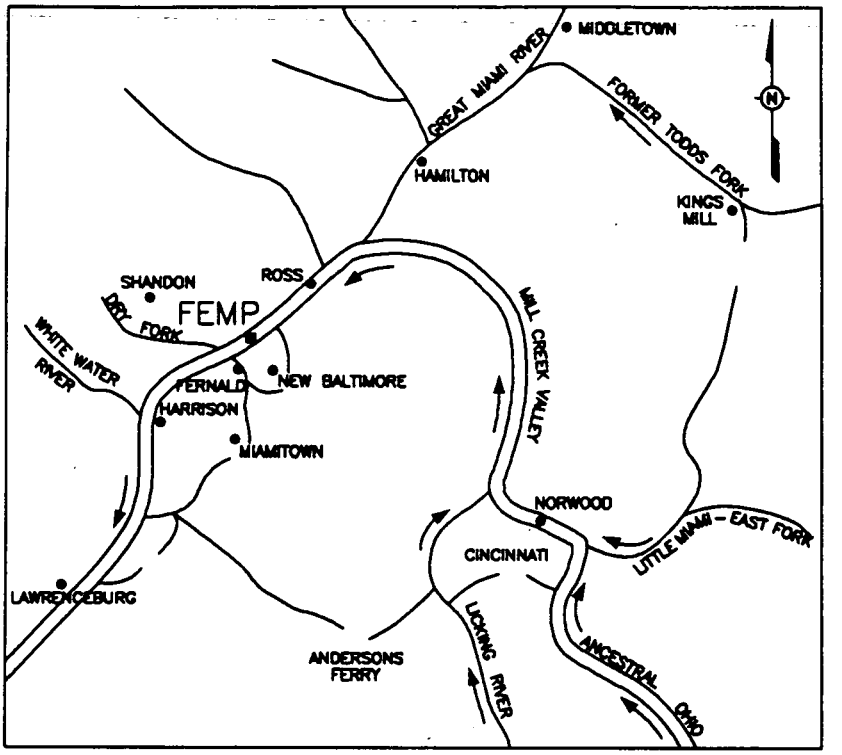

FIGURE 3-5A. DEEP STAGE DRAINAGE SYSTEM

LEGEND:

DIRECTION OF FLOW
ANCESTRAL OHIO RIVER

SOURCE:

FENNEMAN, N.M., 1916 "THE GEOLOGY OF CINCINNATI AND VICINITY", GEOLOGICAL SURVEY OF OHIO, BULLETIN 19.

NOT TO SCALE

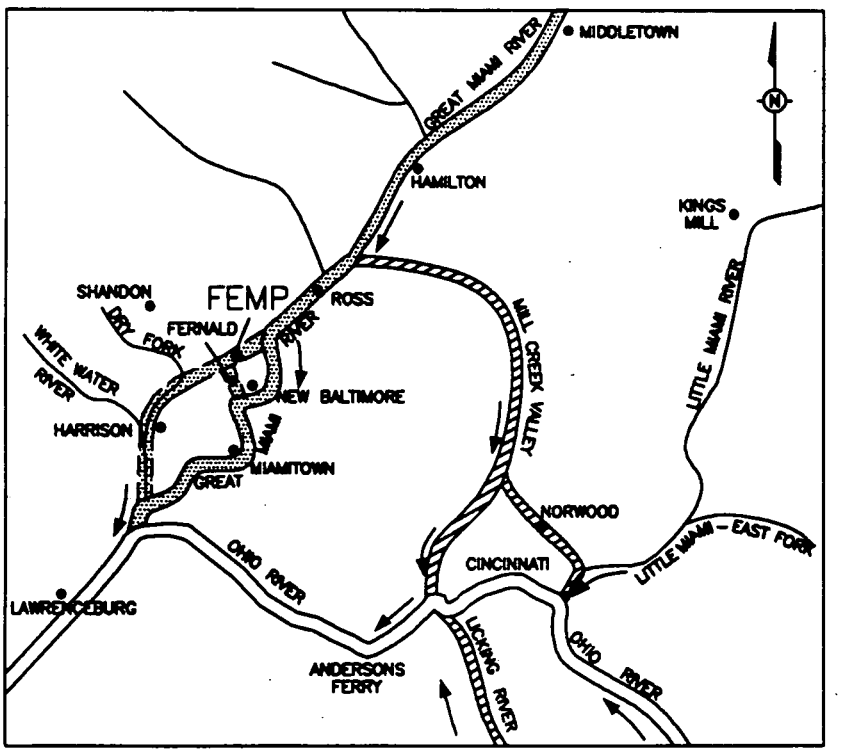

FIGURE 3-5B. PRESENT DRAINAGE SYSTEM

LEGEND:

DIRECTION OF FLOW
GREAT MIAMI AQUIFER
PRESENT OHIO RIVER
NEW HAVEN TROUGH
MILL CREEK BASIN

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FIGURE 3-5. SCHEMATIC DIAGRAMS OF THE DEEP STAGE DRAINAGE AND THE PRESENT DRAINAGE SYSTEM

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Great Miami River and its tributaries carved this, it was much smaller than the ancestral Ohio Valley. This 2-mile-wide valley was termed the New Haven Trough by Fenneman (1916). As the ice retreated, the Deep Stage Valley, including the New Haven Trough, was filled with well-sorted sand and gravel outwash deposits. This formed the Great Miami Aquifer, and the Great Miami and the Ohio rivers were established in their present-day channels.

During the last stage of glaciation, the Wisconsin Glaciation, the ice sheet advanced only as far as the south side of the FEMP's present location. As it retreated, the ice deposited a moraine, which formed a dam. The dam was breached twice, the final breach draining the lake permanently. The lake basin is now occupied by Paddys Run.

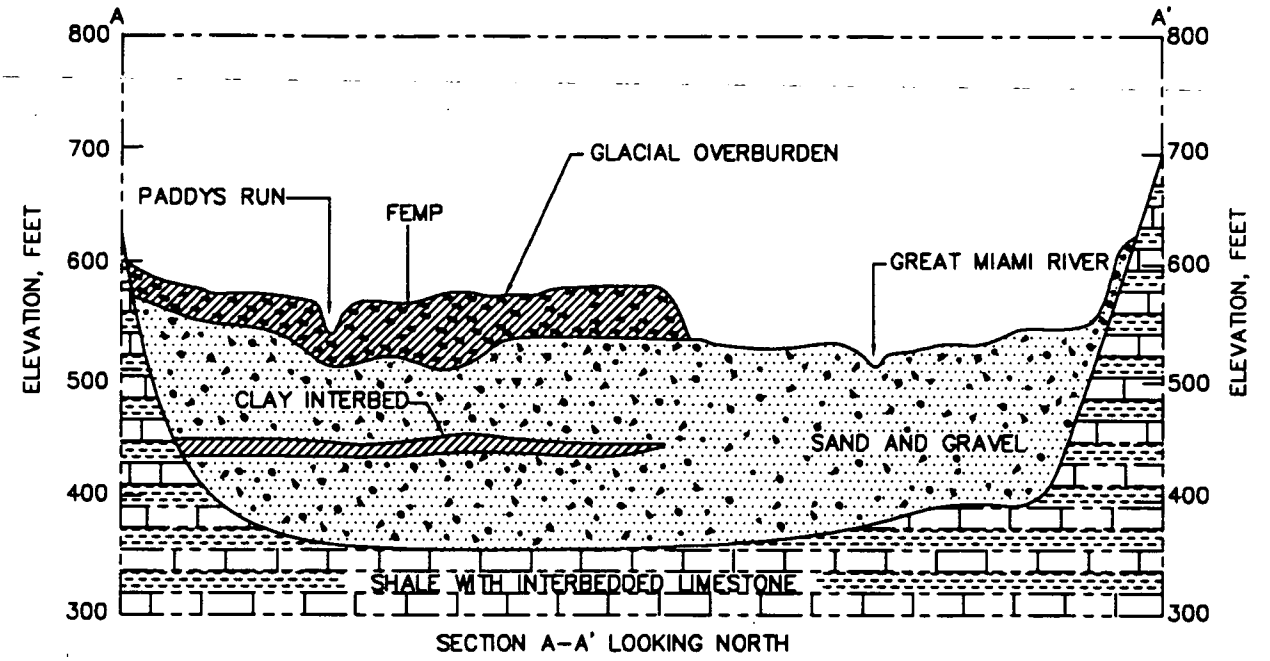
Since the last retreat of continental glaciers, the streams in the area have removed much of the glacial overburden and lacustrine mantle left by the ice sheets. The Great Miami River has eroded through the glacial overburden and is now in direct contact with the glaciofluvial outwash deposits that comprise the Great Miami Aquifer. Paddys Run is also in contact with these deposits in its lower reaches. The FEMP is located on a dissected glacial overburden plain and lacustrine deposits left by the Wisconsin Glaciation.

3.1.3.3 Site-Wide Hydrogeology

The Great Miami Aquifer is the principal aquifer within the FEMP study area. The underground valley in which it occurs varies in width from about 0.5 mile to over 2 miles, having a U-shaped cross section with a broad, relatively flat bottom, and steep valley walls (Figure 3-6). This valley is filled with extensive deposits of sand and gravel that range in thickness from 120 to 200 feet in the valley to only several feet along the valley walls, along with scattered silt and clay deposits. Figure 3-7 is a generalized stratigraphic column of the valley fill deposits.

Contained within the sand and gravel that underlies much of the FEMP property is a relatively continuous, low-permeability clay interbed ranging from about 5 to 15 feet in thickness (Figure 3-6). The clay interbed occurs approximately 130 feet below the land surface and, where present, divides the aquifer into upper and lower sand and gravel units, referred to as the Upper Great Miami Aquifer and the Lower Great Miami Aquifer.

Large groundwater supplies occur in the sand and gravel deposits, allowing the aquifer to yield a considerable amount of water. Wells constructed in the upper portion of the aquifer or areas where the clay interbed is not present can yield as much as 3000 gallons per minute (gpm). The lower portion of the aquifer beneath the clay interbed is classified as a semiconfined or leaky-confined aquifer, with well yields ranging from 100 to 500 gpm. The bedrock uplands outside of the buried valley are generally incapable of transporting large quantities of groundwater, with well yields ranging from 0 to 10 gpm.

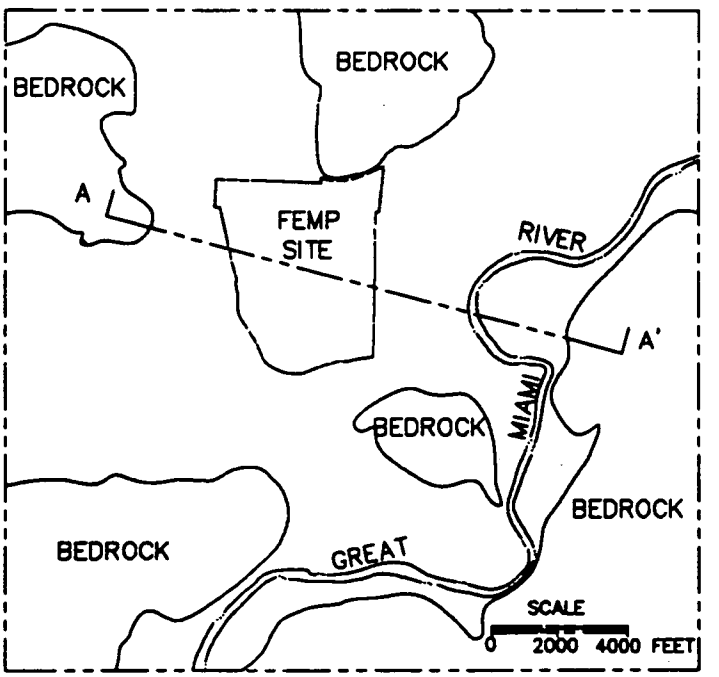


SECTION A–A' LOOKING NORTH

NOTES:

HORIZONTAL SCALE IS APPROXIMATELY 1" = 2500'

INFORMATION CONCERNING THE DEPTH AND ATTITUDE OF THE BEDROCK SHALE WAS OBTAINED FROM IT CORPORATION DRAWING 303317–8208.



LOCATION OF CROSS SECTION

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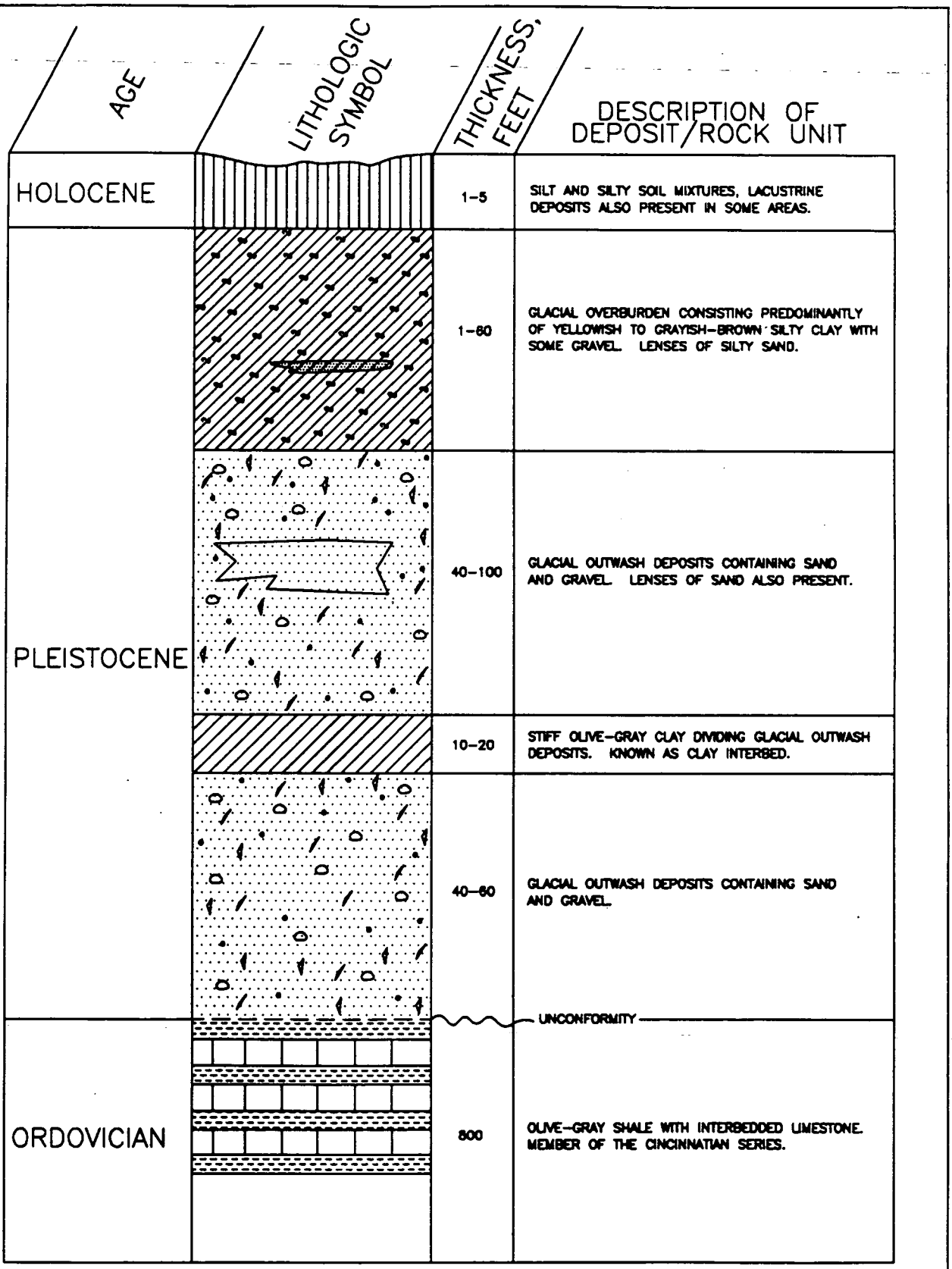
822 A FIG3-06 OU2 OR

FIGURE 3–6. SCHEMATIC CROSS SECTION OF BURIED CHANNEL AQUIFER

135



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002_A_FND419_OU2_TK20_OR

FIGURE 3-7. GENERALIZED STRATIGRAPHIC COLUMN OF THE FEMP REGION

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The principal sources of aquifer recharge in the FEMP study area are direct precipitation and stream infiltration. Infiltration of rainfall and snowmelt is the dominant regional source of groundwater recharge, providing approximately 570,000 gallons per day per square mile, or roughly 12 inches per year to the water table of the aquifer (Dove 1961). Much of the precipitation that runs off the glacial overburden on the FEMP property enters Paddys Run and the storm sewer outfall ditch, both of which are subject to leakage directly to the aquifer along portions of their length. These streams are intermittent and provide recharge on a seasonal basis. The pumping of the SOWC supply wells, located at the Big Bend meander of the Great Miami River east of the FEMP (Figure 3-4), causes a portion of the surface water to infiltrate through the bed of the river and recharge the aquifer. In areas of the river not influenced by the pumping wells, groundwater flows from the aquifer to the river, except during dry periods when the elevation of the water table is below the bed of the river. Although the bedrock's low permeability limits groundwater recharge to the aquifer, small amounts of water do seep through its erratically distributed joints and cracks.

Overlying the aquifer throughout most of the FEMP property are a series of glacial overburden deposits (Figure 3-7). The glacial overburden is composed primarily of dense, silty clay that contains lenses of poorly sorted fine- to medium-grained sand and gravel, silty sand, and silt, with layers of silty clay. This material has relatively low permeability, so most of the precipitation that falls on it is lost to evaporation and surface water runoff. Limited infiltration occurs along the upper weathered portion of the overburden and in isolated areas where more permeable deposits of silt, sand, and gravel are the primary overburden constituents.

The thickness of the glacial overburden ranges from 5 to 50 feet within the FEMP study area, but most commonly averages between 20 and 30 feet. Except for some scattered deposits, this overburden does not exist along the floodplain of the Great Miami River to the east and south of the FEMP. The only on-property areas that lack overburden are certain reaches of Paddys Run and the storm sewer outfall ditch, where this material has been eroded away. These streams are in direct contact with the upper portion of the Great Miami Aquifer along these reaches, allowing surface water leakage directly to the aquifer. Areas of surface water infiltration to the aquifer along Paddys Run and the storm sewer outfall ditch are shown in Figure 3-8.

Erratically distributed pockets of sand and gravel within the glacial overburden contain zones of perched groundwater. Perched groundwater zones are separated from the aquifer by the relatively impermeable clay and silt components of the overburden. Most of the perched zones are lenses with relatively high permeability overlying a clay layer. These units can store groundwater and transmit it slowly downward. Wells constructed in these zones may yield up to 50 gpm.

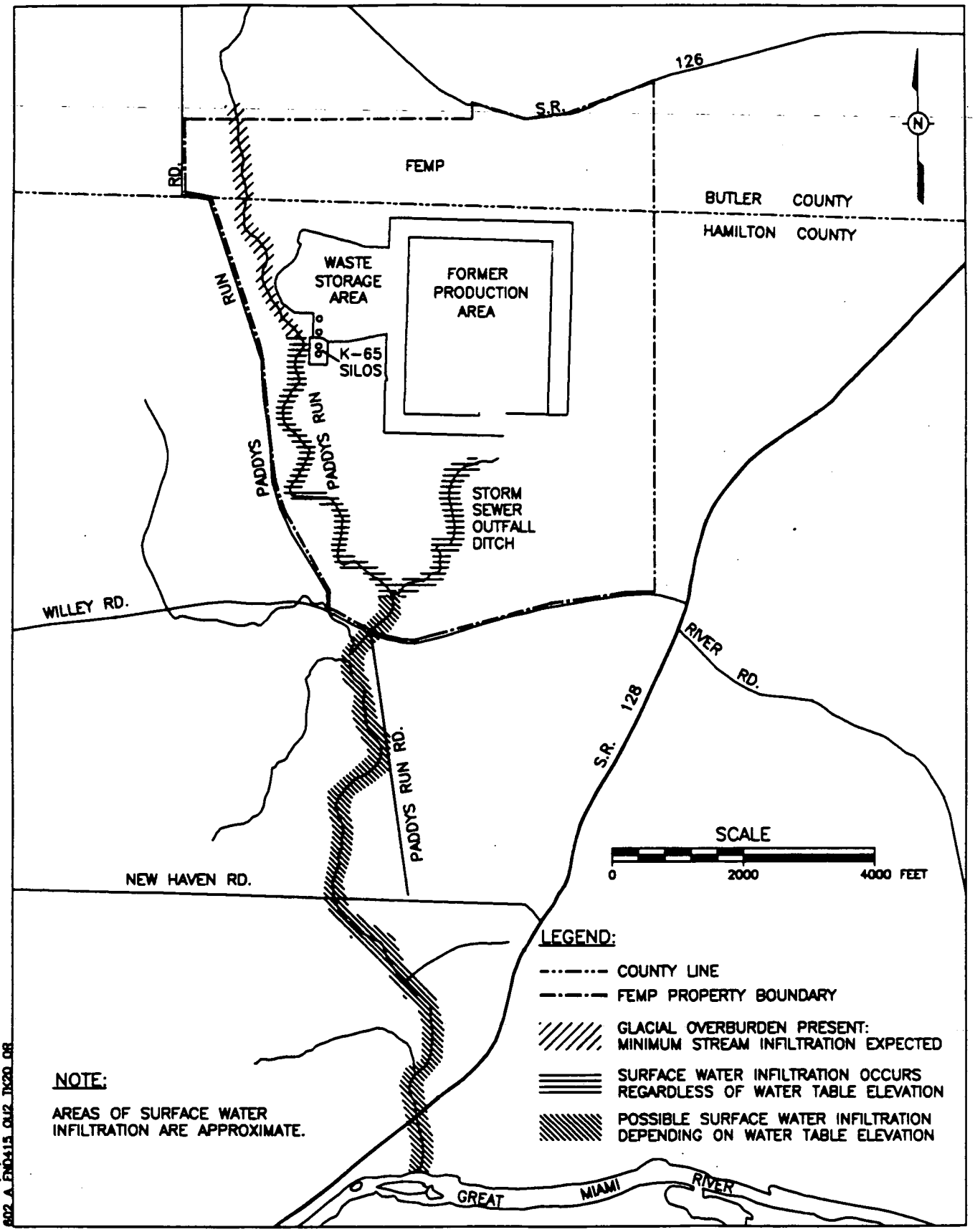

FIGURE 3-8. AREAS OF SURFACE WATER INFILTRATION TO THE GREAT MIAMI AQUIFER ALONG PADDYS RUN AND THE STORM SEWER OUTFALL DITCH

Depth to perched groundwater at the FEMP ranges from 1 to 15 feet below the land surface. This can fluctuate seasonally by up to 10 feet at a single location, with the highest water levels occurring during the early spring and the lowest during the late fall.

Perched groundwater underlying the FEMP property flows generally toward surface drains and vertically downward. There is uncertainty, however, regarding horizontal movement of perched groundwater, since the perched zones may not be interconnected across the property and the materials comprising the overburden vary considerably in their ability to confine or transport water. Other influences on flow patterns within perched zones include seasonal variations in recharge resulting from rainfall and the presence of features such as leaky storm sewers and agricultural drain tiles that were installed before the construction of the FEMP. Consequently, groundwater flow within the glacial overburden is discontinuous and nonuniform across the FEMP.

The generalized groundwater flow in the Great Miami Aquifer is shown in Figure 3-9. Groundwater enters the FEMP study area from three separate flow systems—the Dry Fork Section of the New Haven Trough to the west, the Shandon Tributary to the north, and the Ross Section of the New Haven Trough to the northeast. Natural gradients cause the groundwater to exit the FEMP study area either by flowing east to the Great Miami River, upstream from New Baltimore, or south through the branch of the bedrock channel west of New Baltimore. The Great Miami River is the ultimate receptor of all groundwater in the study area. The large-volume SOWC pumping wells near the Great Miami River Aquifer produce a pronounced and persistent cone of depression, generally defined as a lowering of the aquifer water table in the area surrounding the pumping wells. Groundwater elevation maps indicate that this cone of depression influences groundwater flow patterns beneath the FEMP. In particular, a groundwater-flow divide is created such that groundwater underlying the northern portion of the FEMP, including those areas underlying the waste storage area and the former production area, flows east toward the SOWC wells and the Great Miami River (Figure 3-9). Groundwater from the southern and southwestern portion of the FEMP continues to flow along the natural gradient to the south-southwest through the buried valley. Near the southwest corner of the FEMP, a groundwater component from the west is also present. This causes the recharge from certain reaches of Paddys Run to flow east-southeast until the regional southern component of flow is encountered (Figure 3-9).

Aquifer water table elevations in the study area display a broad cyclic trend on a yearly basis, as shown in Figure 3-10. Maximum water table elevations usually occur during the spring and early summer months, which are also the major groundwater recharge months (Figure 3-11). Minimum water table elevations generally occur during the late fall and early winter months (Figure 3-12). This corresponds with southern Ohio's dry season, which usually starts in late summer or early fall and runs to late fall. During most years, the water table fluctuates 4 to 5 feet, with increases occurring faster than decreases. The average recharge period is 4 to 5 months, while the average discharge period lasts 7 to 8 months. This is a typical water cycle for southern Ohio.

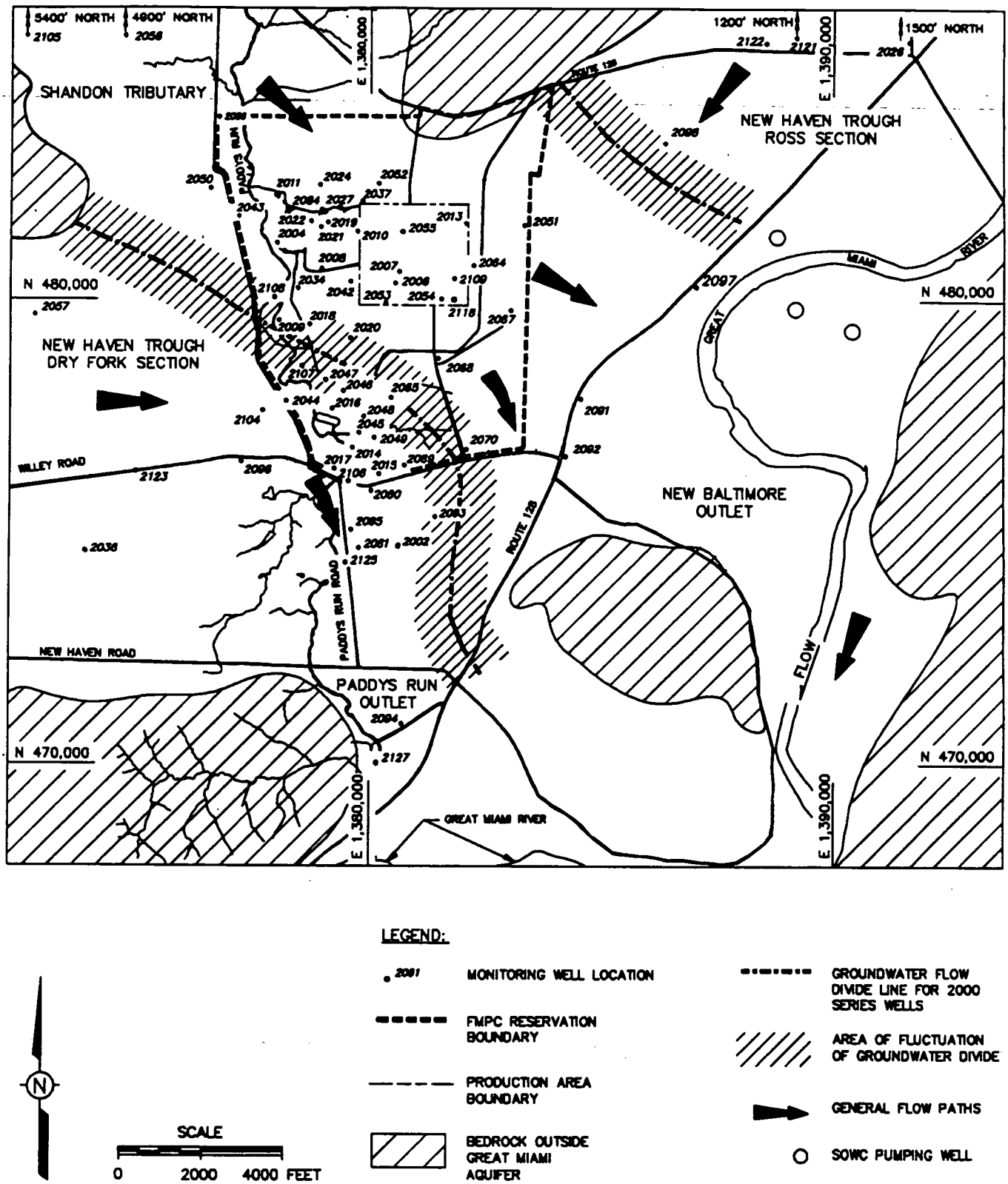

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FIGURE 3-9. GENERALIZED GROUNDWATER FLOW IN BURIED CHANNEL AQUIFER

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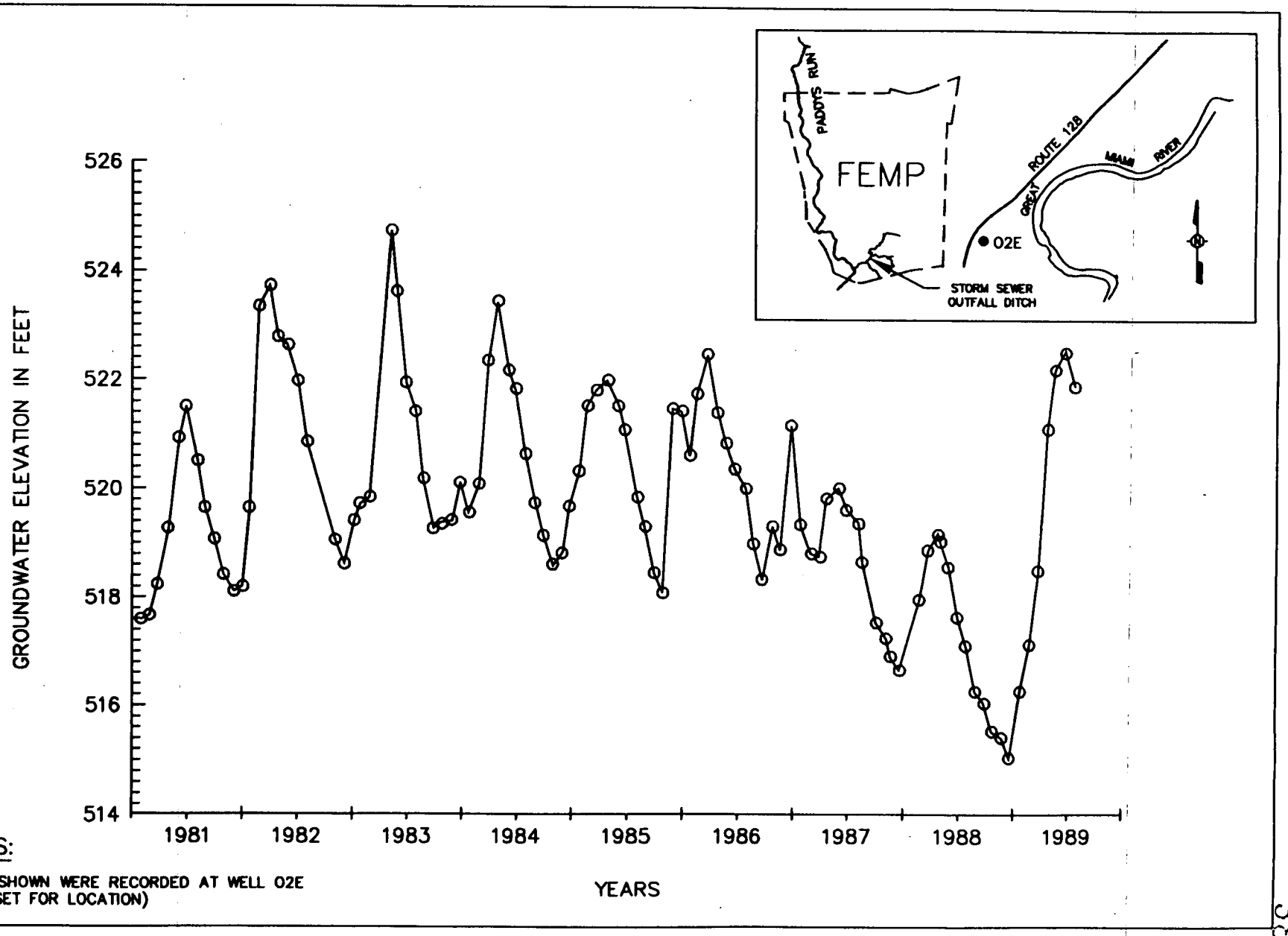

FIGURE 3-10. GROUNDWATER ELEVATION LEVELS RECORDED IN THE STUDY AREA BETWEEN JANUARY 1981 AND DECEMBER 1989

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3836

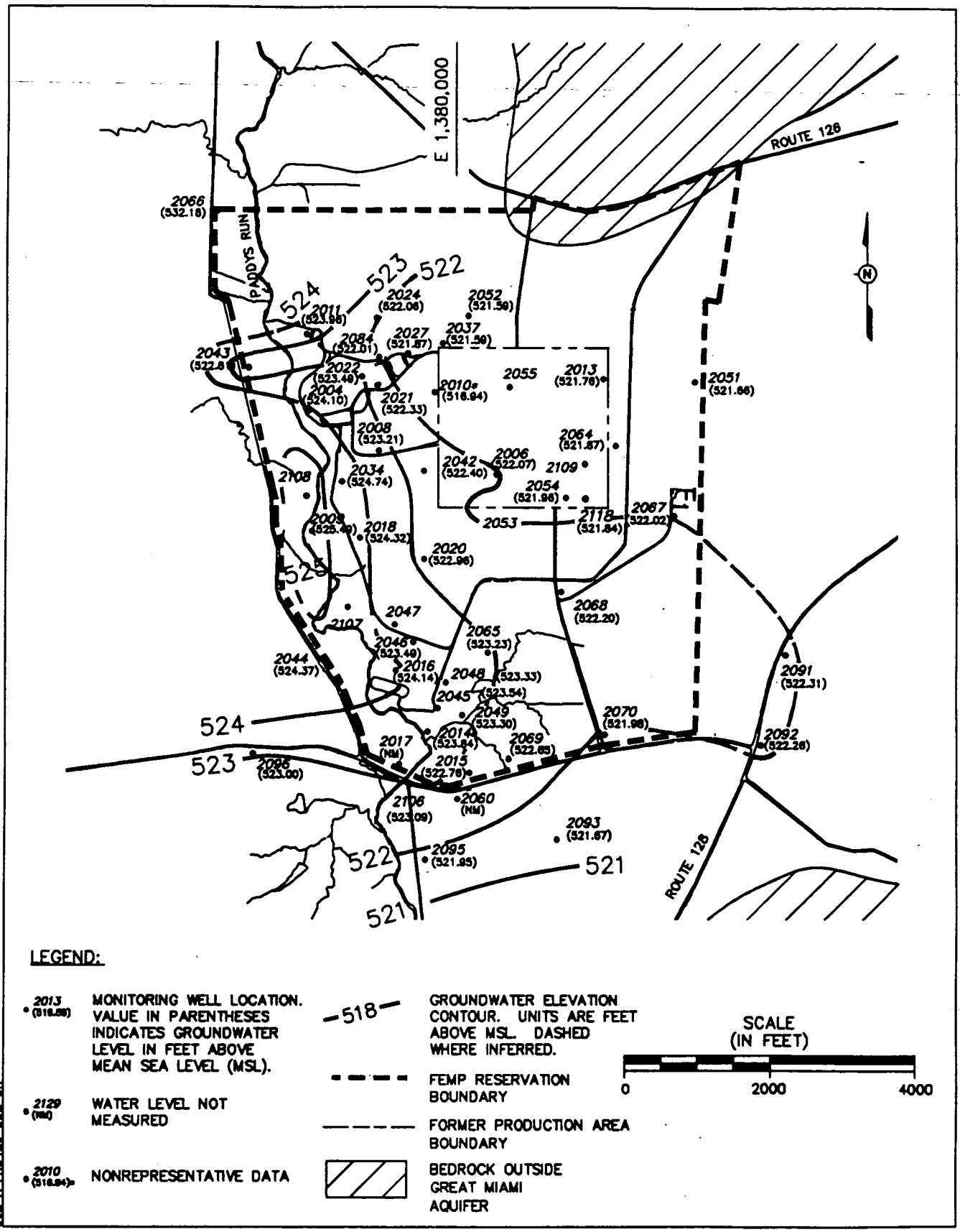

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FIGURE 3-11. GROUNDWATER ELEVATIONS 2000-SERIES WELLS: MAY 1989

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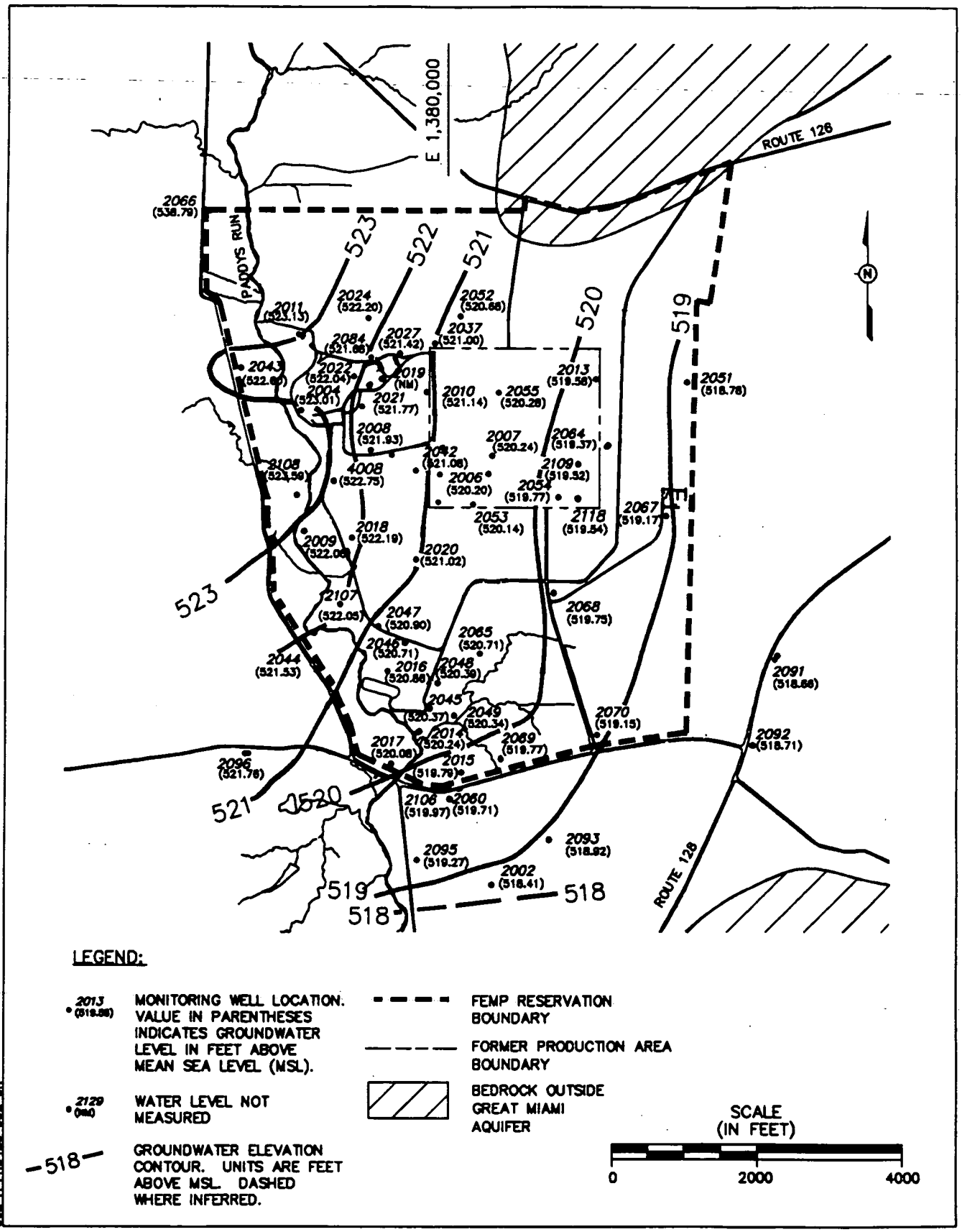

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602 A FIN0428 OU2 OB

FIGURE 3-12. GROUNDWATER ELEVATIONS 2000-SERIES WELLS: DEC 1989

Paddys Run affects local groundwater flow in the aquifer along the western boundary and in the area south of the FEMP. Increases in runoff in Paddys Run lead to the formation of a groundwater mound typically centered on monitoring wells just southwest of the K-65 silos and adjacent to Paddys Run (Figure 3-13). During periods of high flow in Paddys Run, which follow heavy or sustained rainfall, large volumes of stream water infiltrate the aquifer, creating a mound in the local water table (DOE 1990). This groundwater mound affects the direction of flow in its vicinity. For example, groundwater that normally flows to the east in the vicinity of Paddys Run will flow to the west when this seasonal mounding is occurring. As the flow in Paddys Run decreases, reducing infiltration to the aquifer, the mound decreases in size until the flow patterns show only slight influence. This slight influence is seen during the dry months, when there is little recharge to the aquifer from Paddys Run.

3.1.3.4 Seismology

A seismic risk zone of two (on a scale of less-than-one to four), a measurement of earthquake intensity, has been assigned to the region of the FEMP (Algermissen 1969). An earthquake in the region of the FEMP could damage facilities and cause the release of contaminants into the environment. Local geological structures and historical seismicity are used to analyze the potential for seismic events and structural damage.

The presence of minor faults cannot be completely dismissed. Paleozoic rocks in the Fernald area are largely covered by Pleistocene sediments, and fault traces older than Pleistocene could be obscured. The historical record of seismicity and the absence of post-Wisconsin faults, however, show that significant damage from local earthquakes at the FEMP is highly unlikely. Throughout the 19th and 20th centuries, no damaging earthquakes have been recorded within 71 miles of the FEMP. Nine earthquakes caused minor damage between 71 and 199 miles of the FEMP, and one earthquake caused localized moderate damage at Anna, Ohio, about 81 miles north of the FEMP.

3.1.4 Soils

Soil characteristics affect (1) the suitability of a site for agriculture or construction, (2) the likelihood of erosion during remedial actions, and (3) the kinds of habitat, for example wetlands, that can develop on a site. Soils in the region of the FEMP were formed from materials deposited by the Wisconsin and Illinoisan glaciers. These parent materials consist mainly of glacial till, but also include sand, gravel, glacial-lake clays, and silt clays. Three major soil associations (groups of soils that typically occur together) exist in the vicinity of the FEMP—Russell-Xenia-Wynn, Fincastle-Xenia-Wynn, and Fox-Genesee (USDA 1980, 1982). These soils are usually light-colored, acidic, and well-drained. Many of them have developed on wind-blown material (loess), except along river basins where the Fox-Genesee soils are of glacial till origin. The soils are moderately high in productivity and are frequently used for growing cash crops and producing livestock. Engineering, physical, and chemical properties for the soil types found in the vicinity of the FEMP are presented in Tables 3-2, 3-3, 3-4, and 3-5.

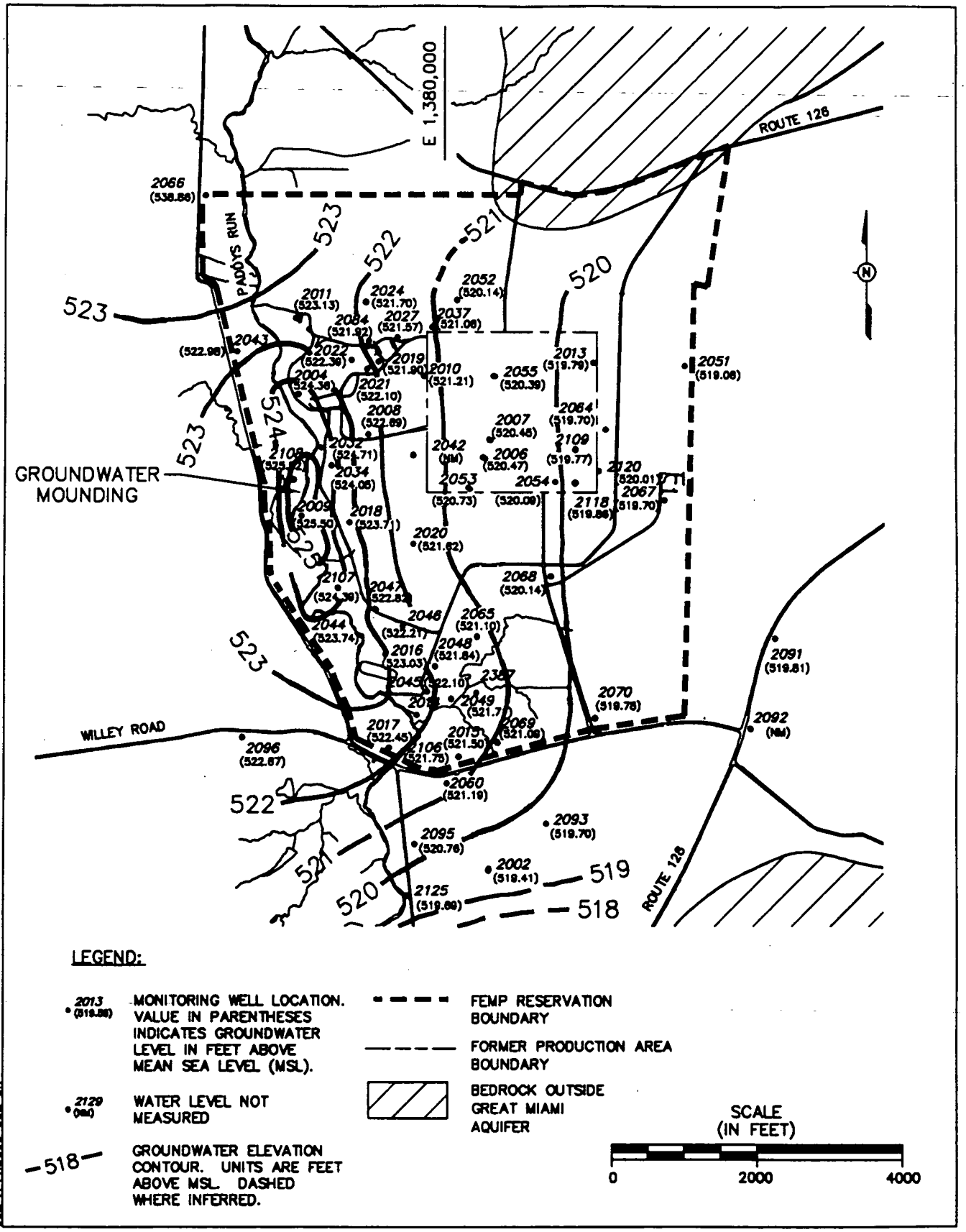

FIGURE 3–13. WATER TABLE MOUNDING AT PADDYS RUN IN FEB. 1990

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TABLE 3-2

ENGINEERING PROPERTIES AND CLASSIFICATIONS OF BUTLER COUNTY SOILS ON THE FEMP

Soil Name and Map Symbol	Depth (In)	USDA Texture	Classification Unified	Percentage Passing Sieve Number 4	10	40	200	Liquid Limit Pct	Plasticity Index
DaA, DaB Dana	0-13	Silt loam	CL	100	100	95-100	85-95	30-35	8-12
	13-40	Silty clay loam	CL	100	100	95-100	85-98	38-50	20-32
	40-44	Clay loam	CL	90-100	90-95	80-90	65-75	37-50	17-30
	44-60	Loam	CL, ML, CL-ML	85-95	80-90	75-85	50-65	17-30	2-14
EcE2, EcF2 Eden	0-5	Silty clay loam	ML, CL	85-100	80-100	75-100	70-100	35-65	12-35
	5-27	Flaggy silty clay,	MH, CH	75-100	70-100	65-100	60-100		
		glaggy clay, silty	MH, CH					45-75	20-45
		clay	CL	NA[a]	NA	NA	NA		
	27-40	Weathered bedrock	NA					NA	NA
FdA, FdB Fincastle	0-8	Silt loam	CL, ML	100	95-100	90-100	75-93	27-36	4-12
	8-28	Silty clay loam	CL, CH	100	100	95-100	85-95	38-54	20-32
	28-42	silty clay loam, clay	CH, CL	95-100	90-98	85-95	75-85	45-58	30-38
		loam		85-95	75-90	70-85	55-75	30-50	15-35
	42-56	Flaggy clay loam	CL	NA	NA	NA	NA	NA	NA
	56	Weathered bedrock	NA						
Gn Genesee	0-8	Loam	ML, CL	100	100	90-100	75-85	26-40	3-15
	8-34	Silt loam, loam	ML, CL	100	100	90-100	75-85	26-40	3-15
	34-60	Stratified sandy loam to silt loam	ML, CL	90-100	85-100	60-80	50-70	26-40	3-15
HoA Henshaw	0-9	Silt loam	ML, CL CL-ML	95-100	95-100	90-100	80-100	25-35	3-10
	9-50	Silty clay loam, silt loam	CL, ML	95-100	95-100	95-100	85-100	30-40	8-18
	50-60	Silt loam, silty clay loam	ML, CL, CL-ML	95-100	90-100	85-100	75-100	25-40	5-15
MsC2, MsD2: Miamian	0-6	Silt loam	ML	95-100	95-100	90-100	70-95	26-40	4-12
	6-22	Silty clay loam, clay loam, clay	CL	85-100	80-100	75-95	70-85	32-50	15-30
	22-60	Loam, silt loam	CL, ML CL-ML	75-95	75-90	65-85	50-75	20-35	3-13

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TABLE 3-2 (continued)

Soil Name and Map Symbol	Depth (In)	USDA Texture	Classification Unified	Percentage Passing Sieve Number 4	10	40	200	Liquid Limit Pct	Plasticity Index
RwB2	0-10	Silt loam	CL, CL-ML	100	95-100	80-100	50-90	20-35	5-15
Russell	10-22	Silty clay loam, silt loam	CL	100	100	95-100	85-95	35-50	20-35
	22-36	Clay loam, loam	CL	90-100	90-95	80-90	65-75	35-50	17-31
	36-60	Loam, clay loam	CL, ML CL-ML	85-95	80-90	75-85	50-65	<30	2-14
Ra	0-12	Silty clay loam	CL	100	100	90-100	80-100	35-50	15-30
Ragsdale	12-50	Silty clay loam	CL	100	100	90-100	80-95	35-50	15-30
	50-72	Silt loam	CL, CL-ML	100	100	90-100	70-90	25-35	5-15
RdA, RdB	0-15	Silt loam	CL, CL-ML	100	100	90-100	75-95	25-35	5-15
Raub	15-37	Silty clay loam	CL, CH	100	100	95-100	80-95	35-55	20-35
	37-43	Clay loam, silty clay loam	CL	95-100	90-100	85-95	60-85	35-50	15-25
	43-60	Loam, clay loam	CL, ML SC, SM	85-95	80-90	70-85	40-65	15-30	NP-15
UnA, UnB	0-10	Silt loam	ML, CL-ML	100	95-100	90-100	80-100	25-35	2-10
Uniontown	10-49	Silt loam, silty clay loam	CL, ML	100	95-100	90-100	85-100	30-45	7-20
	49-66	Silt loam, silty clay loam	ML, CL	90-100	90-100	85-100	75-100	30-45	7-20
XeA, XeB, XeB2	0-10	Silt loam	CL, CL-ML	100	100	90-100	70-100	25-35	5-15
Xenia	10-31	Silty clay loam	CL	100	100	90-100	80-95	35-50	15-30
	31-72	Loam, clay loam	CL, ML SC, SM	85-95	80-90	75-90	40-65	25-30	NP-15
XfA, XfB, XfB2	0-8	Silt loam	CL, CL-ML	100	100	90-100	70-100	25-35	5-15
Xenia	8-26	Silty clay loam	CL	100	100	90-100	80-95	35-50	15-30
	26-42	Clay loam, silty clay loam	CL	92-100	90-95	75-95	65-75	35-50	15-30
	42-59	Stoney clay loam	CL	85-95	75-90	70-85	55-75	30-50	15-35
	59	Weathered bedrock	NA	NA	NA	NA	NA	NA	NA

* Data not available.

Sources: 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.

TABLE 3-3

ENGINEERING PROPERTIES AND CLASSIFICATIONS OF HAMILTON COUNTY SOILS ON THE FEMP

Soil Name and Map Symbol	Depth (In)	USDA Texture	Classification Unified	Percentage Passing Sieve Number 4	10	40	200	Liquid Limit Pct	Plasticity Index
Epa, EpB2, EpC2	0-7	Loam	ML, CL-ML, CL	85-100	80-100	70-100	55-90	20-40	4-14
Eldean	7-36	Clay, clay loam, gravelly clay loam	CL, ML	75-100	60-100	55-95	50-80	38-50	12-23
	36-60	Stratified sand to gravel	GM, SM GP-GM, SP-SM	30-70	20-50	5-40	0-35	NA[a]	NP
FdA	0-8	Silt loam	CL, ML	100	95-100	90-100	75-93	27-36	4-12
Fincastle	8-33	Silty clay loam, silt loam	CL, CH	100	100	95-100	85-95	38-54	20-32
	33-42	Clay loam, loam, silty clay loam	CH, CL	95-100	90-98	85-95	75-85	45-58	30-38
	42-70	Loam, clay loam	CL, ML CL-ML	88-96	82-90	70-86	50-66	20-35	3-12
FeA*:	0-8	Silt loam	CL, ML	100	95-100	90-100	75-93	27-36	4-12
Fincastle	8-33	Silty clay loam, silt loam	CL, CH	100	100	95-100	85-95	38-54	20-32
	33-42	Clay loam, loam, silty clay loam	CH, CL	95-100	90-98	85-95	75-85	45-58	30-38
	42-70	Loam, clay loam	CL, ML, CL-ML	88-96	82-90	70-86	50-66	20-35	3-12
Gn	0-9	Loam	ML, CL	100	100	90-100	75-90	26-40	3-15
Genesee	9-35	Silt loam, loam	ML, CL	100	100	90-100	75-90	26-40	3-15
	35-60	Stratified sandy loam to silt loam	ML, CL, CL-ML	90-100	85-100	60-90	50-90	20-35	3-15
HeF	0-2	Silt loam	CL, CL-ML	90-100	85-100	70-100	60-95	25-40	5-20
Hennepin	2-12	Loam, sandy loam, silt loam	SC, SM-SC, CL, CL-ML	85-100	80-100	65-100	35-95	20-50	5-25
	12-60	Loam, sandy loam, clay loam	SC, SM-SC	85-100	80-100	65-100	35-95	20-50	5-25
HoA	0-8	Silt loam	ML, CL, CL-ML,	95-100	95-100	90-100	80-100	20-35	3-10
Henshaw	8-44	Silty clay loam, silt loam	CL, ML	95-100	95-100	95-100	85-100	30-40	8-18
	44-66	Silt loam, silty clay loam	ML, CL, CL-ML	95-100	90-100	85-100	75-100	25-40	5-15

TABLE 3-3 (continued)

Soil Name and Map Symbol	Depth (In)	USDA Texture	Classification Unified	Percentage Passing Sieve Number 4	10	40	200	Liquid Limit Pct	Plasticity Index
MaB, MaC2, MaD2, MaE2 Markland	0-10	Silty clay loam	CL, CH	100	100	95-100	85-95	35-55	20-35
	10-33	Silty clay, clay, silty clay loam	CL, CH	100	100	95-100	90-95	45-60	25-35
	33-60	Stratified clay to silt loam	CL, CH	100	100	90-100	75-95	35-60	20-35
McA, McB Martinsville	0-9	Silt loam	CL, CL-ML	100	90-100	80-100	60-90	22-33	4-12
	9-34	Clay loam, silty clay loam, sandy clay loam	CL, SC	100	90-100	65-90	40-90	20-35	8-20
	34-44	Sandy loam, sandy clay loam, loam	SM, ML, A-4	100	90-100	60-80	30-60	30-40	2-8
	44-60	Stratified sand to loam	CL, SC, CL-ML SM-SC	95-100	85-100	80-95	40-60	<25	4-9
MoD2, MoE2 Miamian	0-6	Silt loam	ML	95-100	95-100	90-100	70-95	26-40	4-12
	6-24	Silty clay loam, clay loam, clay	CL	85-100	80-100	75-95	70-85	32-50	15-30
	24-60	Loam, clay loam	CL, ML, CL-ML	75-95	75-90	65-85	50-75	20-35	3-13
RwB2 Russell	0-7	Silt loam	CL, CL-ML	100	95-100	80-100	50-90	20-35	5-15
	7-22	Silty clay loam, silt loam	CL	100	100	95-100	85-95	35-50	20-35
	22-43	Clay loam, loam	CL, ML, CL-ML	90-100	90-95	80-90	65-75	35-50	17-31
	43-72	Loam, clay loam	CL, ML, CL-ML	85-95	80-90	75-85	50-65	<30	2-14
XfA, XfB2 Xenia	0-9	Silt loam	CL, CL-ML	100	100	90-100	70-100	25-35	5-15
	9-26	Silty clay loam	CL	100	100	90-100	80-95	35-50	15-30
	26-46	Clay loam	CL	92-100	90-95	75-95	65-75	35-50	15-30
	46-72	Loam	CL, ML, SC, SM	85-95	80-90	75-90	40-65	15-30	NP-15

[a] Data not available.

Sources: 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 Hamilton County, Ohio," USDA, ODNR and Ohio Agricultural Research and Development Center, n.p.

TABLE 3-4

PHYSICAL AND CHEMICAL PROPERTIES OF BUTLER COUNTY SOILS ON THE FEMP

Soil Name and Map Symbol	Depth In	Permeability In/Hr	Available Water Capacity In/In	Soil Reaction pH	Shrink Swell Potential
DaA, DaB Dana	0-13	0.6-2.0	0.22-0.24	5.6-7.3	Low
	13-40	0.6-2.0	0.18-0.20	5.1-6.0	Moderate
	40-44	0.6-2.0	0.15-0.19	6.1-7.3	Moderate
	44-60	0.2-0.6	0.05-0.19	6.6-8.4	Low
EcE2, EcF2 Eden	0-5	0.06-0.6	0.12-0.18	5.1-8.4	Moderate
	5-27	0.06-0.2	0.10-0.15	5.1-8.4	Moderate
	27-40	NA[a]	NA	NA	NA
FdA, FdB Fincastle	0-8	0.6-2.0	0.22-0.24	5.1-6.5	Low
	8-28	0.2-0.6	0.18-0.20	5.1-5.5	Moderate
	28-42	0.06-0.6	0.15-0.19	5.1-6.0	Moderate
	42-56	<0.06	0.04-0.08	7.4-8.4	Moderate
	56	NA	NA	NA	NA
Gn Genesee	0-8	0.6-2.0	0.20-0.24	6.1-7.8	Low
	8-34	0.6-2.0	0.17-0.22	6.1-8.4	Low
	34-60	0.6-2.0	0.19-0.21	7.4-8.4	Low
HoA Henshaw	0-9	0.6-2.0	0.18-0.23	5.6-6.5	Low
	9-50	0.2-0.6	0.15-0.19	5.1-7.3	Low
	50-60	0.2-0.6	0.17-0.22	6.6-8.4	Low
MsC2*, MsD2*: Miamian	0-6	0.6-2.0	0.17-0.20	5.6-7.3	Low
	6-22	0.2-0.6	0.12-0.18	4.5-7.8	Moderate
	22-60	0.2-0.6	0.06-0.10	7.4-8.4	Low
RwB2 Russell	0-10	0.6-2.0	0.21-0.24	5.6-7.3	Low
	10-22	0.6-2.0	0.18-0.20	4.5-6.0	Moderate
	22-36	0.6-2.0	0.15-0.19	5.6-7.3	Moderate
	36-60	0.2-0.6	0.05-0.19	7.4-8.4	Low
Ra Ragsdale	0-12	0.6-2.0	0.21-0.23	6.1-7.3	Moderate
	12-50	0.06-0.2	0.18-0.20	6.1-7.3	Moderate
	50-72	0.06-0.2	0.20-0.22	6.6-8.4	Low

TABLE 3-4 (continued)

Soil Name and Map Symbol	Depth In	Permeability In/Hr	Available Water Capacity In/In	Soil Reaction pH	Shrink Swell Potential
RdA, RdB	0-15	0.6-2.0	0.22-0.24	5.6-7.3	Low
Raub	15-37	0.06-0.2	0.18-0.20	5.1-6.5	Moderate
	37-43	0.06-0.2	0.15-0.19	6.1-7.3	Moderate
	43-60	0.06-0.6	0.05-0.19	7.4-8.4	Low
UnA, Unb	0-10	0.6-2.0	0.19-0.33	5.1-7.3	Low
Uniontown	10-49	0.6-2.0	0.18-0.22	5.1-7.8	Low
	49-66	0.2-2.0	0.18-0.22	6.6-8.4	Low
XeA, XeB, XeB2	0-10	0.6-2.0	0.22-0.24	6.6-7.3	Low
Xenia	10-31	0.2-0.6	0.18-0.20	5.1-6.0	Moderate
	31-72	0.2-2.0	0.05-0.19	7.9-8.4	Low
XfA, XfB, XfB2	0-8	0.6-2.0	0.22-0.24	6.6-7.3	Low
Xenia	8-26	0.2-0.6	0.18-0.20	5.1-6.0	Moderate
	26-42	0.2-0.6	0.15-0.19	5.1-7.3	Moderate
	42-59	0.2-0.6	0.04-0.08	7.9-8.4	Moderate
	59	NA	NA	NA	NA

[a] Data not available.

Source: 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.

TABLE 3-5

PHYSICAL AND CHEMICAL PROPERTIES OF THE HAMILTON COUNTY SOILS ON THE FEMP

Soil Name and Map Symbol	Depth (In)	Moist Bulk Density (g/cm^3)	Permeability (In/Hr)	Available Water Capacity (In/In)	Shrink-Swell Potential
EpA, EpB2, EpC2	0-7	1.30-1.50	0.6-2.0	0.18-0.22	Low
Eldean	7-36	1.40-1.60	0.2-2.0	0.08-0.14	Moderate
	36-60	NA[a]	>6.0	0.01-0.04	Low
FdA	0-8	1.40-1.55	0.6-2.0	0.22-0.24	Low
Fincastle	8-33	1.45-1.65	0.2-0.6	0.18-0.20	Moderate
	33-42	1.45-1.65	0.2-0.6	0.15-0.19	Moderate
	42-70	1.55-1.90	0.06-0.2	0.05-0.19	Low
FeA	0-8	1.40-1.55	0.6-2.0	0.22-0.24	Low
Fincastle	8-33	1.45-1.65	0.2-0.6	0.18-0.20	Moderate
	33-42	1.45-1.65	0.2-0.6	0.15-0.19	Moderate
	42-70	1.55-1.90	0.06-0.2	0.05-0.19	Low
Gn	0-9	1.30-1.50	0.6-2.0	0.20-0.24	Low
Genesee	9-35	1.30-1.50	0.6-2.0	0.17-0.22	Low
	35-60	1.30-1.50	0.6-2.0	0.19-0.21	Low
HeF	0-2	1.20-1.40	0.6-2.0	0.18-0.24	Low
Hennepin	1-12	1.30-1.60	0.2-2.0	0.14-0.22	Low
	12-60	1.45-1.70	0.06-0.6	0.07-0.11	Low
HoA	0-8	1.20-1.40	0.6-2.0	0.18-0.23	Low
Henshaw	8-44	1.20-1.40	0.2-0.6	0.15-0.19	Low
	44-66	1.20-1.40	0.2-0.6	0.17-0.22	Low
MaB, MaC2,	0-10	1.35-1.50	0.2-0.6	0.18-0.23	Moderate
MaD2, MaE2	10-33	1.55-1.70	0.06-0.2	0.11-0.13	High
Markland	33-60	1.55-1.70	0.06-0.2	0.09-0.11	High
McA, McB	0-9	1.30-1.45	0.6-2.0	0.20-0.24	Low
Martinsville	9-34	1.40-1.60	0.6-2.0	0.17-0.20	Moderate
	34-44	1.40-1.60	0.6-2.0	0.12-0.14	Low
	44-60	1.50-1.70	0.6-2.0	0.19-0.21	Low

TABLE 3-5 (continued)

Soil Name and Map Symbol	Depth (In)	Moist Bulk Density (g/cm^3)	Permeability (In/Hr)	Available Water Capacity (In/In)	Shrink-Swell Potential
MoD2, MoE2, Miamiam	0-6	1.30-1.50	0.6-2.0	0.17-0.20	Low
	6-24	1.45-1.70	0.2-0.6	0.12-0.18	Moderate
	24-60	1.60-1.82	0.2-0.6	0.06-0.10	Low
RwB2 Russell	0-7	1.30-1.45	0.6-2.0	0.21-0.24	Low
	7-22	1.40-1.60	0.6-2.0	0.18-0.20	Moderate
	22-43	1.40-1.60	0.6-2.0	0.15-0.19	Moderate
	43-72	1.60-1.80	0.6-2.0	0.05-0.19	Low
XfA, XfB2 Xenia	0-9	1.40-1.55	0.6-2.0	0.22-0.24	Low
	9-26	1.45-1.65	0.2-0.6	0.18-0.20	Moderate
	26-46	1.45-1.65	0.2-0.6	0.15-0.19	Moderate
	46-72	1.55-1.90	0.2-2.0	0.05-0.19	Low

[a] Data not available.

Source: 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 Hamilton County, Ohio," USDA, ODNR and Ohio Agricultural Research and Development Center, n.p.

The Butler County and Hamilton County Soil Surveys (USDA 1980, 1982) have 15 specific soil series or types mapped within FEMP boundaries, (Figure 3-14 and Table 3-6). 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 soils on broad flats. Permeability is low and the available water capacity is high. The seasonal high perched water table is commonly found between 1 and 3 feet below the ground surface from January to April. In areas where these soils are predominant, artificial drainage is required for moderate crop productivity. These soils are associated with the former production area and with the pastures to the east and west of the facility. 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.

The remaining soil series occurring within the FEMP are Dana, Eden, Fox, Genesee, Hennepin, Henshaw, Markland, Martinsville, Miamian, Ragsdale, Raub, Russell, and Uniontown.

3.1.5 Population and Land Use

The FEMP is located approximately 18 miles northwest of Cincinnati, the focal point of a regional market encompassing the following eight counties in Ohio, Kentucky, and Indiana: Hamilton, Butler, Clermont, and Warren counties in Ohio; Boone, Campbell, and Kenton counties in Kentucky; and Dearborn County, Indiana. These eight counties also define the Cincinnati Consolidated Metropolitan Statistical Area. Population within the eight-county metropolitan area was over 1.7 million in 1990; within a five-mile radius of the FEMP, there were an estimated 22,927 residents. Labor force in the multi-county area was over 920,000 with unemployment at approximately 5.5 percent in December of 1991.

The land adjacent to the FEMP is primarily devoted to open land use such as agriculture and recreation (Figure 3-15). Commercial activity is generally restricted to the village of Venice (Ross), approximately 3 miles northeast of the facility, and along State Route 128 just south of the village. Industrial use is concentrated in the areas south of the FEMP, along Paddys Run Road, in Fernald, and in a small industrial park on State Route 128 between Willey Road and New Haven Road. Concentrations of residential units are situated (1) immediately north of the FEMP, (2) in Ross, and (3) directly east in a trailer park adjacent to the intersection of Willey Road and State Route 128. Other residences are scattered around the area, generally associated with farmsteads. Camp Ross Trails, owned by the Great Rivers Girl Scout Council, is located within one mile to the northeast of the FEMP. Over 400 acres of the open land on the FEMP are currently being leased for grazing purposes to local dairymen. Pine plantations are located to the northeast and southwest of the former produc-

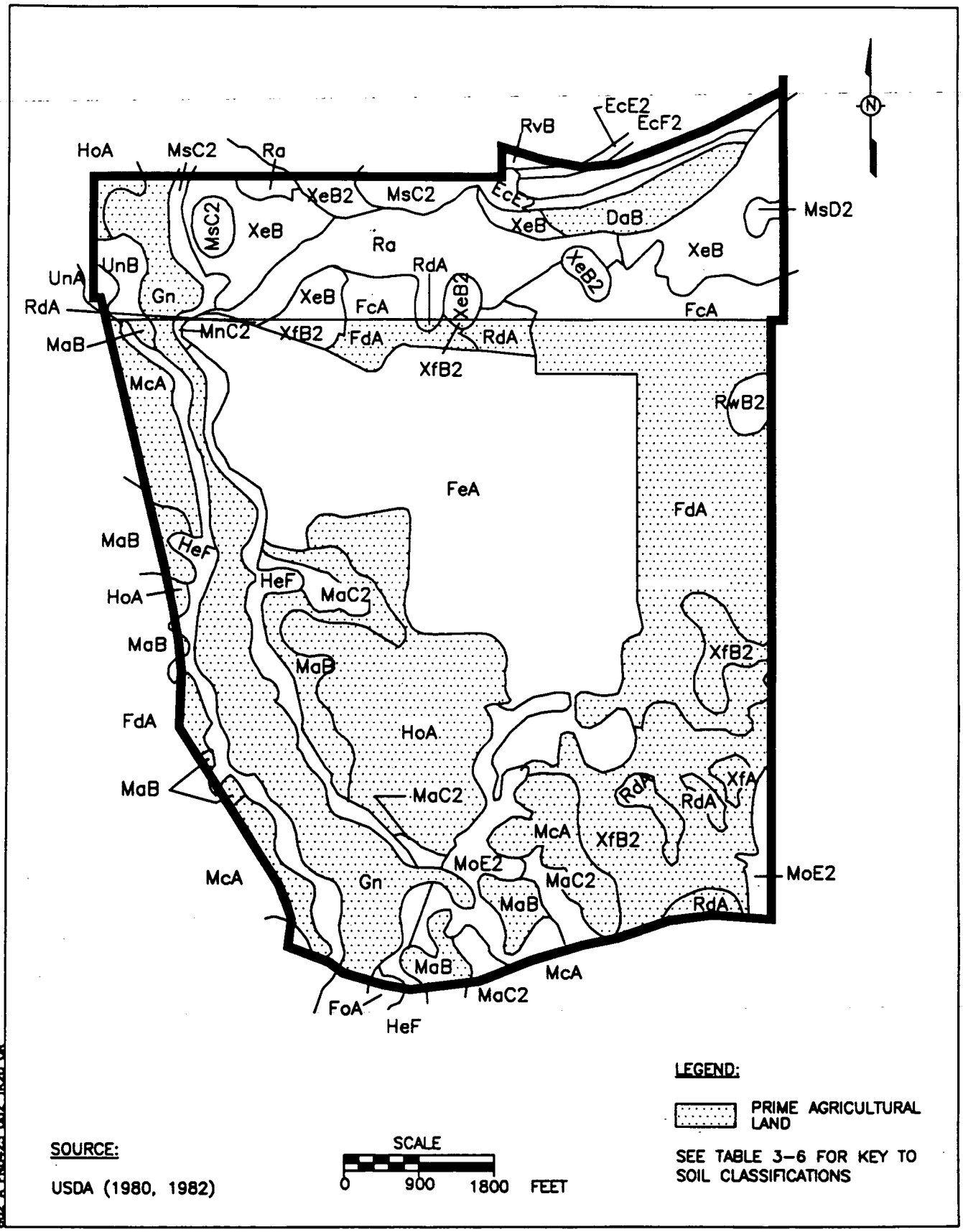

FIGURE 3-14. SOIL CLASSIFICATIONS AND PRIME AGRICULTURAL LAND AT THE FEMP

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TABLE 3-6

DRAINAGE CLASSIFICATIONS FOR SOILS AT THE FEMP

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	Genesee 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	Miamiam-Russell silt loams	2-6	Well drained
MsD2	Miamiam-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

SOURCE: 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.

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, 1982, "Soil Survey of Hamilton County, Ohio," USDA, ODNR and Ohio Agricultural Research and Development Center, n.p.

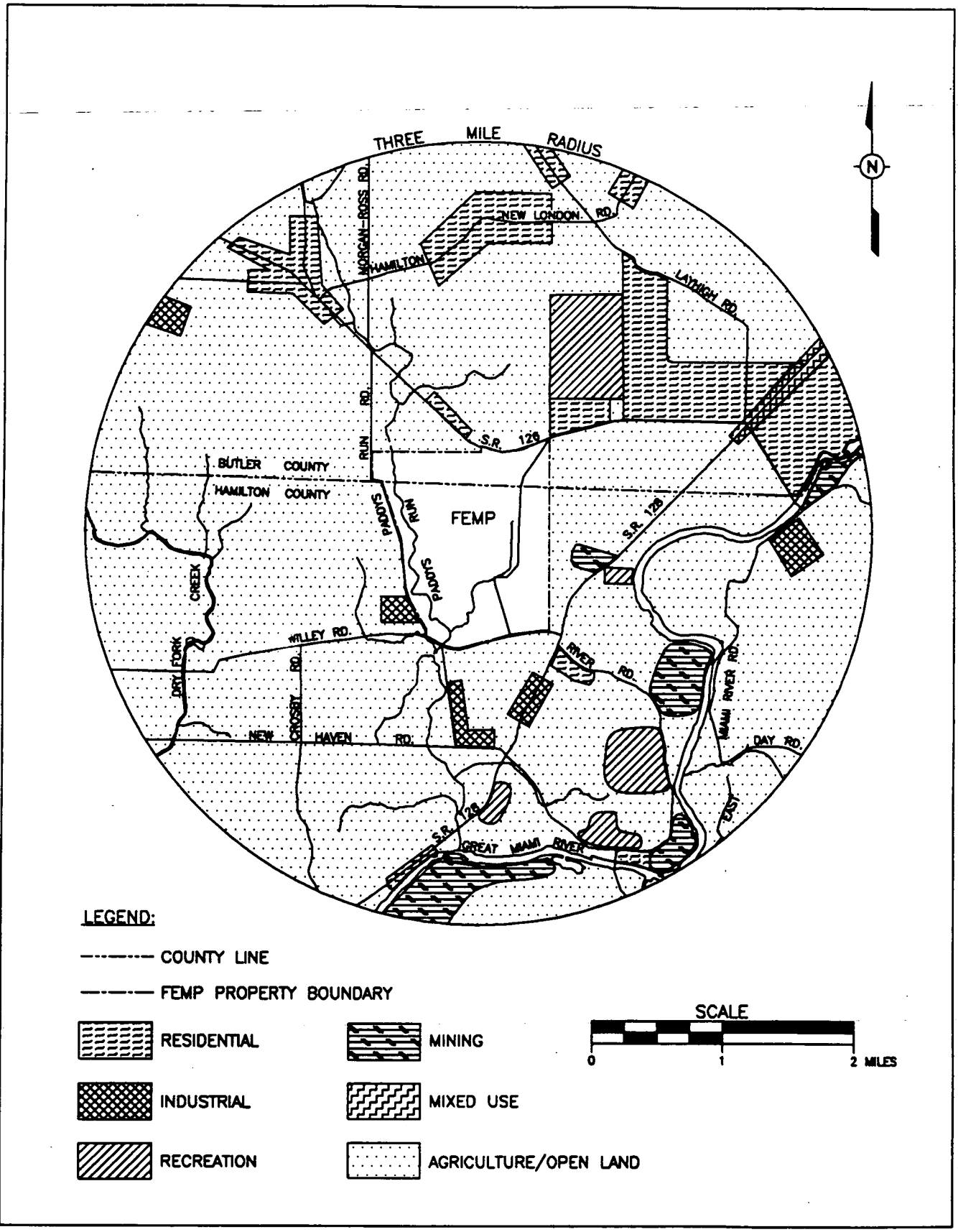

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FIGURE 3-15. LAND USE ADJACENT TO THE FEMP

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tion area. A considerable amount of the soil within the boundaries of the FEMP are designated by the USDA as prime agricultural land (USDA 1980, 1982).

The area surrounding the FEMP has a large and diverse archaeological and historic 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 the vicinity of the FEMP (a two-mile radius from the 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 five miles of the FEMP, five of which are included in the NRHP.

The Ohio State Historic Preservation Officer (SHPO) has stated that remedial activity within the boundaries of the FEMP will not adversely affect any properties listed on or eligible for the NRHP (Luce 1987). Because, however, there is potential for the discovery of cultural resources in the area, the SHPO has requested that an archaeological survey be performed in any areas beyond the boundaries of the FEMP, specifically including the recovery well area associated with the South Plume removal action, prior to any drilling or other intrusive activity (Kitchen 1990). A formalized agreement is currently being negotiated between DOE and the SHPO on a finding of no significant impact to historic properties as a result of removal actions (Ball 1991).

3.1.6 Ecology

This section describes the regional ecology, the aquatic and terrestrial habitats, and the wetlands at the FEMP.

3.1.6.1 Regional Ecology

The FEMP and surrounding areas lie in a transition zone between two distinct sections of the Eastern Deciduous Forest Province, as described by Bailey (1978)—the Oak-Hickory and the Beech-Maple (Figure 3-16). The region is characterized by the presence of a mosaic of these forest types. The Oak-Hickory and Beech-Maple forest sections share many characteristics, including similar fauna and the presence of white oak as a common species. The Beech-Maple section covers northern Ohio, Indiana, and lower Michigan. It is bordered by Oak-Hickory to the southwest, Mixed Mesophytic to the southeast, and Appalachian Oak to the east. Beech-Maple forests are typically dominated by beech trees in the canopy, the uppermost layer of the forest, with sugar maples dominant in the understory, below the canopy. The Oak-Hickory section covers southwest Ohio, western Kentucky and Tennessee, and parts of Indiana, Illinois, Missouri, and Arkansas. The dominant species are oaks, with an abundance of hickories. The fauna vary little between the two forest sections and include white-tailed deer, gray fox, gray squirrel, white-footed mouse, and short-tailed shrew; the cardinal, woodthrush, summer tanager, red-eyed vireo, and the hooded warbler; the box turtle, common garter snake, and timber rattlesnake (Bailey 1978; Shelford 1963).

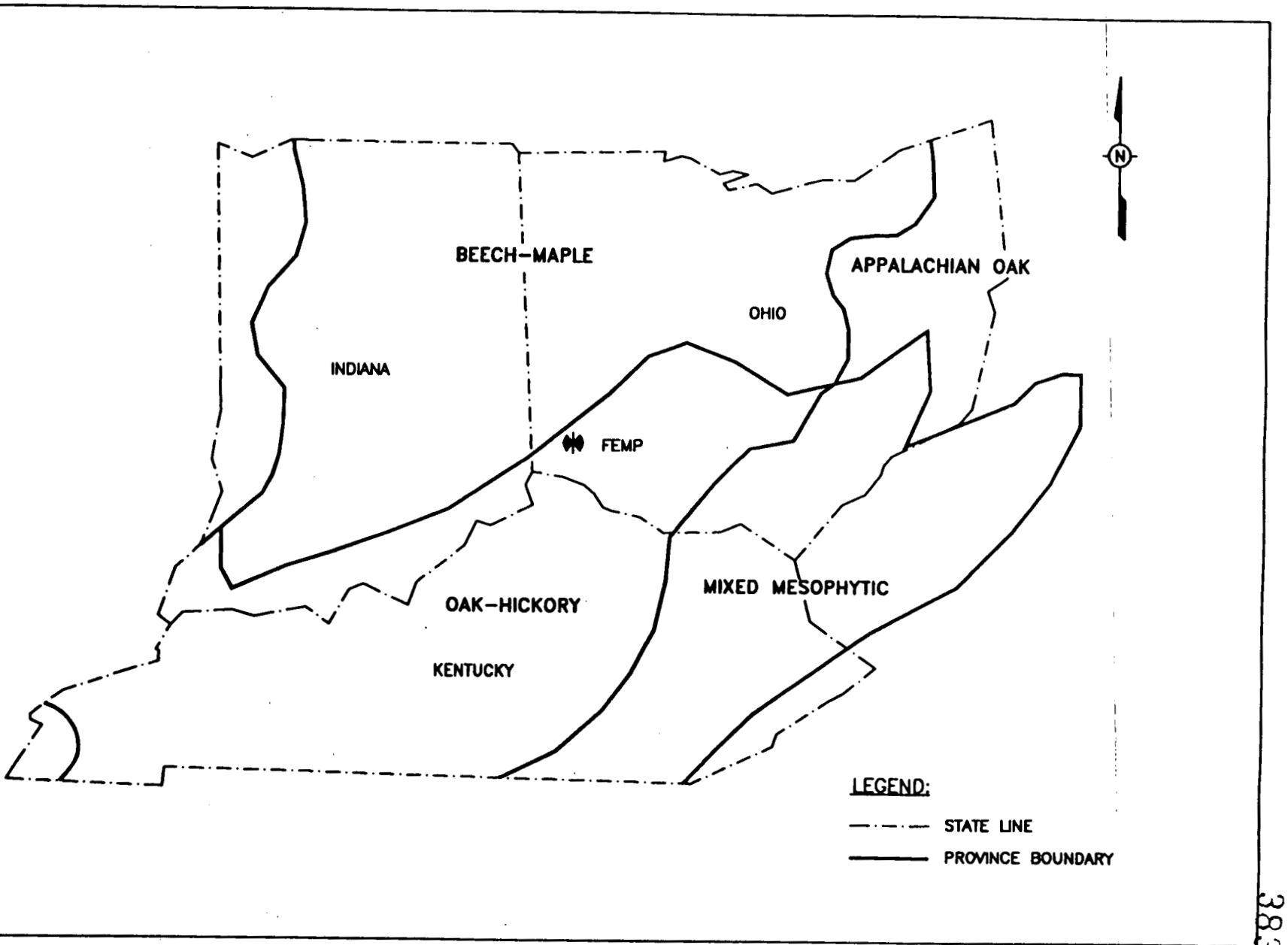

FIGURE 3-16. SECTIONS OF THE EASTERN DECIDUOUS FOREST PROVINCE IN THE REGION OF THE FEMP

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3.1.6.2 Ecological Communities on the FEMP

Ecological communities on the FEMP consist of grazed and ungrazed pastures, two pine plantations, deciduous woodlands, riparian woodlands, and the reclaimed flyash pile area (Figure 3-17). (The reclaimed flyash pile area coincides approximately with the South Field and the Inactive Flyash Pile, and it was considered a distinct habitat by Facemire et al. (1990) due to the unique plant and animal species composition.) A total of 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 macro-invertebrates, and 132 families of terrestrial invertebrates inhabit the FEMP.

Typical grasses found on the FEMP are red fescue, Kentucky bluegrass, timothy, and red top. Herbs include teasel, red and white clovers, and goldenrod. The dominant tree species in the pine plantations are white and Austrian pine, with Norway spruce occurring occasionally. Common trees in the deciduous woodlands are white ash, American elm, shagbark hickory, and slippery elm. Dominant tree species in the riparian woodlands are eastern cottonwood, hackberry, American elm, and box elder. The reclaimed flyash pile is dominated by American elm, eastern cottonwood, and black locust.

Mammal species observed on the FEMP include white-tailed deer, coyote, red fox, opossum, raccoon, groundhog, eastern cottontail, fox squirrel, and several species of bats. Common small mammals are the white-footed mouse, short-tailed shrew, meadow vole, meadow jumping mouse, and eastern chipmunk.

The most common birds breeding on site include the mourning dove, American robin, blue jay, American crow, American goldfinch, northern bobwhite, and common grackle. Species occurring in the greatest density are the goldfinch, song sparrow, and robin. Raptor species observed on site are the northern harrier, red-shouldered hawk, Cooper's hawk, red-tailed hawk, and American kestrel. The eastern screech owl and great horned owl are also common.

Amphibians and reptiles that occur on the FEMP include the American toad, spring peeper, eastern box turtle, and snapping turtle. Several species of snakes also occur on site, including the eastern garter snake, Butler's garter snake, black rat snake, northern water snake, and the queen snake.

Approximately 130 insect families from 15 orders are represented in FEMP habitats. Leaf hoppers are abundant in all habitats, while less abundant groups include short-horned grasshoppers, leaf beetles, springtails, fruit flies, dark-winged fungus gnats, ants, bees, and wasps.

3.1.6.3 Floodplains and Wetlands

Floodplains within the FEMP property are confined to the north-south corridor containing Paddys Run (Figure 3-18) 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 (Figure 3-18). The 100-year floodplain of the river also extends northward along Paddys Run from the confluence of the two streams to a point about 2000 feet from the southern boundary of the FEMP. This area overlaps

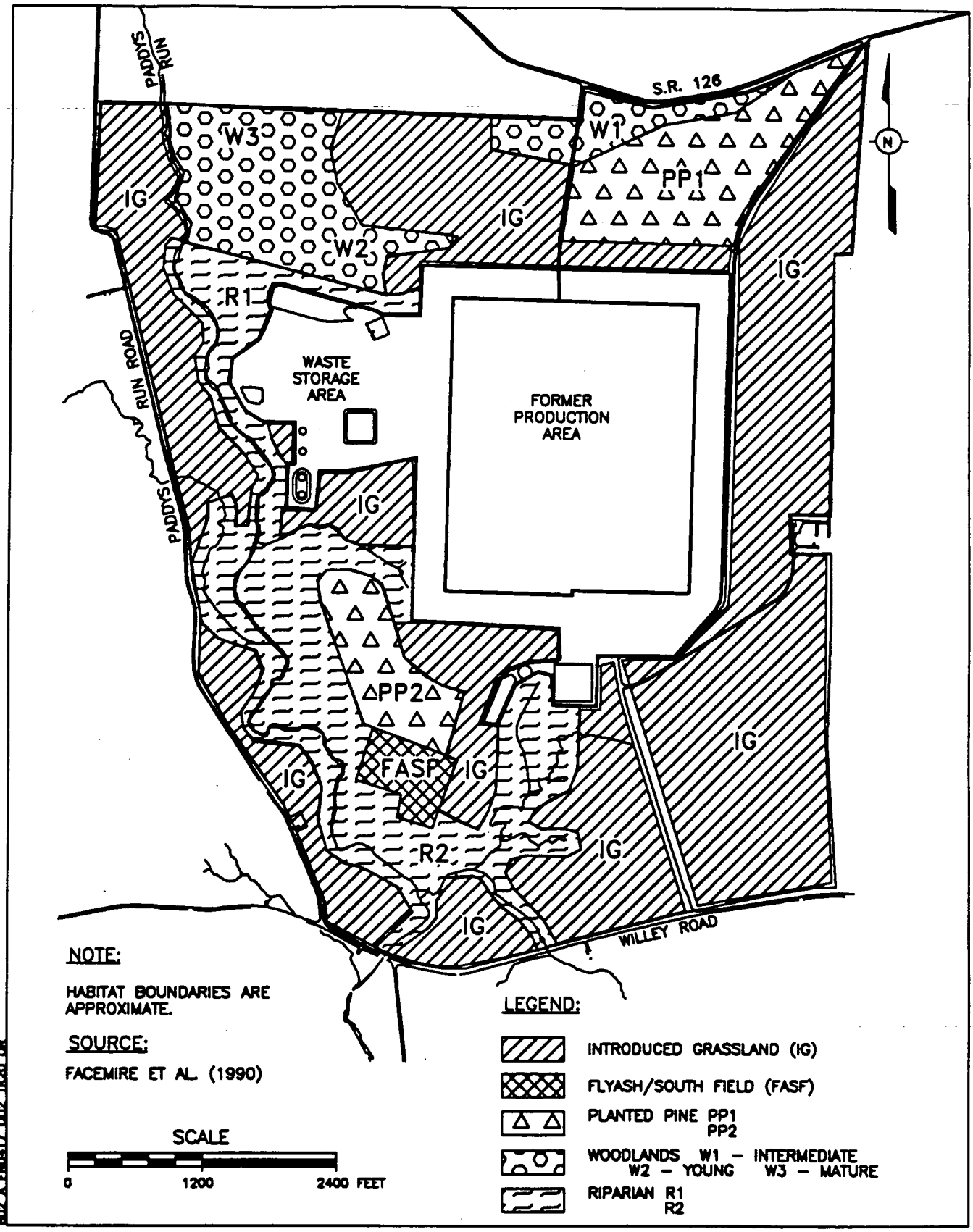

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FIGURE 3–17. HABITAT TYPES PRESENT ON THE FEMP

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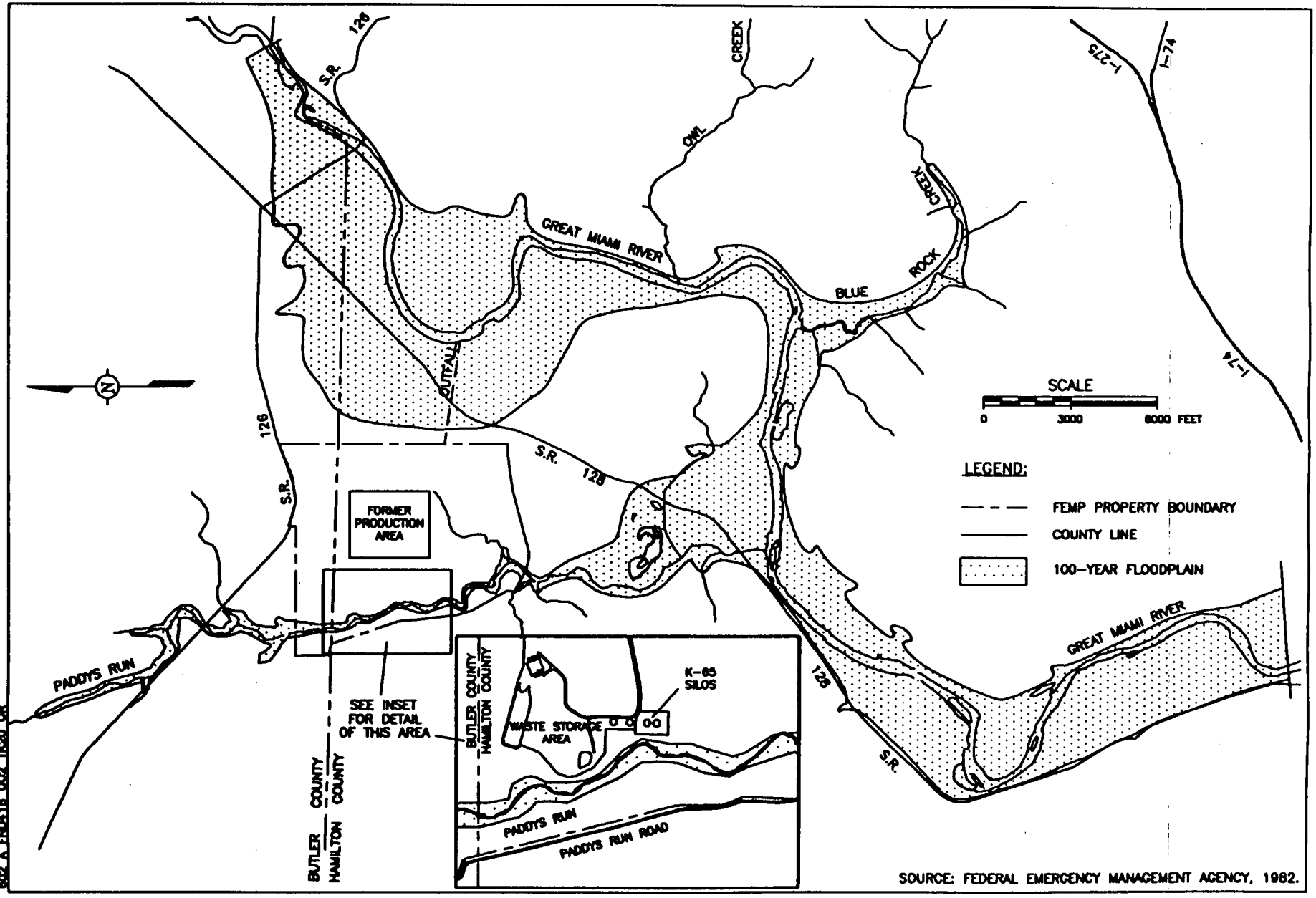

FIGURE 3-18. GREAT MIAMI RIVER AND PADDYS RUN 100-YEAR FLOODPLAIN

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the South Plume, a body of uranium-contaminated groundwater, which is a component of Operable Unit 5.

Identification and delineation of jurisdictional wetlands within the FEMP boundaries were necessary so that remedial activities could meet the requirements of federal and state wetlands regulations (FICWD 1989). Jurisdictional wetlands are identified by the presence of hydric soils (a seasonal high water table within 6 inches of the surface for at least one week during the growing season and typically depleted of oxygen as a result), hydrophytic vegetation (able to grow in water or in soils at least periodically depleted of oxygen due to water saturation), and wetlands hydrology (permanent or periodic inundation or soil saturation for a week or more during the growing season).

The results of a survey indicated that wetlands at the FEMP are limited to a forested wetland of approximately 50 acres in the northern portion of the facility and emergent wetlands associated with tributaries and drainage ditches that feed into Paddys Run (Figure 3-19)(DOE 1992b). Remedial actions affecting these areas would be subject to the substantive requirements of laws, regulations, and orders concerned with wetlands protection. Paddys Run and the remainder of its tributaries, including the storm sewer outfall ditch, 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 wetlands regulations, but remedial actions affecting them would still be subject to the substantive requirements of the Clean Water Act.

3.1.6.4 Threatened and Endangered Species

No federally listed threatened or endangered species have been observed on the FEMP or in its immediate vicinity. One species of mammal, the Indiana bat, is listed as federally endangered and occurs in Butler and Hamilton counties. A breeding population was found on Banklick Creek, a tributary to the Great Miami River, near Ross (Figure 3-20). Although suitable habitat for the Indiana bat occurs along Paddys Run, none were found there (DOE 1992b).

Ohio populations of the cave salamander, an amphibian species recognized as state endangered, are limited to Butler, Hamilton, and Adams counties (ODNR 1974). The cave salamander was not found within FEMP boundaries, but individuals were found near New London Road north of the FEMP and within the boundaries of the Camp Ross Trails northeast of the FEMP (Figure 3-21).

The northern harrier is listed as state endangered (ODNR, DOW Order 1501:31-23-01) and has been observed flying over the pasture of the FEMP areas (Facemire et al. 1990). Another raptor, the red-shouldered hawk, has been observed in the deciduous woodlands north of the production area. This species is listed as a species of special concern by ODNR (ODNR 1982).

Risks to ecological receptors at the FEMP are assessed in the SWCR and will be further discussed in the Operable Unit 5 RI.

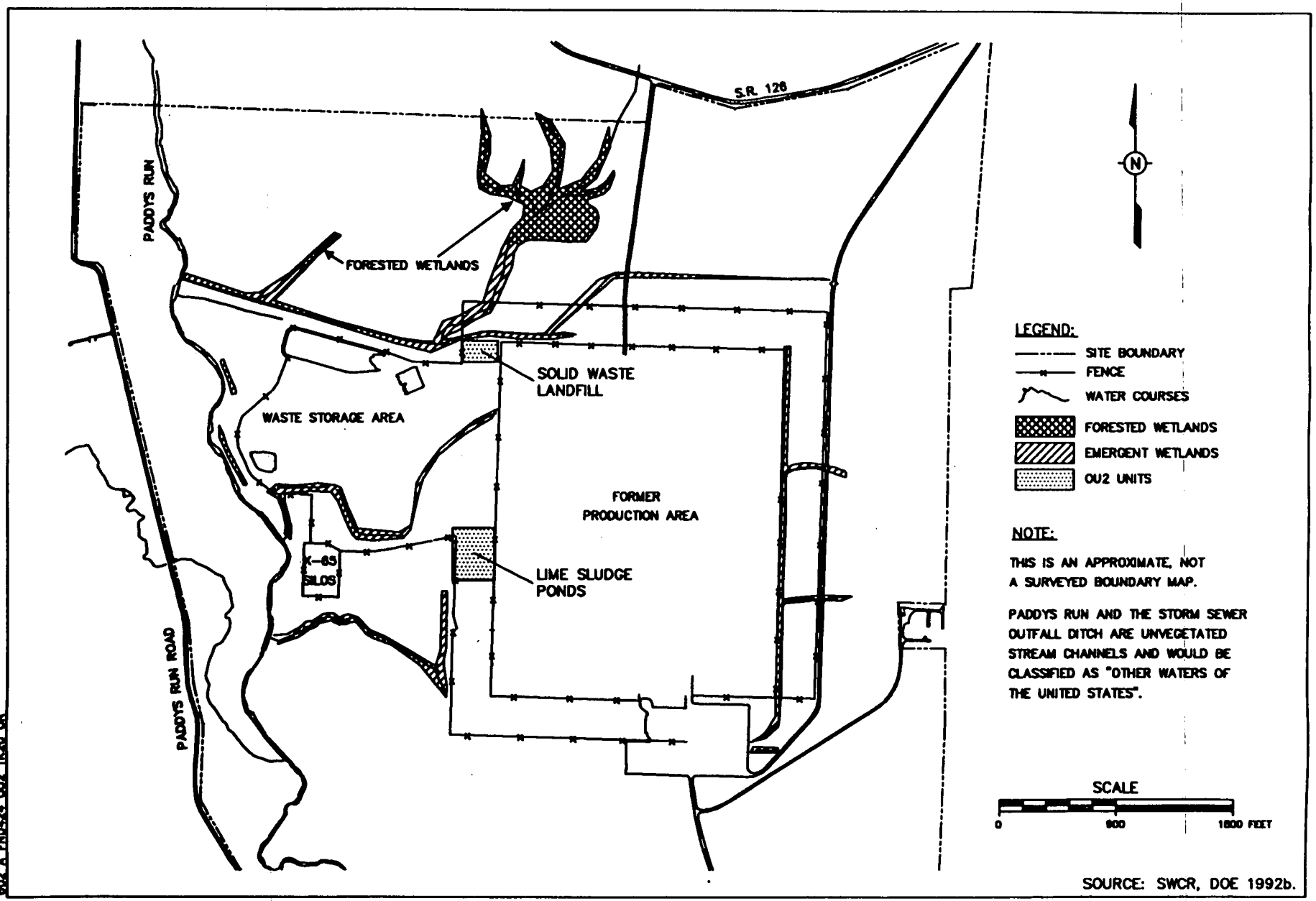

FIGURE 3-19. APPROXIMATE BOUNDARIES OF JURISDICTIONAL WETLANDS AT THE FEMP

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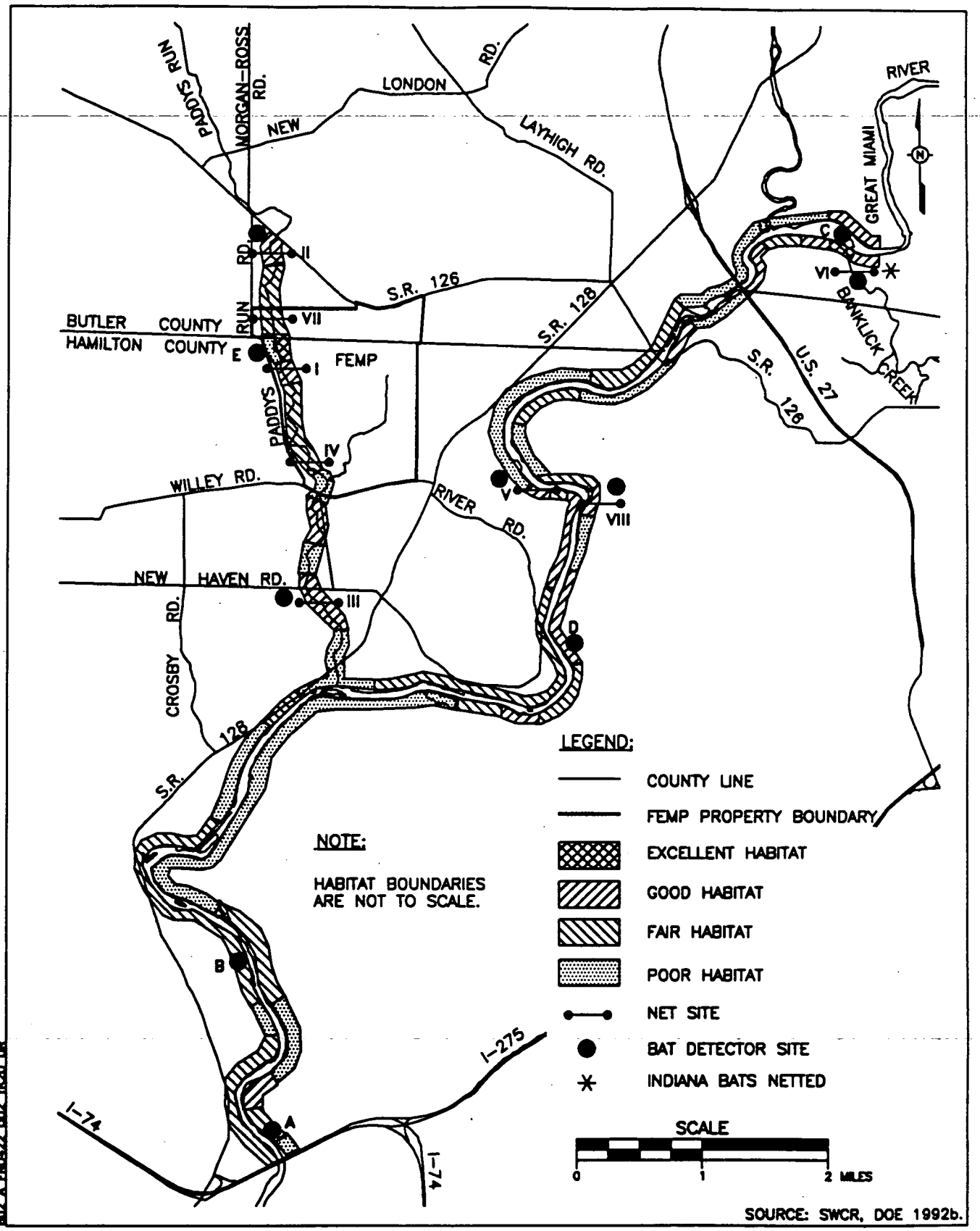

FIGURE 3-20. INDIANA BAT SAMPLING SITES AND HABITAT EVALUATION AT THE FEMP AND VICINITY

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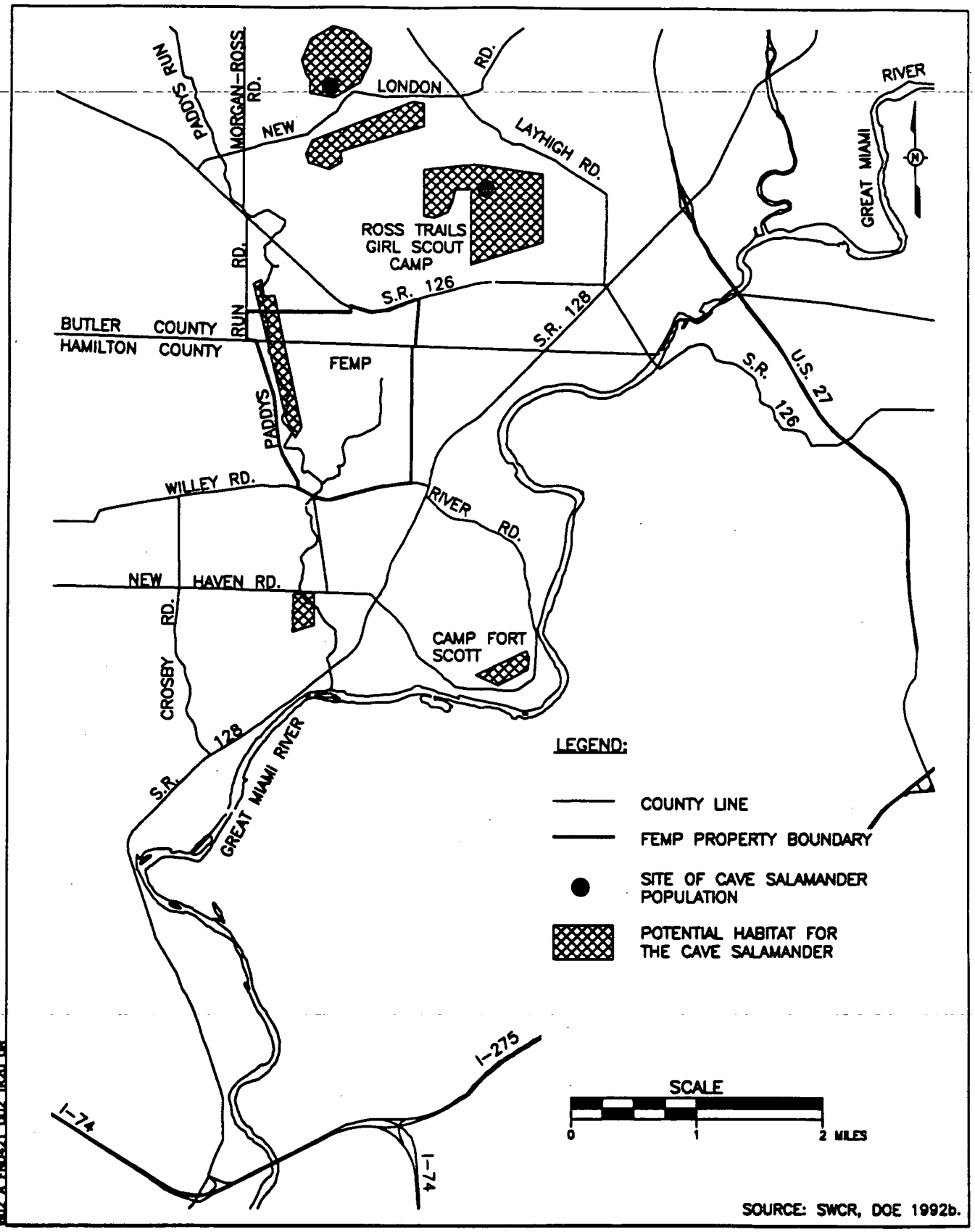

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FIGURE 3-21. POPULATION LOCATIONS AND POTENTIAL HABITAT FOR THE CAVE SALAMANDER IN THE VICINITY OF THE FEMP

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3.2 SOLID WASTE LANDFILL

Against the background of the site-wide physical characteristics discussed in Section 3.1, this section provides a discussion of the physical characteristics of the Solid Waste Landfill.

3.2.1 Topography and Surface Water

Surface drainage at the Solid Waste Landfill has been controlled by recontouring the area so that surface water flows to a naturally occurring intermittent stream channel passing westward along the northern portion of the landfill (Figure 3-22). The landfill forms the southern bank of the drainage channel, which eventually discharges into Paddys Run near the far western boundary of the FEMP. An evaporation pond located along the western boundary of the landfill was designed to receive storm water runoff from the landfill, which would then either evaporate or percolate into the soil. The railroad bed to the south of the landfill serves as a berm to divert any surface water runoff from the landfill into the aforementioned drainage channel. Surface drainage south of the railroad bed and outside the landfill limits has been altered by recontouring the area to allow westwardly flow toward Paddys Run.

The highest point in the landfill, with an elevation of 593 feet above MSL, is situated in its north central portion (Figure 3-22). The landfill's lowest point, excluding those located in the drainage channel, is approximately 584.5 feet above MSL and is located at the culvert crossing near the northwest boundary of the landfill. The access road on the east side of the landfill is at an elevation of approximately 590 feet above MSL.

3.2.2 Geology and Groundwater Hydrology

Subsurface borings and monitoring wells were completed in order to record the lithology of the subsurface strata, determine concentrations of various chemical constituents in groundwater, and determine groundwater elevations. Based on the lithologic descriptions presented in the boring logs (Appendix C), a general description of the strata below the landfill was determined. The groundwater within the Great Miami Aquifer is part of Operable Unit 5, and a detailed discussion of groundwater flow within the aquifer will be included in the Operable Unit 5 RI Report.

The Solid Waste Landfill was used for the disposal of noncontaminated, nonprocess wastes until 1986. The fill consists of a variety of wastes including, but not limited to, styrofoam, plastics, organic matter and interbedded local soils. Boring logs indicate that the depth of fill varies from 0 to 17 feet.

Two geological cross-sections have been prepared for the Solid Waste Landfill. Figure 3-23 shows the section lines, and Figures 3-24 and 3-25 are the cross-sections. The Solid Waste Landfill study area consists of approximately 40 feet of glacial overburden overlying the Great Miami Aquifer. The glacial overburden consists of interbedded layers of hard and stiff clay and silt with varying degrees of sand and gravel. At several locations, vertical fractures with iron staining were also noted. The

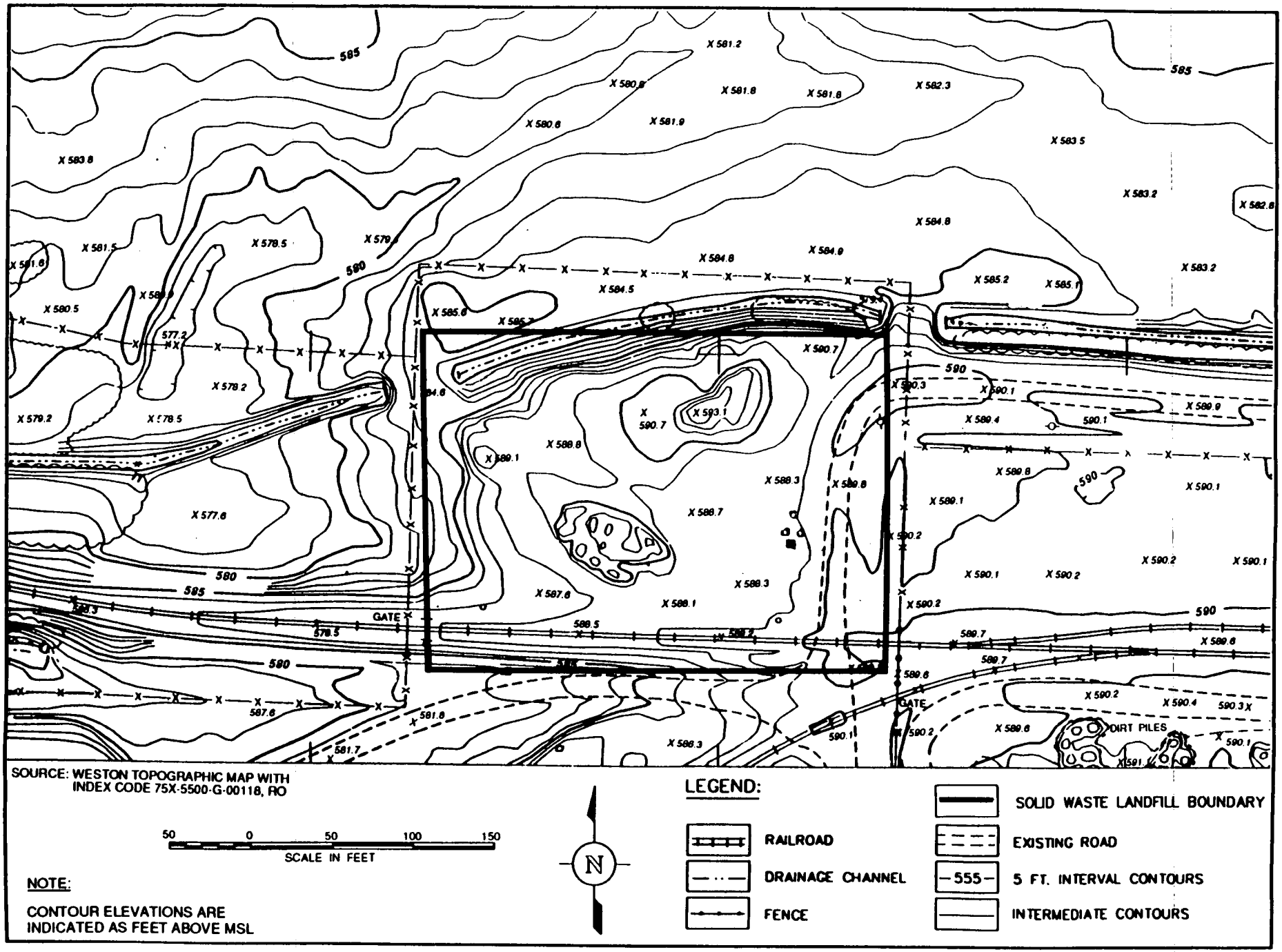
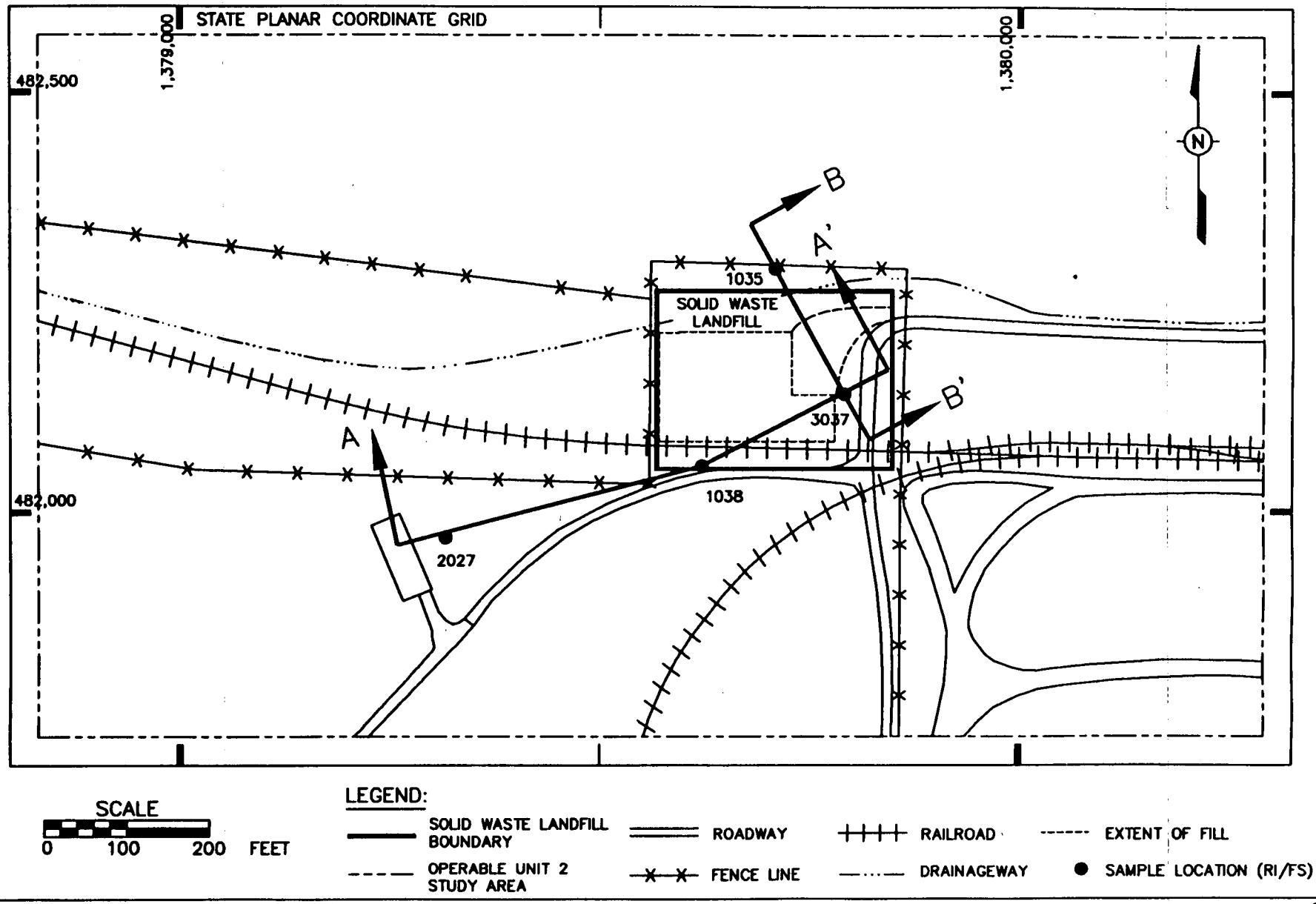


FIGURE 3-22. TOPOGRAPHY OF THE SOLID WASTE LANDFILL



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602 A FIG3-23 OU2 TIC20 OR

FIGURE 3-23. TRAVERSE FOR CROSS SECTION OF THE SOLID WASTE LANDFILL STUDY AREA

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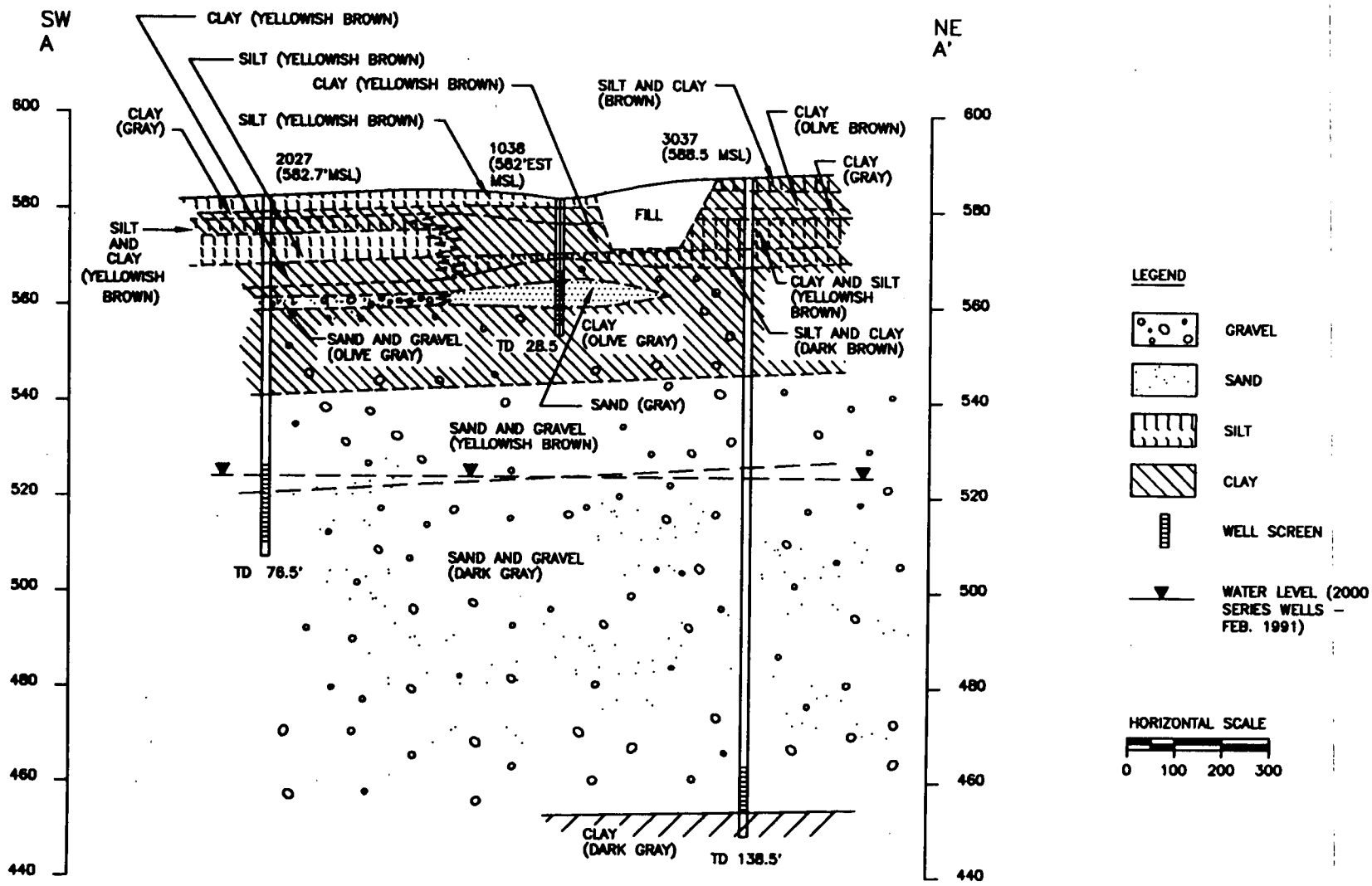

FIGURE 3-24. GEOLOGICAL CROSS SECTION A-A', SOLID WASTE LANDFILL AREA

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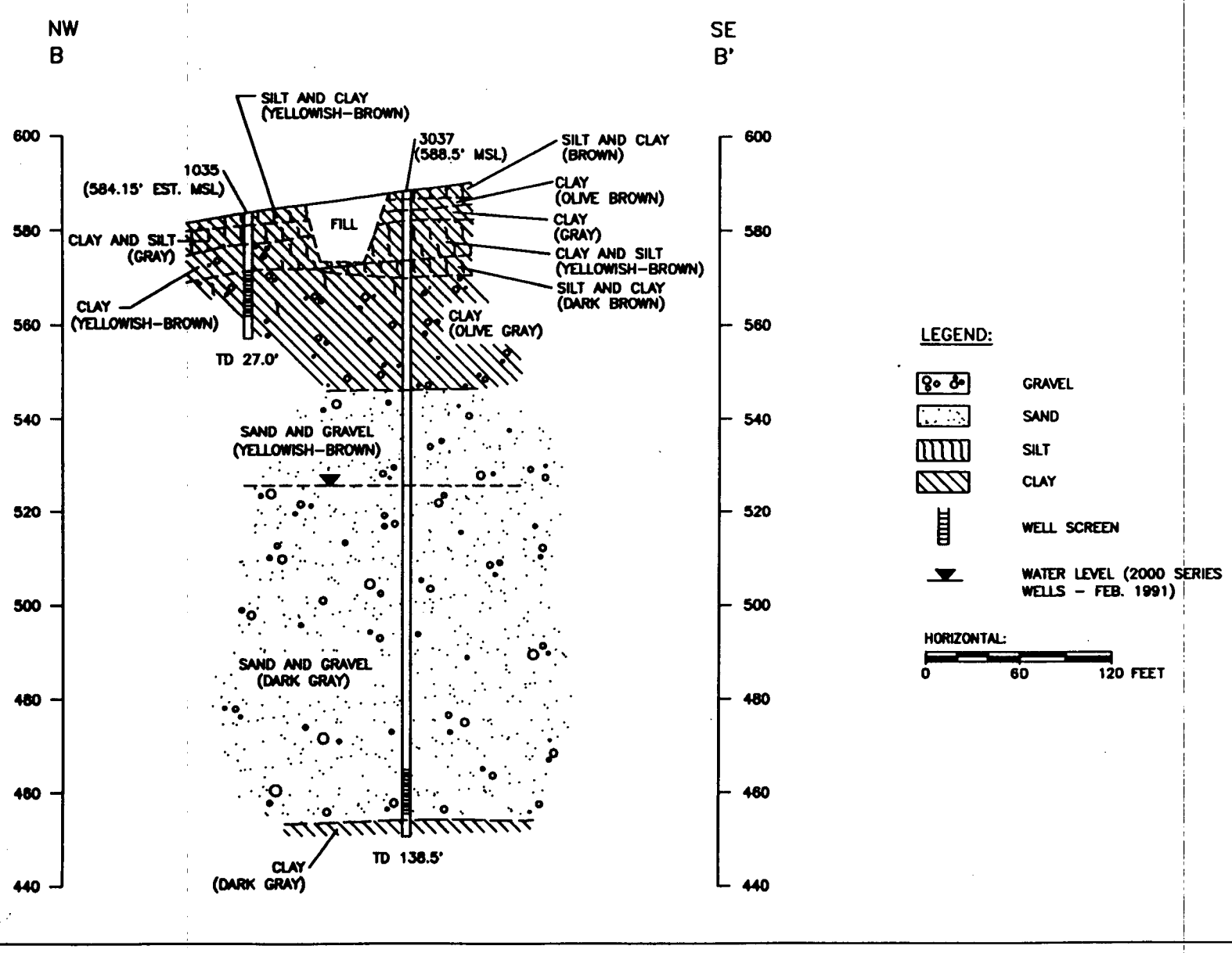

FIGURE 3-25. GEOLOGICAL CROSS SECTION B-B', SOLID WASTE LANDFILL AREA

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602 A FND588 OU2 OR

clay and silt appear as yellowish-brown layers that grade downward into a stiff gray clay. This color transition is thought to be a function of the weathering of the layers that are closer to the ground surface.

The gray clay layer varies in color from olive-gray to dark gray and consists of a very soft to very dense hard clay with some sands and gravels. The thickness of this layer ranges from greater than 15.0 feet at Boring 1038 to 24 feet at Boring 3037. Within this gray clay layer, there appear to be discontinuous lenses of wet gray sand varying in thickness between 2.5 feet at Boring 2027 and 6 feet at Boring 1038. This sand lens was not apparent in Boring 3037. This gray sand is described as a medium dense to very dense, well-graded sand of olive-gray to dark gray color with varying degrees of gravel. Traces of wood fragments were found between 25 and 27 feet below grade in Boring 1038.

A sand and gravel unit, approximately 90.0 feet thick at Boring 3037, underlies the gray clay layer. This unit, described in the boring logs as being a very dense, dark, yellowish-brown sand and gravel layer, is the water-bearing unit known as the Upper Great Miami Aquifer. The Great Miami Aquifer is separated into the Upper and Lower Great Miami Aquifers by a blue clay aquitard. The deepest boring in the area, Boring 3037, terminated a depth of approximately 135 feet in a dark gray clay, which is interpreted to be the blue clay aquitard.

Slug tests conducted in several 1000-series wells throughout the FEMP (DOE 1990) indicated an average hydraulic conductivity for the saturated deposits within the glacial overburden of 1.1×10^{-4} centimeters per second (cm/s). Monitoring Well 1035 (located immediately north of the landfill) yielded a hydraulic conductivity of 2.5×10^{-5} cm/s.

Groundwater elevation within the glacial overburden varies from approximately 550 to 580 feet above MSL. The groundwater within the overburden is in small isolated pockets of saturated materials that are discontinuous; consequently, horizontal groundwater movement is restricted and hydraulic gradients can be steep. This accounts for the difference in hydraulic head between Wells 1035 and 1037 (Figure 3-26).

Groundwater elevation data from 2000-series monitoring wells installed into the top of the Upper Great Miami Aquifer indicate an easterly flow direction with a slight hydraulic gradient. Groundwater elevation within this aquifer is approximately 520 to 525 feet above MSL (Figure 3-27). Groundwater elevation data for the bottom of the Upper Great Miami Aquifer (Well 3037) is approximately the same as the top part. Since the groundwater within the overburden materials is 30 to 60 feet higher than the regional groundwater within the top of the Upper Great Miami Aquifer and because horizontal movement of water within the overburden is limited, there is potential for water to move vertically downward within the overburden materials. Once the water reaches the Great Miami Aquifer, however, the dominant flow direction is horizontal. This is evidenced by the fact that the hydraulic head does not vary between the 2000- and 3000-series wells (i.e., with depth in the aquifer).

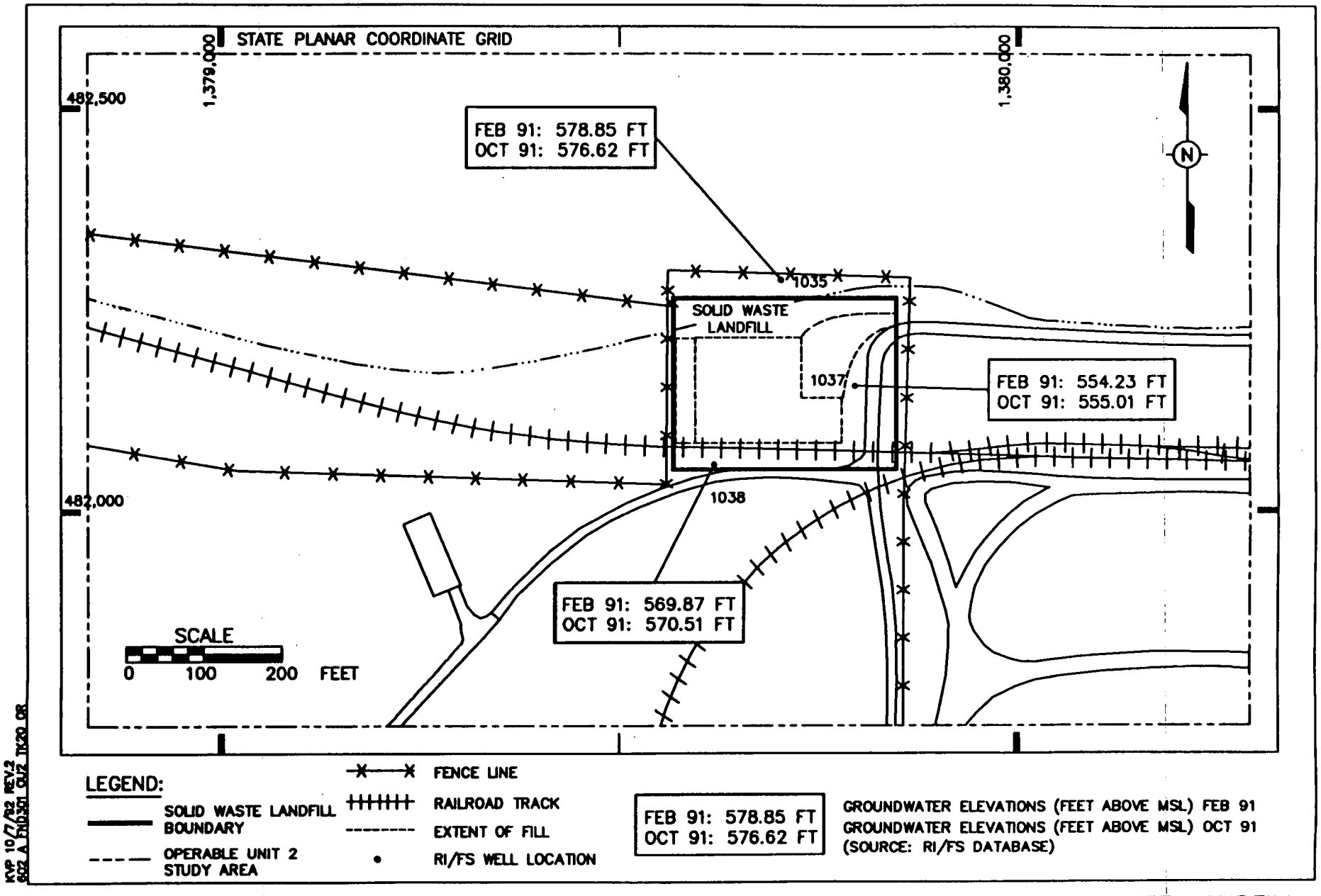

FIGURE 3-26. GROUNDWATER ELEVATIONS FOR 1000-SERIES WELLS IN THE SOLID WASTE LANDFILL STUDY AREA: 22 FEB 91 AND 06 OCT 91

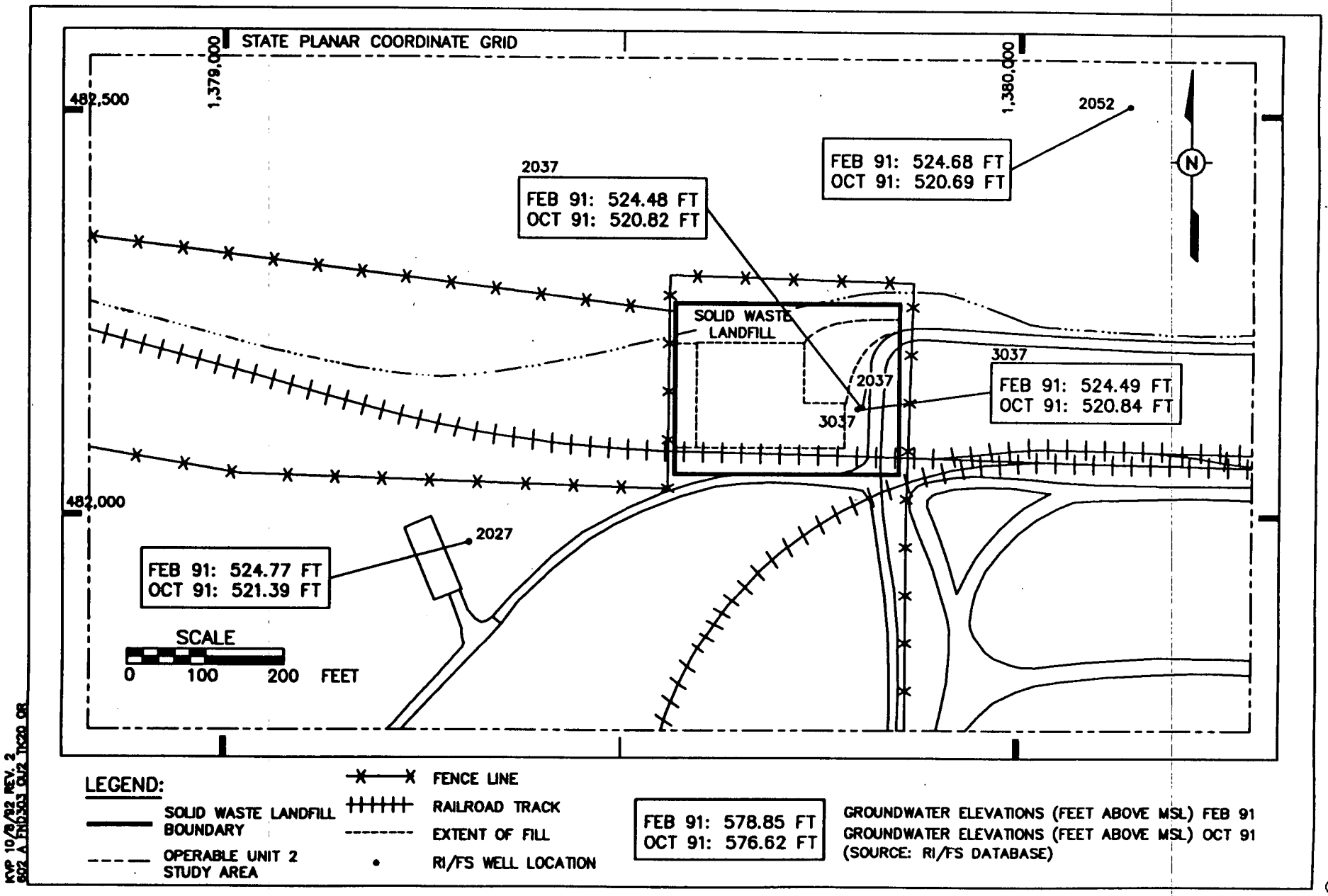

FIGURE 3-27. GROUNDWATER ELEVATIONS FOR 2000-SERIES AND 3000-SERIES WELLS IN THE SOLID WASTE LANDFILL STUDY AREA: 22 FEB 91 AND 06 OCT 91

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3.3 LIME SLUDGE PONDS

Against the background of the site-wide physical characteristics discussed in Section 3.1, this section provides a discussion of the physical characteristics of the Lime Sludge Ponds.

3.3.1 Topography and Surface Water

The Lime Sludge Ponds are located immediately west of the former production area. A north-south railway is located along the western boundary of this waste area (Figure 3-28). Access roads lie to the north and east of the waste area. A portion of the K-65 slurry line (part of Operable Unit 3) that lies in a covered, concrete trench forms the southern boundary. Generally the topography in the vicinity of the ponds slopes very gently to the west. The topography was recontoured to the west of this waste area during construction of the ponds and again during recent alterations of the waste pit area drainage (Figure 3-28).

The ponds are bermed in a manner consistent with unlined surface impoundment construction practices in the preregulatory era. Common to both ponds is a central east-west oriented berm. The berms of the South Pond exhibit elevations from a low of 580.6 feet above MSL to a high of 583.5 feet above MSL (the highest surveyed point within the Lime Sludge Ponds area). The maximum surveyed elevation of the North Pond is located on the east berm and is 579.5 feet above MSL. The North Pond remains active and filled with water. The South Pond normally contains no water, but its bottom is covered with several feet of lime sludge residue. The bottom slopes gently to the west, exhibiting an approximate 3-foot elevation drop. The South Pond has been inactive since the mid-1960s.

3.3.2 Geology and Groundwater Hydrology

Subsurface borings and monitoring wells were completed in order to record the lithology of the subsurface strata, determine concentrations of various chemical constituents in groundwater, and determine groundwater elevations. Based on the lithologic descriptions presented in the boring logs (Appendix D), a general description of the strata below the Lime Sludge Ponds was determined. The groundwater within the Great Miami Aquifer is part of Operable Unit 5, and a detailed discussion of groundwater flow within the aquifer will be included in the Operable Unit 5 Report.

Fill material in the Lime Sludge Ponds consists of residue that has settled out of the sludge. The depth of this lime sludge residue, based on boring logs, was found to vary from 3.5 to 11.5 feet. A geological cross section was prepared for the Lime Sludge Ponds; Figure 3-29 shows the section line and Figure 3-30 shows the section. The Lime Sludge Ponds study area consists of a 30- to 40-foot-thick layer of glacial overburden overlying the Great Miami Aquifer. The glacial overburden consists primarily of clay containing some sand and gravel. The clay appears as a stiff yellowish-brown clay that grades downward into a stiff gray clay, a transition thought to be a function of the weathering of the clay that is closer to the ground surface. The depth at which this transition occurs is approximately 7 feet at Borings 1039 and 2042.

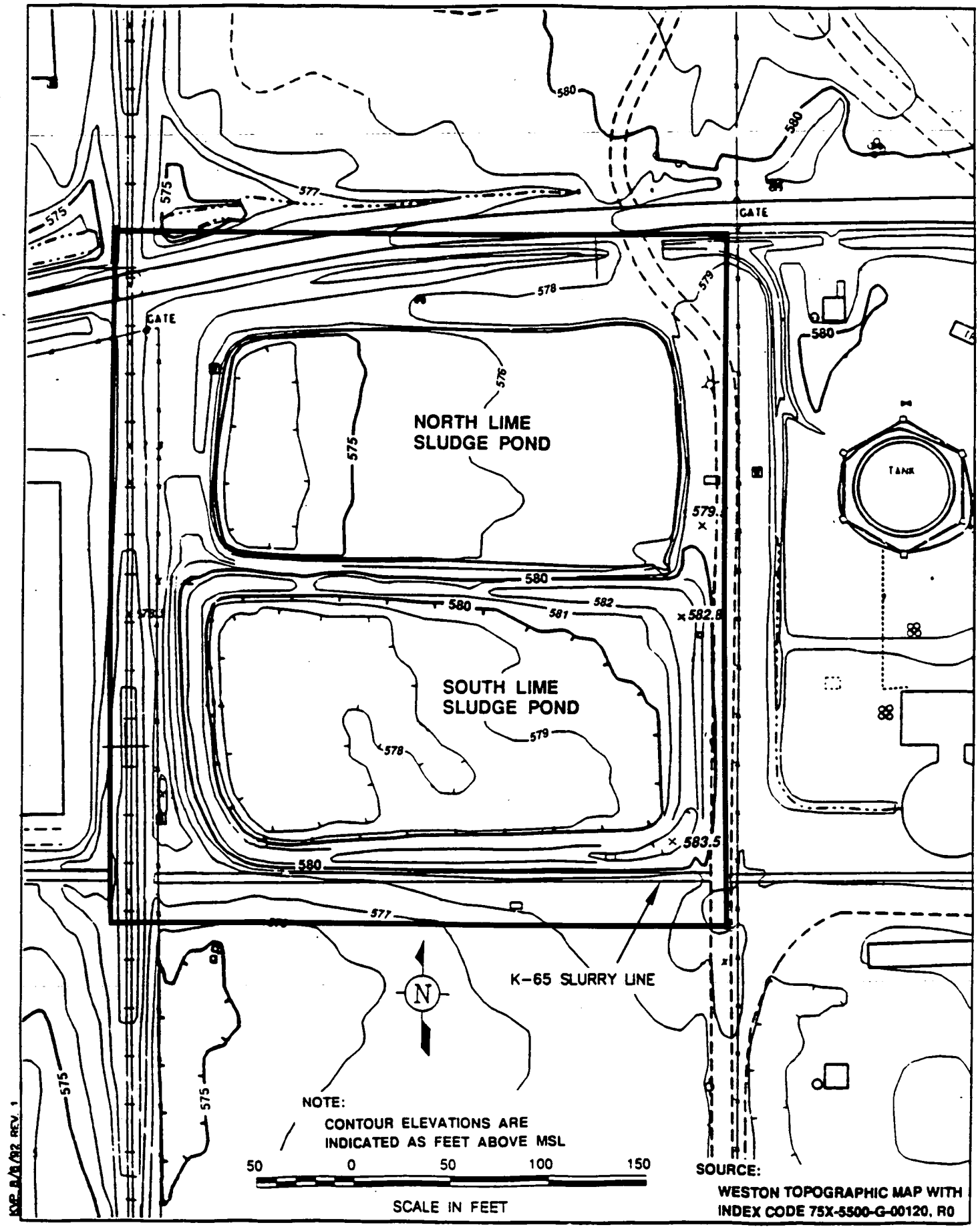


FIGURE 3-28. TOPOGRAPHY OF THE LIME SLUDGE PONDS, DEC 1988

176

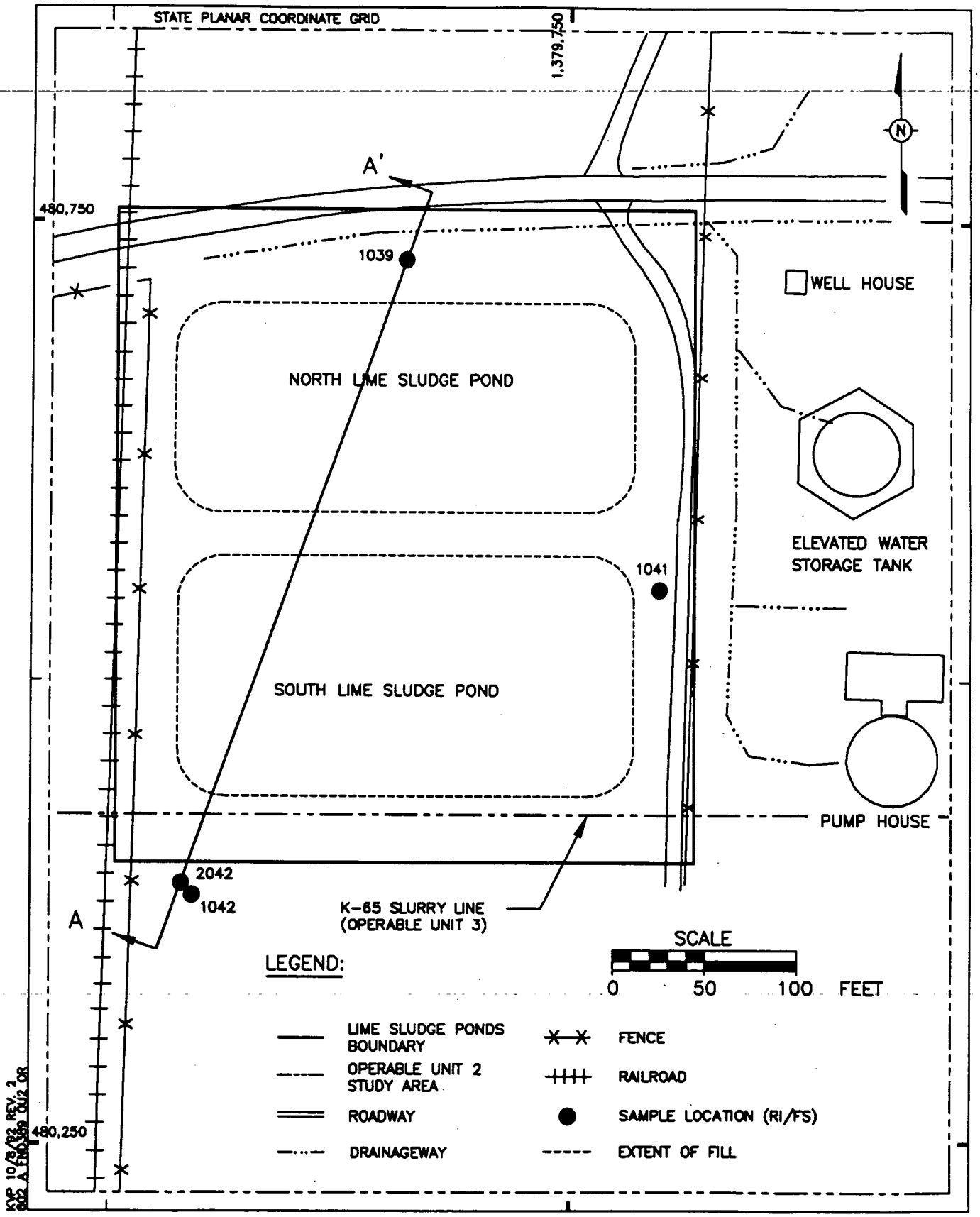
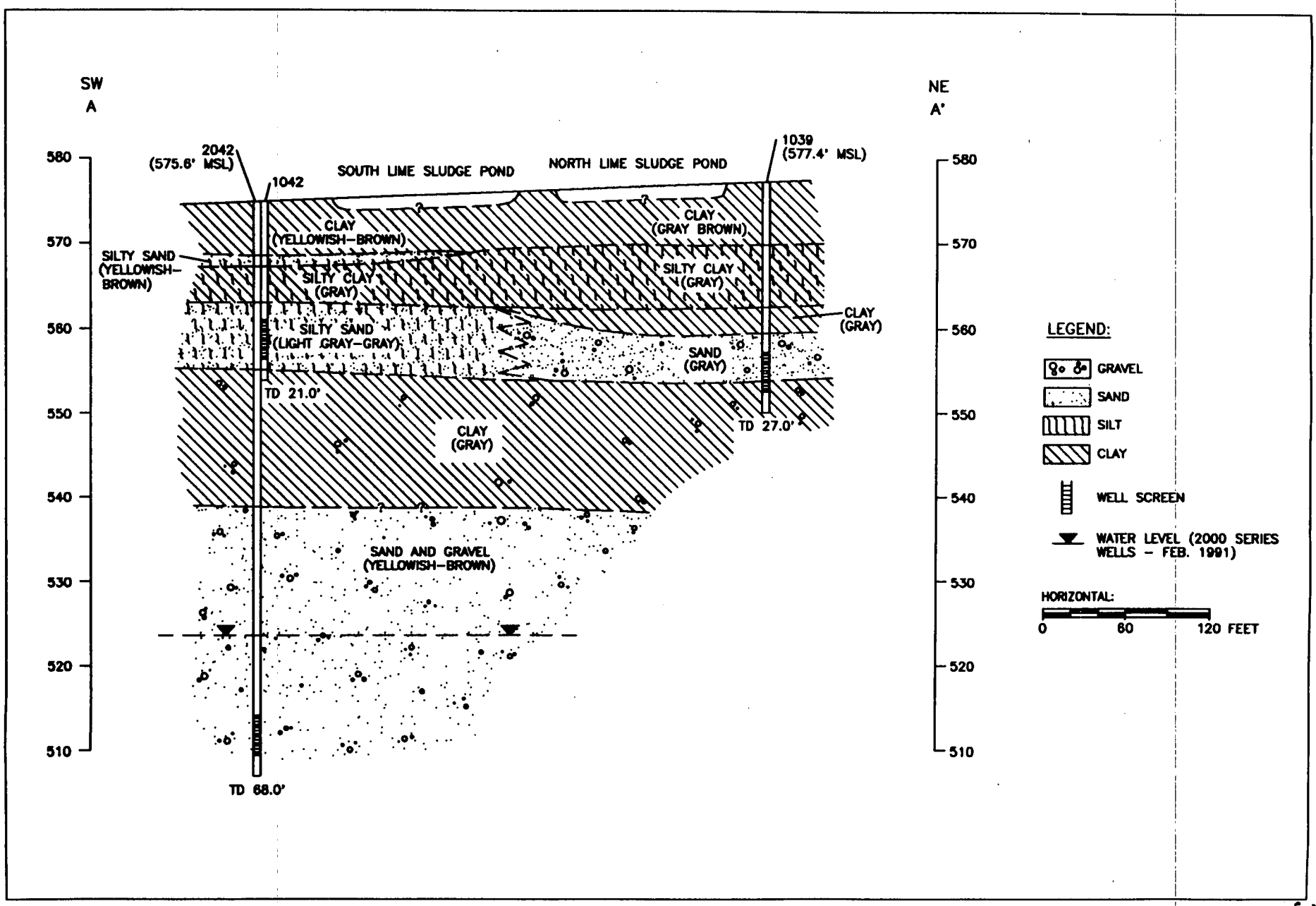


FIGURE 3-29. TRAVERSE FOR CROSS SECTION OF THE LIME SLUDGE PONDS

177



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602 A FNID589 OU2 OR

FIGURE 3-30. GEOLOGICAL CROSS SECTION A-A', LIME SLUDGE PONDS

A lens of sand, detected in the glacial overburden at Borings 1039 and 2042, may extend continuously beneath the Lime Sludge Ponds. The sand lens occurs at a depth of 19 feet at Boring 1039 and at approximately 16.5 feet at Boring 2042. This zone is approximately 5 feet thick and appears to be continuous from northeast to southwest beneath the entire North Pond and through the western portion of the South Pond.

Underlying the overburden deposits is the Great Miami Aquifer, which consists of glacial outwash deposits containing sand and gravel. The Great Miami Aquifer consists of both an upper and a lower unit, but only the upper aquifer was penetrated in the Lime Sludge Ponds study area. The deepest boring in the area, Boring 2042, terminated at a depth of 68.0 feet in the upper aquifer.

Slug tests were conducted in several 1000-series wells throughout the FEMP (DOE 1990a). The tests, conducted in 10 monitoring wells located primarily in silty and clayey materials similar to the weathered and unweathered glacial overburden, indicated that average hydraulic conductivity was approximately 1.1×10^{-4} cm/s. Monitoring Well 1041 (located immediately east of the South Lime Sludge Pond) also yielded a hydraulic conductivity of 1.1×10^{-4} cm/s. The reported values are intended to represent average conditions in the glacial overburden. Wells 1039 and 1042 are screened in sandy materials, however, and their hydraulic conductivities are expected to be higher.

Groundwater elevations for wells in the Lime Sludge Ponds study area are shown in Figure 3-31. The potentiometric surface resides within the Lime Sludge Ponds, indicating possible direct hydraulic connection of the perched groundwater with the impounded materials. Groundwater elevations in Monitoring Wells 1039 and 1041 are at essentially the same elevation; in Well 1042, however, it is typically lower (Figure 3-31).

In the vicinity of the Lime Sludge Ponds, the groundwater elevation of the Great Miami Aquifer averages approximately 515 to 520 feet above MSL throughout the year, with groundwater flow to the east/northeast.

Since the groundwater within the overburden materials is 30 to 60 feet higher than the regional groundwater within the top of the Upper Great Miami Aquifer and because horizontal movement of water within the overburden is limited, there is potential for water to move vertically downward within the overburden materials. Once the water reaches the Great Miami Aquifer, however, the dominant flow direction is horizontal.

3.4 ACTIVE FLYASH PILE

Against the background of the site-wide physical characteristics discussed in Section 3.1, this section provides a discussion of the physical characteristics of the Active Flyash Pile.

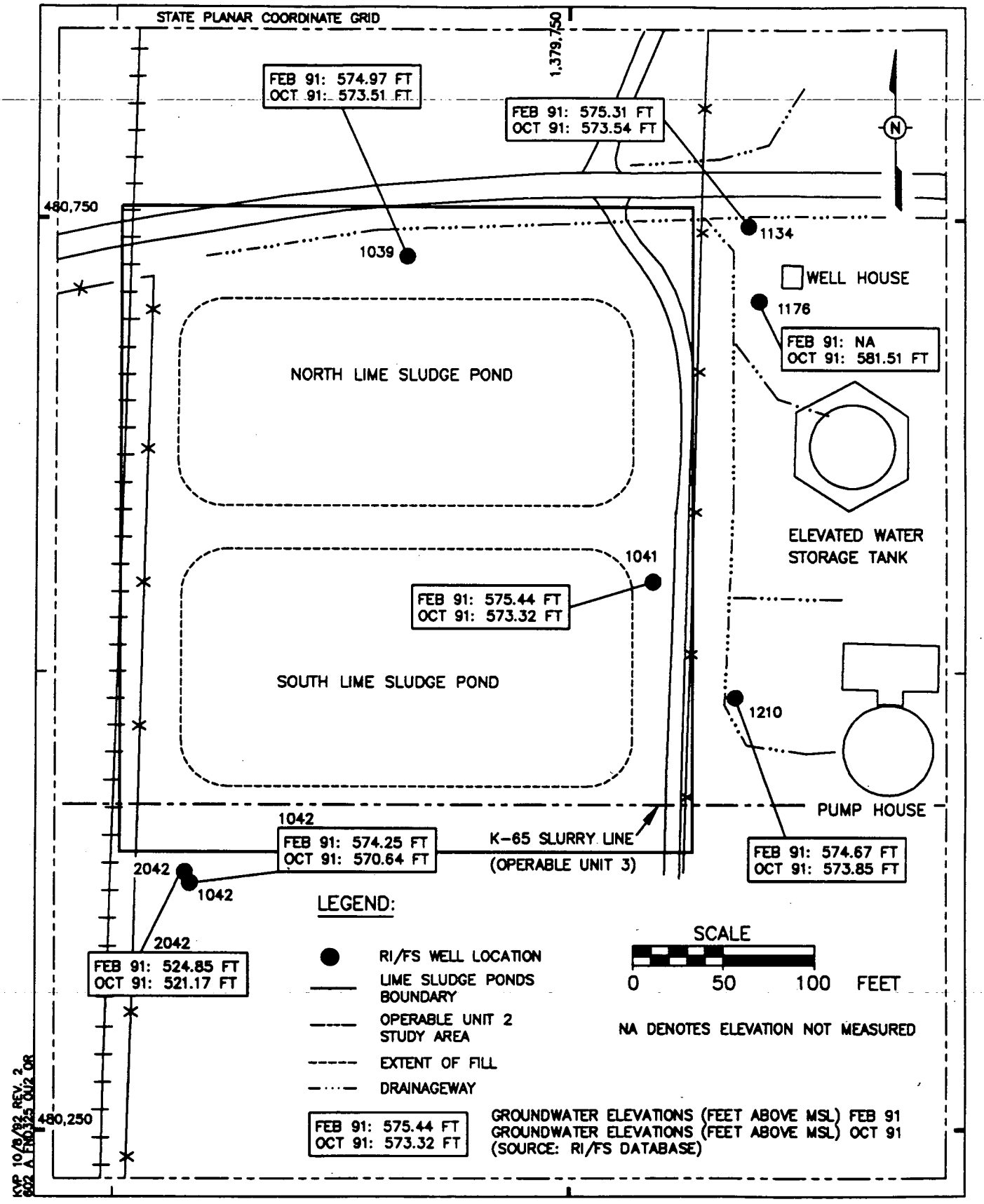

FIGURE 3-31. GROUNDWATER ELEVATIONS FOR WELLS IN THE LIME SLUDGE PONDS STUDY AREA, FEB AND OCT OF 1991

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3.4.1 Topography and Surface Water

The Active Flyash Pile is bounded on the west by a gravel access road that separates it from the South Field (Figure 3-32). A ditch runs between the waste area and the road. To the north, east, and south, the Active Flyash Pile is bounded by an apparently undisturbed area that slopes downward toward the storm sewer outfall ditch. The top of the Active Flyash Pile, at an elevation of approximately 597 feet above MSL, is currently a relatively flat surface that slopes towards the northwest. Steep slopes around the waste area drain surface water radially off the pile. Most surface drainage flows into the storm sewer outfall ditch.

3.4.2 Geology and Groundwater Hydrology

The Active Flyash Pile has been used to dispose of flyash and bottom ash from the coal-fired boiler plant. Subsurface borings indicate that the pile is almost exclusively flyash.

Because the Active Flyash Pile is adjacent to the South Field, the discussion of geology and groundwater hydrology of this unit is combined with the discussion of the South Field in Section 3.6.2.

3.5 INACTIVE FLYASH PILE

Against the background of the site-wide physical characteristics discussed in Section 3.1, this section provides a discussion of the physical characteristics of the Inactive Flyash Pile.

3.5.1 Topography and Surface Water

The Inactive Flyash Pile is bounded on the north by an access road, on the east by a drainage ditch (which separates it from the South Field), and on the south by the running track/shooting range facility (Figure 3-33). Elevations range from approximately 580 to 540 feet above MSL across the waste area from north to south, respectively. The western edge of the area slopes steeply toward Paddys Run, and the southern edge of the area slopes steeply toward the running track to the south. The remainder of this waste area slopes more gently toward the drainage ditch that borders the South Field. Surface water drainage in this ditch flows to the south.

3.5.2 Geology and Groundwater Hydrology

The Inactive Flyash Pile was used to dispose of flyash and bottom ash, from the coal-fired boiler plant. Subsurface borings indicate that the fill consists primarily of flyash, but building rubble (such as concrete, gravel, asphalt, masonry, and steel rebar) is also present.

Because the Inactive Flyash Pile is adjacent to the South Field, the discussion of geology and groundwater hydrology of this waste area is combined with the discussion of the South Field in Section 3.6.2.

3.6 SOUTH FIELD

Against the background of the site-wide physical characteristics discussed in Section 3.1, this section provides a discussion of the physical characteristics of the South Field.

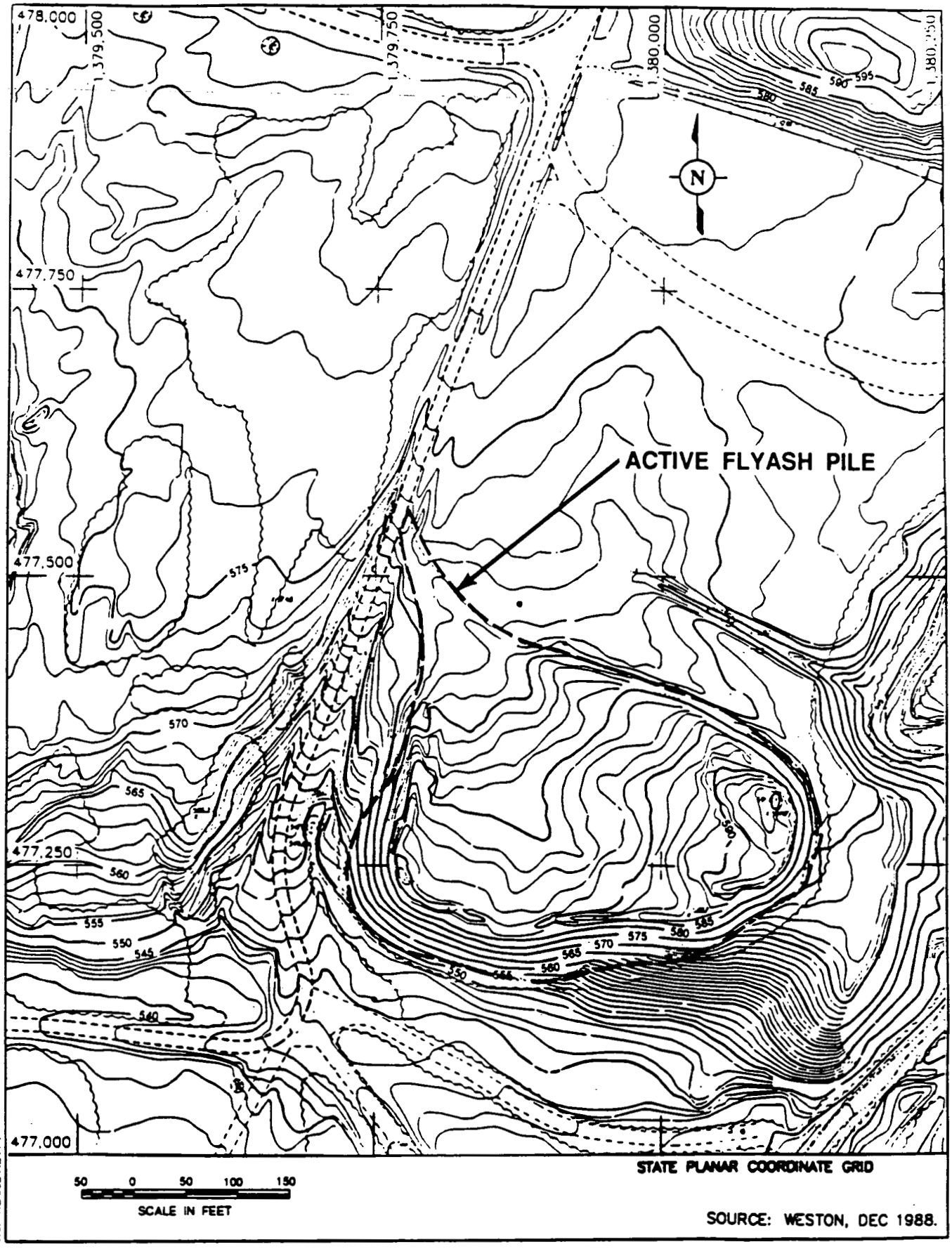

FIGURE 3-32. TOPOGRAPHY OF THE ACTIVE FLYASH PILE

182

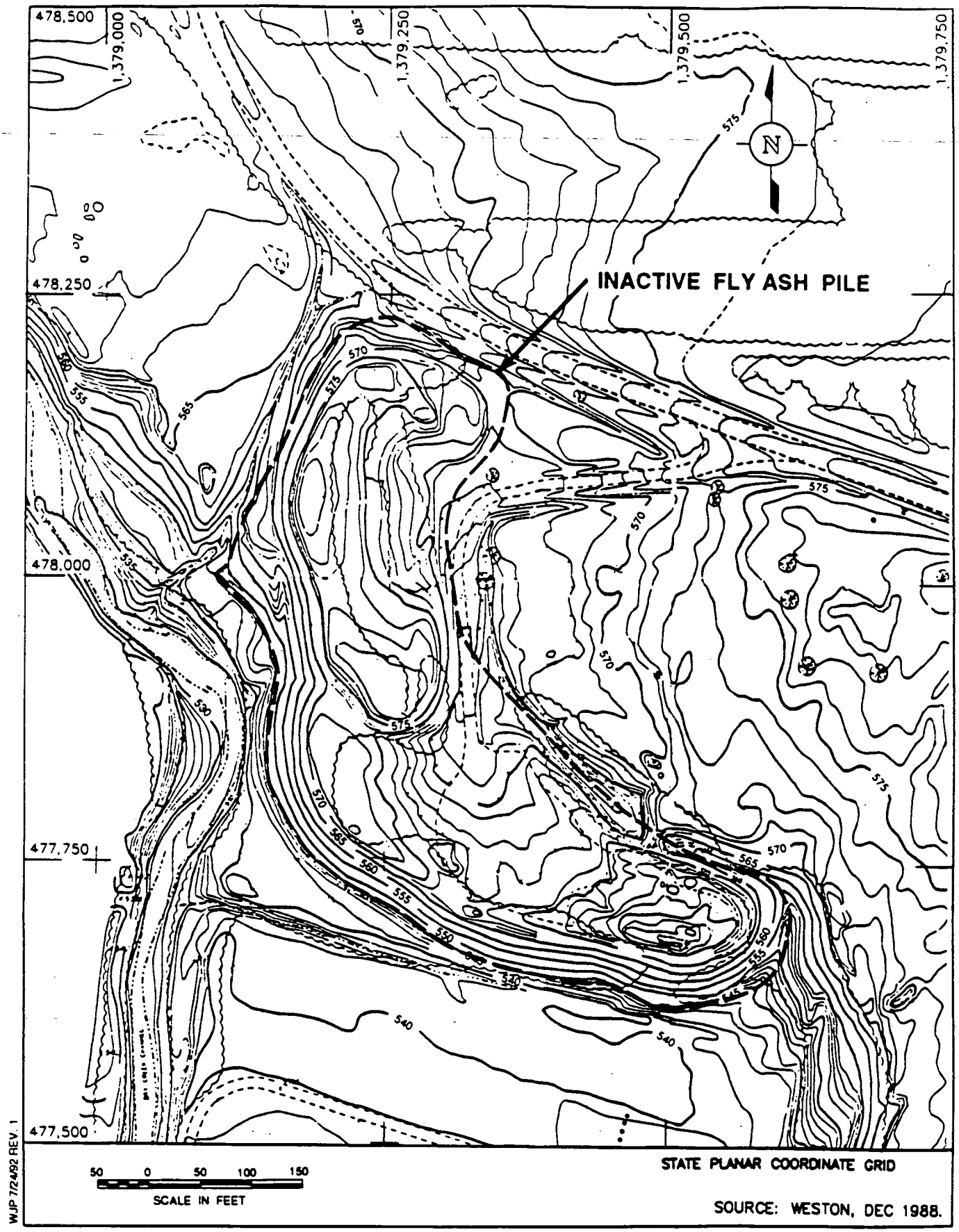

FIGURE 3-33. TOPOGRAPHY OF THE INACTIVE FLYASH PILE

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3.6.1 Topography and Surface Water

The South Field is located south of the former production area. An east-west oriented access road borders the northern extent of the South Field. A north-south oriented access road (which turns east and leads to the running track/shooting range facility), borders the eastern and southern extent of the South Field. The western edge of the South Field is bordered by a drainage ditch which divides the Inactive Flyash Disposal Area from the South Field. Generally, topography in the vicinity of the South Field slopes from the northeast at 595 feet above MSL to the west at 560 feet above MSL and to the south at 540 feet MSL (Figure 3-34). The natural topography of the South Field has been historically recontoured as fill was introduced; the primary surface water runoff pattern is to the south and west.

3.6.2 Geology and Groundwater Hydrology

Subsurface borings and monitoring wells were completed in order to record lithology of the subsurface strata, determine concentrations of various chemical constituents in groundwater, and determine groundwater elevations. Based on the lithologic descriptions presented in the boring logs (Appendices E, F, and G for the Active Flyash Pile, Inactive Flyash Pile, and South Field, respectively), a general description of the strata below the South Field/Flyash study area was determined. Groundwater within the Great Miami Aquifer is part of Operable Unit 5, and detailed discussion of groundwater flow within the aquifer will be included in the Operable Unit 5 RI Report.

The South Field was used as a disposal site for construction rubble; fill consists of soil, burned coal, coke, concrete, building debris, and flyash.

Geological cross-sections based on boring data were prepared for the Flyash/South Field area; Figure 3-35 shows the cross-section lines and Figures 3-36, 3-37, and 3-38 show the cross-sections. The cross-sections indicate that a series of glacial overburden deposits underlie the Flyash/South Field area. Underlying these deposits is the Great Miami Aquifer consisting of glacial outwash deposits containing sand and gravel.

The glacial overburden is composed predominantly of silty clay interbedded with lenses of clay and silt, sandy clay, silty sand, and sand and gravel. All these lithologies are discontinuous and can not be correlated laterally between borings. The color of the overburden generally grades downward from a yellowish brown to brown silty clay into a gray to gray brown clay. This color transition is thought to be a oxidation, which occurred as a result of the upper beds being more susceptible to surface weathering. The depth at which this transition occurs is variable, ranging from 27.0 feet in Boring 2047 to 0.0 feet in Boring 1045.

The thickness of the glacial overburden in the Flyash/South Field area ranges from approximately 5 feet at Boring 2049 (on the south of the Active Flyash Pile) to approximately 27 feet at Boring 1046 (located on the north side of the Inactive Flyash Pile). Overall in the Flyash/South Field area the glacial overburden averages between 20 and 30 feet thick. The only area that lacks overburden

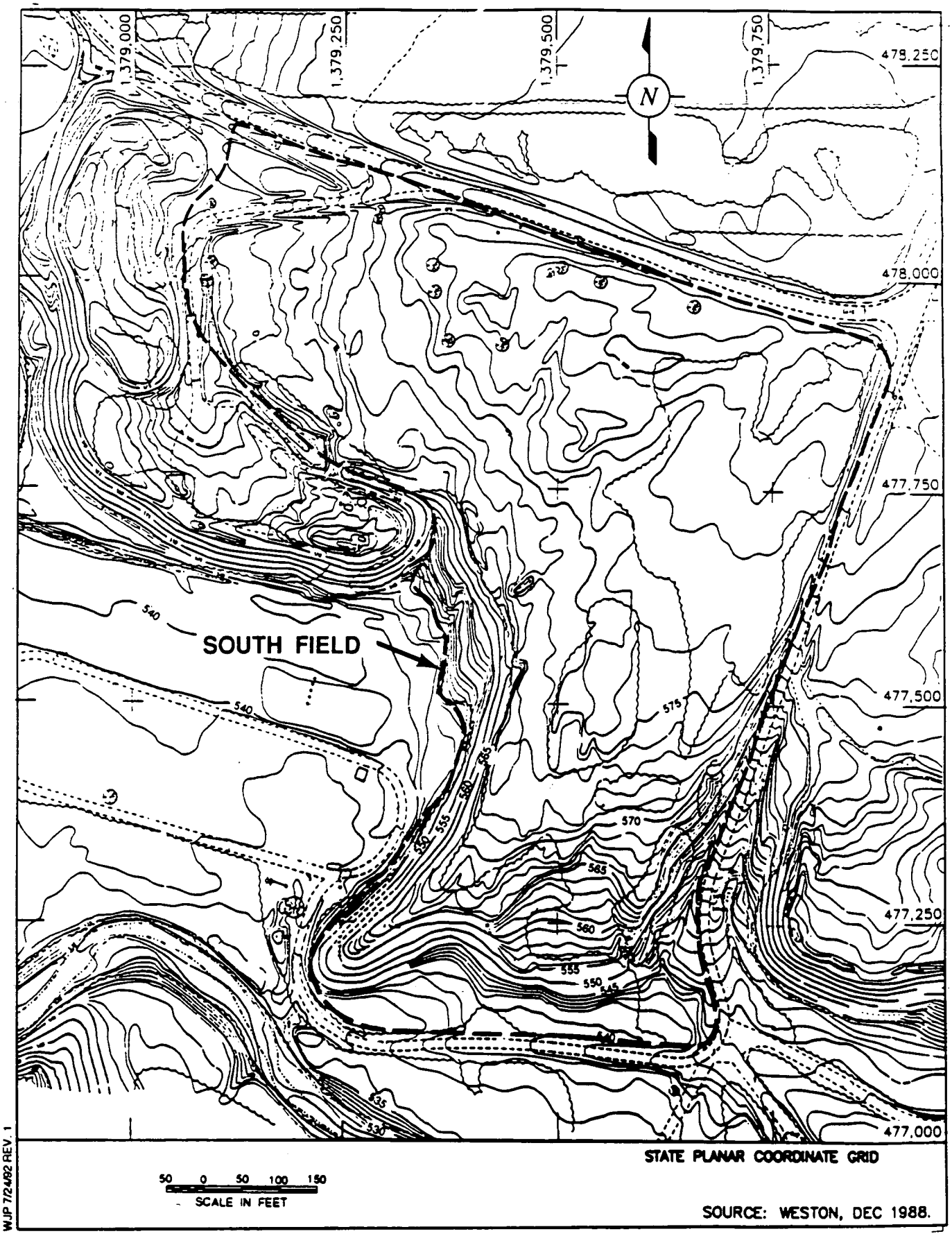
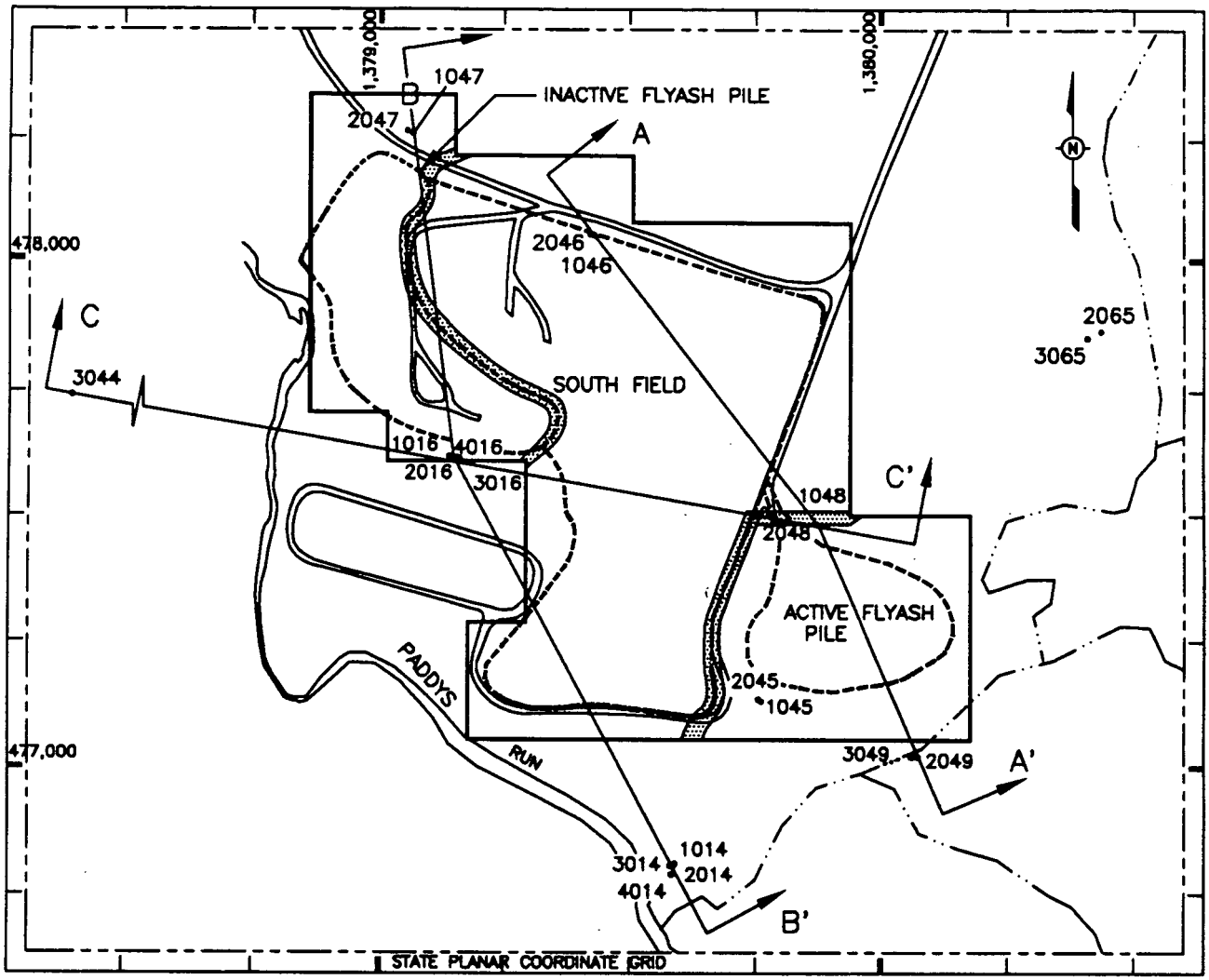


FIGURE 3-34. TOPOGRAPHY OF THE SOUTH FIELD

185



LEGEND:

- ROADWAY
- STORM SEWER OUTFALL DITCH
- WELL LOCATION (RI/FS)
- EXTENT OF FILL
- FLYASH/SOUTH FIELD BOUNDARY
- BOUNDARY BETWEEN FLYASH PILES AND SOUTH FIELD
- OPERABLE UNIT 2 STUDY AREA

SCALE

0 150 300 FEET

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902 A FND414 OU2 OR

FIGURE 3-35. TRAVERSE FOR CROSS SECTION OF THE FLYASH/ SOUTH FIELD AREA

186

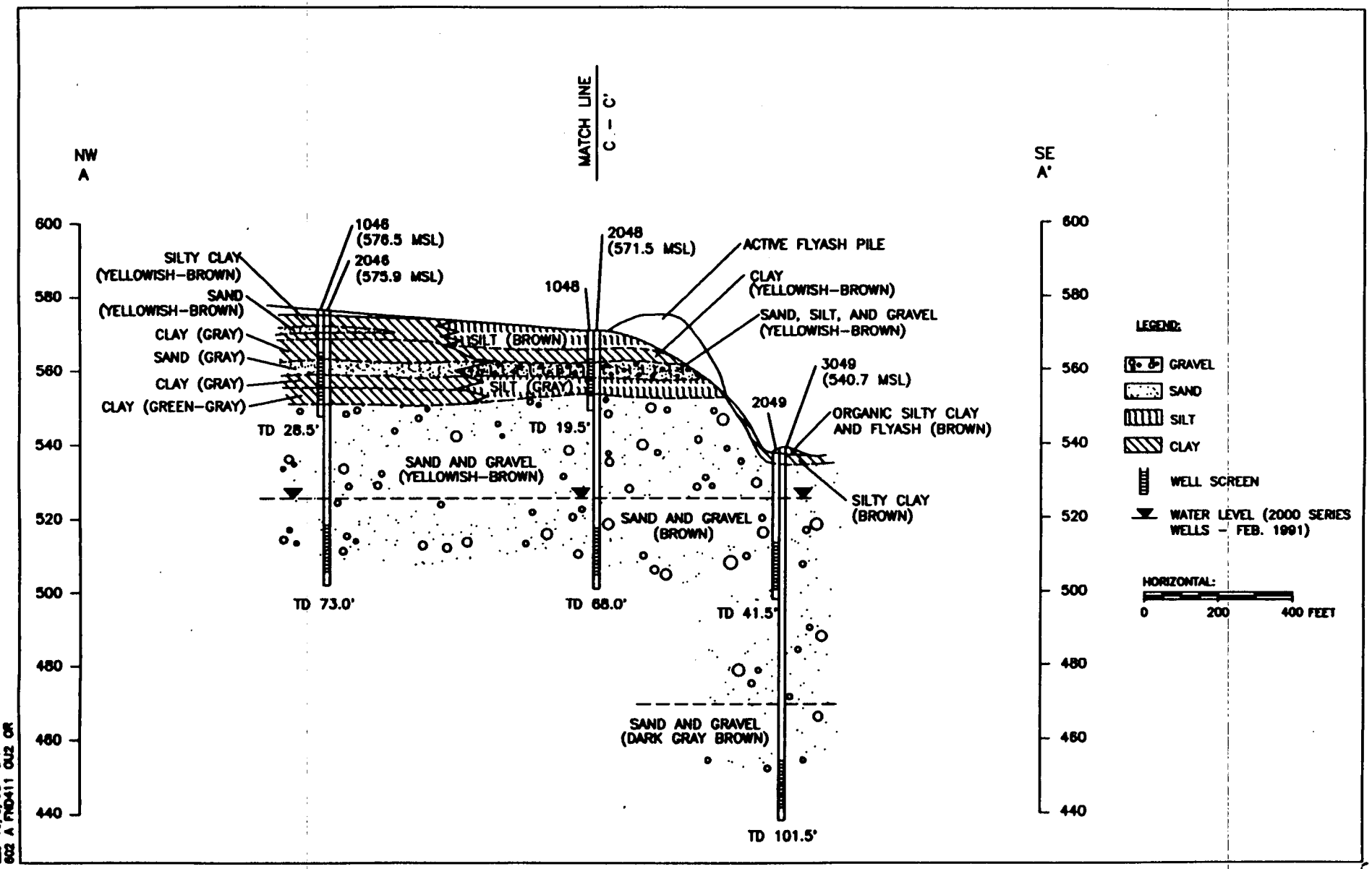

FIGURE 3–36. GEOLOGICAL CROSS SECTION A–A', FLYASH/SOUTH FIELD AREA

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602 A FIG411 GU2 GR

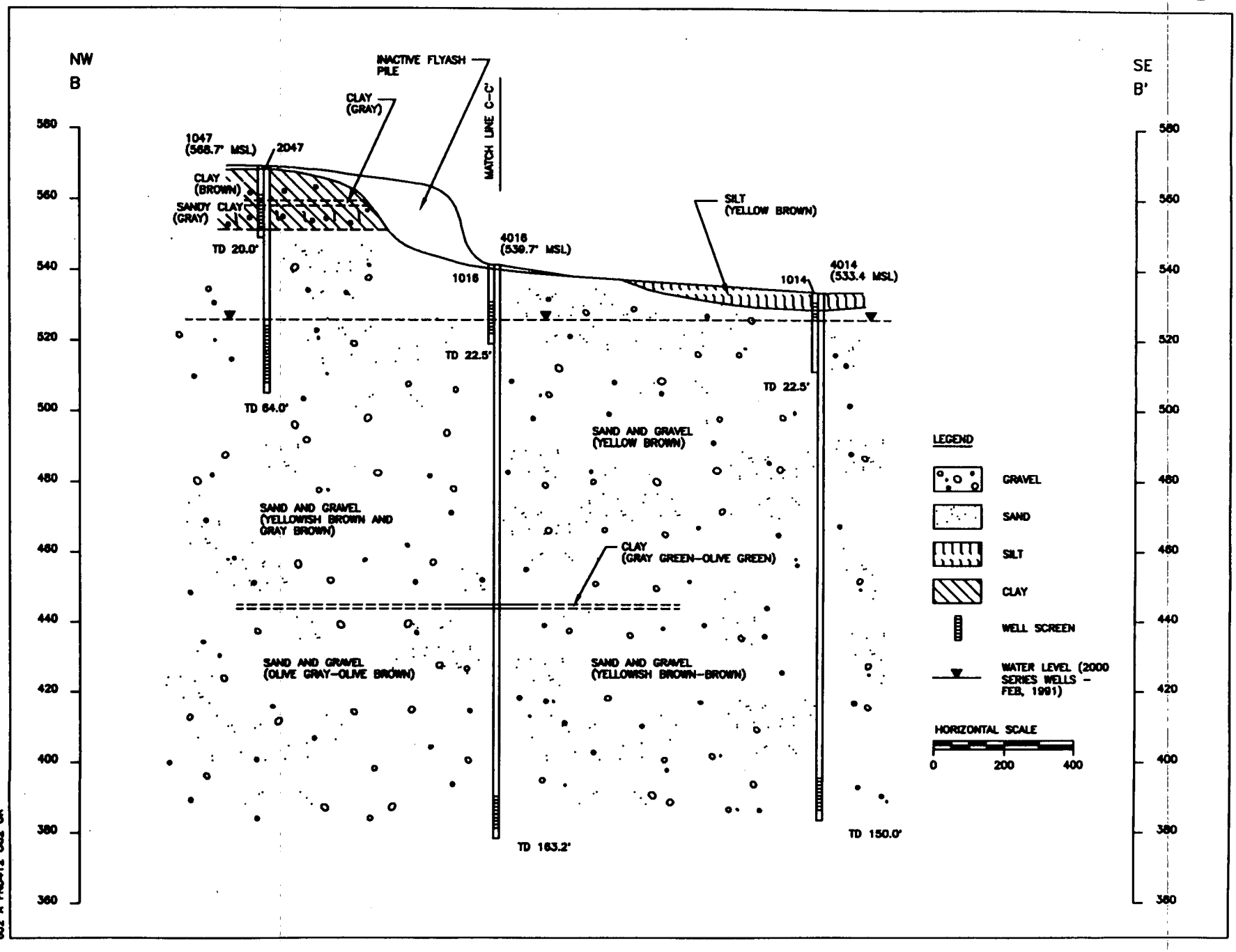

FIGURE 3-37. GEOLOGICAL CROSS SECTION B-B', FLYASH/SOUTHFIELD AREA

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602 A FN0412 OU2 OR

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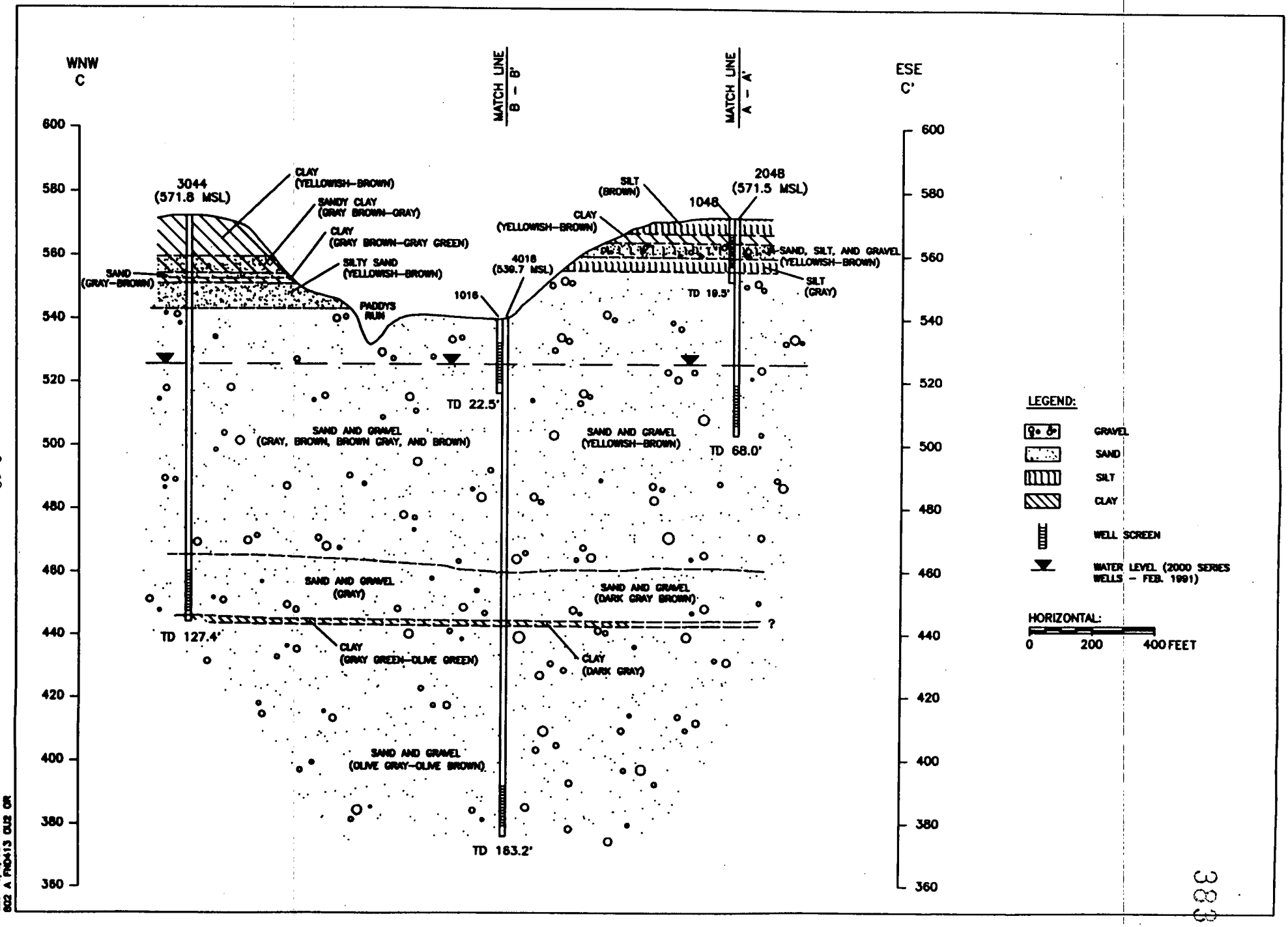

FIGURE 3-38. GEOLOGICAL CROSS SECTION C-C', FLYASH/SOUTH FIELD AREA

LLS 10/15/92 REV. 1
802 A FIG-413 OUZ OR

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3836

deposits is along a section of Paddys Run (at Boring 4016), where these materials have been eroded away. As a result, Paddys Run is in direct contact with the Great Miami Aquifer.

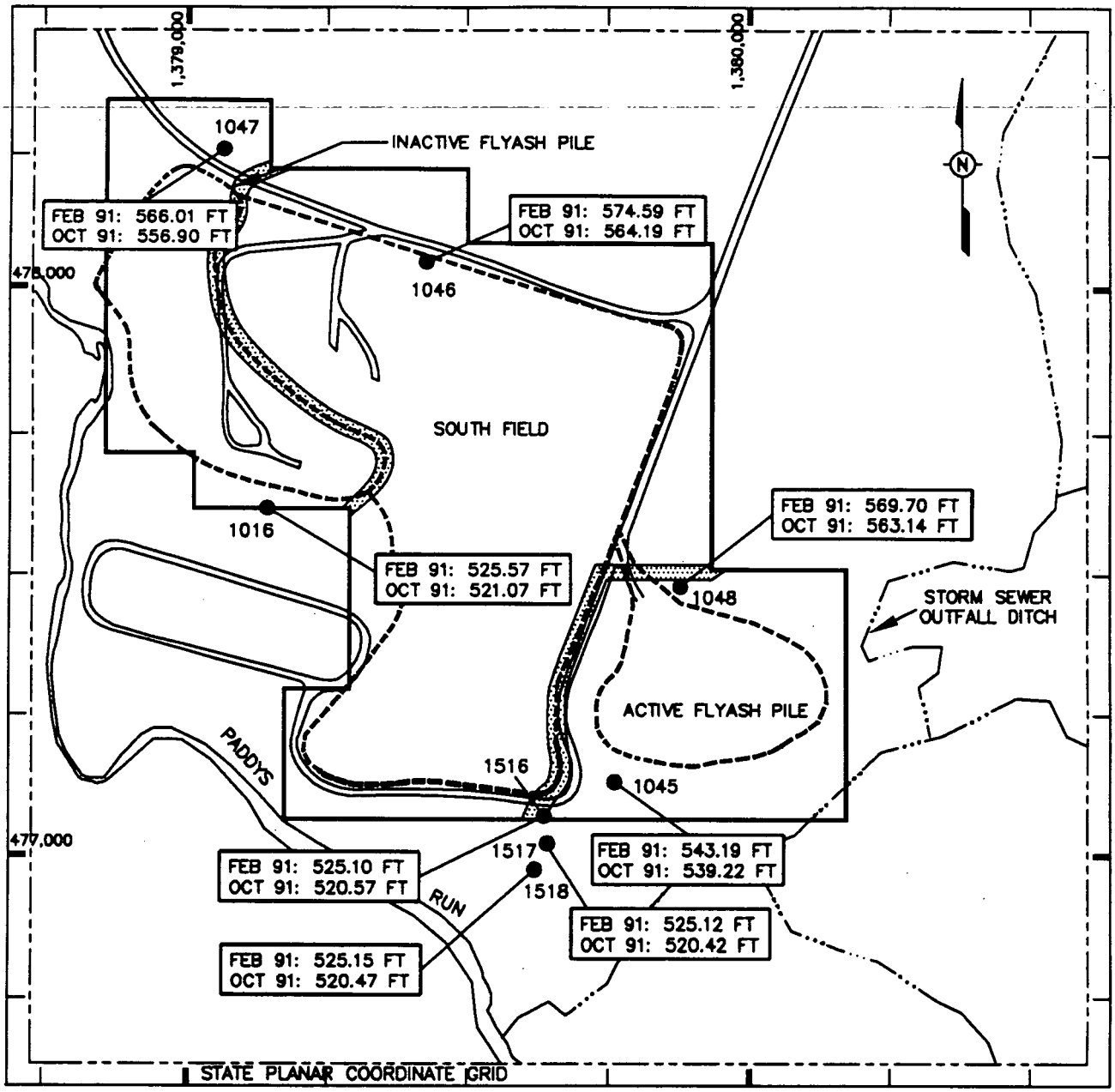
In the Flyash/South Field area, the Great Miami Aquifer was penetrated in every boring. The lithology of the aquifer consists principally of sand and gravel with scattered lenses of clay or fine-grained material occurring in places, but not in sufficient thickness and areal extent to act as semiconfining layers or to otherwise affect groundwater movement. In Boring 4016 (located on the south end of the Inactive Flyash Pile), a gray green-olive green clay was encountered at approximately 443 feet above MSL. The clay is approximately 1.5 feet thick and is found throughout most of the FEMP property. This clay acts as a aquitard which segregates the upper sand and gravel unit and a lower sand and gravel unit within the Great Miami Aquifer.

Slug tests conducted in several 1000-series wells throughout the FEMP (DOE 1990a) indicated an average hydraulic conductivity for the glacial overburden of 1.1×10^{-4} cm/s. An average hydraulic conductivity of 1.6×10^{-5} cm/s was obtained from Monitoring Wells 1045 and 1046.

Groundwater elevation within the glacial overburden varies from approximately 540 to 570 feet above MSL at this site.

Groundwater elevations within the Upper Great Miami Aquifer are approximately 520 to 525 feet above MSL (Figures 3-39 and 3-40). Groundwater elevation data for the 3000- and 4000-series wells (the bottoms of the Upper and Lower Great Miami Aquifer, respectively) (Figure 3-41) are also approximately 520 to 525 feet above MSL.

Because groundwater within the overburden materials is 20 to 50 feet higher than the groundwater at the top of the Upper Great Miami Aquifer and because the horizontal movement of water within the overburden is limited, there is potential for water to move vertically downward within the overburden materials. Once it has reached the Upper Great Miami Aquifer, however, vertical water movement will decrease and horizontal movement will predominate. This is evidenced by the fact that the piezometric (static) head does not vary with depth (the heads in the 2000-, 3000-, and 4000-series wells are similar).



LEGEND:

- ● RI/FS WELL LOCATION
- ------ EXTENT OF FILL
- ——— FLYASH/ SOUTH FIELD BOUNDARY
- BOUNDARY BETWEEN FLYASH PILES AND SOUTH FIELD
- ---- OPERABLE UNIT 2 STUDY AREA

FEB 91: 524.98 FT
OCT 91: 520.39 FT — GROUNDWATER ELEVATIONS (FEET ABOVE MSL) FEB 91
GROUNDWATER ELEVATIONS (FEET ABOVE MSL) OCT 91
(SOURCE: RI/FS DATABASE)

SCALE
0 125 250 FEET

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602_A_FND335_OU2_TK20_OR

FIGURE 3-39. GROUNDWATER ELEVATION FOR 1000-SERIES WELLS IN THE FLYASH/SOUTH FIELD STUDY AREA: FEB 91 AND OCT 91

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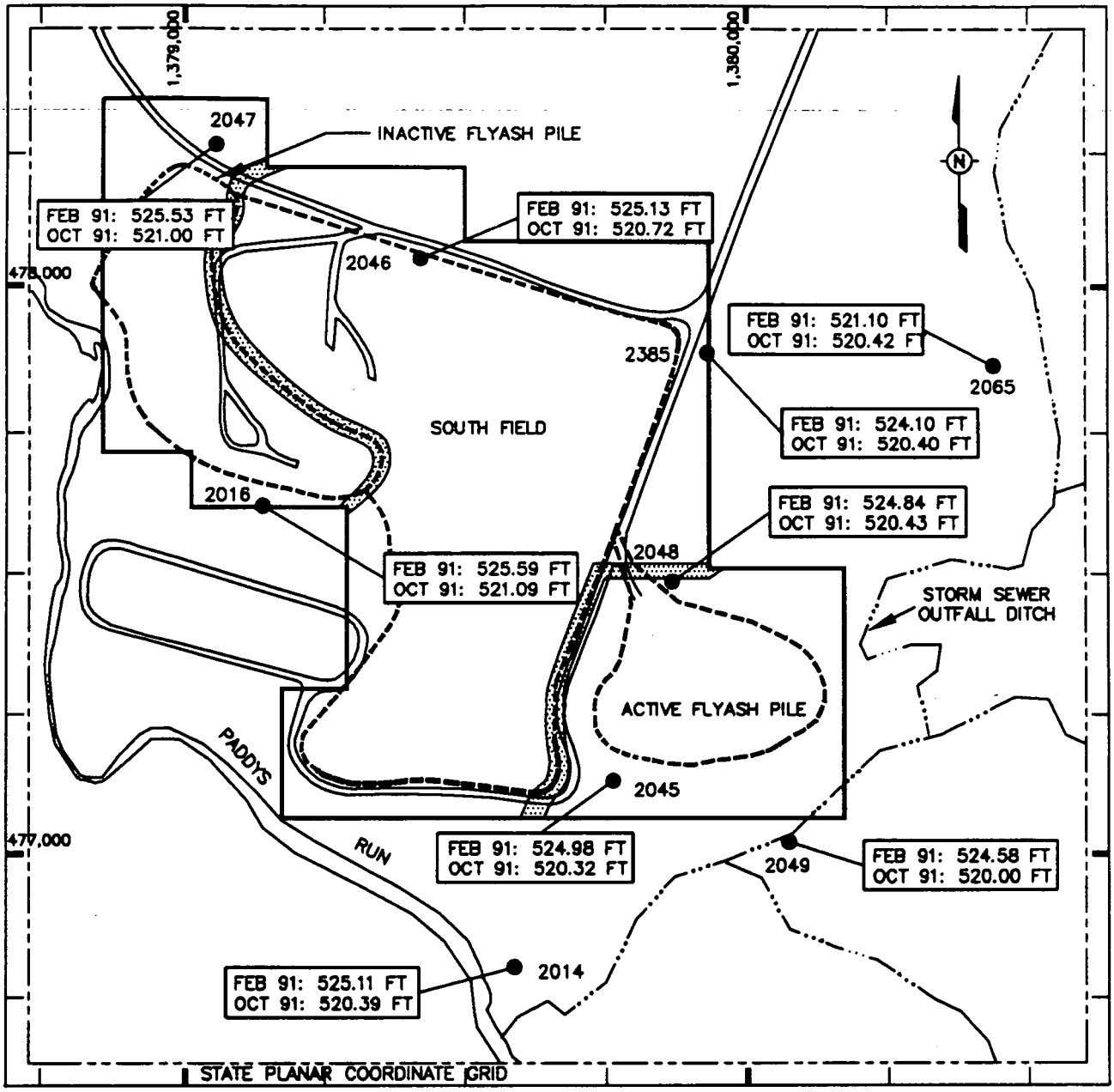

LEGEND:

- ● RI/FS WELL LOCATION
- ------ EXTENT OF FILL
- —— FLYASH/SOUTH FIELD BOUNDARY
- ▒ BOUNDARY BETWEEN FLYASH PILES AND SOUTH FIELD
- ---- OPERABLE UNIT 2 STUDY AREA

FEB 91: 524.98 FT
OCT 91: 520.39 FT — GROUNDWATER ELEVATIONS (FEET ABOVE MSL) FEB 91
GROUNDWATER ELEVATIONS (FEET ABOVE MSL) OCT 91
(SOURCE: RI/FS DATABASE)

SCALE
0 125 250 FEET

KVF 10/8/92 REV. 2
802_A_FIG0340_OU2_TK20_06

FIGURE 3-40. GROUNDWATER ELEVATION FOR 2000-SERIES WELLS IN THE FLYASH/SOUTH FIELD STUDY AREA: FEB 91 AND OCT 91

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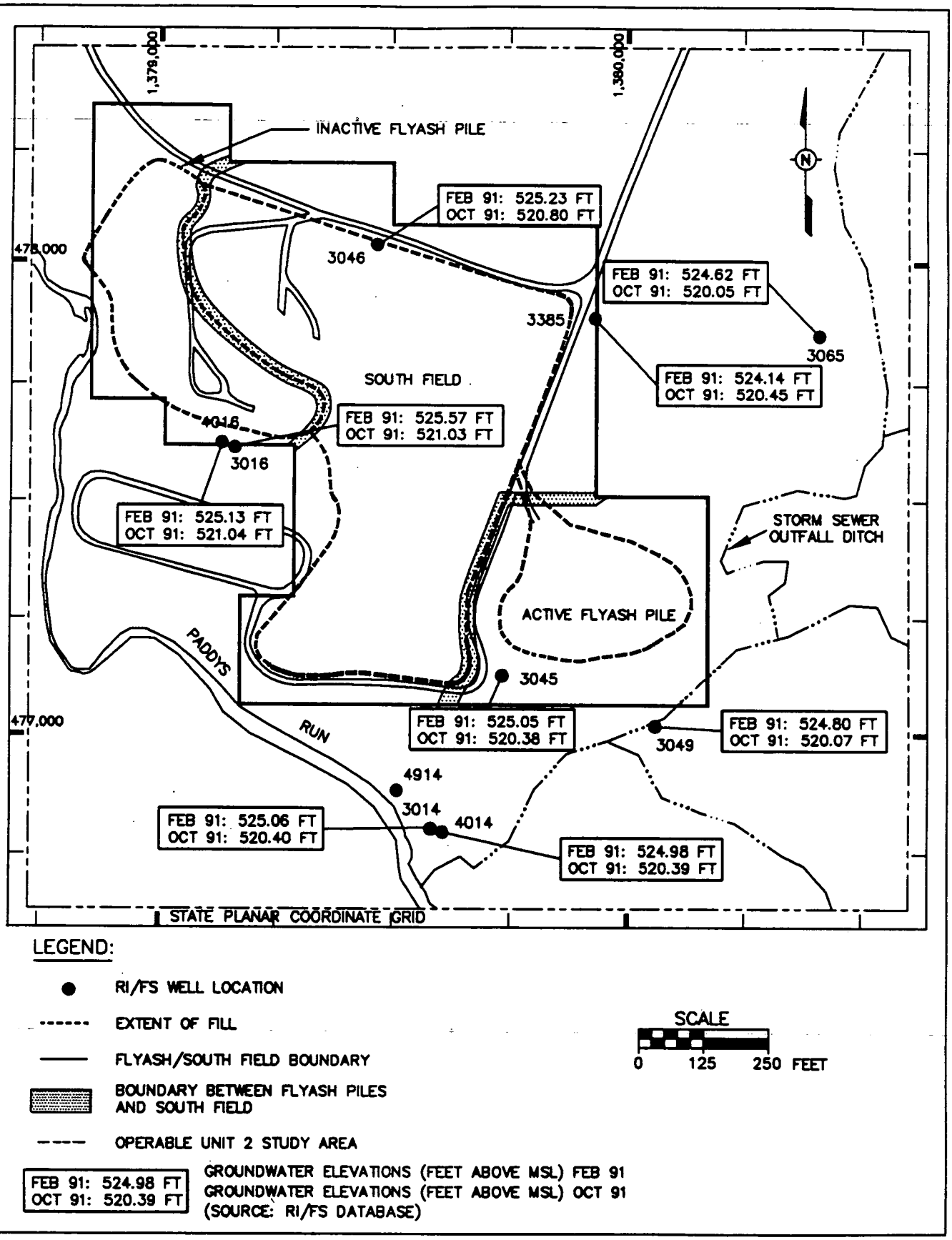

FIGURE 3-41. GROUNDWATER ELEVATION FOR 3000-SERIES AND 4000-SERIES WELLS IN THE FLYASH/SOUTH FIELD STUDY AREA: FEB 91 AND OCT 91

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4.0 NATURE AND EXTENT OF CONTAMINATION

4.1 EVALUATION OF DATA

A large quantity of data has been collected and evaluated from surface and subsurface media (soils, lime sludge residue, and flyash), surface water, stream sediment, perched groundwater and the Great Miami Aquifer. Data collected during the Environmental Survey, CIS, and RI/FS are presented here to describe the nature and extent of contamination in Operable Unit 2. Section 4.1 describes the evaluation and use of data from the various investigations. Sections 4.2 through 4.6 present complete descriptions, the nature and extent of contamination for each of the waste areas.

4.1.1 Evaluation and Presentation of Data from Multiple Sources

As described in Section 2.0, the waste areas of Operable Unit 2 have been investigated and data collected during the Environmental Survey, CIS, and RI/FS. Data collected as part of the RI/FS have undergone data validation in accordance with the RI/FS QAPP (Section 2.1.4) resulting in the assignment of appropriate qualifiers to individual RI/FS laboratory values. However, the methods of sample collection and analysis during the Environmental Survey and CIS were not in strict conformance with procedures adopted in 1988 under the RI/FS QAPP. The data from the Environmental Survey have been included in site characterization but not in the baseline risk assessment. Documentation of procedures, operator training, equipment calibration and QA/QC steps are incomplete. Additionally, although chemical analyses conformed to EPA methods (Table 2-1), CLP protocols were not followed. In the case of the CIS data, some of the QA/QC procedures used during sample analyses were less stringent than the verification requirements required by the QAPP and the current CLP SOW; however, much of the data have sufficient pedigree to be applicable to site characterization and risk assessment uses. Some of the samples collected for the CIS were analyzed at an on-site laboratory for uranium-238, radium-226, and thorium-232. However, documentation of procedures, environmental conditions, operator training, equipment calibration, and QA/QC steps are incomplete, so these data were used only for screening results and were not included in the quantification of risk.

Samples collected for radiological analysis during the Environmental Survey, CIS, and RI/FS were typically analyzed for isotopic species (reported in pCi/g or pCi/ℓ). However, to separately discuss each individual isotope would unnecessarily complicate the understanding of the overall environmental distribution of the elements, particularly since isotopic separation does not occur in the natural environment. Therefore, the discussion in the text covering uranium and thorium contamination will be limited to total uranium and total thorium. Tables and figures accompanying the text contain activities of the individual isotopes and the risk assessment was performed using both isotopic and

total measurements. Although most samples were analyzed for total uranium and total thorium (reported in mg/kg or µg/ℓ) in addition to their isotopic species, CIS samples typically were not. Where total uranium and total thorium results were not available, estimates of these values have been calculated based on the isotopic analyses.

4.1.2 Determination of Waste-Related Constituents

Background concentration data were used in the site characterization process to distinguish waste-related contamination from naturally occurring or other nonsite-related levels of chemicals and radionuclides (Table 4-1). Following is a brief discussion of the use of background data in identifying waste-related constituents. A more detailed discussion is presented in the Baseline Risk Assessment (Appendix A).

The site-specific background data set consists of analyses of a series of soil samples collected approximately 3 to 5 miles from the FEMP. Because the descriptive statistics used for background data sets required that samples with nondetectable concentrations be included along with those exhibiting positive detections, one-half the value of the sample quantitation limit (SQL) was assigned to the nondetected result. The data set was then tested for normality and outliers as described in EPA's Statistical Analysis of Ground Water Monitoring Data at RCRA Facilities (EPA 1989b) and Risk Assessment Guidance for Superfund Part A, Human Health Evaluation Manual (EPA 1989a). The background data were then used to calculate the upper tolerance limit (UTL) for each normally or lognormally distributed compound, as described in EPA guidance (EPA 1989b). The UTL is the upper 95% confidence limit on the 95th quantile of the background distribution. Where UTLs were not calculated from the site-specific background data set, background concentrations were estimated based on (1) evaluation of regional data, (2) secular equilibrium of the radioactive decay process, or (3) the assumption that organic compounds and certain radionuclides (such as technetium-99 and the isotopes of plutonium) do not occur naturally.

Each surface and subsurface media (i.e., soil, lime sludge residue, or flyash) contaminant concentration was compared to the appropriate background value. If the measured value for a given analyte exceeds the corresponding background value for any surface or subsurface media sample from a given waste area, that analyte is considered a waste-related constituent for that waste area. Once identified as a waste-related constituent, that analyte is addressed for each of the media in that area. For example, if uranium-234 is identified as a waste-related constituent of surface media in the Solid Waste Landfill, it is addressed for all media within the Solid Waste Landfill study area, (e.g., subsurface media, ground-water, surface water, etc.).

The background values for stream sediments are taken as the same values calculated for soils. Background values have not been calculated for on-site surface water.

TABLE 4-1

BACKGROUND CONCENTRATIONS[a]
FOR SOILS AND GROUNDWATER

Analytes	Background Concentration[a]				
	Soils	Groundwater			
		Perched	Shandon Tributary	Dry Fork Section	Shandon/Dry Fork Divide
Radionuclides: (pCi/g, pCi/ℓ)					
Bismuth-210	1.51[b]	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Bismuth-214	1.51[b]	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Cesium-137	0.711	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Lead-210	1.33	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Neptunium-237	0.0	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Plutonium-238	0.0	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Plutonium-239	0.0	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Plutonium-240	0.0	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Protactinium-234	2.18[b]	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Radium-224	0.983	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Radium-226	1.51	<1[d]	<1[d]	<1[d]	<1[d]
Radium-228	1.28	<3[d]	<3[d]	<3[d]	<3[d]
Ruthenium-106	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Strontium-90	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Technetium-99	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Thorium-228	1.56	<1[d]	<1d[d]	<1[d]	<1[d]
Thorium-230	2.18	<1[d]	<1[d]	<1[d]	<1[d]
Thorium-232	1.36	<1[d]	<1[d]	<1[d]	<1[d]
Total Thorium (mg/kg, µg/ℓ)	12.4[e]	<9[e]	<9[e]	<9[e]	<9[e]
Uranium-234	1.28	<1[d]	<1[d]	0.25	<1[d]
Uranium-235	0.151	<1[d]	<1[d]	0.012	<1[d]
Uranium 235/236	0.151	<1[d]	<1[d]	0.012	<1[d]
Uranium-238	1.22	<1[d]	<1[d]	0.25	<1[d]
Total Uranium (mg/kg, µg/ℓ)	3.66[f]	<3[f]	<3[f]	0.741	<3[f]

TABLE 4-1
(continued)

Analytes	Background Concentrations[a]				
	Soils	Groundwater			
		Perched	Shandon Tributary	Dry Fork Section	Shandon/Dry Fork Divide
Metals: (mg/kg, mg/ℓ)					
Aluminum	16973	0.72	0.303	0.303[g]	0.303[g]
Antimony	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Arsenic	10.3	0.003	0.385	0.28	0.426
Barium	133	0.132	1.047	0.051	1.056
Beryllium	0.607	0.004	0.004	0.001[g]	0.001
Boron	48.9	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Cadmium	0.650	0.009	0.007	0.004[g]	0.004
Calcium	201722	128.017	136.363	122.960[g]	122.960
Chromium	22.0	0.076	0.039	0.030	0.030
Cobalt	15.8	0.013	0.013[g]	0.013[g]	0.013[g]
Copper	21.2	0.046	0.022	0.090	0.032
Cyanide	0.283	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Iron	33026	1.810	4.131	0.602	4.088
Lead	16.6	0.054	0.051	0.037	0.042
Magnesium	59838	56.792	47.038	27.957	36.035
Manganese	1099	0.202	0.265	1.029	0.521
Mercury	0.292[b]	0.001	0.001	0.001[g]	0.001
Molybdenum	8.8[b]	0.020	0.029	0.010	0.024
Nickel	38.1	0.103	0.026	0.026[g]	0.026[g]
Potassium	1911	25.931	5.068	2.044	6.816
Selenium	0.720[b]	0.016[g]	0.130	0.016[g]	0.016
Silicon	1566	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Silver	8.03[b]	0.05	0.014	0.061	0.052
Sodium	235	59.615	100.309	4.765	148.483
Thallium	0.397	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Vanadium	39.5	0.058	0.034	0.034[g]	0.034[g]
Zinc	81.2	0.064	0.109	0.052[g]	0.052

TABLE 4-1
(continued)

Analytes	Background Concentrations[a]				
	Soils	Groundwater			
		Perched	Shandon Tributary	Dry Fork Section	Shandon/Dry Fork Divide
Organic Compounds: (mg/kg, mg/ℓ)	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]
General Water Quality: (mg/ℓ, mg/kg)	0.0[c]	0.0[c]	0.0[c]	0.0[c]	0.0[c]
Ammonia	0.0[c]	0.362	7.125	0.368	6.343
Chloride	0.0[c]	40.144	110.026	30.061	178.454
Fluoride	0.0[c]	1.624	1.328	0.467	1.560
Nitrate	0.0[c]	0.341	1.527	19.415	12.663
Total Phosphorus	0.0[c]	0.408	0.728	0.163	0.366
Sulfate	0.0[c]	211.217	129.779	60.159	134.828

[a]Background concentrations are based upon Upper Tolerance Limit (UTLs) from site-specific background data except as noted
[b]Value assumed based on secular equilibrium for radioactive decay chain
[c]Value assumed to be zero
[d]Background concentration is less than the detection limit
[e]Calculated from TH 232
[f]Calculated from U-235 and U-238
[g]Value assumed based on lowest background value from other groundwater units
[h]UTL based on Regional background data

Background values were also calculated for groundwater for each of the different hydrologic units of interest to Operable Unit 2, which are (1) perched groundwater across the site, (2) the Shandon Flow Section of the New Haven Trough of the Great Miami Aquifer, which approaches the site from the northwest and flows under the Solid Waste Landfill and the Lime Sludge Ponds, and (3) the Dry Fork Section of the New Haven Trough, which approaches the site from the west and flows under the Flyash/South Field study area (DOE 1990a). The locations of the tributaries are shown in Figure 3-9. Although groundwater analyses are compared to the background values in this section, an analyte is not considered a waste-related constituent in Operable Unit 2 unless it is detected above background in surface or subsurface media (i.e., soil, lime sludge residue, or flyash). Because of the mobility of contaminants in groundwater, and because all Operable Unit 2 waste areas are hydraulically downgradient of other known source areas (i.e., former production area, waste storage area, K-65 silos, etc.), it is considered highly likely that migration from these other areas has occurred. Therefore, if an analyte exceeds the background value in groundwater but not in the overlying soils, it is assumed that the source of this constituent is not Operable Unit 2 and that the contaminant would be addressed within the source operable unit and/or Operable Unit 5, which includes all groundwater at the FEMP.

The one departure from this background comparison method of identifying waste-related constituents is in the North Lime Sludge Pond, where surface water is considered part of the waste. Since no background values for surface water have been established, any constituent of the North Lime Sludge Pond water is considered a waste-related constituent.

Identification of an analyte as a waste-related constituent means only that it is present in concentrations above background level. It does not imply that this contaminant poses a risk to human health or the environment. The question of risk is addressed in the Baseline Risk Assessment (Section 6.0 and Appendix A).

4.1.3 Results of Data Validation

Data validation was performed in accordance with the QAPP on all of the surface and subsurface media RI/FS sample analyses used in characterizing the waste and evaluating the baseline risks. As described in Section 2.1.4, data validation is an after-the-fact, independent, systematic process of evaluating data and comparing it to pre-established criteria. Specific parameters associated with the data are reviewed to determine whether they meet the data quality objectives of precision, accuracy, completeness, comparability, and representativeness. To verify that these objectives are met, both field records and laboratory records are evaluated to determine compliance with appropriate and applicable procedures. Data qualifiers are assigned to the analytical data to identify any nonconformances to the (QA/QC) requirements. Severe nonconformances resulted in the assignment of the "R" qualifier. These data are not suitable for the intended uses, and therefore, were not used in this report.

The major issue identified by the data validation process was matrix interference with VOC and antimony analyses of flyash samples. This issue is addressed in detail in Sections 4.4 and 4.5.

4.2 SOLID WASTE LANDFILL

The analytical results for samples collected from the Solid Waste Landfill are presented in Appendix C of this document. This section reports results only for waste-related constituents; i.e., analytes that were found to exceed background in at least one surface or subsurface media sample. Analytes that have been detected in groundwater, surface water, or sediment, but are less than background in all surface and subsurface media samples, are considered to have originated from upgradient sources and are not discussed here.

Data tables in this section present individual analytical results only for the waste-related radionuclides. Although waste-related organic and inorganic constituents are numerous, they typically exhibit low frequencies of detection and low concentrations. Therefore, only summary tables for these data are given here, but the complete data set is available in Appendix C.

4.2.1 Review of Historical Data

The Solid Waste Landfill was used for the disposal of burnable, possible burnable, and nonburnable wastes from FEMP nonprocess areas and on-site construction/demolition activities. Materials reportedly accepted include nonburnable and nonradioactive solid wastes generated on the property, nonradioactive construction-related rubble, and double-bagged and bulk quantities of nonradioactive asbestos (DOE 1988a; Weston 1987b). Some construction rubble placed in the landfill and the soil used to cover exposed wastes may have been contaminated with radionuclides (DOE 1988a). The following wastes were encountered during the 1992 trenching investigation (DOE 1992e):

- burnable: bagged trash and wood
- possible burnable: respirator cartridges, asphalt roofing materials, medical wastes, firehoses, and rubber hoses/belts
- nonburnable: medicine vials, bagged asbestos, ceramic tiles, magnesium fluoride, glass acid bottles, steel cables/cans, paint cans, and copper tubing

When filled to capacity, the five existing cells were covered with soil. An evaporation pond, which was used for collecting storm water runoff, has been backfilled with soil. Historical aerial photographs show evidence of disposal activity as early as 1954 (EPA 1988b). Use of the landfill was halted in early 1986. Solid wastes (i.e., nonradioactive and nonhazardous trash and food wastes) and general refuse are currently collected for shipment and disposal at approved off-site locations.

4.2.2 Volume and Physical Characteristics of Waste

The Solid Waste Landfill is organized into five cells (Figure 1-5). The maximum depth of fill measured in the landfill was 17.0 feet at CIS Boring 49-01 (Figure 4-1). Previous estimates (Weston 1987b) of actual waste volume indicated that the landfill contained approximately 10,000 cubic yards of waste. Based on an average depth of 13 feet and an area of 40,700 square feet, the volume of fill in the landfill may be estimated at 19,600 cubic yards. This larger estimate includes soil used to cover the waste and to fill the evaporation pond.

The boring logs indicate the fill is comprised of clays and silts intermixed with materials such as plastics, styrofoam, and aluminum. Environmental Survey Test Pit No. 8 included cafeteria waste (e.g., food, paper products, styrofoam containers), asbestos, and miscellaneous construction rubble.

The Solid Waste Landfill is currently covered with soil and vegetation. Surface soils in the Solid Waste Landfill exhibited a dry density of 105 pounds/cubic ft (lb/ft^3). Maximum dry density for CIS Boring 49-03 was 109.7 lb/ft^3 at 18 percent moisture content.

4.2.3 Surface and Subsurface Media in the Solid Waste Landfill

Within the Solid Waste Landfill, samples were taken from surface media, shallow fill, deep fill, and native soil underlying the fill.

Surface media samples were obtained and analyzed during the Environmental Survey, CIS, and RI/FS investigations. Four surface samples were collected as a part of the Environmental Survey (DOE 1988a) (FE0620SS, FE0621SS, FE0622SS, FE0623SS; henceforth to be referenced as ES-620, -621, -622, and -623, respectively). The Environmental Survey samples were tested for asbestos, radionuclides, VOCs, PCBs, and TCLP metals. Two surface samples were collected (FMP-SS-46-238 and FMP-SS-46-362; henceforth referenced as 46-238 and 46-362, respectively) within the bounds of the landfill as part of the CIS (Weston 1987c). Two additional surface samples were collected just outside the boundary of the landfill (FMP-SS-46-348 and FMP-SS-46-349; henceforth referenced as 46-348 and 46-349, respectively). Additional CIS samples were analyzed at the on-site laboratory; however, because the objective of the on-site analytical program was to serve as a screening tool, the resulting data will not be considered in this discussion of surface soil contamination. CIS samples were tested for radionuclides only. For the RI/FS, three surface soil samples (05668, 05669, 05670) were collected just outside the landfill boundary. These were taken from succeeding 2-inch intervals at one location. RI/FS samples were tested for radionuclides only.

Subsurface samples were also collected during the Environmental Survey, CIS, and RI/FS investigations. Two samples (10151S1B and 10151S2B) were collected during the Environmental Survey from depths of 3.5 and 6.5 feet, respectively, from the Test Pit No. 8 and were analyzed for radionuclides

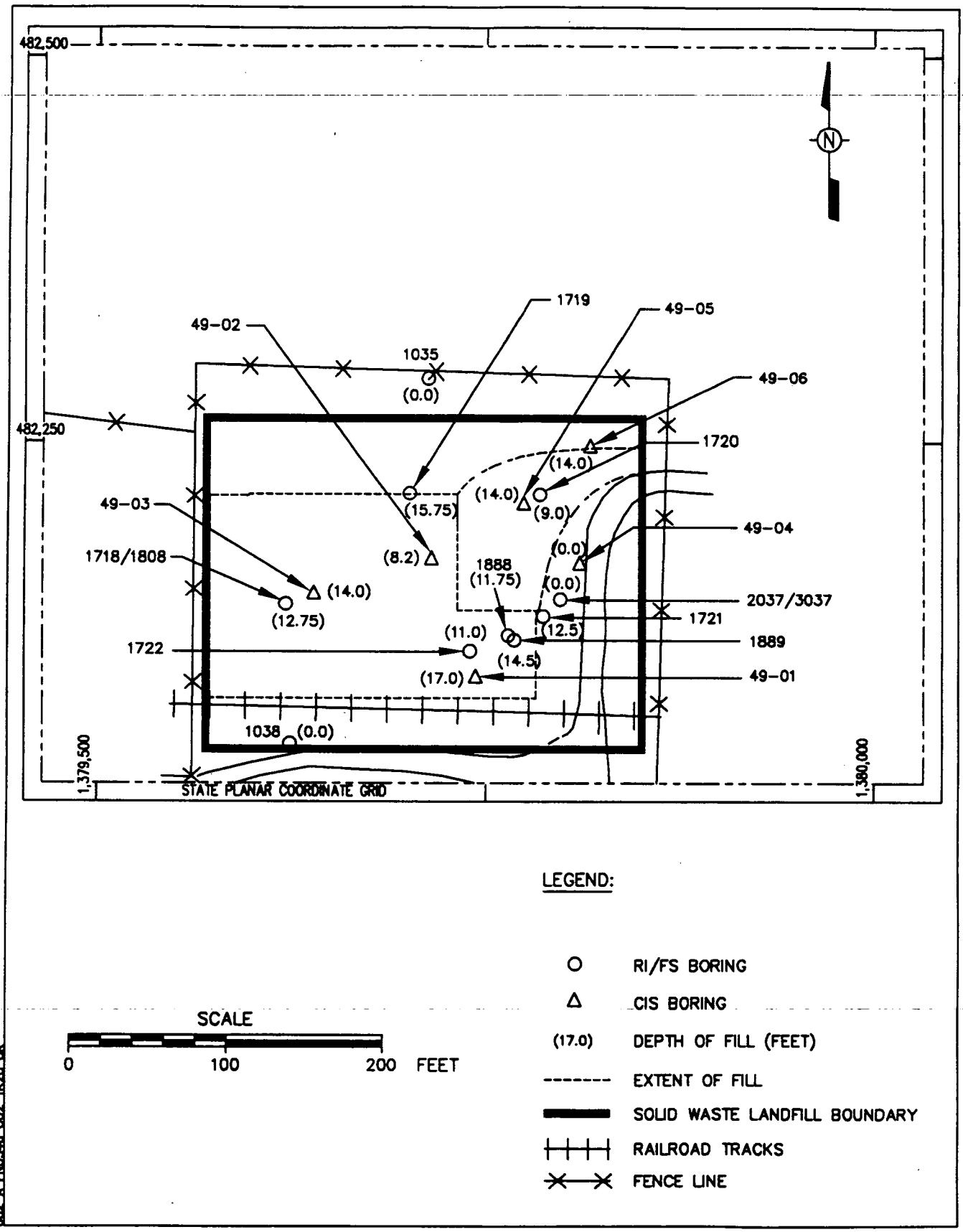

FIGURE 4-1. DEPTH OF FILL IN THE SOLID WASTE LANDFILL

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and TCLP metals. During the CIS, six subsurface borings (49-01 through 49-06) were drilled to depths ranging from 8 to 18 feet. These borings were sampled at 1-foot intervals for analysis at the on-site laboratory for radium-226, thorium-232, and uranium-238. These analyses are presented in this section as an indication of relative vertical distribution. A vertical composite was prepared from each CIS boring and was analyzed at an off-site laboratory for radionuclides, VOCs, SVOCs, PCBs, total metals, and EP toxicity metals.

Three RI/FS samples were collected from Borings 1035, 1038, and 3037, which were drilled as part of the well-installation program. These samples were analyzed for radionuclides. Later, additional RI/FS borings (1718, 1719, 1720, 1721, 1722, 1808, 1888, and 1889) were drilled and samples were collected from each boring from the shallow fill, the deep fill, and native soil immediately below the fill. (Boring 1808 is a redrill of Boring 1718.) These were analyzed for radionuclides, VOCs, SVOCs, pesticides/PCBs, dioxins/furans, metals, and total organic carbon (TOC). One sample (either with the highest HNu reading or from the midpoint of the boring) was collected from each boring for TCLP VOC/SVOC analysis. In addition, the deep fill samples were analyzed for the additional Appendix IX parameters. A composite fill sample from each boring was analyzed for TCLP metals/pesticides/herbicides.

4.2.3.1 Radionuclides in Surface and Subsurface Media

Uranium is the primary radionuclide detected in surface media from the Solid Waste Landfill, having been detected above the background value of 3.66 mg/kg in all of the surface soil samples. Total uranium in surface media within the Solid Waste Landfill boundary was detected at levels as high as 990 mg/kg at 46-238 (Table 4-2, Figure 4-2). Surface samples taken from north and northwest of the waste area (Samples 46-349 and 5669) exhibited total uranium concentrations of 2932 mg/kg and 1180 mg/kg, which are higher than those measured inside the waste area boundaries. These data, along with the proximity of the Solid Waste Landfill to the former production area and the waste storage area, suggest that the surface soil contamination at the Solid Waste Landfill (1) is widespread and extend beyond the boundaries of Operable Unit 2 and (2) has originated from sources other than the Solid Waste Landfill.

In subsurface fill samples, total uranium ranged from 6.7 mg/kg at the shallow fill in Boring 1721 to 940 mg/kg in the shallow fill in Boring 1722 (Tables 4-3 and 4-4, Figure 4-3). Other areas with more elevated total uranium levels are Borings 1719 in deep fill (393 mg/kg) and 1720 in shallow fill (150 mg/kg). Of the seven measurements of total uranium in native soils underlying the fill, five were greater than the background value (3.66 mg/kg). These included samples from Borings 1721 (11.2 mg/kg), 1719 (19.7 mg/kg), 1722 (17.5 mg/kg and 146 mg/kg), and 1720 (5.8 mg/kg). The level of uranium from 12.5 to 14.0 feet in Boring 1722 is eight times higher than that of the soil immediately

TABLE 4-2

WASTE-RELATED RADIONUCLIDE CONCENTRATIONS IN SURFACE MEDIA IN THE SOLID WASTE LANDFILL

		ES Samples and Depths				CIS Samples and Depths				RI/FS Samples and Depths		
Analyte	Background Concentrations	620 0-0.5 ft	621 0-0.5 ft	622 0-0.5 ft	623 0-0.5 ft	46-238 0.5-1 ft	46-362 0-.16 ft	46-348[a] 0-.16 ft	46-349[a] 0-.16 ft	5668[a] 0-0.17 ft	5669[a] .17-.33 ft	5670[a] .33-.5 ft
Radionuclides: (pCi/g)												
Bismuth 214	1.51	0.88±0.4	2.2±0.1	0.83±0.09	0.69±0.03	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.071	I	I	I	I	<0.2	1.1±0.4	0.3±0.2	<0.6	NA	0.6±0.2	0.5±0.1
Plutonium-238	0.0	NA	NA	NA	NA	<0.1	<0.2	<0.1	1.0±0.2	NA	<0.6	<0.6
Plutonium-239/240	0.0	NA	NA	NA	NA	<0.1	<0.2	<0.1	0.5±0.2	NA	<0.6	<0.6
Radium-224	0.983	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226	1.51	0.87±0.04	2.1±0.1	0.83±0.07	0.6±0.03	0.89±.63	2.79±1.32	1.09±.62	<2.77	NA	3.6±0.4	1.1±0.1
Radium-228	1.28	NA	NA	NA	NA	NA	NA	NA	NA	NA	45.5±2.9	2.7±0.3
Strontium-90	0.0	NA	NA	NA	NA	<0.5	<0.5	<0.8	<0.6	NA	<0.5	<0.5
Technetium-99	0.0	NA	NA	NA	NA	<1.6	<1.0	<2.1	12.0±1.0	NA	<0.9	<0.9
Thorium-228	1.56	1.0±0.1	1.6±0.1	1.3±0.1	0.71±0.05	1.3±.30	3.4±.4	1.7±.3	1.9±0.4	NA	17.5±2.2	2.4±0.4
Thorium-230	2.18	NA	NA	NA	NA	8.9±.70	6.4±.5	3.3±.5	7.1±0.8	NA	20.6±2.5	2.4±0.4
Thorium-232	1.36	1.1±0.1	1.2±0.1	1.1±0.2	0.8±0.07	1.0±0.30	1.5±.3	1.6±.3	1.4±0.4	NA	9.2±1.2	1.0±0.2
Total Thorium (mg/kg)	12.4	10.0[b]	10.9[b]	10.0[b]	7.3[b]	9.1[b]	13.6[b]	14.5[b]	12.7[b]	NA	83.6[b]	9.1[b]
Uranium-234	1.28	NA	NA	NA	NA	183±3.0	57.0±2.0	45.0±1.0	141.0±7.0	31.1±7.4	40.2±6.2	25.0±4.2
Uranium-235	0.151	0.89±0.01	N	1.2±0.1	0.69±0.04	17.0±1.0	4.7±0.50	3.3±0.4	14.0±2.0	NA	NA	NA
Uranium-235/236	0.151	NA	NA	NA	NA	NA	NA	NA	NA	4.5±1.4	4.6±1.5	2.4±0.7
Uranium-238	1.22	64±4	N	48±6	I	330±5.0	304±4.0	151.0±2.0	983.0±18	173±39	228±29	133±21
Total Uranium (mg/kg)	3.66	149	66	112	11	990[c]	906.9[c]	450.9[c]	2932.1[c]	517.0[c]	1180±119	368±38

NA = Not analyzed.
N = Nuclide not identified by GAMANAL analysis as being present in the sample; no value reported.
I = Nuclide identified by GAMANAL analysis of sample spectrum, but values did not exceed room background at the 95 percent confidence level; no value reported.
R = Value rejected during data validation
[a] = Samples taken outside of the boundary of waste unit
[b] = Total thorium for ES, CIS, and RI/FS samples are calculated estimates which are based on measured values of thorium-232.
[c] = Total uranium for CIS and RI/FS samples are calculated estimates which are based on measured values of uranium-235 and uranium 238.

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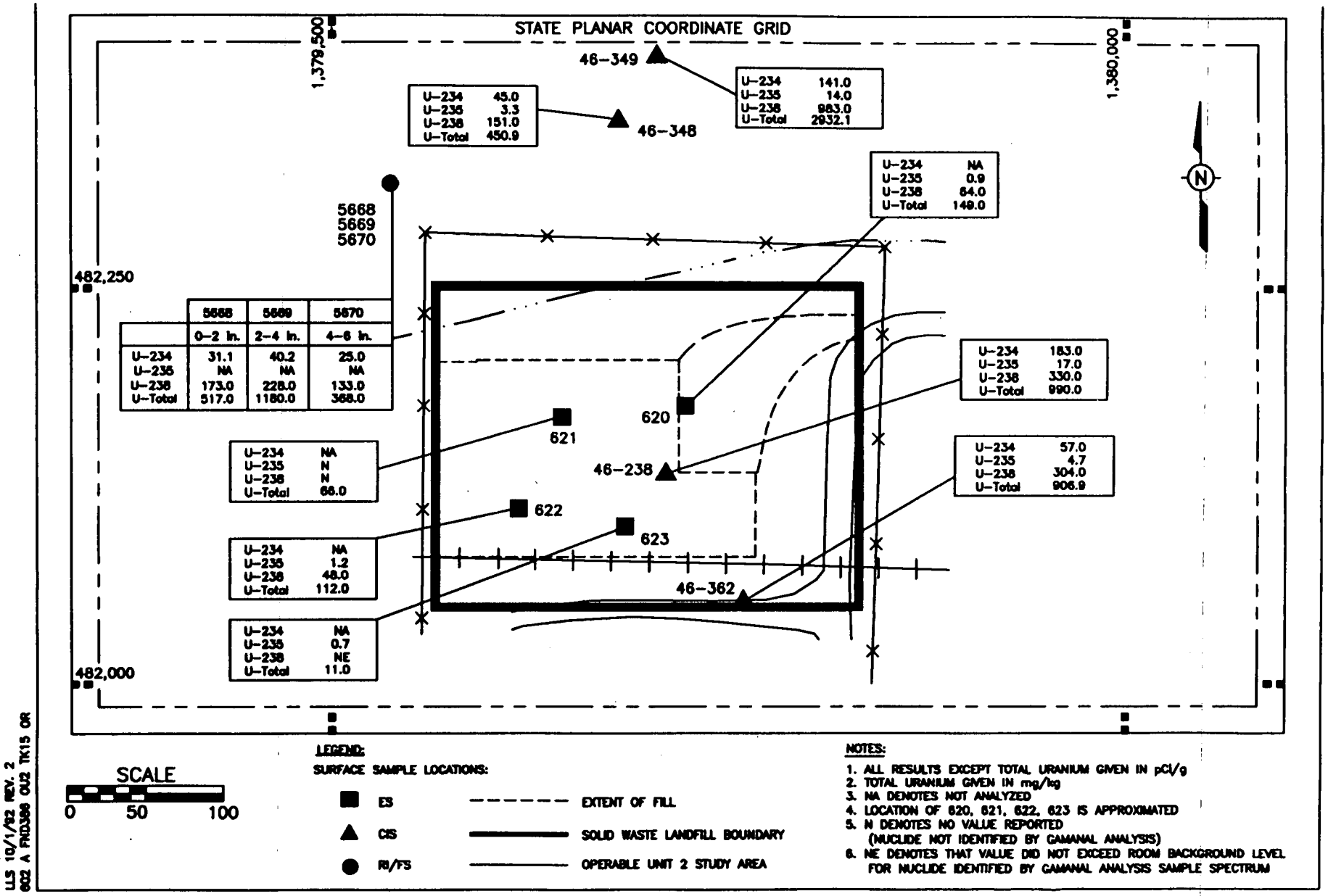

FIGURE 4-2. URANIUM CONCENTRATION IN SURFACE MEDIA IN THE SOLID WASTE LANDFILL STUDY AREA

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TABLE 4-3

WASTE-RELATED RADIONUCLIDE CONCENTRATIONS IN SUBSURFACE MEDIA IN THE SOLID WASTE LANDFILL

Analyte	Background Concentration	ES Test Pit No. 8		CIS Borings, Sample Descriptions and Depths		
		1015IS1B 3.5ft	1015IS2B 6.5ft	49-01 Composite 0-18ft	49-02 Composite 0-12ft	49-03 Composite 0-16ft
Radionuclides: (pCi/g)						
Bismuth 214	1.51	0.78±0.05	0.93±0.06	NA	NA	NA
Cesium-137	0.711	0.14±0.02	I	<0.3	<0.2	<0.2
Plutonium-238	0.0	NA	NA	<0.1	0.1±0.1	<0.1
Plutonium-239/240	0.0	NA	NA	<0.1	<0.1	<0.1
Radium-224	0.983	NA	NA	NA	NA	NA
Radium-226	1.51	0.79±0.04	0.9±0.04	1.0±0.4	1.0±0.5	1.0±0.5
Radium-228	1.28	NA	NA	NA	NA	NA
Strontium-90	0.0	NA	NA	<0.7	<0.3	<0.40
Technetium-99	0.0	NA	NA	NA	NA	<0.6
Thorium-228	1.56	0.97±0.07	0.97±0.06	<0.1	<0.1	<0.1
Thorium-230	2.18	NA	NA	0.1±0.1	0.1±0.10	0.1±0.1
Thorium-232	1.36	0.72±0.09	0.94±0.08	<0.1	<0.1	<0.1
Total Thorium (mg/kg)	12.4	6.5[b]	8.5[b]	<0.9[b]	<0.9[b]	<0.9[b]
Uranium-234	1.28	NA	NA	9.3±0.5	8.5±0.4	28.0±1.0
Uranium-235	0.151	0.72±0.01	0.41±0.01	0.5±0.1	0.4±0.1	1.4±0.2
Uranium-235/236	0.151	NA	NA	NA	NA	NA
Uranium-238	1.22	99±5	64±4	16.0±1.0	13.0±1.0	35.0±1.0
Total Uranium (mg/kg)	3.66	228.0	250	47.9[c]	38.9[c]	104.8[c]

This table is to be read horizontally
NA = Not analyzed
I = Nuclide identified by GAMANAL analysis of sample spectrum but did not exceed room background at the 95 percent confidence level; no value reported
R = Value rejected during data validation
[a] = Samples taken outside of the boundary of the waste unit
[b] = Total thorium for ES and CIS samples are calculated estimates which are based on measured values of thorium-232.
[c] = Total uranium for CIS samples are calculated estimates which are based on measured values of uranium-235 and uranium-238.

TABLE 4-3
(continued)

Analyte	Background Concentration	CIS Borings, Sample Descriptions, and Depths			RI/FS Borings, Sample Descriptions, and 1718		
		49-04 Composite 0-8 ft	49-05 Composite 0-14 ft	49-06 Composite 0-18 ft	Shallow Fill 67266 1.5-3.0 ft	Deep Fill 67275 9-10.5 ft	Native Soil 67279 15-16.5 ft
Radionuclides: (pCi/g)							
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.2	<0.3	<0.2	<0.2	<0.2	<0.2
Plutonium-238	0.0	<0.1	<0.1	<0.1	<0.6	<0.6	<0.6
Plutonium-239/240	0.0	<0.1	<0.1	<0.1	<0.6	<0.6	<0.6
Radium-224	0.983	NA	NA	NA	NA	NA	NA
Radium-226	1.51	0.8 ±0.3	0.5 ±0.4	0.8 ±0.2	1.41 ±0.14	1.1±0.1	1.03 ±0.13
Radium-228	1.28	NA	NA	NA	3.2±0.3	1.1±0.1	0.8±0.1
Strontium-90	0.0	<0.5	<0.3	<0.4	0.7±0.2 R	0.9±0.2	<0.5 R
Technetium-99	0.0	<0.4	<0.6	<4.0	<0.9	<0.9	<0.9
Thorium-228	1.560	<0.1	<0.1	<0.1	3.4±0.9	2.3±0.6	1.0±0.4
Thorium-230	2.18	<0.1	0.1±0.1	0.2±0.1	2.3±0.6	1.7±0.5	0.7±0.3
Thorium-232	1.36	<0.1	<0.1	<0.1	2.2±0.6	1.3±0.4	<0.6
Total Thorium (mg/kg)	12.4	<0.9[b]	<0.9[b]	<0.9[b]	20.0±6.0	11.3±3.9	4.0±2.6
Uranium-234	1.28	4.9±0.4	6.4±0.4	8.4±0.5	23.3±2.9	8.7±1.4	0.9±0.1
Uranium-235	0.151	0.4±0.1	0.4±0.1	0.6±0.1	NA	NA	NA
Uranium-235/236	0.151	NA	NA	NA	1.6±0.3	1.1±0.4	<0.6
Uranium-238	1.22	12.0±1.0	13.0±1.0	30.0±1.0	22.1±2.8	40.8±5.5	1.1±0.2
Total Uranium (mg/kg)	3.66	35.9[c]	38.9[c]	89.6[c]	67.2±8.2	124.0±13.0	3.0±2.0

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TABLE 4-3
(continued)

Analyte	Background Concentration	RI/FS Borings, Sample Descriptions, and Depths					
		1719			1720		
		Shallow Fill 67286 1.5-3 ft	Deep Fill 67292 10.5-12 ft	Native Soil 67296 16.5-18 ft	Shallow Fill 67306 1.5-3 ft	Deep Fill 67310 7.5-9 ft	Native Soil 67313 9-10.5 ft
Radionuclides: (pCi/g)							
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Plutonium-238	0.0	<0.6	<1.0	<0.6	<0.6	<0.6	<0.6
Plutonium-239/240	0.0	<0.6	<1.0	<0.6	<0.6	<0.6	<0.6
Radium-224	0.983	NA	NA	NA	NA	NA	NA
Radium-226	1.51	1.24 ±0.20	1.05±0.1	0.38±0.08	1.06 ±0.14	1.01±0.14	1.55±0.18
Radium-228	1.28	1.1±0.29	1.00±0.13	<0.5	1.4±0.2	1.1±0.2	1.5±0.2
Strontium-90	0.0	0.86±0.23	1.07±0.33	1.16±0.30	1.6±0.3	3.1±0.4	0.9±0.2
Technetium-99	0.0	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9
Thorium-228	1.56	1.24±0.36	NA	1.12±0.35	2.1±0.5	1.2±0.3	2.0±0.5
Thorium-230	2.18	1.88±0.46	NA	1.15±0.36	3.5±0.8	2.5±0.5	1.9±0.5
Thorium-232	1.36	0.64±0.25	NA	0.74±0.28	1.4±0.4 R	0.7±0.2 R	1.1±0.3 R
Total Thorium (mg/kg)	12.4	5.8±2.2	NA	6.7±2.5	12.7±3.9 R	6.7±2.0 R	9.6±3.2 R
Uranium-234	1.28	5.53±0.82	20.5±3.8	0.91±0.21	18.5±2.7	1.4±0.2	1.2±0.2
Uranium-235	0.151	NA	NA	NA	NA	NA	NA
Uranium-235/236	0.151	1.23±0.29	4.51±1.31	<0.6	1.3±0.4	<0.6	<0.6
Uranium-238	1.22	8.66±1.18	141±22	1.59±0.28	45.2±6.1	3.5±0.5	1.8±0.3
Total Uranium (mg/kg)	3.66	10.6±4.1	393±40	19.7±3.5	150±22.0	13±3.1	5.8±2.7

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TABLE 4-3
(continued)

Analyte	Background Concentration	RI/FS Borings, Sample Descriptions, and Depths					
		1721			1722		
		Shallow Fill 67230 3-4.5 ft	Deep Fill 67233 7.5-9 ft	Native Soil 67238 15-16.5 ft	Shallow Fill 67251 3-4.5 ft	Native Soil 67257 11-12.5 ft	Native Soil 67258 12.5-14 ft
Radionuclides: (pCi/g)							
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Plutonium-238	0.0	<0.6	<0.6	<0.6	NA	<0.6	<0.6
Plutonium-239/240	0.0	<0.6	<0.6	<0.6	NA	<0.6	<0.6
Radium-224	0.983	NA	1.2±0.2	NA	NA	1.5±0.2	1.1±0.1
Radium-226	1.51	0.89±0.11	0.88±0.14	0.98±0.91	1.5±0.15	1.01±0.14	0.87±0.14
Radium-228	1.28	0.7±0.1	1.04±0.24	0.7±0.1	1.03±0.15	1.32±0.27	0.98±0.25
Strontium-90	0.0	0.8±0.2	<0.9	0.7±0.2	<0.5	1.42±0.63	<0.9
Technetium-99	0.0	<0.9	<0.9	<0.9	NA	<0.9	<0.9
Thorium-228	1.56	1.6±0.4	1.0±0.3	1.4±0.4	1.61±0.48	1.09±0.32	0.96±0.31
Thorium-230	2.18	1.4±0.4	<0.6	1.7±0.4	12.3±2.3	2.40±0.53	3.81±0.74
Thorium-232	1.36	0.7±0.2	0.9±0.3	0.9±0.3	<1.0	1.20±0.34	0.85±0.28
Total Thorium (mg/kg)	12.4	6.4±2.5	8.5±2.3	8.4±3.0	8.99±3.26	10.8±3.0	2.65±0.55
Uranium-234	1.28	1.4±0.2	1.6±0.4	1.8±0.2	334±46	4.51±0.70	30.9±3.9
Uranium-235	0.151	NA	<0.3	NA	NA	<0.4	1.89±0.36
Uranium-235/236	0.151	<0.6	<0.6	0.1±0.1	22.4±5.7	<0.6	2.47±0.61
Uranium-238	1.22	2.3±0.3	1.9±0.54	3.6±0.4	420±57	4.41±0.68	37.2±2.9
Total Uranium (mg/kg)	3.66	6.7±2.0	8.9±3.1	11.2±2.0	940±133	17.5±3.9	146±16

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TABLE 4-3
(continued)

Analyte	Background Concentration	RI/FS Borings, Sample Descriptions, and Depths								
		1035[a]	1038	1808			1888	3037		
		Native Soil 08388 21-22.5 ft	Native Soil 07901 7.5-9 ft	Shallow Fill 67393 1.5-3.0 ft	Deep Fill 67398 10.5-12 ft	Native Soil 67400 13.5-15ft	Deep Fill 67718 6.0-7.5ft	Native Soil 07968 22.5-24 ft	Native Soil 08107 45-46.5 ft	Native Soil 08117 95-96.5 ft
Radionuclides: (pCi/g)										
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.2	<0.2	<0.2 R	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Plutonium-238	0.0	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6 R	<0.6 R	<0.6 R
Plutonium-239/240	0.0	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6 R	<0.6 R	<0.6 R
Radium-224	0.983	NA	NA	NA	NA	2.1±0.2	NA	NA	NA	NA
Radium-226	1.507	0.8±0.1	0.8±0.1	1.03±0.14	1.05±0.12	0.68±0.08	1.1±0.1	0.6±0.1	<0.3	<0.3
Radium-228	1.275	0.6±0.1	1.0±0.1	3.56±0.37	1.16±0.16	0.6±0.11	1.6±0.2	0.6±0.2	<0.6	<0.6
Strontium-90	0.0	<0.5	<0.5	<0.5	<0.5	<0.5	1.0±0.4	<0.5	<0.5	<0.5
Technetium-99	0.0	<0.9	<2.8	<0.9	<0.9	<0.9	<0.9	<2.5	<2.9 DR	<2.5 DR
Thorium-228	1.56	0.8±0.4	2.3±0.7	4.01±0.71	1.17±0.31	1.17±0.39	1.37±0.38	1.2±0.4	0.7±0.3	<0.6
Thorium-230	2.18	1.1±0.4	1.2±0.4	2.76±0.53	2.42±0.52	1.92±0.55	2.30±0.54	1.3±0.4 R	<0.6	0.7±0.3
Thorium-232	1.36	0.7±0.3	1.2±0.4	3.59±0.65	1.12±0.30	<0.6	1.58±0.41	<0.6	<0.6	<0.6
Total Thorium (mg/kg)	12.4	6.4[b]	10.9[b]	32.4±5.9	10.1±2.7	5.08±2.33	14.3±3.7	<5.5[b]	<5.5[b]	<5.5[b]
Uranium-234	1.28	5.2±1.3	0.8±0.3	17.6±2.4	6.26±1.09	0.92±0.24	4.1±0.6	<0.6	<0.6	<0.6
Uranium-235	0.151	NA	NA	NA	NA	NA	8.27±0.22	NA	NA	NA
Uranium-235/236	0.151	<0.26	<0.6	1.17±0.34	0.61±0.28	<0.6	<0.6	<0.6	<0.6	<0.6
Uranium-238	1.22	18.1±3.4	0.9±0.3	17.3±2.4	21.0±2.9	1.08±0.27	4.3±0.6	0.9±0.3	<0.6	<0.6
Total Uranium (mg/kg)	3.66	54.0[c]	3.0[c]	49.9±7.7 R	66.8±10.0	3.21±1.35	19.0±4.0	3.0[c]	<2.1[c]	<2.1[c]

TABLE 4-4

RADIONUCLIDE CONCENTRATIONS IN SUBSURFACE MEDIA PROFILES OF THE SOLID WASTE LANDFILL

	CIS Borings and Analytes[a]																	
	49-01			49-02			49-03			49-04			49-05			49-06		
Depth (ft)	U-238	Ra-226 (pCi/g)	Th-232	U-238	Ra-226 (pCi/g)	Th-232	U-238	Ra-226 (pCi/g)	Th-232	U-238	Ra-226 (pCi/g)	Th-232	U-238	Ra-226 (pCi/g)	Th-232	U-238	Ra-226 (pCi/g)	Th-232
0-1	18.2	1.8	1.0	15.4	<0.9	2.0	19.3	<0.2	2.4	<4.6	0.5	<0.3	5.9	0.8	1.6	13.9	<1.6	1.0
1-2	6.7	<0.6	0.7	4.9	<1.1	1.0	"	"	"	"	"	"	"	"	"	8.8	<2.5	1.2
2-3	6.1	0.8	< 5.3	7.1	0.7	1.3	6.1	<0.7	1.2	<10.3	1.0	<0.3	9.4	0.7	1.2	No Sample Recovery		
3-4	"	"	"	<9.6	0.7	<4.7	"	"	"	9.3	0.9	1.0	4.2	<0.5	<2.3	No Sample Recovery		
4-5	35.1	4.6	1.9	3.5	0.7	<3.2	4.4	0.7	<3.5	<4.7	<1.5	<0.3	14.8	0.6	1.1	8.2	<1.8	0.8
5-6	"	"	"	<9.2	0.6	<0.3	13.7	1.0	1.3	<8.6	1.1	1.0	<7.7	0.7	0.8	"	"	"
6-7	9.3	<1.5	<2.2	5.3	0.9	1.0	388	<5.2	79.7	<5.3	<0.7	<0.3	<8.1	<0.1	1.2	<7.5	0.7	<4.3
7-8	<7.3	0.6	<0.3	"	"	"	"	"	"	"	"	"	<10.6	<0.9	<1.4	<8.3	0.8	1.2
8-9	No Sample Recovery			<12.7	0.9	1.0	146	<1.9	17.1				<9.8	0.9	<0.3	No Sample Recovery		
9-10	No Sample Recovery			<12.6	0.7	1.1	"	"	"				<3.9	0.4	1.3	No Sample Recovery		
10-11	<6.1	<1.0	1.2	<8.3	1.1	1.0	198	<2.0	12.8				3.2	0.6	0.8	<8.1	<2.8	<4.1
11-12	"	"	"	4.3	1.4	1.6	"	"	"				<10.4	0.6	0.6	<13.2	<0.2	1.1
12-13	8.1	<0.6	1.0				48.9	<1.4	3.1				No Sample Recovery			3.8	<0.9	0.7
13-14	<11.3	0.9	<2.6				9.2	<1.7	<0.4				11.3	<1.8	<1.4	<6.6	0.6	0.8
14-15	<15.5	<1.0	0.8				<7.0	<0.8	0.6							3.3	0.8	<6.0
15-16	"	"	"				6.3	0.8	1.1							<5.7	<1.3	<3.2
16-17	<5.0	0.9	<0.3													<16.1	<0.8	<0.4
17-18	<10.5	0.9	0.7													12.3	0.8	<0.4

[a]Analytes are uranium (U); radium (Ra); and thorium (Th).
Source: Weston, Inc., Roy F., 1987b, "Characterization Investigation Study, Volume 2: Chemical and Radiological Analysis of the Waste Pits," prepared for Westinghouse Materials Co. of Ohio, U.S. Dept. of Energy Feed Materials Production Center, Fernald, OH.

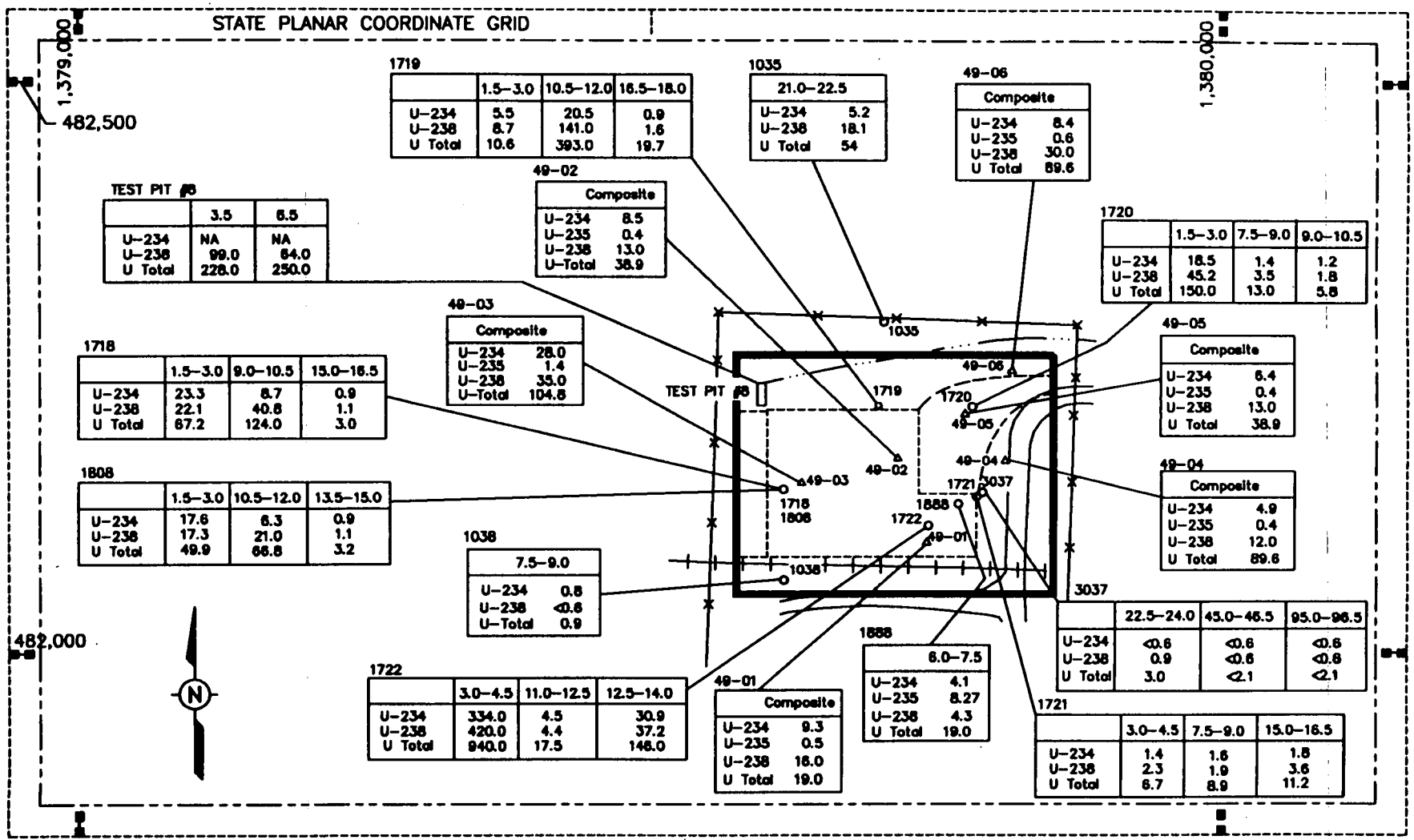

FIGURE 4–3. EXTENT OF URANIUM CONCENTRATION IN SUBSURFACE MEDIA IN THE SOLID WASTE LANDFILL STUDY AREA

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above it, indicating the heterogeneous distribution of uranium near the soil-fill interface. The other native soil measurements do not indicate substantial vertical migration of uranium.

4.2.3.2 Organic Compounds in Surface and Subsurface Media

Due to the nature of the material accepted (rubbish, cafeteria waste, and other trash), a wide range of organic compounds was detected in subsurface samples from the Solid Waste Landfill. A total of 16 samples from seven RI/FS borings and six composite samples from the six CIS borings were analyzed for organics.

Volatile compounds detected with the highest frequency are generally the common laboratory contaminants acetone, 2-butanone and methylene chloride (Table 4-5). The majority of samples in which the compounds were detected were also associated with contaminated laboratory method blanks (Appendix-C). Detected concentrations were less than 0.3 mg/kg for each of these compounds. The highest concentration of any volatile compound was that of 1,4-dioxane, detected in RI/FS Boring 1721 at 12.9 mg/kg. It was also detected in RI/FS Boring 1808 at 0.066 mg/kg. Toluene was detected in samples from both fill and native soil at concentrations ranging from 0.002 to 0.180 mg/kg, with the highest concentration found in a CIS sample from Borehole 49-03. Other volatile compounds found in the subsurface soils of this subunit were detected at both low concentration and frequency.

A variety of polynuclear aromatic hydrocarbons was detected in more than half of all samples analyzed at the Solid Waste Landfill. Compounds with the highest concentrations were acenaphthene (28 mg/kg), naphthalene (19 mg/kg), and 2-methylnaphthalene (11 mg/kg). All other compounds were detected at concentrations less than 10 mg/kg.

Phthalate esters were detected sporadically within the waste unit. Concentrations for each of the phthalate esters detected were less than 0.95 mg/kg.

PCBs were detected a total of nine times in RI/FS and CIS samples. Aroclor-1254 was detected in a shallow sample from Boring 1808 at 0.15 mg/kg, and Aroclor-1260 was detected at 0.61 mg/kg in Boring 1721 at a depth of 9 feet. The remaining PCBs were detected in samples from each of the CIS borings. Boring 49-06, located in the northeast corner of the Solid Waste Landfill, was the only boring that contained more that one type of PCB. This sample contained Aroclor-1248 (0.565 mg/kg), Aroclor-1254 (0.719 mg/kg), and Aroclor-1242 (0.078 mg/kg). PCBs were not detected in any of the four Environmental Survey samples.

TABLE 4-5

ORGANIC COMPOUNDS DETECTED IN SUBSURFACE MEDIA IN THE SOLID WASTE LANDFILL

Compound	Frequency of Detection	Range (mg/kg)
Volatile Compounds		
Acetone	19/21	0.004–0.250
2-Butanone	9/21	0.002–0.120
1,4-Dioxane	2/2	0.066–12.9
Ethylbenzene	2/22	0.018–0.091
2-Hexanone	3/21	0.001–0.012
4-Methyl-2-pentanone	2/21	0.001–0.001
Pyridine	1/4	0.003
Styrene	1/22	0.002–0.002
Toluene	12/22	0.002–0.180
Total Xylenes	3/22	0.006–0.320
Chlorinated Volatile Compounds		
Chlorobenzene	2/22	0.002–0.006
Chloromethane	1/22	0.006
1,1-Dichloroethane	2/22	0.016–0.130
1,2-Dichloroethane	2/22	0.016
1,2-Dichloroethylene	3/22	0.002-0.012
Dichlorodifluoromethane	1/1	0.576
Methylene chloride	18/22	0.005–0.160
Tetrachloroethene	1/22	0.030–0.097
Polynuclear Aromatic Hydrocarbons		
Acenaphthene	7/21	0.053-28.000
Anthracene	7/19	0.130–2.800
Benzo(a)anthracene	9/20	0.043–5.100
Benzo(a)pyrene	8/20	0.069–7.000
Benzo(b)fluoranthene	9/20	0.054–6.700
Benzo(ghi)perylene	7/20	0.300-6.000
Benzo(k)fluoranthene	6/20	0.084–4.900
Chrysene	10/21	0.047–5.600

TABLE 4-5
(continued)

Compound	Frequency of Detection	Range (mg/kg)
Dibenzo(a,h)anthracene	6/20	0.049–2.100
Fluoranthene	8/20	0.094–2.200
Fluorene	5/20	0.880–2.500
Indeno(1,2,3-cd)pyrene	8/20	0.210–5.700
2-Methylnapthalene	4/19	0.066–11.000
Naphthalene	4/19	0.041–19.000
Phenanthrene	8/21	0.053–4.800
Phenol	2/20	0.061-0.310
Pyrene	9/19	0.073–6.300
<u>Phthalate Esters</u>		
Bis(2-ethylhexyl) phthalate	4/18	0.040–0.920
Butyl benzyl phthalate	1/19	0.320
Di-n-butyl phthalate	4/19	0.050–0.330
Di-n-octyl phthalate	2/20	0.300–0.350
Diethyl phthalate	3/21	0.045-0.750
<u>PCBs</u>		
Aroclor-1242	4/20	0.078–1.600
Aroclor-1248	2/20	0.180–0.565
Aroclor-1254	2/20	0.150–0.719
Aroclor-1260	1/20	0.610
<u>Chlorinated Dioxins and Furans</u>		
Heptachlorodibenzofuran	1/16	0.00025
Heptachlorodibenzo-p-dioxin	2/16	0.00065–0.00090
Octachlorodibenzo-p-dioxin	13/16	0.00005–0.00780
1234678 Heptachlorodibenzofuran	1/16	0.00038
1234678 Heptechlorodibenzo-p-dioxin	1/16	0.00007

TABLE 4-5
(continued)

Compound	Frequency of Detection	Range (mg/kg)
Other Semivolatile Compounds		
Benzoic acid	2/18	0.046–2.200
2-Chlorophenol	1/20	0.049
4-Chloro-3-Methylphenol	1/20	0.055
Dibenzofuran	5/19	0.160–1.900
2,4-Dimethylphenol	1/19	0.240
2-Methylphenol	1/18	0.096
4-Methylphenol	1/19	0.360
N-nitrosodiphenylamine	1/17	0.067
Pentachlorophenol	1/20	1.800

[1]Data compiled from Environmental Survey, CIS, and RI/FS sampling and analysis programs
[2]Data qualified with an "R" (i.e., rejected data) are not included

Substituted chlorinated dioxins and furans were detected a total of 18 times. Octachlorodibenzo-p-dioxin was detected in 13 of the 16 samples analyzed at concentrations ranging from 0.000055 mg/kg to 0.0078 mg/kg. The other five dioxin and furan compounds were detected in a sample from the 3-to 4-foot-depth interval in Boring 1719.

Of the remaining SVOCs detected in subsurface samples from the landfill area, only dibenzofuran was detected more than twice (Table 4-5). This compound was detected in 5 of 19 samples analyzed from both RI/FS and CIS borings at concentrations ranging from 0.160 to 1.9 mg/kg.

Hazardous waste toxicity characteristic thresholds (40CFR261.24) were not exceeded for any organic compound in the eight samples that underwent TCLP analysis nor in the three samples that underwent EP Toxicity analysis.

4.2.3.3 Metals in Surface and Subsurface Media

The RCRA metals detected at concentrations above background were arsenic (above background in 3 of 22 samples), barium (3 of 22), cadmium (19 of 22), chromium (11 of 22), lead (5 of 22), mercury (3 of 22), and silver (9 of 22) (Table 4-6). Cadmium concentrations in native soil were similar to those in fill. The highest measured concentration was 6.5 mg/kg in the shallow fill at Boring 1888, 10 times the background level (0.65 mg/kg). Chromium was above background (20.0 mg/kg) in both fill and native soil, with the highest concentration being 51.8 mg/kg in the shallow fill at Boring 1888. Silver was above background (8.03 mg/kg) in fill and native soil samples, with the highest measurement (19.7 mg/kg) being in the shallow fill sample from Boring 1888.

Other metals detected at concentrations above background in half or more of the samples were antimony (above background in 11 of 22 samples) beryllium (12 of 22), and molybdenum (13 of 16). Antimony was above background (0.0 mg/kg) in both fill and native soil samples, and no trend with depth was observed. The highest concentration (22.6 mg/kg) was measured in native soil from Boring 1889. Beryllium was above background (0.607 mg/kg) in both fill and native soil samples, with the highest concentration (1.6 mg/kg) in the shallow fill of Boring 1888. Molybdenum was detected above background (8.8 mg/kg) in both fill and native soil, and no trend with depth was observed. The highest concentration was 29.3 mg/kg in the deep fill sample from Boring 1888.

Hazardous waste toxicity characteristic thresholds (40CFR261.24) were not exceeded for any metals in the TCLP or EP toxicity extracts.

No asbestos was detected in the Environmental Survey samples. However, asbestos was encountered in the 1992 trenching investigation (DOE 1992e).

TABLE 4-6

INORGANICS DETECTED IN SUBSURFACE MEDIA
IN THE SOLID WASTE LANDFILL

Analyte	Background Concentration (mg/kg)	Frequency of Detection	Range (mg/kg)	Frequency Above Background Concentration
Aluminum	16973	21/22	748-25,200	3/22
Antimony	0.0	11/22	3.8–22.6	11/22
Arsenic	10.3	21/22	2.2–15.4	3/22
Barium	133	21/22	16.7–223.0	3/22
Beryllium	0.607	16/22	0.18-1.6	12/22
Boron	48.9	9/11	1.2-36.2	0/11
Cadmium	0.650	21/22	0.48–6.5	19/22
Calcium	201722	22/22	6330–141,000	0/22
Chromium	22.0	22/22	6.3–51.8	11/22
Cobalt	15.8	16/22	2.4-26.0	4/22
Copper	21.2	22/22	4.2-41.5	9/22
Cyanide	0.283	3/22	0.14-0.79	2/22
Iron	33026	22/22	3350-42,600	4/22
Lead	16.6	22/22	6.5-147	5/22
Magnesium	59838	22/22	3320-31,500	0/22
Manganese	1099	22/22	115-1690	1/22
Mercury	0.292	3/22	0.14-0.20	3/22
Molybdenum	8.8	16/16	2.90-18.80	13/16
Nickel	38.1	22/22	4.40-47.10	5/22
Potassium	1911	22/22	830-2430	6/22
Selenium	0.720	1/22	0.54	0/22
Silicon	1566	14/14	127-2620	2/14
Silver	8.03	15/22	3.3-19.7	9/22
Sodium	235	16/22	30.0-342	2/22
Thallium	0.397	3/22	0.6-12.5	3/22
Vanadium	39.5	21/22	6.5-68.8	2/22
Zinc	81.2	22/22	10.3-166.72	3/22

NOTES: 1. Data compiled from Environmental Survey, CIS, AND RI/FS sampling and analysis programs
2. Data qualified with an "R" (i.e., rejected data are not included)

4.2.4 Surface Water and Sediment in the Solid Waste Landfill Study Area

A drainage ditch runs along the northern edge of the Solid Waste Landfill. The storm water runoff from the landfill flows into this drainage path and then flows westerly towards Paddys Run. A series of on-site analyses of sediment samples (FMP-SD-21-007 through FMP-SD-21-011, henceforth referenced as 21-007 through 21-011, respectively) were performed for the CIS within the boundaries and immediately downstream of the landfill. These analyses were by the on-site laboratory and are presented for comparison only. Only one sample (21-009) was taken to the off-site laboratory for radiochemical analyses. One surface water sample was collected from location ASIT-021, and it was analyzed for radionuclides, VOCs, SVOCs, pesticides/PCBs, metals, and the general water quality parameters.

4.2.4.1 Radionuclides in Surface Water and Sediment

Of the five CIS sediment samples, 21-009 (located near the downstream boundary of the Solid Waste Landfill) was identified by on-site analysis as being the most contaminated and underwent further laboratory analysis (Table 4-7, Figure 4-4). The laboratory analysis of Sample 21-009 indicated a calculated total uranium concentration of 68.7 mg/kg. This is less than surface soil samples in the Solid Waste Landfill, but is above background in soils for this analyte (3.66 mg/kg). A potential source of sediment contamination is the surface soil in the Solid Waste Landfill. Another potential source includes surface runoff from the northwestern portion of the former production area, which is upstream from the landfill (Figure 1-2). Suspended surface soil particles are carried in surface water runoff to the drainage ditch where they are eventually redeposited.

The surface water sample collected from ASIT-021 exhibited a total uranium concentration of 26 µg/ℓ. The potential sources for this uranium are: (1) leachate from the Solid Waste Landfill, (2) surface water runoff from the Solid Waste Landfill, and (3) other upstream sources.

4.2.4.2 Organic Compounds in Surface Water and Sediment

Bis(2-ethylhexyl) phthalate, di-n-butyl phthalate, and acetone are the waste-related constituents that were detected in the surface water sample, all at levels less than 0.004 mg/ℓ. Bis(2-ethylhexyl) phthalate and acetone were found in the laboratory blanks, indicating that these analytes may have been introduced during laboratory analysis.

No sediment sample from the Solid Waste Landfill study area was analyzed for organic compounds.

4.2.4.3 Metals in Surface Water and Sediment

Thirteen waste-related metals were detected in the surface water sample, including cadmium (0.00633 mg/ℓ), chromium (0.0175 mg/ℓ), beryllium (0.0015 mg/ℓ), and molybdenum (0.023 mg/ℓ).

TABLE 4-7

WASTE-RELATED RADIONUCLIDE CONCENTRATIONS IN SURFACE WATER AND SEDIMENTS IN THE SOLID WASTE LANDFILL STUDY AREA

		Sediment						Surface Water
		CIS Sample Locations, and Depths						RI/FS Sample Location and Number
Analyte	Background Concentration[a]	21-007[b] 0-1.0ft	21-008[b] 0-.75ft	21-009[b] 0-.75ft	21-009[c] 0-.8ft	21-010[b] 0-.5ft	21-011[b] 0-.25ft	ASIT-021 01161
Radionuclides: (pCi/g, pCi/ℓ)								
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.10	<0.10	<0.70	<0.20	<0.60	<0.60	<20.0 R
Plutonium-238	0.0	NA	NA	NA	0.3±0.1	NA	NA	<1.0 R
Plutonium-239/240	0.0	NA	NA	NA	<0.1	NA	NA	<1.0 R
Radium-224	0.983	NA	NA	NA	NA	NA	NA	NA
Radium-226	1.51	0.7±0.2	<0.9	0.8±0.3	1.31±0.49	0.4±0.2	0.6±0.2	<1.0
Radium-228	1.28	NA	NA	NA	NA	NA	NA	<3.0
Strontium-90	0.0	NA	NA	NA	<0.30	NA	NA	<5.0
Technetium-99	0.0	NA	NA	NA	<0.30	NA	NA	<30.0
Thorium-228	1.56	NA	NA	NA	1.2±0.3	NA	NA	<1.0
Thorium-230	2.18	NA	NA	NA	5.0±0.7	NA	NA	<1.0
Thorium-232	1.36	0.6±0.3	0.7±0.50	<1.80	1.0±0.4	0.70±0.30	0.5±0.4	<1.0
Total Thorium (mg/kg, µg/ℓ)	12.4	5.5[d]	6.4[d]	<16.4[d]	9.1[d]	6.4[d]	4.5[d]	<9.1[d]
Uranium-234	2.109	NA	NA	NA	12.0±1.0	NA	NA	6.1±0.9
Uranium-235	0.097	NA	NA	NA	0.5±0.2	NA	NA	NA
Uranium-235/236	0.097	NA	NA	NA	NA	NA	NA	<1.0
Uranium-238	2.109	4.2±2.5	6.3±2.6	6.8±3.1	23.0±1.0	3.2±1.8	2.9±1.8	9.7±1.4
Total Uranium (mg/kg, µg/ℓ)	3.66	12.5[e]	18.8[e]	20.2[e]	68.7[e]	9.5[e]	8.6[e]	26.0±5.0

NA = Not analyzed
R = Value rejected during data validation
[a] = Background concentrations for sediment are taken as soil UTLs. No UTLs have been calculated for surface water
[b] = Sample analyzed in on-site gamma spectroscopy laboratory
[c] = Sample analyzed in off-site laboratory
[d] = Total thorium for CIS and RI/FS samples are calculated estimates which are based on measured values of thorium-232
[e] = Total uranium for CIS samples are calculated estimates which are based on measured values of uranium-235 and uranium-238

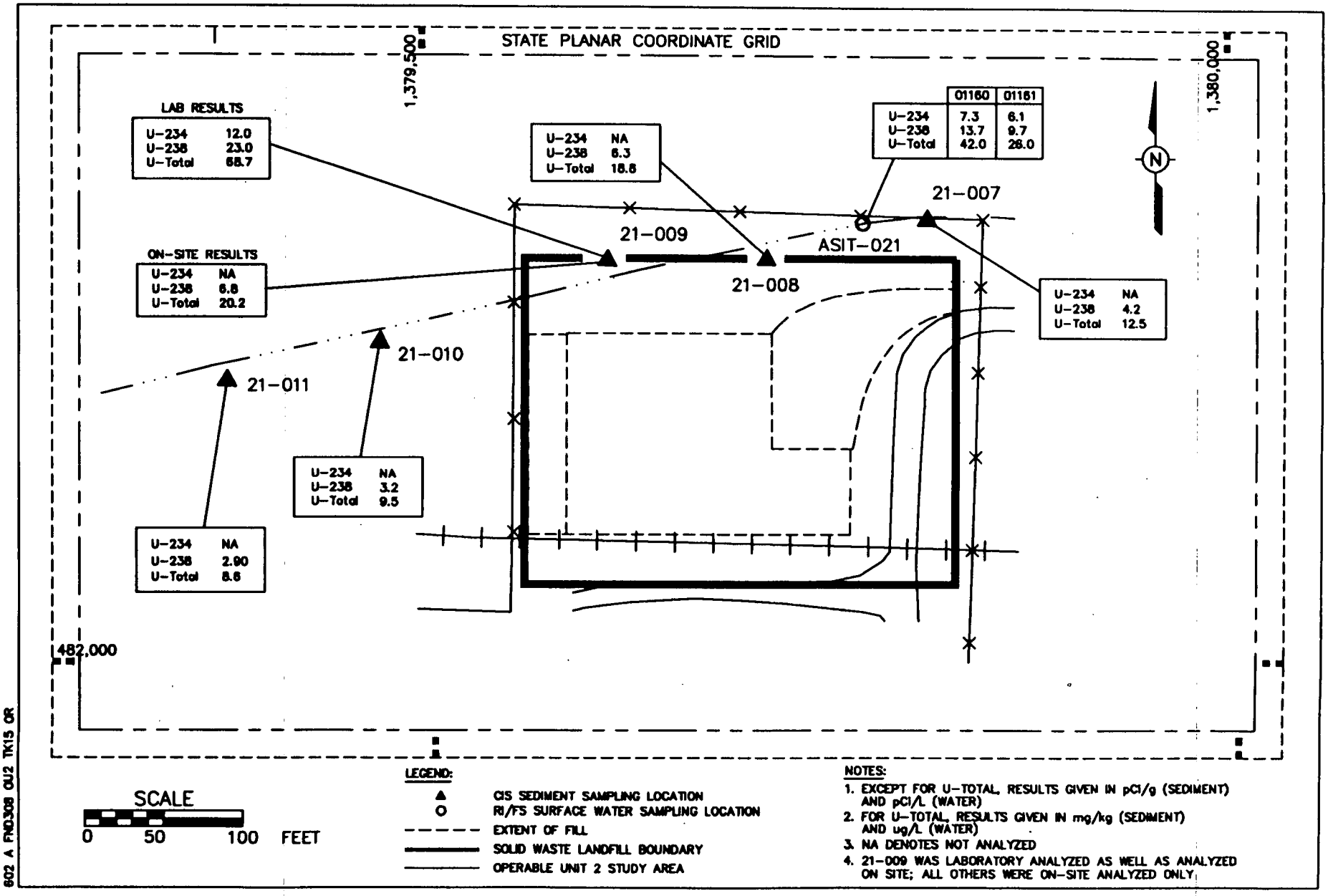

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FIGURE 4-4. URANIUM CONCENTRATIONS IN SURFACE WATER AND SEDIMENT IN SOLID WASTE LANDFILL STUDY AREA

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4.2.5 Groundwater in the Solid Waste Landfill Study Area

A perched groundwater system is located beneath the northern portion of the landfill. This perched horizon consists of a sand lens within the lower portions of the weathered silty clay zone. Horizontal flow within this system could result in the lateral migration of contaminants into areas beyond the landfill boundaries. However, vertical contaminant migration to the underlying Great Miami Aquifer may be retarded by the clays of the underlying glacial overburden. The Great Miami Aquifer in this area is fed by the Shandon Tributary of the New Haven Trough, and the hydraulic gradient of the Upper Great Miami Aquifer indicates an easterly direction of flow.

Environmental Survey Test Pit No. 8 is situated within the western boundary of the landfill. Using nonstandard sampling methods, two grab groundwater samples were taken from the pit (at a depth of 3.5 to 4 feet) and analyzed for uranium. These samples are not comparable to groundwater samples collected from monitoring wells.

Groundwater wells located in the landfill study area were sampled for four quarters during 1988 and 1989 as a part of the RI/FS. Analyses conducted on these samples included radionuclides, metals, and the general water quality parameters. Selected samples were also analyzed for VOCs, SVOCs, pesticides/PCBs, dioxins/furans, and organophosphorus pesticides.

4.2.5.1 Radionuclides in Groundwater

The uranium background values for perched groundwater and for the Shandon Tributary of the Great Miami Aquifer has been calculated to be <3 µg/ℓ. Concentrations of uranium consistently exceeded background in Wells 1038 and 2027 (Table 4-8, Figure 4-5). Uranium intermittently exceeded background in Well 2037. Single occurrences of elevated uranium were noted in Wells 1035 and 3037, but these results were not confirmed by subsequent sampling and therefore are not considered representative. Because the upgradient well (2052) contains higher concentrations of uranium, an upgradient source is indicated for dissolved uranium in the Great Miami Aquifer at this location.

The two samples collected from the bottom of Environmental Survey Test Pit No. 8 contained uranium at 2230 and 3270 µg/ℓ. However, these samples are not comparable to those collected from monitoring wells. Monitoring wells are constructed and developed to produce water that is relatively free of suspended sediment load, whereas the trench samples were collected from seepage to the trench bottom and probably contained significant solid materials, including uranium contaminated surface and/or subsurface media. Additionally, CIS and RI/FS samples were filtered prior to acidification and analysis. There is no indication that filtration was performed on the Environmental Survey Test Pit No. 8 samples.

TABLE 4-8

WASTE-RELATED RADIONUCLIDE CONCENTRATIONS IN GROUNDWATER IN THE SOLID WASTE LANDFILL STUDY AREA

		RI/FS Well Numbers, Sample Numbers, and Dates of Sample Collection										
		1035[a]					1038[a]					
Analytes	Background Concentration[b]	03245 05/25/88	03560 08/11/88	03736 11/15/88	03931 02/05/89	66826 01/06/90	03183 05/11/88	03518 08/22/88	03762 11/20/88	03947 02/05/89	66431 06/18/89	66666 11/21/89
Radionuclides: (pCi/ℓ)												
Bismuth-214	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-237	0.0/0.0	<20.0	<20.0	<20.0	<20.0	NA	<20.0	<20.0	<20.0	<20.0	NA	NA
Plutonium-238	0.0/0.0	<1.0	<1.0	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	NA	NA
Plutonium-239/240	0.0/0.0	<1.0	<1.0	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	NA	NA
Radium-224	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226	<1/<1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radium-228	<3/<3	5.0±1.6	<3.0	<3.0	<3.0	NA	<3.0	<3.0	<3.0	<3.0	NA	NA
Strontium-90	0.0/0.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0	<5.0	<5.0	<5.0	NA	NA
Technetium-99	0.0/0.0	<30.0	<30.0	<30.3	<30.0	<1.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0
Thorium-228	<1/<1	4.0±0.9	<1.0	<1.0	<1.0	1.9±0.8	<1.0	<1.0	<1.0	<1.0	<1.0	4.4±2.0
Thorium-230	<1/<1	4.6±1.0	<1.0	<1.0	<1.0	2.0±0.8	<1.0	<1.0	<1.0	<1.0	<1.0	<1.8
Thorium-232	<1/<1	2.6±0.7	<1.0	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	NA	3.8±1.9
Total Thorium (μg/ℓ)	<9/<9	23.6[d]	<3.0	<4.0	<3.0	NA	<9.1[d]	<5.0	<5.0	<3.0	NA	3.45[d]
Uranium-234	<1/<1	4.6±0.7	<1.0	1.2±0.4	<1.0	1.6±0.6	1.7±0.3	1.9±0.4	2.3±0.7	1.5±0.4	3.1±0.7	6.9±1.2
Uranium-235	<1/<1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235/236	<1/<1	<1.0	<1.0	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Uranium-238	<1/<1	3.9±0.6	1.0±0.3	1.2±0.4	<1.0	2.9±0.8	1.4±0.3	1.4±0.3	1.2±0.5	1.5±0.4	2.0±0.5	5.9±1.1
Total Uranium (μg/ℓ)	<3/<3	17.0±3.0	2.0±1.0	3.0±1.0	3.0±1.0	8.2±0.9	5.0±1.0	4.0±1.0	4.5±0.6	4.0±1.0	5.0±1.0	11.0±2.0

This table is to be read horizontally
NA = Not Analyzed
R = Value rejected during data validation
* = Duplicate
a = Perched groundwater wells
b = Background concentrations are given for perched water/Shandon Tributary of the Great Miami Aquifer
c = Great Miami Aquifer wells
d = Total thorium for RI/FS samples are calculated estimates which are based on measured values of thorium-232
e = Total uranium for RI/FS samples all calculated estimates which are based on measured values of uranium-235 and uranium-238

TABLE 4-8
(continued)

Analytes	Background Concentration[b]	RI/FS Well Numbers, Sample Numbers, and Dates of Sample Collection									
		2027[c]									
		03168 05/09/88	03453 08/10/88	03454* 08/10/88	03731 12/01/88	03941 03/08/89	66447 06/27/89	66580 09/10/89	66581* 09/10/89	66708 11/16/89	66742* 11/16/89
Radionuclides: (pCi/ℓ)											
Bismuth-214	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-237	0.0/0.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	NA	NA	NA	NA
Plutonium-238	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA	NA	NA	NA	NA
Plutonium-239/240	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA	NA	NA	NA	NA
Radium-224	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226	<1/<1	1.6±0.8	1.2±0.4	<1.0	<1.0	<1.0	NA	NA	NA	NA	NA
Radium-228	<3/<3	<3.0	<3.0	<3.0	<3.0	<3.0	NA	NA	NA	NA	NA
Strontium-90	0.0/0.0	<5.0	<5.0	<5.0	<5.0	<5.0	NA	NA	NA	NA	NA
Technetium-99	0.0/0.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0
Thorium-228	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Thorium-230	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Thorium-232	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	NA	NA	NA	NA	NA
Total Thorium (μg/ℓ)	<9/<9	<9.1[d]	<4.0	<5.0	<11.0	<4.0	NA	NA	NA	NA	NA
Uranium-234	<1/<1	1.6±0.5	2.5±0.6	2.2±0.5	<1.0	3.3±0.6	18.7±2.3	2.4±0.1	7.9±1.1	6.3±0.9	6.0±0.9
Uranium-235	<1/<1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235/236	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Uranium-238	<1/<1	2.0±0.6	2.3±0.5	3.1±0.6	<1.0	2.4±0.5	15.4±2.0	4.7±0.7	6.3±0.9	5.2±0.8	5.2±0.8
Total Uranium (μg/ℓ)	<3/<3	6.0±1.0	6.0±1.0	6.0±1.0	6.0±1.0	7.0±1.0	46.0±8.0	20.0±3.0	20.0±3.0	13.0±2.0	12.0±3.0

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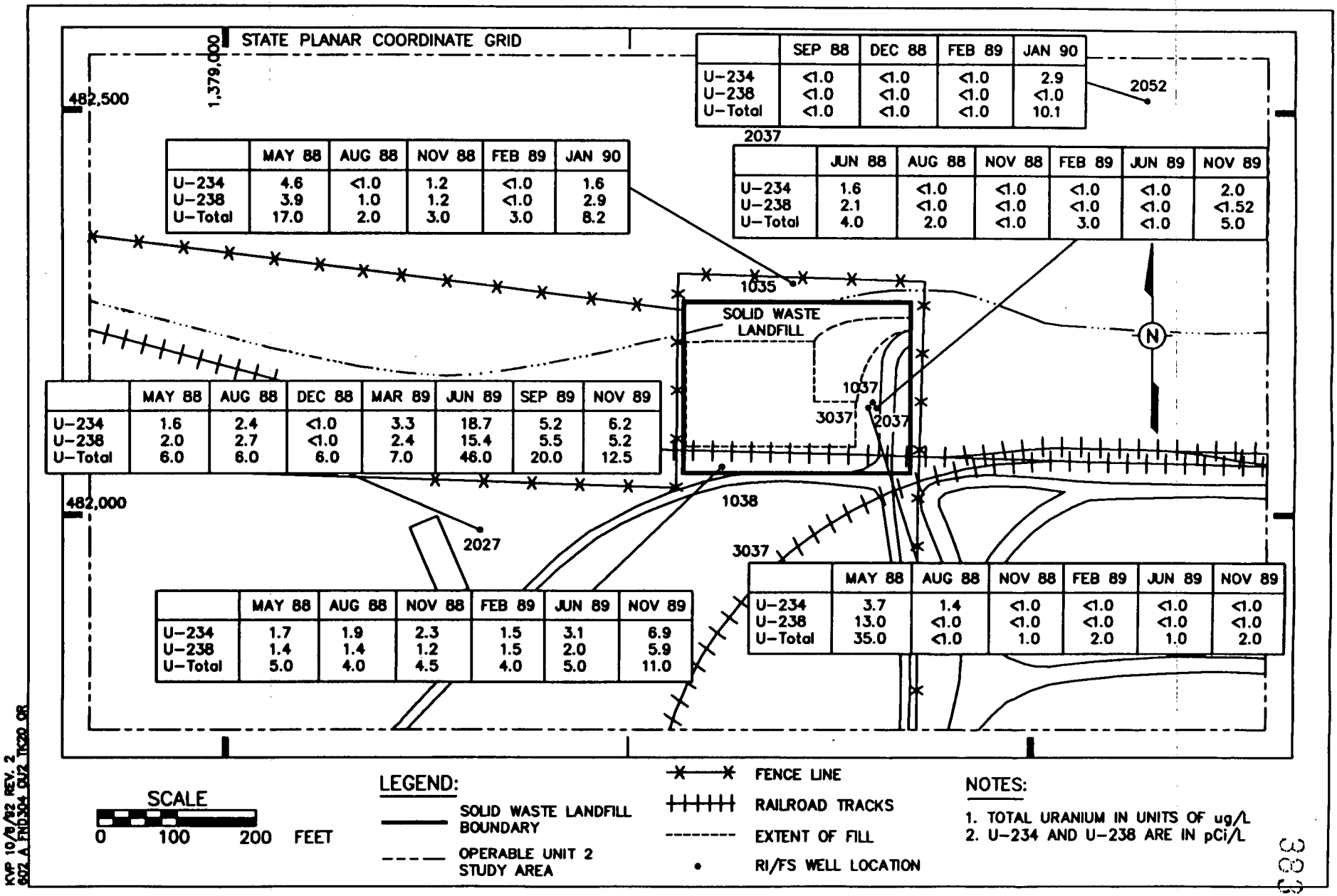
TABLE 4-8
(continued)

Analytes	Background Concentration[b]	RI/FS Well Numbers, Sample Numbers, and Dates of Sample Collection							
		2037[c]							
		03248 06/01/88	03249* 06/01/88	03448 08/08/88	03718 11/18/88	03917 02/22/89	66461 06/28/89	66710 11/19/89	
Radionuclides: (pCi/ℓ)									
Bismuth-214	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	
Cesium-237	0.0/0.0	<20.0	<20.0	<20.0	<20.0	<20.0	NA	NA	
Plutonium-238	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA	NA	
Plutonium-239/240	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA	NA	
Radium-224	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	
Radium-226	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	NA	NA	
Radium-228	<3/<3	<3.0	<3.0	<3.0	<3.0	<3.0	NA	NA	
Strontium-90	0.0/0.0	<5.0	<5.0	<5.0	<5.0	<5.0	NA	NA	
Technetium-99	0.0/0.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	R
Thorium-228	<1/<1	<1.0	1.3±0.5	<1.0	<1.0	<1.0	<1.0	<1.0	R
Thorium-230	<1/<1	<1.0	2.8±0.8	<1.0	<1.0	<1.0	<1.0	<1.0	R
Thorium-232	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	NA	NA	
Total Thorium (μg/ℓ)	<9/<9	<9.1[d]	<9.1[d]	<2.0	<4.0	<3.0	NA	NA	
Uranium-234	<1/<1	1.7±0.4	1.4±0.3	<1.0	<1.0	<1.0	<1.0	2.0±0.5	R
Uranium-235	<1/<1	NA	NA	NA	NA	NA	NA	<1.0	R
Uranium-235/236	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA	
Uranium-238	<1/<1	2.0±0.4	2.2±0.4	<1.0	<1.0	<1.0	<1.0	1.52±0.41	R
Total Uranium (μg/ℓ)	<3/<3	4.0±1.0	4.0±1.0	2.0±1.0	<1.0	3.0±1.0	<1.0	5.0±1.0	

TABLE 4-8
(continued)

Analyte	Background Concentration[b]	RI/FS Well Numbers, Sample Numbers, and Dates of Sample Collection											
		2052[c]					3037[c]						
		03476 12/16/88	03587 09/13/88	03791* 12/16/88	03892 02/08/89	66847 01/04/90	03152 05/05/88	03447 08/08/88	03717 11/18/88	03916 02/22/89	66462 06/28/89	66712 11/19/89	
Radionuclides: (pCi/ℓ)													
Bismuth-214	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Cesium-137	0.0/0.0	<20.0	<20.0	<20.0	<20.0	NA	<20.0	<20.0	<20.0	<20.0	NA	NA	
Plutonium-238	0.0/0.0	<1.0	<1.0	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	NA	NA	
Plutonium-239/240	0.0/0.0	<1.0	<1.0	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	NA	NA	
Radium-224	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Radium-226	<1/<1	<1.0	<1.0	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	NA	NA	
Radium-228	<3/<3	<3.0	5.9±1.5	<3.0	<3.0	NA	<3.0	<3.0	<3.0	<3.0	NA	NA	
Strontium-90	0.0/0.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0	<5.0	<5.0	<5.0	NA	NA	
Technetium-99	0.0/0.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	R
Thorium-228	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	R
Thorium-230	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	1.0±0.7	<1.0	<1.0	<1.0	<1.0	<1.0	R
Thorium-232	<1/<1	<1.0	<1.0	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	NA	NA	
Total Thorium (μg/ℓ)	<9/<9	<4.0	<3.0	<7.0	<2.0	NA	<9.1[d]	<6.0	<8.0	<5.0	NA	NA	
Uranium-234	<1/<1	<1.0	<1.0	<1.0	<1.0	2.9±0.5	3.7±0.9	1.4±0.4	<1.0	<1.0	<1.0	1.0±0.3	R
Uranium-235	<1/<1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<1.0	R
Uranium-235/236	<1/<1	<1.0	<1.0	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	<1.0	NA	
Uranium-238	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	13.0±2.2	<1.0	<1.0	<1.0	<1.0	<1.0	R
Total Uranium (μg/ℓ)	<3/<3	<1.0	<1.0	<1.0	<1.0	10.1±1.1	35.0±6.0	<1.0	1.0±1.0	2.0±1.0	1.1±1.0	2.0±1.0	R



	SEP 88	DEC 88	FEB 89	JAN 90
U-234	<1.0	<1.0	<1.0	2.9
U-238	<1.0	<1.0	<1.0	<1.0
U-Total	<1.0	<1.0	<1.0	10.1

	MAY 88	AUG 88	NOV 88	FEB 89	JAN 90
U-234	4.6	<1.0	1.2	<1.0	1.6
U-238	3.9	1.0	1.2	<1.0	2.9
U-Total	17.0	2.0	3.0	3.0	8.2

	JUN 88	AUG 88	NOV 88	FEB 89	JUN 89	NOV 89
U-234	1.6	<1.0	<1.0	<1.0	<1.0	2.0
U-238	2.1	<1.0	<1.0	<1.0	<1.0	<1.52
U-Total	4.0	2.0	<1.0	3.0	<1.0	5.0

	MAY 88	AUG 88	DEC 88	MAR 89	JUN 89	SEP 89	NOV 89
U-234	1.6	2.4	<1.0	3.3	18.7	5.2	6.2
U-238	2.0	2.7	<1.0	2.4	15.4	5.5	5.2
U-Total	6.0	6.0	6.0	7.0	46.0	20.0	12.5

	MAY 88	AUG 88	NOV 88	FEB 89	JUN 89	NOV 89
U-234	1.7	1.9	2.3	1.5	3.1	6.9
U-238	1.4	1.4	1.2	1.5	2.0	5.9
U-Total	5.0	4.0	4.5	4.0	5.0	11.0

	MAY 88	AUG 88	NOV 88	FEB 89	JUN 89	NOV 89
U-234	3.7	1.4	<1.0	<1.0	<1.0	<1.0
U-238	13.0	<1.0	<1.0	<1.0	<1.0	<1.0
U-Total	35.0	<1.0	1.0	2.0	1.0	2.0

FIGURE 4-5. URANIUM CONCENTRATIONS IN GROUNDWATER IN THE SOLID WASTE LANDFILL STUDY AREA

4.2.5.2 Organic Compounds in Groundwater

Organic compounds detected in the Solid Waste Landfill study area groundwater that were also detected in soils include di-n-butyl phthalate, acetone, and methylene chloride, all at levels less than 0.006 mg/ℓ.

4.2.5.3 Metals in Groundwater

Waste-related metals consistently detected in one or more wells at concentrations above their applicable background concentrations include molybdenum (Well 1038).

4.2.6 Biota in the Solid Waste Landfill Study Area

Cattail leaves at Location 9B (Figure 2-5) contained 3.3 pCi/g of uranium (reported as the sum of uranium-234, uranium-235, and uranium-238 activities) (Table 4-9) (DOE 1992b).

A composite of internal organs from small mammals (white-footed mice and short-tailed shrews) collected near Location 9B contained uranium (reported as the sum of uranium-234, uranium-235, and uranium-238 activities) at 19.0 pCi/g. Therefore, uranium has entered the food chain since it was detected in internal organs. However, the total carcass composite of these same animals showed no detectable levels of radionuclides.

No biota samples taken from near the Solid Waste Landfill were tested for SVOCs, pesticides/PCBs, or metals.

4.2.7 Solid Waste Landfill Summary

Uranium, the primary waste-related contaminant in the Solid Waste Landfill, exists at levels approaching 1000 mg/kg in both the surface media and the subsurface fill. The highest levels of uranium appear to be scattered across the unit in the surface media at ES-620 and ES-622, the shallow fill of Boring 1722, in the deep fill of Boring 1719, and the deep fill of Boring 49-03. Surface soil samples collected near the Solid Waste Landfill, but outside its boundaries, exhibited uranium concentrations similar to those inside the boundary. This, along with the fact that no clear pattern is observed in the distribution of uranium in surface and near-surface media and its proximity to the former production area and waste storage area, indicates that sources outside the Solid Waste Landfill have contributed to the overall extent of contamination.

Except for Boring 1721, uranium concentrations in native soils are much less than those in the overlying fill. The 2000-series well with the highest elevated uranium concentration (Well 2027) is upgradient of the site. The near-background level of uranium in the Great Miami Aquifer wells closest to the Solid Waste Landfill further indicates that contaminants have not migrated from the waste into the aquifer.

TABLE 4-9

URANIUM, CESIUM AND STRONTIUM CONCENTRATIONS IN BIOTA IN THE SOLID WASTE LANDFILL

	Uranium[a]	Cesium-137	Strontium-90
Location 9B:			
Cattail leaf (pCi/g)	3.3	<0.4	<1.0
Cattail root (pCi/g)	<0.6	<0.2	<0.5
Small mammal organs (pCi/g) (composite)	19.0	<1.1	<2.5
Small mammal carcasses (pCi/g) (composite)	<0.6	<0.2	<0.1

[a]This is a sum of all uranium-234, uranium-235, and uranium-238 activities
Source: U.S. Department of Energy, 1992, "Site-Wide Characterization Report," DOE, Fernald Field Office, Fernald, OH.

In general, most organic compounds were detected in soils at low concentrations and frequency of occurrence. Chlorinated dioxins and furans were detected a total of 18 times with concentrations ranging from 0.000055 to 0.0078 mg/kg. Seventeen polynuclear aromatic hydrocarbons (PAHs) were detected in soils with concentrations ranging from 0.041 mg/kg to 28 mg/kg and PCBs were detected a total of nine times at a maximum concentration of 1.6 mg/kg. Only the waste-related constituents of acetone, methylene chloride and di-n-butylphthalate were present in the groundwater. Acetone and methylene chloride are common laboratory contaminants.

A number of inorganic constituents were detected in subsurface media above their respective background concentrations. The most frequent such detections were for cadmium, chromium, silver, antimony, beryllium, and molybdenum. Molybdenum was consistently detected above background in one perched groundwater well.

4.3 LIME SLUDGE PONDS

The analytical results for samples collected from the North and South Lime Sludge Ponds are provided in Appendix D of this document. This section reports results only for waste-related constituents; i.e., analytes which were found to exceed background in at least one surface or subsurface media (soil or lime sludge residue) sample or were found at detectable levels in the North Lime Sludge Pond water. No background values have been calculated for on-site surface water. Analytes that were detected in groundwater, but are less than background in all surface and subsurface media samples and in all North Lime Sludge Pond water samples, are considered to have originated from upgradient sources and are not discussed here.

Data tables in this section present the individual analytical results only for waste-related radionuclides of concern. The waste-related organic and inorganic constituents are numerous, but typically exhibit low frequencies of detection and low concentrations. Therefore, only summary tables for these data are given here, but the complete data set is available in Appendix D.

4.3.1 Review of Historical Data

Spent lime sludges from the FEMP water treatment plant, sludges from neutralization and boiler plant blowdown, and the coal pile storm water runoff have been stored in the Lime Sludge Ponds since the facility became operational. Typical constituents of the sludges include aluminum, calcium, iron, magnesium, manganese, and potassium (WMCO 1989).

4.3.2 Volume and Physical Characteristics of the Waste

The North Lime Sludge Pond is unlined and is approximately 125 by 225 feet in size. It is approximately 90 percent filled and has a previously reported lime-sludge residue depth of 6 to 8 feet (DOE

1988a). This pond is partially covered with water at a depth normally of 2 to 3 feet, but ranging up to 7 feet. The volume of water can vary, depending on plant operations and precipitation.

As part of the CIS, the lime sludge residue in the North Pond was sampled to the depth that equipment refusal occurred (Weston 1987b). Based on the depth of sampling equipment refusal, the depth of lime-sludge residue is estimated at 3.5, 5.5, and 7.0 feet (Figure 4-6). Based on an average depth of 5.3 feet and an area of 28,100 square feet (based on average fill dimensions of 125 feet by 225 feet, considering side slopes), the volume of lime-sludge residue in the North Pond is estimated at 5,500 cubic yards. The volume of berm materials is estimated to be 1100 cubic yards (DOE 1991).
The South Lime Sludge Pond, also unlined, is approximately 125 by 225 feet in size, and it is now overgrown with grass and shrubs in some locations. Borehole log information (Weston 1988) indicates the maximum depth of lime sludge residue to be approximately 11.5 feet (Figure 4-6). Based on an average depth of 11.2 feet and an area of 28,100 square feet (based on average fill dimensions of 125 feet by 225 feet, considering side slopes), the lime sludge residue volume is estimated at 11,700 cubic yards. The volume of the berm material is estimated to be 2800 cubic yards (DOE 1991).

The dry density of surface media was measured at 47 lb/ft^3 in the North Pond and 45 to 50 lb/ft^3 in the South Pond.

4.3.3 Surface and Subsurface Media in the Lime Sludge Ponds

Within the Lime Sludge Ponds, samples were taken from surface media and subsurface fill. Surface media samples were obtained and analyzed during the Environmental Survey, CIS, and RI/FS investigations by three different investigators.

As part of the Environmental Survey, four surface media samples were collected from the South Lime Sludge Pond (FE0616SS, FE0617SS, FE0618SS, FE0619SS; henceforth to be referenced as ES-616, -617, -618 and -619, respectively). These surface media samples were tested for radionuclides, VOCs, SVOCs, PCBs, TCLP organic metals, and asbestos.

As part of the CIS, ten surface media samples were collected from the media surrounding the Lime Sludge Ponds (FMP-SS-23-005, FMP-SS-23-012, etc.; henceforth to be referenced as 23-005, 23-012, etc.,). These samples were analyzed for radionuclides only. Additional CIS samples were analyzed at the on-site laboratory; however, because the objective of the on-site analytical program was to serve as a screening tool, the resulting data are not considered in this discussion of surface media contamination. As part of the RI/FS well installation program, surface media Sample 08448 was collected from Boring 1041. This media sample was analyzed for radionuclides.

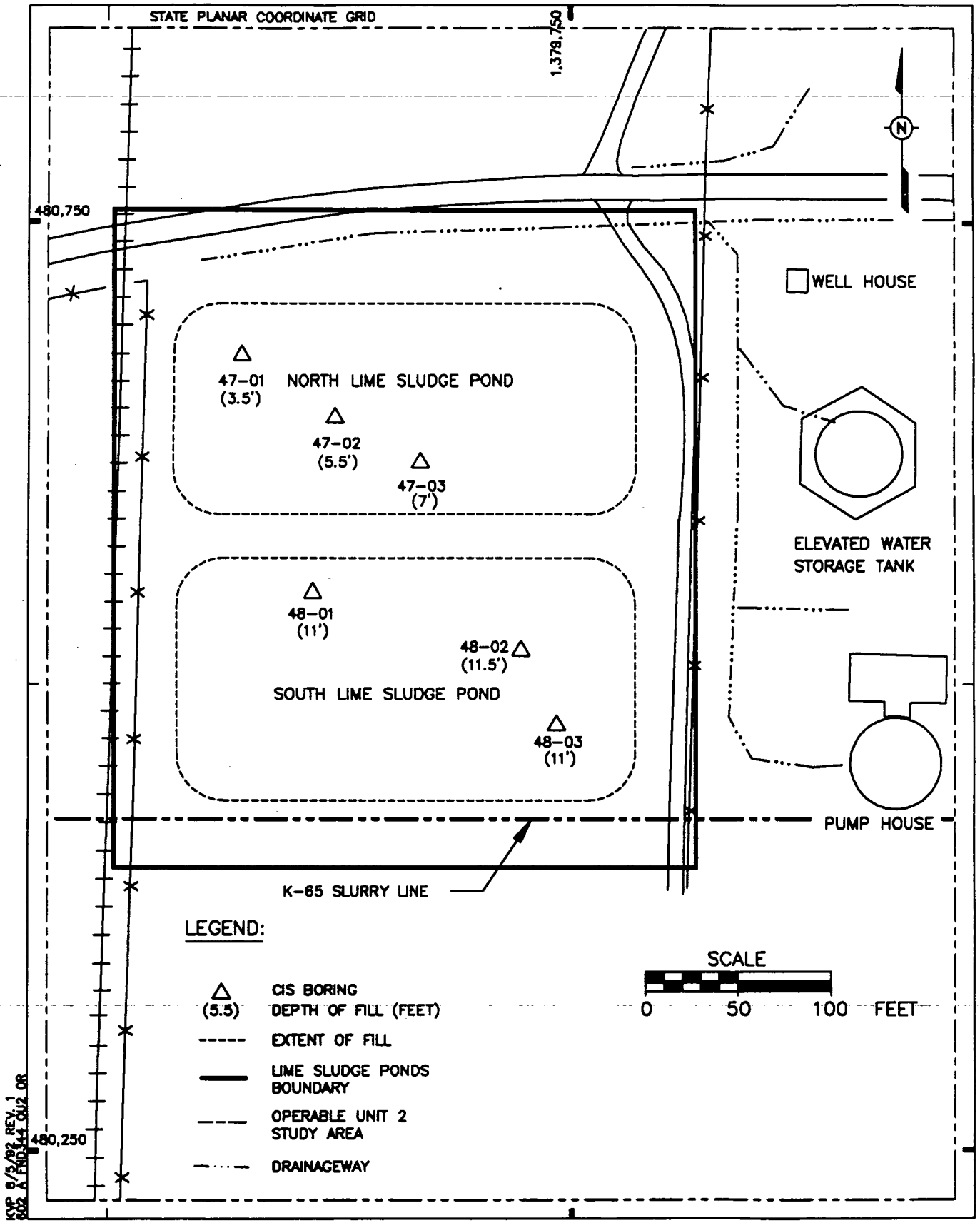


FIGURE 4-6. DEPTH OF LIME SLUDGE RESIDUE

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Subsurface samples were collected only during the CIS and the RI/FS. During the CIS, three borings (47-01, 47-02 and 47-03) were drilled in the North Lime Sludge Pond, and three borings (48-01, 48-02, and 48-03) were drilled in the South Lime Sludge Pond. The depths of these borings ranged from 3.5 to 12.0 feet. Samples were analyzed on-site at various intervals (typically 1 foot) for radium-226, thorium-232 and uranium-238. These analyses are presented as an indication of relative vertical isotopic distribution. A vertical composite was prepared from each CIS boring and was analyzed at an off-site laboratory for radionuclides, VOCs, SVOCs, PCBs, total metals, and EP toxicity metals.

Three RI/FS subsurface samples were collected from Borings 1039 and 2042, which were drilled as part of the well installation program. These samples were analyzed for radionuclides. Later, Boring 1716 was augered into the North Lime Sludge Ponds, and Boring 1717 was augered into the South Lime Sludge Pond (Figure 2-7). Samples from these two borings were analyzed for radionuclides, VOCs, SVOCs, pesticides/PCBs, dioxins/furans, total uranium, metals, TCLP metals/organic, and TOC.

WEMCO conducted a sampling and analysis program as part of a RCRA Facility Assessment of the North Lime Sludge Pond. As part of this investigation, a series of lime sludge residue samples were collected and analyzed for VOCs and the full list of TCLP analytes.

4.3.3.1 Radionuclides in Surface and Subsurface Media

Uranium and thorium are the primary radionuclides in surface media of the Lime Sludge Ponds. Total uranium in surface media ranged from 14 mg/kg at ES-616, in the northwest corner of the South Lime Sludge Pond, to 492 mg/kg at 46-526 along the K-65 slurry line (Tables 4-10 and 4-11; Figure 4-7). Eight other surface media samples along the slurry line exhibited total uranium levels ranging from 29.6 mg/kg to 257 mg/kg. The second highest total uranium concentration in the Lime Sludge Ponds was 257 mg/kg at 46-187, on the northern side of the North Lime Sludge Pond. Based on this finding, it does not appear that surface media immediately adjacent to the K-65 slurry line contains higher levels of uranium than media sampled elsewhere in the Lime Sludge Ponds.

Total thorium was found at concentrations ranging from <0.9 mg/kg at 46-527 to 165 mg/kg at 46-543. Only three samples contained thorium less than its background concentration. Since all but one thorium analysis of surface media are located along the K-65 slurry line, the areal distribution of data are insufficient to show whether surface media along the slurry line are more contaminated with thorium than those elsewhere in the Lime Sludge Ponds area.

Uranium and thorium were also measured in subsurface media samples collected in and around the lime sludge ponds (Tables 4-12 and 4-13). However, analyses of these and other radionuclides are less than or only slightly above background in almost every sample. Furthermore, they are typically

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TABLE 4-10

WASTE-RELATED RADIONUCLIDE CONCENTRATIONS IN SURFACE MEDIA IN THE SOUTH LIME SLUDGE POND

Analyte	Background Concentration	ES Sample Locations and Depths			
		616 0-0.5 ft	617 0-0.5 ft	618 0-0.5 ft	619 0.0.5 ft
Radionuclide: (pCi/g)					
Cesium-137	0.711	I	0.27±0.04	I	0.21±0.02
Lead-210	1.33	NA	NA	NA	NA
Neptunium-237	0.0	NA	NA	NA	NA
Plutonium-238	0.0	NA	NA	NA	NA
Plutonium-239/240	0.0	NA	NA	NA	NA
Radium-226	1.51	I	0.38±0.07	I	0.27±0.03
Strontium-90	0.0	NA	NA	NA	NA
Technetium-99	0.0	NA	NA	NA	NA
Thorium-228	1.56	I	I	I	I
Thorium-230	2.18	NA	NA	NA	NA
Thorium-232	1.36	I	I	I	I
Total Thorium (mg/kg)	12.4	NA	NA	NA	NA
Uranium-234	1.28	NA	NA	NA	NA
Uranium-235	1.51	N	0.18±0.02	N	0.44±0.02
Uranium-238	1.22	N	1.6±0.3	41.0±6.0	22.0±4.0
Total Uranium (mg/kg)	3.66	14	19	36	28

I = Nuclide identified by GAMANAL analysis of spectrum, but value did not exceed room background at the 95% confidence level; no value reported
N = Nuclide not identified by GAMANAL analysis as being present in the sample; no value reported
NA = The analytes were not analyzed

TABLE 4-11

WASTE-RELATED RADIONUCLIDE CONCENTRATIONS IN SURFACE MEDIA IN AND SURROUNDING THE LIME SLUDGE PONDS

Analyte	Background Concentration	CIS Sample Locations and Depths										RI/FS Boring
		23-005 0-0.5ft	23-012[a] 0-0.5ft	23-013[a] 0-0.5ft	46-187 0-0.5ft	46-526 0-0.16ft	46-527 0.16-0.5ft	46-534 0-0.16ft	46-542 0-0.16ft	46-543 0.16-0.5ft	46-544 0.16-0.5ft	1041 08448 0-1.5 ft
Radionuclides: (pCi/g)												
Cesium-137	0.711	<0.6	<0.6	2.3±0.6	0.6±0.3	<0.9	<0.3	<0.9	<0.5	<0.7	<0.6	<0.2
Lead-210	1.33	44.0±3.0	30.±2.0	12.0±1.0	NA	NA	NA	NA	NA	NA	NA	NA
Neptunium-237	0.0	<0.1	<0.1	2.7±0.5	<0.2	4.0±0.9	<0.1	<0.1	<0.1	<0.3	<0.2	<0.6
Plutonium-238	0.0	<0.1	<0.1	0.3±0.1	0.3±0.2	0.1±0.1	<0.1	0.2±0.1	<0.1	<0.1	<0.1	<0.6
Plutonium-239/240	0.0	<0.1	<0.1	0.2±0.1	<0.1	2.0±0.4	<0.1	0.4±0.1	<0.1	<0.1	<0.1	<0.6
Radium-226	1.55	21.46±2.24	29.39±1.93	9.64±1.3	<0.86	19.98±1.57	5.61±0.65	6.58±1.43	14.96±1.97	10.45±1.55	NA	1.1±0.1
Strontium-90	0.0	<0.4	<0.5	<0.7	0.80±0.5	<0.8	<0.5	<0.4	<0.8	<0.3	<0.3	<0.5
Technetium-99	0.0	<1.0	<0.2	91.0±4.0	4.0±0.3	37.0±1.0	17.0±2.0	16.0±1.0	<1.0	<2.0	<1.0	<0.9
Thorium-228	1.56	3.5±0.3	0.4±0.1	3.3±0.3	3.4±0.3	17.0±2.0	0.1±0.1	7.9±0.5	1.4±0.4	16.0±1.0	14.0±1.0	1.3±0.5
Thorium-230	2.18	217.0±2.0	13.0±1.0	21.0±1.0	31.0±1.0	442.0±3.0	2.3±0.2	19.0±1.0	25.0±1.0	251.0±4.0	209.0±3.0	3.8±0.9
Thorium-232	1.36	3.6±0.3	0.2±0.1	0.5±0.1	2.8±0.3	4.0±3.0	<0.1	2.6±0.3	2.1±0.5	18.0±1.0	14.0±1.0	1.5±0.5
Total Thorium (mg/kg)	12.4	32.7[b]	1.8[b]	4.5[b]	25.5[b]	36.4[b]	<0.9[b]	23.6[b]	19.1[b]	163.6[b]	127.3[b]	13.6[b]
Uranium-234	1.28	55.0±1.0	25.0±1.0	84.0±2.0	24.0±1.0	180.0±2.0	8.2±0.3	38.0±1.0	22.0±1.0	22.0±1.0	17.0±1.0	3.8±0.8
Uranium-235	0.151	2.2±0.2	1.0±0.1	3.8±0.3	1.8±0.2	9.0±0.4	0.4±0.1	1.7±0.2	0.7±0.1	0.9±0.2	0.8±0.2	NA
Uranium-238	1.22	55.0±1.0	27.0±1.0	83.0±2.0	86.0±1.0	164.0±2.0	9.9±0.3	36.0±1.0	25.0±1.0	23.0±1.0	20.0±1.0	5.9±1.1
Total Uranium (mg/kg)	3.66	164.7[c]	80.8[c]	248.8[c]	256.8[c]	492.3[c]	29.6[c]	107.9[c]	74.7[c]	68.9[c]	59.9[c]	17.6[c]

NA = Not Analyzed.
[a] = These samples are not within the Lime Sludge Pond Boundary
[b] = Total thorium for CIS and RI/FS samples are calculated estimates which are based on measured values of thorium-232
[c] = Total uranium for CIS and RI/FS samples are calculated estimates which are based on measured values of uranium-235 and uranium-238

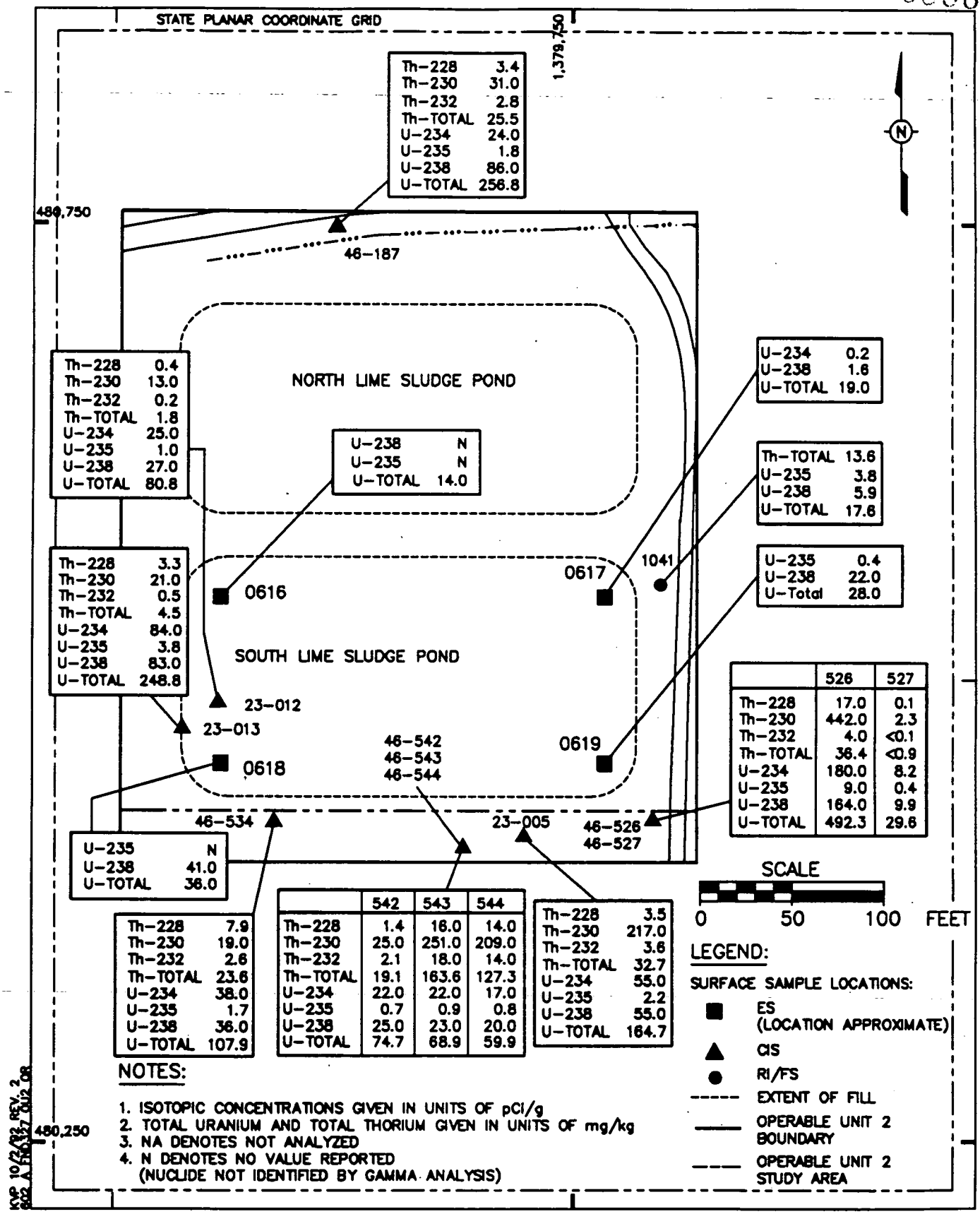

FIGURE 4-7. URANIUM AND THORIUM CONCENTRATIONS IN SURFACE MEDIA IN THE LIME SLUDGE PONDS STUDY AREA

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TABLE 4-12

WASTE-RELATED RADIONUCLIDE CONCENTRATIONS IN SUBSURFACE MEDIA IN THE NORTH LIME SLUDGE POND

Analyte	Background Concentration	CIS Borings and Depth Intervals			ASI Sample Locations, Sample Number, and Depth Intervals		
		47-01 (0-3.5ft)	47-02 (0-5.5ft)	47-03 (0-7ft)	1039 08439 (12-13.5ft)	1716 67904 (2.ft)	
Radionuclides: (pCi/g)							
Cesium-137	0.711	<1.0	<2.0	<0.8	<0.2	<0.2	
Lead-210	1.33	NA	NA	NA	NA	NA	
Neptunium-237	0.0	<0.03	<0.04	<0.03	<0.6	NA	
Plutonium-238	0.0	<0.06	<0.09	<0.05	<0.6	<0.6	
Plutonium-239/240	0.0	<0.05	<0.05	<0.05	<0.6	<0.6	R
Radium-226	1.51	<6.20	<2.0	<3.90	0.9±0.1	<0.3	
Strontium-90	0.0	2.2±0.9	<0.5	<0.5	<0.5	<0.5	
Technetium-99	0.0	<0.3	<0.4	<0.3	<0.9	<0.9	R
Thorium-228	1.56	0.2±0.2	0.2±0.1	0.2±0.1	0.7±0.2	1.04±0.30	
Thorium-230	2.18	20.0±1.0	5.0±0.4	0.5±0.1	1.5±0.4	<0.6	
Thorium-232	1.36	0.2±0.2	0.2±0.1	0.2±0.1	0.9±0.3	<0.6	
Total Thorium (mg/kg)	12.4	1.8[a]	1.8[a]	1.8[a]	8.2[a]	<1.0	
Uranium-234	1.28	2.5±0.2	2.5±0.2	2.1±0.2	0.8±0.3	1.57±0.40	
Uranium-235	0.151	0.1±0.1	0.2±0.1	0.1±0.1	NA	NA	
Uranium-238	1.22	7.6±0.4	2.4±0.2	2.7±0.2	0.7±0.2	1.33±0.36	
Total Uranium (mg/kg)	3.66	22.7[b]	7.2[b]	8.1[b]	2.1[b]	5.49±1.8	

NA = Not analyzed
R = Value rejected during data validation
[a] = Total thorium for CIS and RI/FS samples are calculated estimates which are based on measured values of thorium-232
[b] = Total uranium for CIS and RI/FS samples are calculated estimates which are based on measured values of uranium-235 and uranium-238

TABLE 4-13

WASTE-RELATED RADIONUCLIDE CONCENTRATIONS IN SUBSURFACE MEDIA IN THE SOUTH LIME SLUDGE POND

Analyte	Background Concentration	CIS Borings and Depth Intervals			RI/FS Sample Locations, Sample Numbers, and Depth Intervals		
		48-01 (0-8ft)	48-02 (0-9ft)	48-03 (0-9ft)	1717 67902 (1.5-2ft)	2042[a] 08509 (45-46.5ft)	2042[a] 08869 (3-4.5ft)
Radionuclides: (pCi/g)							
Cesium-137	0.711	<0.6	<0.6	<0.5	<0.2	<0.2	<0.2
Lead-210	1.33	NA	NA	NA	NA	NA	NA
Neptunium-237	0.0	<0.07	<0.03	<0.03	NA	<0.6	<0.6
Plutonium-238	0.0	<0.05	<0.05	<0.05	<0.6	<0.6	<0.6
Plutonium-239/240	0.0	<0.05	<0.05	<0.05	<0.6 R	<0.6	<0.6
Radium-226	1.51	<2.3	<2.5	<1.1	0.35±0.06	0.4±0.1	1.0±0.1
Strontium-90	0.0	<0.5	<0.5	<0.5	<0.5	<0.5	6.0±0.8
Technetium-99	0.0	<0.4	<0.4	<0.3	<0.9 R	<0.9	<0.9
Thorium-228	1.56	0.3±0.3	0.1±0.1	0.2±0.2	1.46±0.40	<0.6	1.0±0.2
Thorium-230	2.18	7.0±1.0	1.1±0.2	0.9±0.2	1.20±0.35	1.3±0.2	2.3±0.4
Thorium-232	1.36	0.3±0.2	0.1±0.1	0.2±0.1	<0.6	<0.6	1.3±0.3
Total Thorium (mg/kg)	12.4	2.7[b]	0.9[b]	1.8[b]	<1.2	<5.5[b]	11.8[b]
Uranium-234	1.28	3.1±0.8	1.8±0.3	2.0±0.3	0.9±0.2	<0.6	0.8±0.2
Uranium-235	0.151	0.3±0.3	0.1±0.1	0.1±0.1	NA	NA	NA
Uranium-238	1.22	2.2±0.7	2.8±0.3	2.7±0.3	0.7±0.2	<0.6	0.9±0.2
Total Uranium (mg/kg)	3.66	6.7[c]	8.4[c]	8.1[c]	2.08±1.10	<1.8[c]	2.7[c]

NA = Not analyzed
R = Value rejected during data validation
[a] = Boring 2042 is outside waste unit boundary
[b] = Total thorium for CIS and RI/FS samples are calculated estimates which are based on measured values of thorium-232
[c] = Total uranium for CIS and RI/FS samples are calculated estimates which are based on measured values of uranium-235 and uranium-238

10 to 100 times less than the surface soil analyses. This subsurface soil sampling indicates minimal or no vertical migration of radionuclides has occurred within the soil zone. The CIS profiles provide additional evidence for this conclusion (Table 4-14).

4.3.3.2 Organic Compounds in Surface and Subsurface Media

The concentrations of detected organic compounds in soils and residue are low (Table 4-15). Samples collected at each pond that underwent organic analysis included one discrete sample from the RI/FS Boring and three composite samples from CIS borings. Data from the North and South Ponds have been presented separately.

The most commonly detected compounds in the North Pond are acetone and methylene chloride. Each was detected in all samples at low concentrations. Other compounds detected in two or more samples include carbon disulfide and the phthalate esters. In most cases, the detected concentrations of these compounds were less than 0.4 mg/kg. Exceptions were butyl benzyl phthalate (2.8 mg/kg), Aroclor-1248 (1.2 mg/kg), and chlordane (1.2 mg/kg). Other than these single detections of Aroclor-1248 and chlorodane, no other pesticides or PCBs were detected in the Lime Sludge Ponds.

Fewer organic compounds were detected in samples from the South Lime Sludge Pond. Acetone and methylene chloride were again the most frequently detected compound. Five phthalate esters were detected at concentrations less than 0.400 mg/kg. Each of the remaining four compounds found in the area (2-hexanone, 2-butanone, benzoic acid, and phenol) were detected one time and at low concentrations (Table 4-15).

Organics detected in two or more of the 32 subsurface residue samples collected for VOC analyses during the North Lime Sludge Pond RCRA Facility Assessment included, (1) acetone in 16 samples at concentrations up to 0.675 mg/kg, (2) methylene chloride in 12 samples at concentrations up to 0.011 mg/kg, (3) 1,1,1-trichloroethane in two samples at concentrations up to 0.023 mg/ℓ, and (4) 2-butanone in two samples at concentrations up to 0.008 mg/kg. All of these compounds were detected in the associated laboratory blanks, indicating the laboratory as the source, rather than the North Lime Sludge Pond.

Hazardous waste toxicity characteristic thresholds (40CFR261.24) were not exceeded for any organic compound in the TCLP extracts from the two samples that underwent analysis.

4.3.3.3 Metals in Surface and Subsurface Media

The RCRA metals detected at concentrations above background in the Lime Sludge Ponds were arsenic (above background in 2 of 8 samples), cadmium (2 of 8), chromium (4 of 8), mercury (2 of 8),

TABLE 4-14

RADIONUCLIDE CONCENTRATIONS IN SUBSURFACE MEDIA PROFILES IN THE LIME SLUDGE PONDS

North Lime Sludge Pond Boring and Analytes

47-01				47-02				47-03			
Depth (ft)	U-238 (pCi/g)	Ra-226 (pCi/g)	Th-232 (pCi/g)	Depth (ft)	U-238 (pCi/g)	Ra-226 (pCi/g)	Th-232 (pCi/g)	Depth (ft)	U-238 (pCi/g)	Ra-226 (pCi/g)	Th-232 (pCi/g)
0-0.5	5.8	0.7	0.9	0-0.5				0-2.0			
0.5-1.8	2.3	<0.6	<2.4	0.5-2.2	1.7	<0.6	0.5	2.0-3.6	<6.8	<1.3	0.5
1.8-3.5	<8.3	<1.3	<0.4	2.2-3.8	<4.3	<0.5	<0.4	3.6-5.3	<3.8	<0.1	<1.3
				3.8-5.5	2.8	<0.7	<0.3	5.3-7.0	6.9	0.9	<1.4

South Lime Sludge Pond Borings and Analytes

48-01				48-02				48-03			
Depth (ft)	U-238 (pCi/g)	Ra-226 (pCi/g)	Th-232 (pCi/g)	Depth (ft)	U-238 (pCi/g)	Ra-226 (pCi/g)	Th-232 (pCi/g)	Depth (ft)	U-238 (pCi/g)	Ra-226 (pCi/g)	Th-232 (pCi/g)
0-1	No Sample Recovery			0-1	4.0	<0.2	<0.4	0-1	3.2	<0.2	<0.4
1-2	No Sample Recovery			1-2	4.0	<0.2	<0.4	1-2	<10.1	<0.1	<0.4
2-3	6.7	<1.7	0.6	2-3	<4.8	<1.6	<2.6	2-3	<9.8	1.1	<0.7
3-4	<7.4	<1.2	<0.5	3-4	2.7	<0.1	<0.3	3-4	<13.4	2.0	<0.6
4-5	2.8	<1.3	<0.2	4-5	<11.2	<0.1	<0.3	4-5	<5.6	<1.0	<0.4
5-6	<4.2	<0.6	<0.2	5-6	<5.5	<2.2	<0.4	5-6	4.7	<0.7	<0.4
6-7	4.1	<1.4	<0.3	6-7	2.0	<1.5	<1.5	6-7	<7.2	<0.5	0.3
7-8	<5.6	<1.3	<1.5	7-8	<12.0	<1.4	0.4	7-8	<6.9	<0.9	<0.2
8-9				8-9	<1.8	<0.2	<1.1	8-9	4.4	<1.0	<2.3

Source: U.S. Department of Energy, 1992, "Site-Wide Characterization Report," DOE, Fernald Field Office, Fernald, OH

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TABLE 4-15

ORGANIC COMPOUNDS DETECTED IN SUBSURFACE MEDIA
IN THE NORTH AND SOUTH LIME SLUDGE PONDS

	North Lime Sludge Pond		South Lime Sludge Pond	
Compound	Frequency of Detection	Range (mg/kg)	Frequency of Detection	Range (mg/kg)
Volatile Compounds				
Acetone	4/4	0.020-0.150	3/4	0.017-0.140
Carbon disulfide	3/4	0.007-0.009		
Toluene	1/4	0.020		
2-Butanone			1/4	1.800
2-Hexanone			1/4	0.002
Chlorinated Volatile Compounds				
Methylene chloride	4/4	0.012-0.026	4/4	0.008-0.240
1,1-Dichloroethane	1/4	0.003		
1,1,2 Trichloro-1,2,2 trifluoroethane	2/3	0.050-0.081		
Phthalate Esters				
Bis(2-ethylhexyl) phthalate	3/4	0.150-0.310	3/4	0.230-0.310
Butyl benzyl phthalate	2/4	0.370-2.80		
Di-n-butyl phthalate	3/4	0.089-0.120	2/4	0.047-0.073
Pesticides/PCBs				
Aroclor-1248	1/4	1.200		
Chlordane	1/3	1.200		
Other Semivolatile Compounds				
Benzoic acid			1/4	0.160
Phenol	1/4	0.610	1/4	0.089

Notes: 1. Date compiled from Environment Survey, CIS, and RI/FS sampling and analysis programs.
2. Data qualified with an "R" (i.e., rejected data) are not included.

and silver (2 of 8) (Table 4-16). Chromium was above background (22.0 mg/kg) in both ponds, with the highest concentration being 28.2 mg/kg at Boring 1716.

Hazardous waste toxicity characteristic thresholds (40CFR261.24) were not exceeded for any metals in the TCLP or EP toxicity extracts.

4.3.4 Surface Water in the Lime Sludge Ponds

Four surface water samples were collected from the North Lime Sludge Pond in 1991, and were analyzed for radionuclides, VOCs, SVOCs, pesticides/PCBs, and metals. One sample was tested for the additional Appendix IX parameters. Three samples were collected by WEMCO as part of the RCRA Facility Assessment. These were analyzed for VOCs and the full list of TCLP analytes. Since no standing water was present in the South Pond, no surface water sample was taken. Because the chemical composition of surface water is dependent on the type of material in which it is contained and the period of contact, no background values are available for on-site surface water; therefore, all of the analytes detected in the North Lime Sludge Pond water samples are considered waste-related constituents.

4.3.4.1 Radionuclides in Surface Water

One surface water sample was collected from the North Lime Sludge Pond and analyzed for radionuclides. No radiological analytes were detected in this sample (Table 4-17).

4.3.4.2 Organic Compounds in Surface Water

Organic constituents detected in North Lime Sludge Pond water, along with their maximum concentrations (given in mg/ℓ), are as follows: acetone (0.01), methylene chloride (0.007), and 2-butanone (0.01). Methylene chloride was found in the associated blanks as well as the samples, indicating that this contaminant may have been introduced during sample handling and laboratory analysis.

The three water samples collected for the RCRA Facility Assessment all contained 2-butanone at approximately 0.05 mg/ℓ. Acetone was detected in one sample at 0.0165 mg/ℓ.

4.3.4.3 Metals in Surface Water

Metals detected in one or more of the three samples of the North Lime Sludge Pond water, along with their maximum concentrations (given in mg/ℓ), are as follows: aluminum (0.0997), antimony (0.0369), arsenic (0.0036), barium (0.0427), boron (0.243), cadmium (0.0092), calcium (47.9), chromium (0.0156), iron (0.0333), lead (0.002), magnesium (47.8), manganese (0.1140), molybdenum (0.0183), potassium (13.2), silicon (1.04), silver (0.0113), sodium (272.0), and zinc (0.1930).

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TABLE 4-16

INORGANICS DETECTED IN SUBSURFACE MEDIA IN THE NORTH AND SOUTH LIME SLUDGE PONDS

Analyte	Background Concentration (mg/kg)	North Lime Sludge Pond			South Lime Sludge Pond		
		Frequency of Detection	Range (mg/kg)	Frequency above BC[a]	Frequency of Detection	Range (mg/kg)	Frequency above BC
Aluminum	16973	4/4	4580–18600	1/4	4/4	2700–6015	0/4
Antimony	0.0	1/4	22.100	1/4	1/4	20.000	1/4
Arsenic	10.3	4/4	4.200–16.000	2/4	1/4	1.700	0/4
Barium	133	1/4	71.000	0/4	2/4	63.400–73.340	0/4
Beryllium	0.607	1/4	0.760	1/4	1/4	0.650	1/4
Boron	48.9	1/1	37.000	0/1	1/1	28.900	0/1
Cadmium	0.650	1/4	4.000	1/4	1/4	2.500	1/4
Calcium	201722	4/4	252000–323000	4/4	4/4	298311.720–339000	4/4
Chromium	22.0	4/4	14.000–28.200	2/4	4/4	5.040–28.000	1/4
Cobalt	15.8	1/4	5.100	0/4	1/4	3.900	0/4
Copper	21.2	4/4	15.000–24.000	1/4	2/4	8.400–12.100	0/4
Cyanide	0.283			0/4	1/4	1.700	1/4
Iron	33026.3	4/4	3980–2060	0/4	4/4	3240–6936.07	0/4
Lead	16.6	1/4	2.000	0/4	2/4	0.980–2.140	0/4
Magnesium	59838	4/4	19100–21200	0/4	4/4	13300–17981.64	0/4
Manganese	1099	4/4	515.000–638.000	0/4	4/4	499–746.770	0/4
Mercury	0.292	2/4	0.300	2/4			
Molybdenum	8.8	1/1	8.200	0/4	1/1	5.700	0/4
Nickel	38.1	1/4	11.700	0/4	1/4	9.000	0/4
Potassium	1911	4/4	68.700–1670	0/4	2/4	216.000–343.200	0/4
Silicon	1566	1/1	5920	1/1	1/1	3220	1/1
Silver	8.03	1/4	22.000	1/4	1/4	21.700	1/4
Sodium	235	4/4	304.000–1530	4/4	1/4	327.000	1/4
Thallium	0.397	1/4	0.510	1/4			
Vanadium	39.5	1/4	17.500	0/4	1/4	17.108	0/4
Zinc	81.2	4/4	38.000–75.000	0/4	4/4	8.200–16.590	0/4

[a] BC = Background Concentration

NOTES: 1. Data compiled from Environmental Survey, CIS, and RI/FS sampling and analysis programs.
2. Data qualified with an "R" (i.e., rejected data) are not included.

TABLE 4-17

WASTE-RELATED RADIONUCLIDE CONCENTRATIONS
IN SURFACE WATER IN THE NORTH LIME SLUDGE POND

Analyte	Background Concentration	RI/FS Sample Number 67500
Radionuclides: (pCi/ℓ)		
Cesium-137	NC	<20.0
Lead-210	NC	NA
Neptunium-237	NC	<1.0
Plutonium-238	NC	<1.0
Plutonium-239/240	NC	<1.0
Radium-226	NC	<1.0
Strontium-90	NC	<5.0
Technetium-99	NC	<30.0
Thorium-228	NC	<1.0
Thorium-230	NC	<1.0
Thorium-232	NC	<1.0
Total Thorium	NC	<4.7
Uranium-234	NC	<1.0
Uranium-235	NC	NA
Uranium-238	NC	<1.0
Total Uranium (µg/ℓ)	NC	<1.0

NA = Not Analyzed
NC = None Calculated

4.3.5 Groundwater in the Lime Sludge Pond Study Area

A perched groundwater system surrounds the Lime Sludge Ponds within a few feet of ground surface. The potentiometric surface resides within the Lime Sludge Ponds, indicating possible direct hydraulic connection of the perched groundwater with impounded materials. Horizontal flow in this system could result in lateral migration of contaminants from the Lime Sludge Ponds. The Great Miami Aquifer in this area is fed by the Shandon Tributary of the New Haven Trough, and the hydraulic gradient indicates an easterly direction of flow.

Groundwater wells within the Lime Sludge Pond study area (1039, 1041, 1042, 1134, 1210, 2042, 4101 and 4102) (Figure 2-9) were sampled during the last three quarters of 1988 and the first quarter of 1989. Well 2042 was also analyzed during the first and second quarters of 1990. Analyses conducted on these samples included radionuclides, VOCs, SVOCs, pesticides/PCBs, organophosphorus pesticides, metals, and the general water quality parameters.

4.3.5.1 Radionuclides in Groundwater

Concentrations of total uranium slightly exceeded the background concentration (<3 µg/ℓ) in Well 1041, which exhibited an average concentration of about 7.3 µg/ℓ (Table 4-18). In Well 1042, the level of total uranium increased from <1 µg/ℓ to 30 µg/ℓ between May 1988 and March 1989. Wells 1134 and 1210 exhibited uranium concentrations of 21.0 µg/ℓ and 8.4 µg/ℓ respectively. Because of the apparent attenuation of uranium in surface soils in the Lime Sludge Pond area (Section 4.3.3.1), an upgradient source for the uranium in Well 1042 is indicated. Well 1039 exhibits no radionuclide above background. In Well 2042, total uranium measurements have averaged about 3.7 µg/ℓ, as compared to a background value of <3 µg/ℓ for the Shandon Tributary.

4.3.5.2 Organic Compounds in Groundwater

Acetone was detected in Well 2042 at 0.007 mg/ℓ and in Well 4101 at 0.005 mg/ℓ. Well 4101 exhibited concentrations of 2-Hexanone and 4-methyl-2-pentanone at 0.003 mg/ℓ for both. Methylene chloride was detected at 0.009 mg/ℓ in Well 2042. No other samples were analyzed for organic compounds.

4.3.5.3 Metals in Groundwater

Chromium, which was detected in 3 of 8 subsurface media samples, was not consistently detected above background in any of the wells in the Lime Sludge Pond study area.

4.3.6 Biota in the Lime Sludge Pond Study Area

No biota samples were collected or analyzed within the Lime Sludge Pond study area.

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TABLE 4-18

WASTE-RELATED RADIONUCLIDE CONCENTRATIONS IN GROUNDWATER IN THE LIME SLUDGE PONDS STUDY AREA

		RI/FS Well Numbers, Sample Numbers, and Dates of Sample Collection							
		1039[a]				1041[a]			
Analyte	Background Concentration[b]	03179 05/11/88	03491 08/10/88	03733 11/20/88	03928 02/05/89	03180 05/11/88	03490 08/10/88	03732 11/17/88	03924 03/01/89
Radionuclides: (pCi/ℓ)									
Cesium-137	0.0/0.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0
Lead-210	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA
Neptunium-237	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Plutonium-238	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Plutonium-239/240	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Radium-226	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Strontium-90	0.0/0.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Technetium-99	0.0/0.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0
Thorium-228	<1/<1	<1.0	<1.0	<1.0	<1.0	1.2±0.5	<1.0	<1.0	1.1±0.7
Thorium-230	<1/<1	<1.0	<1.0	<1.0	1.4±0.5	1.6±0.6	<1.0	<1.0	1.4±0.7
Thorium-232	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Thorium (μg/ℓ)	<9/<9	<9.1[d]	<12.0	<7.0	<4.0	<9.1[d]	<10.0	<2.0	<8.0
Uranium-234	<1/<1	<1.0	<1.0	<1.0	1.4±0.5	1.8±0.3	2.1±0.5	1.4±0.4	2.4±0.6
Uranium-235	<1/<1	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-238	<1/<1	<1.0	<1.0	<1.0	1.8±0.5	2.4±0.4	1.7±0.5	2.1±0.6	2.4±0.6
Total Uranium (μg/ℓ)	<3/<3	2.0±1.0	1.0±1.0	1.8±0.3	1.0±1.0	9.0±1.0	6.0±1.0	6.0±1.0	8.0±1.0

This table is to be read horizontally
NA = Not analyzed
a = Perched groundwater well
b = Background concentrations of the Great Miami Aquifer
c = Great Miami Aquifer well
d = Total thorium for RI/FS samples are calculated estimates which are based on measured values of thorium-232
e = Total uranium for RI/FS samples are calculated estimates which are based on measured values of uranium-235 and uranium-238
* = Duplicate

TABLE 4-18
(continued)

Analyte	Background Concentration[b]	RI/FS Well Numbers, Sample Numbers, and Dates of Sample Collection											
		1042[a]				1134	1210	2042[c]					
		03182 05/11/88	03416 08/09/88	03723 11/17/88	03922 03/01/89	045426 10/18/89	045739 10/22/89	03150 05/04/88	03415 08/09/88	03722 11/17/88	03921 03/01/89	04036* 03/01/89	66845 01/05/90
Radionuclides: (pCi/ℓ)													
Cesium-137	0.0/0.0	<20.0	<20.0	<20.0	<20.0	NA	NA	<20.0	<20.0	<20.0	<20.0	<20.0	NA
Lead-210	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Neptunium-237	0.0/0.0	<1.0	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Plutonium-238	0.0/0.0	<1.0	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Plutonium-239/240	0.0/0.0	<1.0	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Radium-226	<1/<1	<1.0	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Strontium-90	0.0/0.0	<5.0	<5.0	<5.0	<5.0	NA	NA	<5.0	<5.0	<5.0	<5.0	<5.0	NA
Technetium-99	0.0/0.0	<30.0	<30.0	<30.0	<30.0	NA	NA	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0
Thorium-228	<1/<1	<1.0	<1.0	<1.0	<1.0	NA	NA	1.6±0.8	<1.0	<1.0	<1.0	<1.0	<1.0
Thorium-230	<1/<1	<1.0	<1.0	<1.0	<1.0	NA	NA	1.0±0.6	<1.0	<1.0	<1.0	<1.0	1.2±0.9
Thorium-232	<1/<1	<1.0	<1.0	<1.0	<1.0	NA	NA	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Total Thorium (µg/ℓ)	<9/<9	<9.1[d]	<3.0	<5.0	3.0	NA	NA	9.1[d]	<3.0	<2.0	<3.0	<3.0	NA
Uranium-234	<1/<1	<1.0	2.5±0.5	3.3±0.7	9.5±1.5	NA	NA	1.4±0.5	1.1±0.3	<1.0	1.2±0.4	1.2±0.4	1.9±0.5
Uranium-235	<1/<1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-238	<1/<1	<1.0	2.2±0.5	3.2±0.7	9.7±1.5	NA	NA	1.5±0.5	<1.0	<1.0	<1.0	<1.0	<1.0
Total Uranium (µg/ℓ)	<3/<3	<1.0	6.0±1.0	11.0±2.0	30.0±5.0	21.0±3.0	8.4±0.9	4.0±1.0	2.0±1.0	2.0±1.0	3.0±1.0	3.0±1.0	7.4±0.8

TABLE 4-18
(continued)

Analyte	Background Concentration[b]	RI/FS Well Numbers, Sample Numbers, and Dates of Sample Collection													
		4101[c]							4102[c]						
		03207 05/18/88	03208* 05/19/88	03409 08/08/88	03410* 08/08/88	03719 11/18/88	03918 03/15/89	66736 12/07/89	03205 05/19/88	03206* 05/19/88	03412 08/08/88	03413* 08/08/88	03720 11/18/88	03919 02/23/89	66738 12/07/89
Radionuclides: (pCi/ℓ)															
Cesium-137	0.0/0.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	NA	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	NA
Lead-210	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Neptunium-237	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Plutonium-238	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Plutonium-239-240	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Radium-226	<1/<1	<1.0	<1.0	1.9±0.5	1.7±0.5	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Strontium-90	0.0/0.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	NA
Technetium-99	0.0/0.0	<30.0	<30.0	<30.0	<30.0	<30.0	<33.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0
Thorium-228	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Thorium-230	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Thorium-232	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Total Thorium (μg/ℓ)	<9/<9	<9.1[d]	<9.1[d]	<3.0	<3.0	<2.0	<7.0	<9.1[d]	<9.1[d]	<9.1[d]	<3.0	<4.0	<3.0	<3.0	NA
Uranium-234	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.6±0.4	<1.0
Uranium-235	<1/<1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-238	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.0±0.3	<1.0
Total Uranium (μg/ℓ)	<3/<3	<1.0	<1.0	<1.0	<1.0	<1.0	<0.1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

4.3.7 Lime Sludge Pond Summary

Uranium and thorium are the primary waste-related constituents in the Lime Sludge Ponds. Total uranium and thorium exist in surface media (which includes soil and lime-sludge residues) at levels up to 492 mg/kg and 164 mg/kg, respectively.

Subsurface media samples exhibited uranium and thorium activities that were approximately 10 to 100 times less than those of surface media and which were below or only slightly above background. This limited data indicates that there is substantial vertical attenuation of uranium and thorium by media in this area. Perched groundwater analyses indicate elevated uranium in Wells 1041 and 1042, but limited subsurface media samples do not indicate that waste-related radioactive constituents are migrating from the waste area.

Low levels of VOCs were detected in samples collected from both pond areas. Only acetone, 2-hexanone, methylene chloride, and 4-methyl-2-pentanone were detected in the groundwater. Other SVOCs detected in media included phthalate esters and a single occurrence of chlordane and Aroclor-1248. None of these compounds were detected in groundwater.

Chromium was detected in half of the subsurface media samples above its background concentration, but it was not detected above background in groundwater.

4.4 ACTIVE FLYASH PILE

The analytical results for samples collected from the Active Flyash Pile are presented in Appendix E of this document. This section reports results only for waste-related constituents; i.e., analytes which were found to exceed background in at least one surface or subsurface media (soil or flyash) sample. Analytes which have been detected in surface water or sediment but are less than background in all surface or subsurface media samples are considered to have originated from upgradient sources and are not discussed here.

Data tables in this section present individual sample analyses only for waste-related radionuclides. The waste-related organic and inorganic constituents are numerous, but typically exhibit low frequencies of detection and low concentrations. Therefore, only summary tables for these data are given here, but the complete data set is available in Appendix E.

4.4.1 Review of Historical Data

The Active Flyash Pile contains flyash (mechanical and electrostatic precipitator ash) and bottom ash from the coal-fired boiler plant. The flyash is loaded into dump trucks and transported to the Active Flyash Pile (Weston 1987b). It has been reported that, in the past, waste oil containing PCBs and uranium was applied to the Active Flyash Pile as a dust suppressant (DOE 1988a, Weston 1987b).

Attempts to document this practice have been unsuccessful. Typical constituents of FEMP flyash are aluminum, calcium, iron, magnesium, silicon, and titanium (Bogar 1987). Concentrations of natural uranium-238 in flyash and bottom ash from typical Illinois and Kentucky coal are approximately 1.5 pCi/g (UN 1982).

4.4.2 Volume and Physical Characteristics of Waste

The depth-of-fill in the Active Flyash Pile may be estimated by changes in elevation during the time that waste disposal occurred. Where borings were drilled, the fill/native soil interface can be measured more accurately. Based on a review of topographic maps from 1951 and 1988 (DOE 1988b, EPA 1988b) and boring logs from the Active Flyash Pile (Appendix E) the maximum depth-of-fill is 40 feet (Figure 4-8). Using north-south cross-sections at 125-foot intervals across the area, the average-end-area method was used to estimate fill volume at 58,800 cubic yards.

Boring logs (Appendix E) show the presence of construction rubble between 1 and 7 feet deep at Boring 1820, which is located near the northern boundary of the Active Flyash Pile.

No surface vegetation is present on the Active Flyash Pile. The in situ dry density of surface media in the Active Flyash Pile is approximately 50 to 65 lb/ft^3.

4.4.3 Surface and Subsurface Media in the Active Flyash Pile

Within the Active Flyash Pile, samples were taken from surface media, shallow fill, deep fill, and native soil underlying the fill. The locations of these samples are shown in Figure 2-11.

As part of the Environmental Survey, eight surface media samples (FE0100WP2B, FE0101WP2B, etc.; henceforth to be referenced as ES-100, -101 etc.,) (Figure 4-9) were collected. These samples were analyzed for radionuclides, VOCs, PCBs, TCLP metals, and asbestos.

Subsurface samples were collected during the Environmental Survey and the RI/FS. Three samples (FE0601WP1B, FE0602WP1B, FE0603WP1B; henceforth referenced as ES-601, -602 and -603) were collected from a single boring during the Environmental Survey. These were analyzed for radionuclides, VOCs, PCBs, TCLP metals, and asbestos.

Four borings (1048, 2048, 1045, and 2045) were drilled outside the fill area as part of the RI/FS well-installation program. Samples from these borings were analyzed for radionuclides. Later, additional borings (1723, 1724, 1726, 1820, and 1846) were drilled, and samples were collected from the shallow fill, deep fill and native soil immediately below the fill. These were analyzed for radionuclides, VOCs, SVOCs, pesticides/PCBs, total metals, and TOC. One sample (either with the highest HNu reading or from the midpoint of the boring) was collected from each boring for TCLP VOC/SVOC

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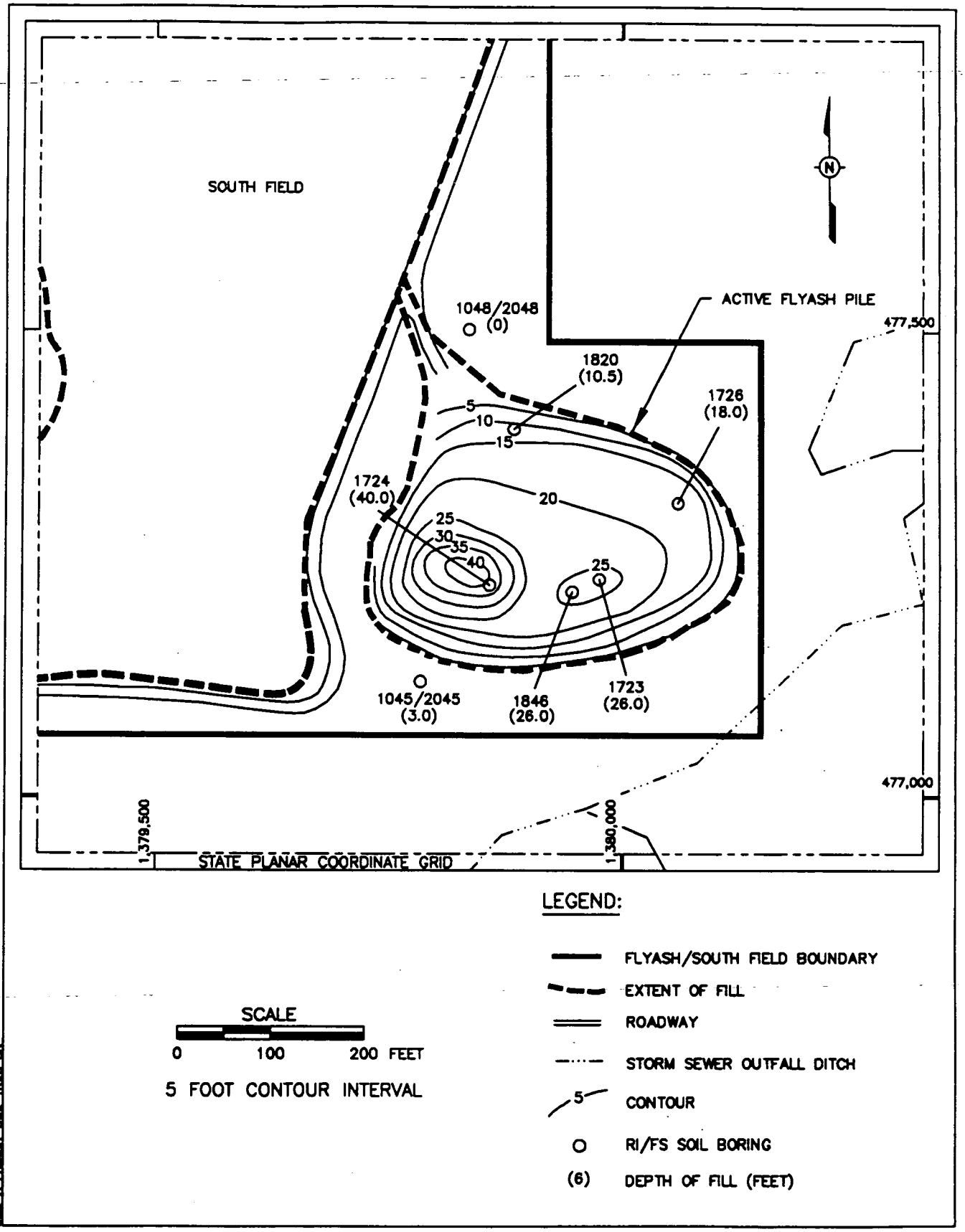

FIGURE 4–8. DEPTH OF FILL IN THE ACTIVE FLYASH PILE

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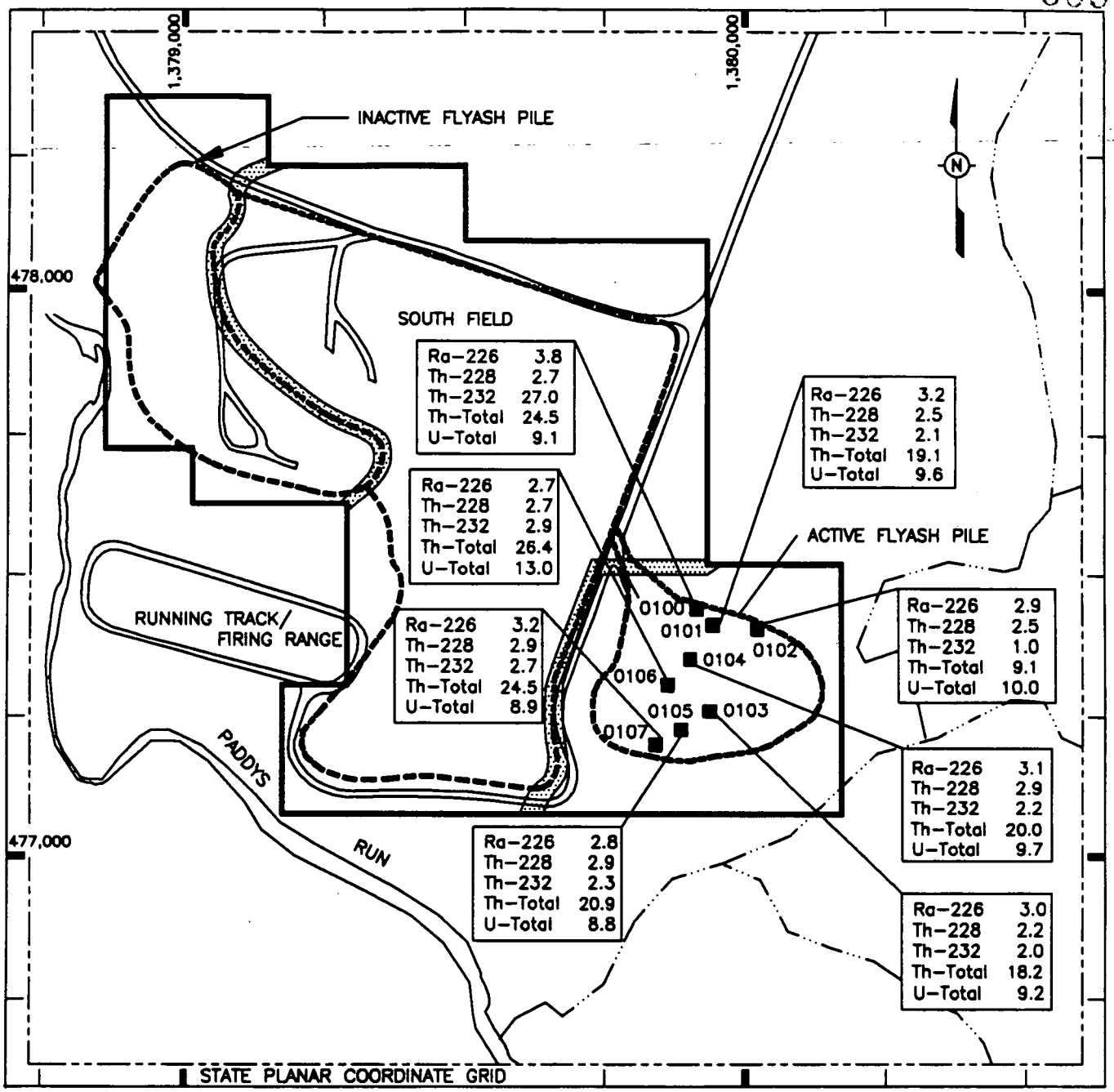

LEGEND:

- ES SURFACE SAMPLE LOCATION
- EXTENT OF FILL
- FLYASH/SOUTH FIELD BOUNDARY
- BOUNDARY BETWEEN FLYASH PILES AND SOUTH FIELD
- OPERABLE UNIT 2 STUDY AREA

SCALE

0 125 250 FEET

NOTES:

1. ALL RESULTS EXCEPT TOTAL URANIUM GIVEN IN pCi/g
2. TOTAL URANIUM VALUES ARE GIVEN IN mg/kg

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602_A_FN0357_OU2_TK20_OR

FIGURE 4-9. URANIUM, THORIUM, AND RADIUM CONCENTRATION IN SURFACE MEDIA IN THE ACTIVE FLYASH PILE

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analysis. A composite fill sample from each boring was analyzed for TCLP metals/pesticides/herbicides.

4.4.3.1 Radionuclides in Surface and Subsurface Media

Total uranium was found in all of the Active Flyash Pile surface materials at levels up to 13 mg/kg (Table 4-19, Figure 4-9). This is approximately 3.5 times the background concentration for soils (3.66 mg/kg). Radium-226 and total thorium were also detected at levels slightly above their respective background concentrations (1.51 pCi/g and 12.4 mg/kg) in most samples.

In subsurface fill, total uranium was detected in all samples at levels up to 31.3 mg/kg in Boring 1723 (Table 4-20). Total uranium appears to be uniformly distributed throughout the deeper fill at approximately 25 mg/kg and throughout the shallow fill at approximately 13 mg/kg. Total thorium was detected at levels ranging from 17.0 to 45.8 mg/kg in fill samples.

Concentrations of uranium and thorium in the native soil samples underlying the fill were less than background, except for the sample from Boring 1724, which had a total uranium concentration of 7.17 mg/kg. These findings do not indicate that substantial vertical migration of radionuclides has occurred.

4.4.3.2 Organic Compounds in Surface and Subsurface Media

A total of thirteen samples from five RI/FS borings and three samples from one Environmental Survey boring in the Active Flyash Pile were analyzed for organic compounds. The most frequently detected compound was methylene chloride, a common laboratory contaminant (Table 4-21). In 9 of 14 samples, 1,1,1-trichloroethane was detected at a maximum concentration of 1.30 mg/kg. Compounds that were detected at the highest concentrations were the phthalate esters. Bis(2-ethylhexyl) phthalate and di-n-octylphthalate were detected at concentrations as high as 2.7 and 3.0 mg/kg, respectively. Because of matrix interference problems, many of the VOC analyses of flyash samples were qualified with an "R" (i.e., were rejected). This is not considered a major limitation on site characterization or risk assessment, however, since (1) the materials known or suspected to be present in the Inactive Flyash Pile do not indicate the presence of VOCs above trace levels, and (2) HNu readings taken during the RI/FS drilling were at or below background for all borings in the Inactive Flyash Pile.

Hazardous waste toxicity characteristic thresholds (40CFR261.24) were not exceeded for any organics in the eight TCLP extracts or the three samples that underwent EP toxicity testing.

4.4.3.3 Metals in Surface and Subsurface Media

The RCRA metals detected at concentrations above background were arsenic (above background in 7 of 11 samples), barium (5 of 11), cadmium (3 of 11), chromium (2 of 11), lead (8 of 11), selenium (8

TABLE 4-19

WASTE-RELATED RADIONUCLIDE CONCENTRATIONS IN SURFACE MEDIA IN THE ACTIVE FLYASH PILE

Analyte	Background Concentration	ES Samples							
		100	101	102	103	104	105	106	107
Radionuclides: (pCi/g)									
Bismuth-214	1.51	3.9±0.1	2.5±0.2	4.0±0.4	3.3±0.3	2.7±0.2	3.0±0.2	3.1±0.2	3.3±0.2
Lead-210	1.33	NA	NA	NA	NA	NA	NA	NA	NA
Radium-224	0.983	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226	1.51s	3.8±0.3	3.2±0.2	2.9±0.3	3.0±0.2	3.1±0.1	2.8±0.1	2.7±0.1	3.2±0.2
Radium-228	1.28	NA	NA	NA	NA	NA	NA	NA	NA
Strontium-90	0.0	NA	NA	NA	NA	NA	NA	NA	NA
Thorium-228	1.56	2.7±0.1	2.5±0.3	2.5±0.4	2.2±0.4	2.9±0.2	2.9±0.2	2.7±0.2	2.9±0.3
Thorium-230	2.18	NA	NA	NA	NA	NA	NA	NA	NA
Thorium-232	1.36	2.7±0.2	2.1±0.3	1.0±0.5	2.0±0.6	2.2±0.3	2.3±0.2	2.9±0.3	2.7±0.3
Total Thorium (mg/kg)	12.4	24.5[a]	19.1[a]	9.1[a]	18.2[a]	20.0[a]	20.9[a]	26.4[a]	24.5[a]
Uranium-234	1.28	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235	0.151	N	N	N	N	N	N	N	N
Uranium-238	1.22	N	N	N	N	N	N	N	N
Total Uranium (mg/kg)	3.66	9.1	9.6	10.0	9.2	9.7	8.8	13.0	8.9

NA = Not Analyzed
N = Nuclide not identified by GAMANAL analysis as being present in the samples; no value reported
I = Nuclide identified by GAMANAL analysis of sample spectrum, but values did not exceed room background at the 95% confidence level; no value reported
[a] = Total thorium for ES samples are calculated estimates which are based on measured values of thorium-232

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TABLE 4-20

WASTE-RELATED RADIONUCLIDE CONCENTRATIONS IN SUBSURFACE MEDIA IN THE ACTIVE FLYASH PILE

		ES Boring, Sample Numbers and Depths			RI/FS Boring, Sample Description, and Depth					
					1045	1048		1723		
Analyte	Background Concentration	601 0-5 ft	602 5-11 ft	603 11-13.5 ft	Native Soil 007207 7.5-9.0 ft	Native Soil 07217 1.5-3.0 ft	Native Soil 07220* 1.5-3.0 ft	Shallow Fill 67166 3.0-4.5 ft	Deep Fill 67172 12-13.5 ft	Native Soil 67182 26-27.5 ft
Radionuclides: (pCi/g)										
Bismuth-214	1.51	3.1±0.2	3.5±0.1	2.4±0.1	NA	NA	NA	NA	NA	NA
Lead-210	1.33	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radium-224	0.983	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226	1.51	2.5±0.1	3.3±0.1	2.3±0.1	<0.4 R	0.9±0.1	0.5±0.1	4.12±0.38	4.05±0.4	0.8±0.1
Radium-228	1.28	NA	NA	NA	<0.5 R	1.2±0.2	0.6±0.1	3.89±0.45	2.8±0.4	0.6±0.1
Strontium-90	0.0	NA	NA	NA	1.2±0.3 R	<0.5	<0.5	1.0±0.32	1.09±0.31	0.70±0.25
Thorium-228	1.56	2.9±0.2	2.8±0.1	1.1±0.1	1.1±0.4 R	1.6±0.5	1.2±0.5	3.46±0.60	2.99±0.57	1.76±0.51
Thorium-230	2.18	NA	NA	NA	1.8±0.6 R	1.9±0.6 R	2.2±0.7 R	3.55±0.61	3.02±0.58	0.85±0.34
Thorium-232	1.36	2.8±0.3	2.7±0.1	1.4±0.1	1.2±0.4 R	0.9±0.4	1.0±0.4	2.84±0.51	1.93±0.41	0.61±0.29
Total Thorium (mg/kg)	12.4	25.5[a]	24.5[a]	12.7[a]	10.9[a]	8.2[a]	9.1[a]	25.6±4.6	17.4±3.7	5.49±2.59
Uranium-234	1.28	NA	NA	NA	1.0±0.4 R	1.0±0.3	1.4±0.5	4.77±0.68	4.34±0.59	0.96±0.19
Uranium-235	0.151	N	N	N	NA	NA	NA	NA	NA	NA
Uranium-238	1.22	N	I	I	0.9±0.3 R	2.4±0.6	2.8±0.8	4.92±0.63	7.95±0.99	1.05±0.20
Total Uranium (mg/kg)	3.66	17.0	15.0	5.5	2.7[b]	7.1[b]	8.3[b]	11.7±3.7	31.3±6.2	2.72±1.11

This table is to be read horizontally
NA = Not Analyzed
I = Nuclide identified by GAMANAL analysis of sample spectrum, but values did not exceed room background at the 95% confidence level; no value reported.
N = Nuclide not identified by GAMANAL analysis as being present in the samples; no value reported.
R = Value rejected during data validation
* = Duplicate
a = Total thorium for ES and RI/FS samples are calculated estimates which are based on measured values of thorium-232
b = Total uranium for RI/FS samples are calculated estimates which are based on measured values of uranium-235 and uranium-238

TABLE 4-20
(continued)

Analyte	Background Concentration	RI/FS Boring, Sample Description, and Depth							
		1724			1726				
		Shallow Fill 67192 3.0-4.5 ft	Deep Fill 67200 14.5-16.0 ft	Native Soil 67217 40.0-41.5 ft	Shallow Fill 67146 4.5-6.0 ft	Shallow Fill 67148 7.5-9.0 ft	Deep Fill 67153 15.0-16.5 ft	Deep Fill 67154 16.5-18.0 ft	Native Soil 67156 19.5-21.0 ft
Radionuclides: (pCi/g)									
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA	NA	NA
Lead-210	1.33	NA	NA	NA	1.5±0.5	NA	1.6±0.6	NA	NA
Radium-224	0.983	NA	NA	NA	3.44±0.39	NA	3.74±0.43	NA	NA
Radium-226	1.51	6.22±0.52	3.6±0.33	1.13±0.14	3.04±0.26	4.51±0.45	3.76±0.30	4.52±0.42	1.45±0.17
Radium-228	1.28	5.32±0.53	2.76±0.32	0.82±0.19	2.91±0.36	3.61±0.49	2.85±0.38	3.45±0.43	1.04±0.19
Strontium-90	0.0	1.53±0.36	1.27±0.34	3.61±0.50	<0.9	1.37±0.30	<0.9	1.16±0.28	1.21±0.27
Thorium-228	1.56	5.79±1.09	3.21±0.68	1.16±0.36	2.91±0.59	3.46±0.71	2.93±0.54	4.47±1.11	2.09±0.55
Thorium-230	2.18	6.08±1.14	3.45±0.52	1.33±0.39	5.92±0.99	3.70±0.75	3.80±0.65	3.62±0.95	1.97±0.53
Thorium-232	1.36	5.08±0.98	2.42±0.52	0.5±0.23	2.91±0.58	2.80±0.60	2.37±0.46	2.80±0.79	0.90±0.33
Total Thorium (mg/kg)	12.4	45.8±8.86	21.9±4.72	4.69±2.16	26.2±5.2	25.3±5.4	21.4±4.1	25.3±7.1	8.14±3.01
Uranium-234	1.28	4.75±0.72	4.01±0.61	1.27±0.23	17.3±2.2	3.90±0.54	12.3±1.7	5.7±0.77	0.93±0.19
Uranium-235	0.151	NA	NA	NA	0.6±0.31	NA	<0.4	NA	NA
Uranium-238	1.22	4.96±0.75	5.53±0.79	2.04±0.32	6.31±0.84	3.77±0.53	6.55±0.87	7.93±1.02	1.11±0.21
Total Uranium (mg/kg)	3.66	18.4±4.3	16.4±3.6	7.17±2.4	28.1±5.1	18.5±5.2	27.7±5.0	28.1±5.8	3.08±1.92

TABLE 4-20
(continued)

Analyte	Background Concentration	RI/FS Boring, Sample Description, and Depth					
		1820			2045	2048	3045
		Shallow Fill 67503 1.5-3.0 ft	Deep Fill 67505 6.0-7.5 ft	Native Soil 67506 9.5-12.0 ft	Native Soil 08948 35.0-36.5 ft	Native Soil 20498 65.0-66.5 ft	Native Soil 032609 105.0-106.5 ft
Radionuclides: (pCi/g)							
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA
Lead-210	1.33	NA	NA	NA	NA	NA	NA
Radium-224	0.983	NA	NA	NA	NA	NA	NA
Radium-226	1.51	3.16±0.33	2.53±0.24	0.47±0.12	0.4±0.1	<0.3	0.6±0.05
Radium-228	1.28	2.70±0.37	2.23±0.31	0.74±0.52	<0.5	<0.6	0.5±0.06
Strontium-90	0.0	1.40±0.40	<0.5	<0.6	0.5±0.2	<0.5	<0.5
Thorium-228	1.56	3.18±0.69	3.44±0.86	0.813±0.22	<0.6	<0.6	1.2±0.2
Thorium-230	2.18	3.00±0.66	4.01±0.97	1.12±0.27	0.7±0.3	0.7±0.2	1.4±0.3
Thorium-232	1.36	1.89±0.47	2.82±0.74	<0.6	0.6±0.3	<0.6	1.0±0.2
Total Thorium (mg/kg)	12.4	17.0±4.2	25.4±6.7	3.38±1.26	5.5[a]	<5.5[a]	8.7±2.2
Uranium-234	1.28	3.68±0.53	3.08±0.51	0.92±0.19	<0.6	<0.6	0.9±0.2
Uranium-235	0.151	NA	NA	NA	NA	NA	NA
Uranium-238	1.22	3.15±0.47	7.23±0.98	0.97±0.20	<0.6	<0.6	0.8±0.2
Total Uranium (mg/kg)	3.66	9.08±3.23	20.7±4.4	<3.9	2.0±2.0	2.0±2.0	2.8±0.7

TABLE 4-21

ORGANIC COMPOUNDS DETECTED IN SUBSURFACE MEDIA IN THE ACTIVE FLYASH PILE

Compound	Frequency of Detection	Range (mg/kg)
Volatile Compounds		
2-Butanone	3/8	0.003–0.006
4-Methyl-2-pentanone	2/9	0.011–0.025
Acetone	8/9	0.009–0.140
Benzene	1/8	0.002
Carbon Disulfide	1/10	0.007
Chloroform	1/9	0.011
Toluene	5/12	0.013–0.110
Chlorinated Volatile Compounds		
1,1-Dichloroethene	1/6	0.002
1,1,1-Trichloroethane	9/14	0.025–1.300
Methylene Chloride	10/10	0.006–0.200
Polynuclear Aromatic Hydrocarbons		
2-Methylnaphthalene	3/13	0.049–0.160
Naphthalene	2/13	0.052–0.082
Phenanthrene	3/13	0.043–0.072
Phthalate Ester		
Bis(2-ethylhexyl)phthalate	4/13	0.042–2.700
Di-n-butylphthalate	3/13	0.047–0.069
Di-n-octylphthalate	1/13	3.000
Other Semivolatile Compounds		
2-Chlorophenol	1/13	0.048
4-Chloro-3-methylphenol	1/13	0.058
4-Nitrophenol	1/13	0.048
Benzoic Acid	6/13	0.052–2.000
Phenol	1/13	0.058

NOTES: 1. Data compiled from Environmental survey, CIS, and RI/FS sampling and analysis programs.
2. Data qualified with an "R" (i.e., rejected data) are not included.

of 11), and silver (2 of 11) (Table 4-22). Arsenic concentrations in native soil were lower than those in both the shallow fill and deep fill. The highest concentration was 66.5 mg/kg in the shallow fill at Boring 1726, six times the background level (10.3 mg/kg). Lead concentrations in native soil were below background (16.6 mg/kg) whereas shallow and deep fill samples were above background, with the highest concentration at 61.7 mg/kg in deep fill from Boring 1724. Selenium was above background (0.72 mg/kg) in fill and native soil samples with the highest concentration at 10.2 mg/kg in shallow fill from Boring 1726.

Other metals detected at concentrations above background in half or more of the samples were antimony (above background in 3 of 3 samples), beryllium (11 of 11), copper (9 of 11), molybdenum (6 of 11), and thallium (6 of 11). Antimony was above background (0 mg/kg) in three native soil samples. The highest concentration (31.1 mg/kg) was measured in native soil from Boring 1723. Beryllium was above background (0.607 mg/kg) in both fill and native soil samples, with the highest concentration (4.6 mg/kg) in the deep fill of Boring 1723. The fill samples were consistently higher in concentration than the native soil samples. Molybdenum was above background (8.8 mg/kg) in both fill and native soil samples, with the highest concentration (18.8 mg/kg) measured in shallow fill from Boring 1726. No trend with depth was observed.

Because of matrix interference problems, all of the antimony analyses of flyash samples were qualified with an "R" (i.e., were rejected). Concentrations of antimony flyash in the three underlying soil samples, however, are well above background. This indicates that antimony is present in the flyash and has leached into the underlying soil. However, an evaluation of antimony results for the Inactive Flyash Pile indicates that the antimony concentrations in the underlying soil are similar to those in the flyash itself. Furthermore, the three native soil samples at the Active Flyash Pile exhibit antimony concentrations similar to both the flyash and the native soils of the Inactive Flyash Pile. Therefore, the three native soil antimony analyses are adequate to characterize antimony concentration in the Active Flyash Pile.

Hazardous waste toxicity characteristic thresholds (40CFR261.24) were not exceeded for any metals in the TCLP or EP toxicity extracts.

No asbestos was detected in the Environmental Survey Samples.

4.4.4 Surface Water and Sediment in the Active Flyash Pile Study Area

Surface water and sediments were sampled in four locations as a part of the RI/FS (Figure 4-10). Sample locations ASIT-004 and -005 are in a drainage ditch that runs along the western edge of the Active Flyash Pile and flows to the south. Locations ASIT-006 and -007 are located in a ditch, north of the fill, which discharges to the storm sewer outfall ditch. All of these sediment samples were

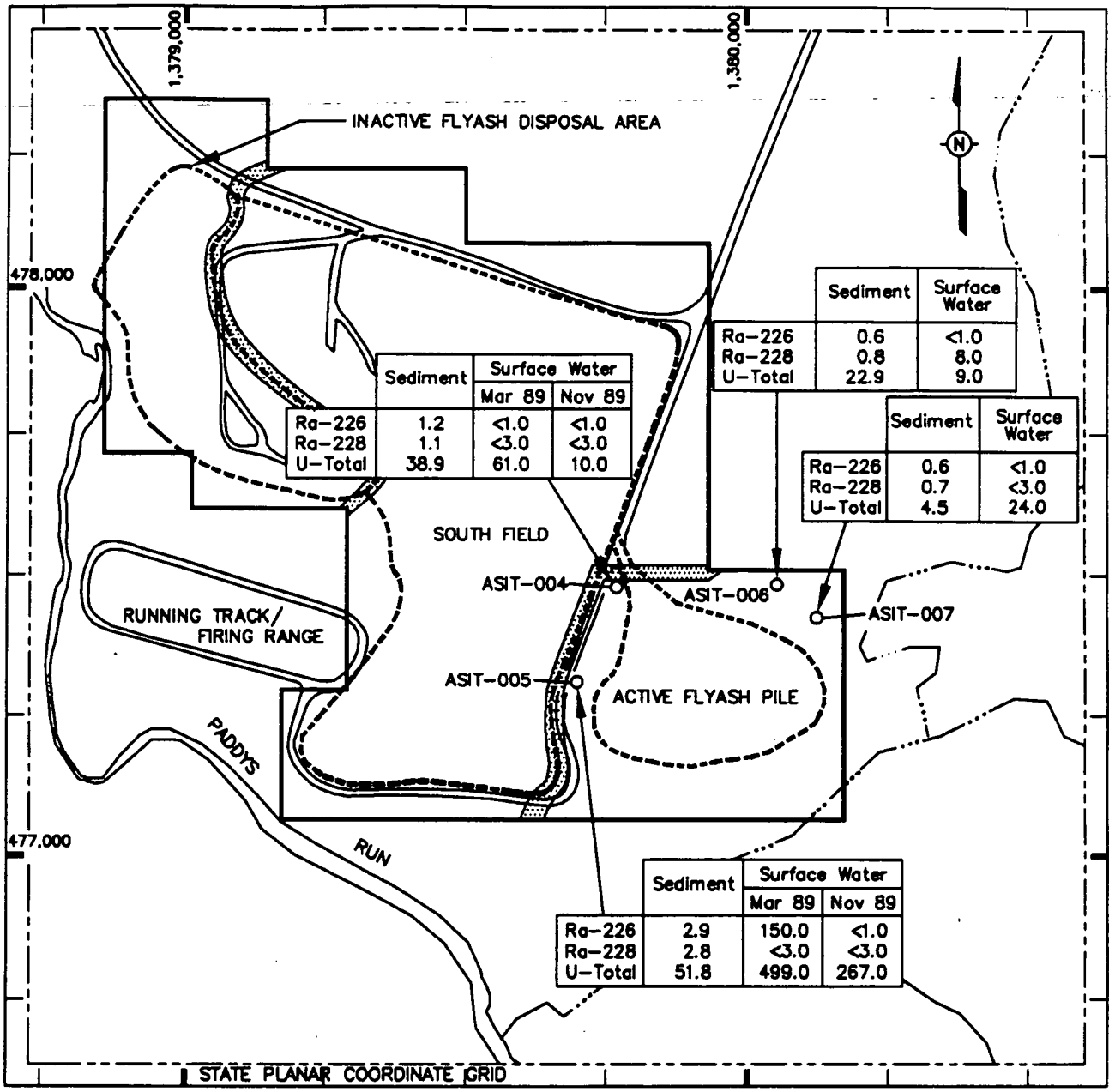
TABLE 4-22

INORGANICS DETECTED IN SUBSURFACE MEDIA
IN THE ACTIVE FLYASH PILE

Analyte	Background Concentration (mg/kg)	Frequency of Detection	Range (mg/kg)	Frequency Above Background Concentration
Aluminum	16973	11/11	1570-17900	1/11
Antimony	0.0	3/3	9.0-31.1	3/3
Arsenic	10.3	11/11	4.6-66.5	7/11
Barium	133	11/11	16.7-508.0	5/11
Beryllium	0.607	11/11	0.47-4.6	11/11
Cadmium	0.650	3/11	1.3-5.2	3/11
Calcium	201722	11/11	826-155000	0/11
Chromium	22.0	11/11	4.4-26.8	2/11
Cobalt	15.8	10/11	5.0-18.8	2/11
Copper	21.2	11/11	14.3-66.1	9/11
Cyanide	0.283	6/11	0.17-0.69	2/11
Iron	33026	11/11	2260-31100	0/11
Lead	16.6	11/11	5.8-61.7	8/11
Magnesium	59838	11/11	150-37200	0/11
Manganese	1099	11/11	8.2-523	0/11
Mercury	0.292	1/11	0.16	0/11
Molybdenum	8.8	11/11	4.3-18.8	6/11
Nickel	38.1	11/11	6.2-45.7	1/11
Potassium	1911	11/11	242-1230	0/11
Selenium	0.720	8/11	0.85-10.2	8/11
Silver	8.03	3/11	6.6-18.5	2/11
Sodium	235	11/11	92.7-312.0	3/11
Thallium	0.397	6/11	0.96-2.10	6/11
Vanadium	39.5	11/11	15.0-40.3	2/11
Zinc	81.2	11/11	18.9-117.0	2/11

NC = None calculated

NOTES: 1. Data compiled from Environmental Survey, CIS, and RI/FS sampling and analysis programs.
2. Data qualified with an "R" (i.e., rejected data) are not included.



	Sediment	Surface Water Mar 89	Surface Water Nov 89
Ra-226	1.2	<1.0	<1.0
Ra-228	1.1	<3.0	<3.0
U-Total	38.9	61.0	10.0

	Sediment	Surface Water
Ra-226	0.6	<1.0
Ra-228	0.8	8.0
U-Total	22.9	9.0

	Sediment	Surface Water
Ra-226	0.6	<1.0
Ra-228	0.7	<3.0
U-Total	4.5	24.0

	Sediment	Surface Water Mar 89	Surface Water Nov 89
Ra-226	2.9	150.0	<1.0
Ra-228	2.8	<3.0	<3.0
U-Total	51.8	499.0	267.0

SCALE

0 125 250 FEET

LEGEND:

- RI/FS SEDIMENT SAMPLE LOCATION
- EXTENT OF FILL
- FLYASH/SOUTH FIELD BOUNDARY
- BOUNDARY BETWEEN FLYASH PILES AND SOUTH FIELD
- OPERABLE UNIT 2 STUDY AREA

NOTES:

1. U-TOTAL HAS UNITS OF mg/kg FOR SEDIMENT RESULTS AND ug/L FOR THE SURFACE WATER RESULTS
2. RADIUM HAS UNITS OF pCI/g FOR SEDIMENT RESULTS AND pCI/L FOR SURFACE WATER RESULTS

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FIGURE 4-10. RADIUM AND URANIUM CONCENTRATIONS IN SURFACE WATER AND SEDIMENT SAMPLES FROM THE ACTIVE FLYASH PILE STUDY AREA

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analyzed for radium-226, radium-228, and total uranium. A sediment sample from ASIT-007 was also analyzed for VOCs, SVOCs, pesticides/PCBs, and metals. Surface water samples from all four locations were analyzed for radium-226, radium-228, and total uranium. Samples from ASIT-004 and -005 were also analyzed for metals.

4.4.4.1 Radionuclides in Surface Water and Sediment

Total uranium was found to exist in all four sediment samples above background, with the highest concentration being 51.8 mg/kg at ASIT-005 (Table 4-23; Figure 4-10). This measurement of total uranium is higher than for any of the samples collected from the fill itself. The total uranium found in the surface water was measured as high as 274 and 499 µg/ℓ at ASIT-005. (Table 4-23, Figure 4-10). Potential sources of this contamination include the Active Flyash Pile, the South Field, and the soils north of the Active Flyash Pile.

4.4.4.2 Organic Compounds in Surface Water and Sediment

Acetone and methylene chloride were detected in the sediment sample from ASIT-007 at 0.055 and 0.016 mg/kg, respectively, but these analytes were also detected in the associated laboratory blank, indicating that they may have been introduced during sample handling and/or laboratory analysis.

4.4.4.3 Metals in Surface Water and Sediment

Nineteen waste-related metals were detected in the surface water samples, including arsenic (0.0455 mg/ℓ), lead (0.0362 mg/ℓ), selenium (0.0291 mg/ℓ), copper (0.0221 mg/ℓ), and molybdenum (0.0183 mg/ℓ).

4.4.5 Groundwater in the Active Flyash Pile Study Area

Groundwater monitoring wells that exist within the boundaries of (or downgradient of) the Active Flyash Pile are also downgradient of the South Field. Since the groundwater at these wells could be influenced by both units, the discussion of results for these wells is included in Section 4.6.5.

4.4.6 Biota in the Active Flyash Pile Study Area

Levels of uranium (reported as the sum of uranium-234, uranium-235, and uranium-238 activities), strontium-90, and cesium-137 were reported for two samples collected from each of the following media at Location 28 (Figure 2-13): surface soil, grass roots, grass leaves, forb roots, and forb leaves (DOE 1992b).

At Location 28, uranium was highest in each of the two forb root samples at 35.5 and 10.1 pCi/g, respectively (Table 4-24). Cesium-137 was detected in one grass root sample at 0.9 pCi/g. Terrestrial vegetation appears to be concentrating uranium and cesium at a level higher than the uranium and cesium concentrations in the adjacent surface soils.

TABLE 4-23

WASTE-RELATED RADIONUCLIDE CONCENTRATIONS IN SURFACE WATER AND SEDIMENT IN THE ACTIVE FLYASH PILE

		Sediment				Surface Water		
		RI/FS Sample Location and Number				RI/FS Sample Location and Number		
Analyte	Background Concentration[a]	ASIT-004 09044	ASIT-005 09045	ASIT-006 09046	ASIT-007 09047	ASIT-004 01128	ASIT-004 01222	ASIT-004* 01223
Radionuclides: (pCi/g, pCi/ℓ)								
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA	NA
Lead-210	1.33	NA	NA	NA	NA	NA	NA	NA
Radium-224	0.983	NA	NA	NA	NA	NA	NA	NA
Radium-226	1.51	1.24±0.1	2.89±0.3 R	0.64±0.1	0.64±0.1	<1.0 R	<1.0 R	<1.0 R
Radium-228	1.28	1.08±0.1	2.77±0.4 R	0.85±0.2	0.70±0.1	<3.0 R	<3.0 R	<3.0 R
Strontium-90	0.0	NA	NA	NA	NA	NA	<5.0 R	<5.0 R
Thorium-228	1.56	NA	NA	NA	NA	NA	<1.0	<1.0
Thorium-230	2.18	NA	NA	NA	NA	NA	<1.0	<1.0
Thorium-232	1.36	NA	NA	NA	NA	NA	<1.0	<1.0
Total Thorium (mg/kg, µg/ℓ)	12.4	NA	NA	NA	NA	NA	3.9±1.7	<4.7
Uranium-234	1.28	NA	NA	NA	NA	NA	26.0±3.5	28.9±4.4
Uranium-235	0.151	NA	NA	NA	NA	NA	NA	NA
Uranium-238	1.22	NA	NA	NA	NA	NA	43.3±5.6	45.9±6.7
Total Uranium (mg/kg, µg/ℓ)	3.66	38.9±2.4	51.8±8.3	22.9±4.7	4.53±1.2	61.0±11.0	107.0±15.0	98.0±14.0

This table is to be read horizontally
NA = Not analyzed
R = Value rejected during data validation
[a] = Background concentration for sediment are taken as soil background concentration. No background concentrations have been calculated for surface water
* = Duplicate

TABLE 4-23
(continued)

Analyte	Background Concentration[a]	Surface Water RI/FS Sample Location and Number: ASIT-005 01130	ASIT-005 01224	ASIT-005* 01225	ASIT-006 01137	ASIT-007 01139
Radionuclides: (pCi/g, pCi/ℓ)						
Bismuth-214	NC	NA	NA	NA	NA	NA
Lead-210	NC	NA	NA	NA	NA	NA
Radium-224	NC	NA	NA	NA	NA	NA
Radium-226	NC	150.0±20.0	<1.0 R	<1.0 R	<1.0	<1.0
Radium-228	NC	<3.0 R	<3.0 R	<3.0 R	8.0±4.0	<3.0
Strontium-90	NC	NA	<5.0 R	<5.0 R	NA	NA
Thorium-228	NC	NA	<1.0	<1.0	NA	NA
Thorium-230	NC	NA	<1.0	<1.0	NA	NA
Thorium-232	NC	NA	<1.0	<1.0	NA	NA
Total Thorium (mg/kg, µg/ℓ)	NC	NA	<2.3	<5.3	NA	NA
Uranium-234	NC	58.0±8.0	89.0±13.0	99.0±14.0	NA	NA
Uranium-235	NC	NA	NA	NA	NA	NA
Uranium-238	NC	NA	102.0±15.0	111.0±16.0	NA	NA
Total Uranium (mg/kg, µg/ℓ)	NC	499±83	274.0±36.0	260.0±35.0	9.0±4.0	24.0±4.0

TABLE 4-24

RADIONUCLIDE, SVOC, AND METAL CONCENTRATIONS IN BIOTA IN THE ACTIVE FLYASH PILE

	Uranium[a] (pCi/g)	Cesium-137 (pCi/g)	Strontium-90 (pCi/g)	Technetium-99 (pCi/g)	Butyl benzyl phthalate (mg/kg)	Arsenic (mg/kg)	Aluminum (mg/kg)	Barium (mg/kg)	Mercury (mg/kg)	Lead (mg/kg)	Vanadium (mg/kg)	Zinc (mg/kg)
Location 28												
Sample 1:												
Soil	32.5	0.8	0.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
Grass leaves	2.6	<0.2	<0.5	NA	<20.0	7.0	2840.0	12.5	15.3	<3.0	<1.0	12.3
Grass roots	4.6	0.9	<0.5	NA	1.6	11.0	1680.0	24.9	67.1	4.0	4.0	20.6
Forb leaves	2.2	<0.2	<0.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
Forb roots	35.5	<0.4	<0.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sample 2:												
Soil	32.5	0.8	0.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
Grass leaves	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Grass roots	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Forb leaves	2.7	<0.3	0.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
Forb roots	10.1	<0.4	<0.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
Small Mammal:												
Muscle composite	<0.6	<0.7	<0.5	<0.9	<1.0	8.0	<4.0	<0.2	<0.2	<3.0	<1.0	10.9
Carcass composite	<0.6	<0.2	<0.5	ISFA	<10.0	13.0	42.0	1.0	<0.24	<3.0	<1.0	38.3

[a] this is a sum of all uranium-234, uranium-235, and uranium-238 activities
NA = not analyzed
ISFA = insufficient sample for analysis

Source: U.S. Department of Energy, 1992, "Site-Wide Characterization Report," DOE, Fernald Field Office, Fernald, OH

Butyl benzyl phthalate was found in grass roots at 1.6 mg/kg. Metals detected in grass leaves and roots included arsenic, aluminum, barium, mercury, lead, vanadium, and zinc. No PCBs or pesticides were detected in terrestrial vegetation.

In the small mammal composite samples (white-footed mice, short-tailed shrews, and eastern cottontail rabbits) taken from Location 28, no radionuclides were detected. However, arsenic, aluminum, barium, and zinc were found in composite samples of muscles and composite samples of carcasses (Table 4-24). This indicates that trace amounts of metals have entered the food chain since the metals have been assimilated by small mammals into their muscle tissues. No SVOCs, PCBs, or pesticides were detected in these composite samples.

4.4.7 Active Flyash Pile Summary

Uranium and thorium appear to be the primary waste-related constituents of the Active Flyash Pile, with concentrations in subsurface media up to 31.3 and 45.8 mg/kg, respectively. Migration of these radionuclides into the native soil, which underlies the fill, is not indicated. Waste materials may be migrating from the area via the surface water pathway, based on uranium concentrations measured in the surface water and sediments in drainages leading away from the waste area. Other potential sources of this contamination include South Field and the soils north of the Active Flyash Pile.

Low levels of organic compounds were detected in subsurface media in the Active Flyash Pile. The highest concentration for any compound detected was 3.0 mg/kg for di-n-octylphthalate. The most frequently occurring compound was methylene chloride with a maximum concentration of 0.200 mg/kg. Three PAHs were detected a total of eight times with a maximum concentration of 0.16 mg/kg.

A number of inorganic constituents were detected in subsurface media above their respective background concentrations. The most frequent such detections were for arsenic, antimony, beryllium, copper, lead, molybdenum, selenium, and thallium.

4.5 INACTIVE FLYASH PILE

The analytical results for samples collected from the Inactive Flyash Pile are presented in Appendix F of this document. This section reports results only for waste-related constituents; i.e., analytes which were found to exceed background in at least one surface or subsurface (soil or flyash) sample. Analytes which have been detected in groundwater, surface water, or sediment, but are less than background in surface or subsurface media samples, are considered to have originated from upgradient sources and are not discussed here.

Data tables in this section present individual sample analyses only for waste-related radionuclides. The waste-related organic and inorganic constituents are numerous, but typically exhibit low frequencies of detection and low concentrations. Therefore, only summary tables for these data are given here, but the complete data set is available in Appendix F.

4.5.1 Review of Historical Data

The Inactive Flyash Pile contains flyash from the coal-fired boiler plant. Disposal activities at this site began around 1952 (DOE 1988a). Historical photographs indicate that disposal activity ceased here between 1964 and 1968 (EPA 1988b). The flyash was loaded into dump trucks and transported to this waste area (Weston 1987b). Typical constituents of FEMP flyash are aluminum, calcium, iron, magnesium, silicon, and titanium (Bogar 1987). Concentrations of natural uranium-238 in flyash and bottom ash from typical Illinois and Kentucky coal are approximately 1.5 pCi/g (UN 1982).

In addition to flyash, building rubble such as concrete, gravel, asphalt, masonry, transite and steel rebar were discarded here. In the past, the area may have been contaminated as a result of the reported practice of spreading PCB- and uranium-contaminated waste oils over the flyash to control dust (DOE 1988a, Weston 1987b). Attempts to document this practice have been unsuccessful.

4.5.2 Volume and Physical Characteristics of Waste

The depth-of-fill in the Inactive Flyash Pile may be estimated by changes in elevation during the time that waste disposal occurred. Where borings were drilled, the fill/native soil interface can be measured more accurately. Based on a review of topographic maps from 1951 and 1988 (DOE 1988b, EPA 1988b), and boring logs from the Inactive Flyash Pile (Appendix F), the maximum depth of fill is 34 feet (Figure 4-11). Using north-south cross-sections at 125-foot intervals across the unit, the average-end-area method was used to estimate fill volume at 78,500 cubic yards.

Boring logs (Appendix F) indicate the presence of concrete rubble at a depth of 25 feet in Boring 1710, which is located on the northwest side of the Inactive Flyash Pile. Pieces of wood, one with a nail embedded, were found in Boring 24-10 at a depth of 19 feet. Also from this boring, clear glass was discovered at a depth of 21 feet indicating the presence of fill material at these depths.

The Inactive Flyash Pile is currently covered with vegetation. In situ dry density of surface material in the Inactive Flyash Pile is approximately 50 lb/ft^3.

4.5.3 Surface and Subsurface Media in the Inactive Flyash Pile

Within the Inactive Flyash Pile, samples were taken from surface media, shallow fill, deep fill, and native soil underlying the fill.

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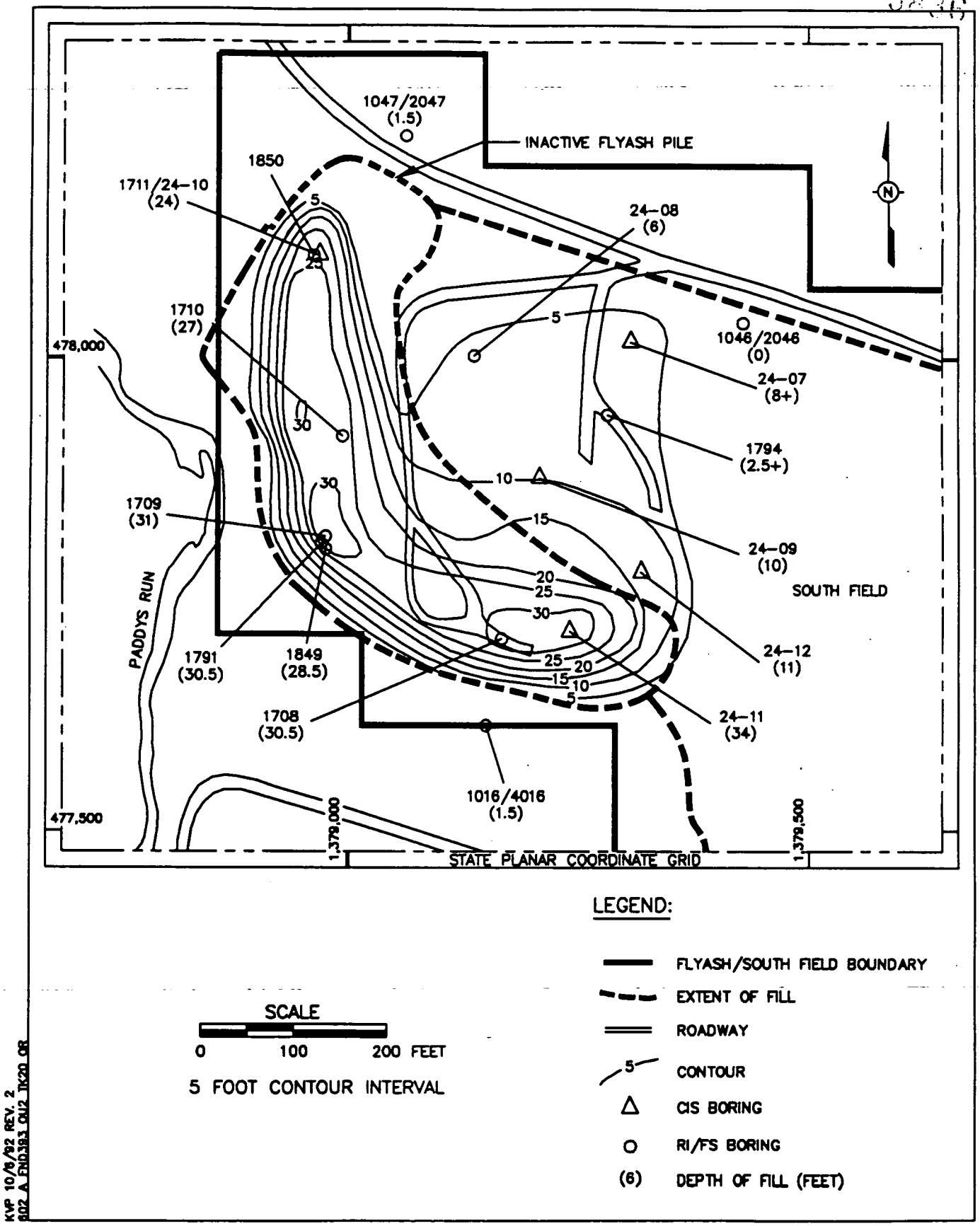

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FIGURE 4-11. DEPTH OF FILL IN THE INACTIVE FLYASH PILE

Surface media samples were obtained and analyzed during the Environmental Survey, CIS, and RI/FS investigations. Environmental Survey (DOE 1988a) samples (FE0111SS4B, FE0113SS4B, and FE0114SS2B; henceforth to be referenced as ES-111, -113, and -114) were analyzed for radionuclides, VOCs, PCBs, TCLP metals, and asbestos. Four surface media samples (FMP-SS-24-137, FMP-SL-24-188, etc., henceforth to be referenced as 24-137, 24-188, etc., respectively) were collected as part of the CIS (Weston 1987c). These samples were analyzed for radionuclides only. Additional CIS samples were analyzed at the on-site laboratory; however, because the objective of the on-site analytical program was to serve as a screening tool, the resulting data will not be considered in this discussion of surface media contamination. One RI/FS sample (05017) was collected and analyzed for radionuclides only.

Subsurface samples were also collected during the Environmental Survey, CIS, and RI/FS investigation.

Five borings were drilled for the Environmental Survey, and samples were collected (FE0604WP3B, FE0605WP3B, FE0607WP3B, FE0608WP3B and FE0609WP3B, henceforth to be referenced as ES-604,-605, etc., respectively). These were analyzed for radionuclides, VOCs, PCBs, TCLP metals, and asbestos.

Two CIS subsurface borings (24-10 and 24-11) were drilled to 26 and 34 feet deep, respectively. These borings were sampled at 1-foot intervals for analysis at the on-site laboratory for radium-226, thorium-232 and uranium-238. These analyses are presented as an indication of relative vertical distribution. A vertical composite was prepared from each CIS boring and was analyzed at an off-site laboratory for radionuclides, VOCs, SVOCs, PCBs, total metals, and EP toxicity metals.

RI/FS samples were taken from Borings 1016, 1047, 2047, and 4016, which were drilled outside of the fill area as part of the well installation program. These samples were analyzed for radionuclides only. Later, additional RI/FS borings (1708, 1709, 1710, 1711, 1791, 1849, and 1850) were drilled and samples were collected from each boring from the shallow fill, deep fill, and native soil immediately below the fill. These samples were analyzed for radionuclides, VOCs, SVOCs, pesticides/PCBs, total metals, and TOC. One sample from each boring (either with the highest HNu reading or from the midpoint of the boring) was collected from each boring for TCLP VOCs/SVOCs analysis. A composite fill sample from each boring was analyzed for TCLP metals/pesticides/herbicides.

4.5.3.1 Radionuclides in Surface and Subsurface Media

Uranium is the primary waste-related constituent of surface media of the Inactive Flyash Pile, having been detected above background in all eight surface media samples. Total uranium was calculated to

be as high as 26600 mg/kg at 24-241 (Table 4-25, Figure 4-12). Uranium contamination was widely scattered over the surface of the fill.

Subsurface samples exhibited pockets of uranium contamination scattered throughout the fill (Tables 4-26 and 4-27, Figure 4-13). The composite sample from Boring 24-10 had a total uranium concentration of 150 mg/kg. The on-site analysis of profile samples from Boring 24-10 indicated uranium-238 was present at activities up to 160 pCi/g at 21 feet deep. Total uranium was measured at 67 mg/kg in the shallow fill at Boring 1709, at 120 mg/kg in the deep fill at Boring 1710, at 123 mg/kg in the shallow fill at Boring 1711. Furthermore, samples intended to be collected from native soils exhibited total uranium levels of 68.2 mg/kg in Boring 1708, 660 mg/kg in Boring 1710, and 873 mg/kg in Boring 1791. In each of these three borings, the "native soil" sample was more contaminated than the overlying fill. Therefore, it appears that these samples may have been collected from contaminated soils which were placed in the Inactive Flyash Pile and subsequently covered with ash. Another possibility is that uranium leached from the flyash and then was precipitated from the leachate when it encountered the underlying fill.

Technetium-99 was detected in surface media sample 24-241 at an activity of 594 pCi/g and in the native soil sample of Boring 1047 at 1.5 pCi/g.

4.5.3.2 Organic Compounds in Surface and Subsurface Media

Sixteen samples from six RI/FS borings, two composite samples from the two CIS borings, and five samples from two borings in the Environmental Survey in the Inactive Flyash Pile were analyzed for the presence of organic compounds.

Methylene chloride, acetone and 1,1,1-trichloroethane were the most consistently detected organic compounds (Table 4-28). The maximum reported concentration for methylene chloride was 0.11 mg/kg. Acetone was detected in 13 of 20 samples analyzed at concentrations ranging from 0.002 to 0.190 mg/kg. 1,1,1-Trichloroethane was detected in 10 of 20 samples analyzed at concentrations ranging from 0.004 to 0.150 mg/kg. Toulene was detected in 8 of 14 samples at levels up to 0.11 mg/kg. Other organic compounds were detected in less than 30 percent of the samples analyzed and were generally at concentrations less than 0.5 mg/kg (Table 4-28). The highest reported concentration for any compound was for the single occurrence of bis(2-ethylhexyl)phthalate at 0.620 mg/kg. PCBs were detected in two samples with a maximum concentration of 0.290 mg/kg.

Because of matrix interference problems, many of the VOC analyses of flyash samples were qualified with an "R" (i.e., were rejected). This is not considered a major limitation on site characterization or risk assessment, however, since (1) the materials known or suspected to be present in the Inactive Flyash Pile do not indicate the presence of VOCs above trace levels, and (2) HNu readings taken

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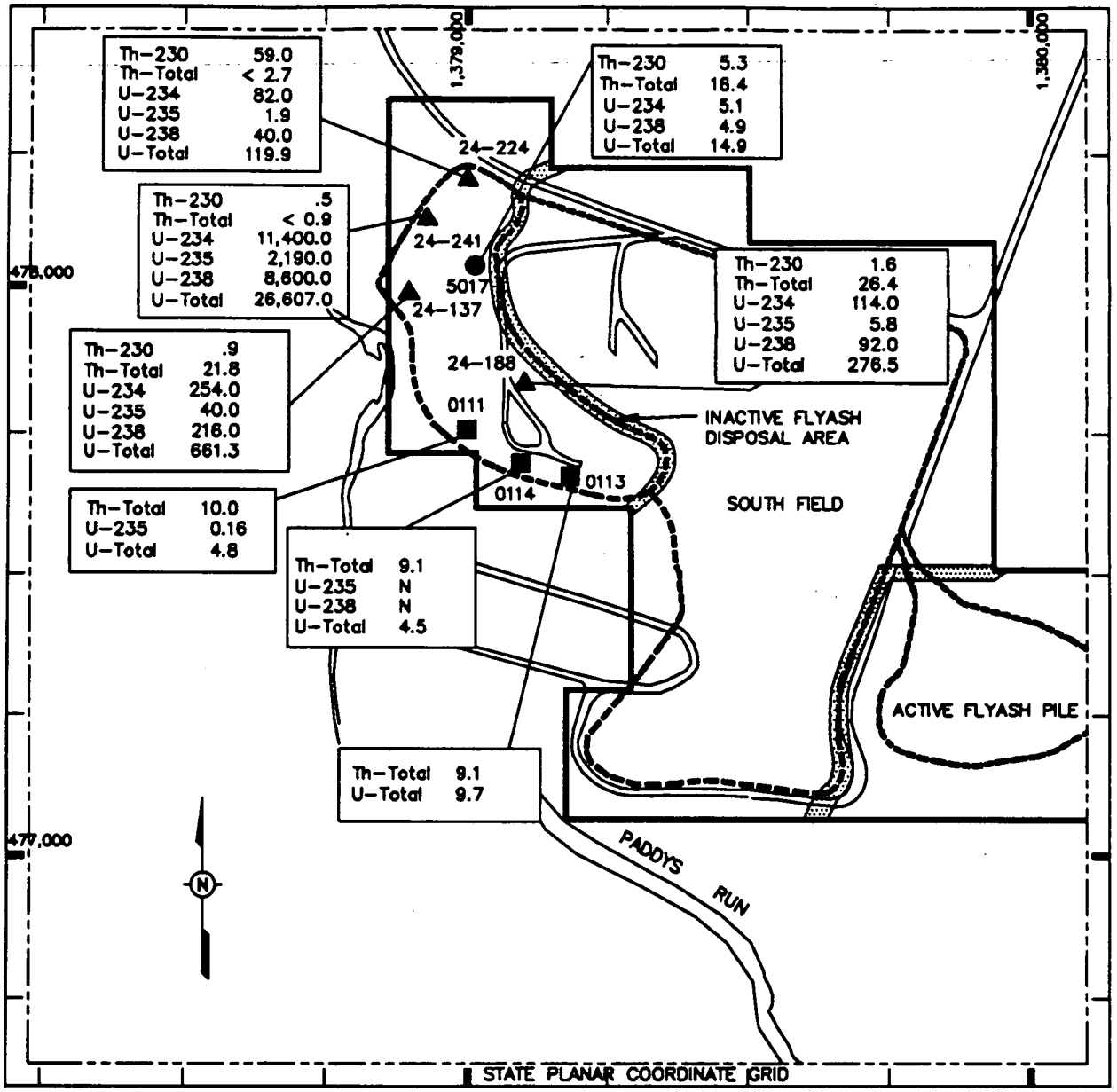
TABLE 4-25

WASTE-RELATED RADIONUCLIDE CONCENTRATIONS IN THE SURFACE MEDIA IN THE INACTIVE FLYASH PILE

Analyte	Background Concentration	ES Samples			CIS Samples and Depths				RI/FS Sample and Depth
		111	113	114	24-137 0-0.16 ft	24-188 1-1.5 ft	24-224 0.-0.16 ft	24-241 0-0.5 ft	5017 0-0.16 ft
Radionuclides: (pCi/g)									
Bismuth-214	1.51	1.2±0.04	1.0±0.1	1.0±0.1	NA	NA	NA	NA	NA
Cesium-137	0.711	0.07±0.02	0.44±0.04	B	<0.8	<0.2	<0.8	<0.9	0.7±0.2
Lead-210	1.33	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-239/240	0.0	NA	NA	NA	<0.1	<0.1	<0.1	1.5±0.4	<0.6
Radium-224	0.983	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226	1.51	1.2±0.1	0.89±0.06	1.0±0.1	<8.75	<2.35	48.88±3.06	<29.30	1.4±0.4
Radium-228	1.28	NA	NA	NA	NA	NA	NA	NA	<1.0
Strontium-90	0.0	NA	NA	NA	<0.4	<0.8	<0.7	<0.4	<0.5
Technetium-99	0.0	NA	NA	NA	<0.6	<0.4	<0.4	594±51	<1.1
Thorium-228	1.56	1.0±0.05	1.2±0.1	1.0±0.1	2.2±0.80	3.6±0.5	<0.9	<0.1	0.9±0.3
Thorium-230	2.18	NA	NA	NA	0.9±0.6	1.6±0.30	59±4.0	0.5±0.1	5.3±1.0
Thorium-232	1.36	1.1±0.1	1.0±0.1	1.0±0.1	2.4±0.80	2.9±0.50	<0.4	<0.1	1.8±0.5
Total Thorium (mg/kg)	12.4	10.0[a]	9.1[a]	9.1[a]	21.8[a]	26.4[a]	<2.7[a]	<0.9[a]	16.4[a]
Uranium-234	1.28	NA	NA	NA	254±3	114.0±2.0	82±1	11400±100	5.1±1.0
Uranium-235	0.151	0.16±0.01	N	N	40±1.0	5.8±0.40	1.9±0.2	2190±30	NA
Uranium-235/236	0.151	NA	NA	NA	NA	NA	NA	NA	<0.6
Uranium-238	1.22	N	N	N	216±3	92±2.0	40±1	8600±100	4.9±1.0
Total Uranium (mg/kg)	3.66	4.8	9.7	4.5	661.3[b]	276.5[b]	119.9[b]	26607.7[b]	14.9[b]

NA = Not analyzed
I = Nuclide identified by GAMANAL analysis of sample spectrum, but values did not exceed room background at the 95% conficence level; no value reported
N = Nuclide not identified by GAMANAL analysis as being present in the sample; no value reported.
[a] = Total thorium for ES, CIS and RI/FS samples are calculated estimates which are based on measured values of thorium-232
[b] = Total uranium for CIS and RI/FS samples are calculated estimates which are based on measured values of uranium-235 and uranium-238



NOTES:

1. ALL RESULTS EXCEPT TOTAL URANIUM GIVEN IN pCi/g
2. TOTAL URANIUM VALUES ARE GIVEN IN mg/kg
3. NA DENOTES NOT ANALYZED
4. N DENOTES NO VALUE REPORTED (NUCLIDE NOT IDENTIFIED BY GAMMA ANALYSIS)

SCALE

0 125 250 FEET

LEGEND:

SURFACE SAMPLE LOCATIONS:

- ■ ES
- ▲ CIS
- ● RI/FS
- EXTENT OF FILL
- FLYASH/SOUTH FIELD BOUNDARY
- BOUNDARY BETWEEN FLYASH PILES AND SOUTH FIELD
- OPERABLE UNIT 2 STUDY AREA

LLS 10/1/92 REV. 2
002 A FIG3-20 DU2 TK20.DR

FIGURE 4-12. URANIUM AND THORIUM CONCENTRATIONS IN SURFACE MEDIA IN THE INACTIVE FLYASH PILE

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TABLE 4-26

WASTE-RELATED RADIONUCLIDE CONCENTRATIONS IN SUBSURFACE MEDIA IN THE INACTIVE FLYASH PILE

Analyte	Background Concentration	ES Borings and Depths					CIS Borings, Sample Descriptions, and Depths	
		604 0-2.17 ft	605 0-5 ft	607 5-10 ft	608 10-15 ft	609 15-20 ft	24-10 Composite 0-26 ft	24-11 Composite 0-34 ft
Radionuclides: (pCi/g)								
Bismuth-214	1.51	1.4±0.1	1.9±0.2	2.4±0.2	2.1±0.1	1.6±0.1	NA	NA
Cesium-137	0.711	I	I	I	I	I	NA	NA
Lead-210	1.33	NA	NA	NA	NA	NA	5.0 ±1.0	3.0 ±1.0
Plutonium-239/240	0.0	NA	NA	NA	NA	NA	NA	NA
Radium-224	0.983	NA	NA	NA	NA	NA	NA	NA
Radium-226	1.51	1.2±0.1	1.7±0.1	2.4±0.2	1.8±0.1	1.5±0.1	4.1±0.7	1.5±0.5
Radium-228	1.28	NA	NA	NA	NA	NA	2.0±0.7	1.7±0.7
Strontium-90	0.0	NA	NA	NA	NA	NA	NA	NA
Technetium-99	0.0	NA	NA	NA	NA	NA	NA	NA
Thorium-228	1.56	1.2±0.1	2.2±0.2	2.4±0.2	2.2±0.1	2.2±0.1	2.3±0.8	0.2±0.1
Thorium-230	2.18	NA	NA	NA	NA	NA	11±2.0	0.2±0.1
Thorium-232	1.36	0.94±0.12	2.2±0.3	2.4±0.4	2.1±0.1	2.2±0.1	2.6±0.8	0.1±0.1
Total Thorium (mg/kg)	12.4	8.5[a]	20.0[a]	21.8[a]	19.1[a]	20.0[a]	23.6[a]	0.9[a]
Uranium-234	1.28	NA	NA	NA	NA	NA	48.0±1.0	3.7±0.3
Uranium-235	0.151	N	N	N	N	N	2.2±0.2	0.2±0.1
Uranium-235/236	0.151	NA	NA	NA	NA	NA	NA	NA
Uranium-238	1.22	I	N	N	N	I	50.0±1.0	6.6±0.4
Total Uranium (mg/kg)	3.66	17.0	12.0	9.4	8.4	10.0	149.8[b]	19.7[b]

This table is to be read horizontally
NA = Not Analyzed
I = Nuclide identified by GAMANAL analysis of sample spectrum, but value did not exceed room background at the 95% confidence level; no value reported
N = Nuclide not identified by GAMANAL analysis as being present in the sample; no value reported
R = Value rejected during data validation
[a] = Total thorium for ES, CIS and RI/FS samples are calculated estimates which are based on measured values of thorium-232
[b] = Total uranium for CIS and RI/FS samples are calculated estimates which are based on measured values of uranium-235 and uranium-238

TABLE 4-26
(continued)

Analyte	Background Concentration	RI/FS Borings and Sample Location							
		1016	1047	1708			1709		
		Shallow Fill 07233 1.5-3.0 ft	Native Soil 07301 9.0-10.5 ft	Shallow Fill 67095 6.0-7.5 ft	Lower Fill 67101 15.0-16.5 ft	Native Soil 67111 30.0-31.5 ft	Shallow Fill 67062 4.5-6 ft	Deep Fill 67072 15-16.5 ft	Very Deep Fill 67081 28.5-30 ft
Radionuclides: (pCi/g)									
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Lead-210	1.33	NA	NA	NA	NA	NA	0.80±0.56	1.25±0.58	1.17±0.61
Plutonium-239/240	0.0	<0.6	<0.6	<0.6 R	<0.6 R	<0.6 R	<0.6	<0.6	<0.6
Radium-224	0.983	NA	NA	NA	NA	NA	2.29±0.29	2.96±0.36	3.05±0.37
Radium-226	1.51	0.7±0.1	0.7±0.1	3.1±0.3	2.7±0.3	1.7±0.1	1.96±0.20	2.79±0.25	2.13±0.22
Radium-228	1.28	0.8±0.1	0.6±0.1	3.1±0.4	2.5±0.3	1.1±0.20	1.66±0.29	2.2±0.34	2.19±0.34
Strontium-90	0.0	<0.5	<0.5	1.23±0.30	1.25±0.29	<0.7	<0.9	<0.8	<0.9
Technetium-99	0.0	<0.9	1.5±0.4	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9
Thorium-228	1.56	1.1±0.5	0.8±0.3	3.1±0.6	2.70±0.52	1.6±0.3	2.08±0.48	2.78±0.69	2.51±0.54
Thorium-230	2.18	0.9±0.4 R	1.4±0.4	3.0±0.62	2.73±0.52	2.93±0.50	3.74±0.73	4.50±0.96	3.07±0.62
Thorium-232	1.36	0.6±0.3	<0.6	2.42±0.54	1.81±0.38	1.17±0.2	2.02±0.47	2.65±0.66	2.21±0.49
Total Thorium (mg/kg)	12.4	5.5[a]	5.5[a]	21.8±4.8	16.3±3.5	10.6±2.3	18.3±4.3	23.9±6.0	20.0±4.4
Uranium-234	1.28	10.7±2.0	<0.6	3.65±0.5	2.88±0.4	20.64±2.72	4.40±0.76	4.63±0.8	3.52±0.58
Uranium-235	0.151	NA	NA	NA	NA	NA	1.10±0.32	<4.4	<0.5
Uranium-235/236	0.151	<0.6	<0.6	<0.6	<0.6	0.687±0.267	0.96±0.3	<0.6	<0.6
Uranium-238	1.22	11.4±2.1	0.7±0.3	3.94±0.58	2.97±0.43	21.94±2.87	11.0±1.5	3.43±0.7	3.36±0.75
Total Uranium (mg/kg)	3.66	34.2[b]	2.4[b]	15.6±3.7	11.1±3.4	68.2±10.2	67.0±8.4	14.5±4.1	14.4±4.3

TABLE 4-26
(continued)

Analyte	Background Concentration	RI/FS Borings and Sample Location						
		1710			1711			1791
		Shallow Fill 67028 3.0-4 ft	Deep Fill 67043 22.5-24 ft	Native Soil 67046 27.0-28.5 ft	Upper Fill 67010 1.5-3 ft	Deep Fill 67014 7.5-9 ft	Native Soil 67019 13.5-15 ft	Native Soil 67121 27.0-28.5 ft
Radionuclides: (pCi/g)								
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Lead-210	1.33	1.18±0.57	2.75±0.64	16.8±2.1	1.24±0.69	1.87±0.59	0.71±0.48	NA
Plutonium-239/240	0.0	<0.6	<0.6	<1.0	<0.6	<0.6	<0.6	<0.6
Radium-224	0.983	3.05±0.36	3.11±0.36	3.49±0.43	2.94±0.36	3.22±0.38	1.71±0.24	NA
Radium-226	1.51	2.35±0.23	6.36±0.42	36.0±1.9	2.74±0.25	4.11±0.32	1.48±0.17	1.39±0.19
Radium-228	1.28	2.46±0.35	2.88±0.34	3.12±0.44	2.16±0.32	2.67±0.35	1.27±0.26	1.03±0.29
Strontium-90	0.0	<0.9	<0.5	1.7±0.3	<1.1	<0.9	<0.9	<1.0
Technetium-99	0.0	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9	<0.9
Thorium-228	1.56	2.54±0.51	4.10±0.79	3.03±0.66	0.79±0.23	3.34±0.79	1.56±0.38	1.10±0.24
Thorium-230	2.18	3.31±0.71	12.8±2.0	54.6±7.8	1.41±0.33	6.09±1.21	2.14±0.47	1.73±0.32
Thorium-232	1.36	2.47±0.58	4.0±0.78	3.28±0.69	0.80±0.24	3.10±0.74	1.10±0.32	0.95±0.21
Total Thorium (mg/kg)	12.4	22.2±5.2	36.1±7.0	29.6±6.3	7.22±2.14	28.8±6.7	9.89±2.75	8.6±1.93
Uranium-234	1.28	11.4±1.6	51.4±5.9	187±25	42.0±4.8	5.95±0.85	4.95±0.72	NA
Uranium-235	0.151	0.57±0.29	2.04±0.39	12.7±1.2	2.42±0.44	<0.5	<0.4	NA
Uranium-235/236	0.151	0.88±0.28	3.29±0.59	18.5±4.9	5.34±0.82	0.87±0.24	<0.6	NA
Uranium-238	1.22	9.57±1.03	33.3±2.6	180±13	34.1±2.7	6.07±0.85	3.52±0.66	NA
Total Uranium (mg/kg)	3.66	38.2±5.84	120.0±14	660±67	123±14	18.2± 4.3	18.0±4.0	873.0±124

TABLE 4-26
(continued)

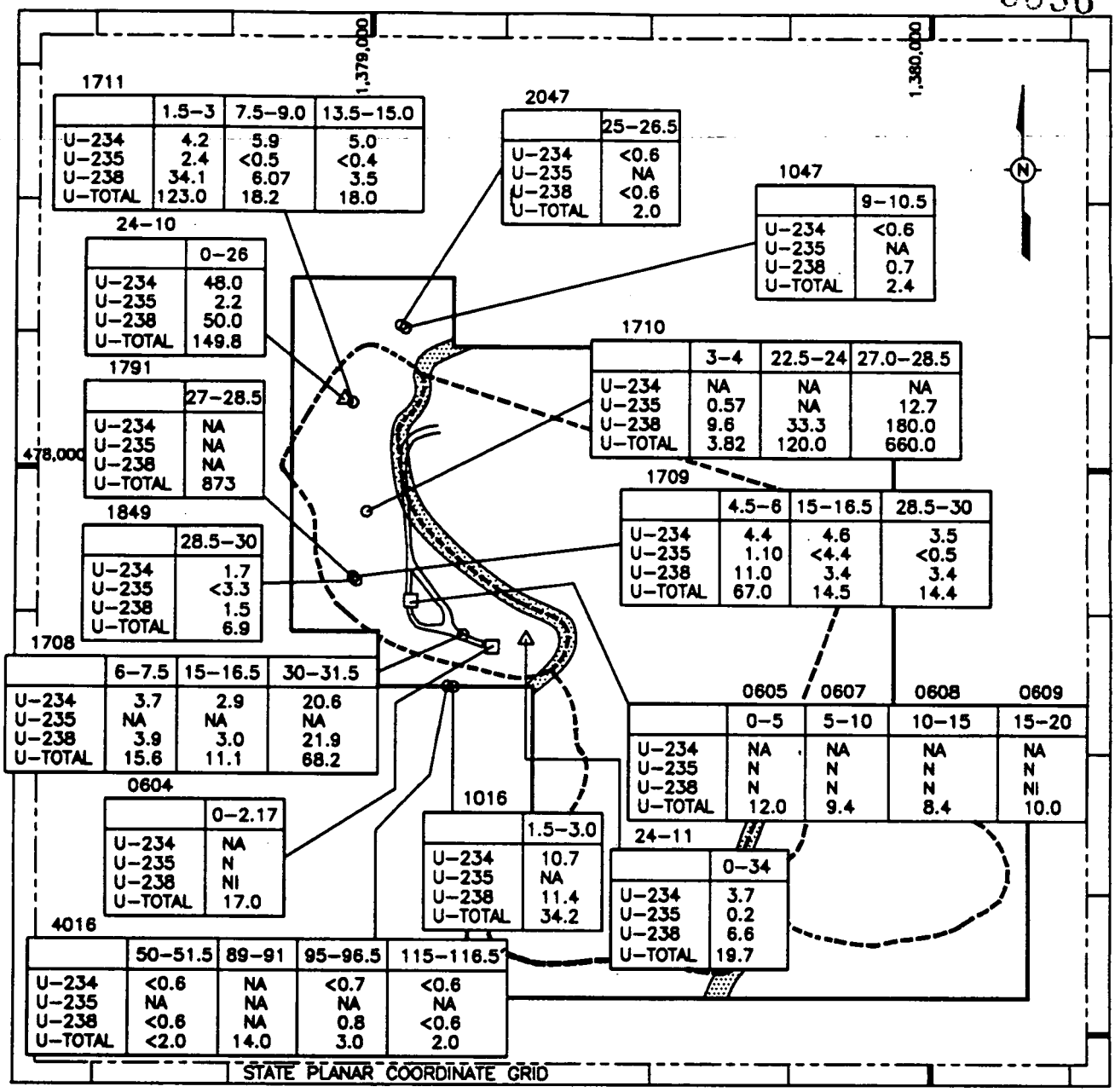
Analyte	Background Concentration	RI/FS Borings and Sample Location					
		1849	2047	4016			
		Native Soil 67618 28.5-30.0 ft	Native Soil 08960 25-26.5 ft	Native Soil 10441 50.0-51.5 ft	Native Soil 10449 89.0-91.0 ft	Native Soil 10450 95.0-96.5 ft	Native Soil 10454 115.0-116.5 ft
Radionuclides: (pCi/g)							
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.2	<0.2	<0.2	NA	<0.2	<0.2
Lead-210	1.33	0.79±0.45	NA	NA	NA	NA	NA
Plutonium-239/240	0.0	<0.6	<0.6	<0.6	NA	<0.6	<0.6
Radium-224	0.983	1.02±0.16	NA	NA	NA	NA	NA
Radium-226	1.51	0.95±0.14	0.4±0.1	0.5±0.1	NA	0.9±0.1	<0.3
Radium-228	1.28	0.74±0.22	<0.5	<0.5	NA	1.2±0.2	<0.5
Strontium-90	0.0	0.77±0.46	0.7±0.2	<0.5	NA	4.0±0.6	0.9±0.2
Technetium-99	0.0	<0.9	<0.9	<0.9	NA	<0.9	<0.9
Thorium-228	1.56	1.44±0.38	<0.6	<0.6	NA	1.1±0.2	<0.6
Thorium-230	2.18	1.69±0.43	1.0±0.2	<0.6	NA	1.2±0.2	<0.6
Thorium-232	1.36	0.91±0.29	<0.6	<0.6	NA	0.9±0.2	<0.6
Total Thorium (mg/kg)	12.4	8.21±2.61	<5.5[a]	<5.5[a]	NA	8.2[a]	<5.5[a]
Uranium-234	1.28	1.73±0.33	<0.6	<0.6	NA	<0.7±0.2 R	<0.6
Uranium-235	0.151	<3.3	NA	NA	NA	NA	NA
Uranium-235/236	0.151	<0.6	<0.6	<0.6	NA	<0.6 R	<0.6
Uranium-238	1.22	1.47±0.54	<0.6	<0.6	NA	0.8±0.2 R	<0.6
Total Uranium (mg/kg)	3.66	6.93±3.21	2.0±2.0	<2.0	14.0±4.2	3.0±2.0	2.0±1.0

TABLE 4-27

RADIONUCLIDE CONCENTRATIONS IN SUBSURFACE MEDIA PROFILES OF THE INACTIVE FLYASH PILE

	Borings and Analytes					
	24-10			24-11		
Depth (ft)	U-238 (pCi/g)	Ra-226 (pCi/g)	Th-232 (pCi/g)	U-238 (pCi/g)	Ra-226 (pCi/g)	Th-232 (pCi/g)
0-1	19.8	<1.8	1.8	<15.1	1.7	2.2
1-2	11.8	1.2	<0.4	17.0	1.1	1.3
2-3	20.2	2.5	1.6	13.7	1.0	1.5
3-4	23.5	2.7	2.9	9.1	<0.8	1.5
4-5	<7.7	3.7	2.7	<10.9	<0.9	1.3
5-6	<16.5	2.4	3.5	7.6	1.7	1.0
6-7	18.0	2.0	2.5	11.9	1.7	2.2
7-8	<14.7	3.0	<4.3	<10.3	2.9	3.1
8-9	<8.3	2.8	2.4	<10.7	1.8	2.3
9-10	<11.0	3.0	1.5	<10.2	2.6	2.0
10-11	<7.7	2.9	2.6	<9.3	2.1	2.9
11-12	<6.9	2.1	1.6	<9.2	2.0	2.2
12-13	<15.6	2.1	3.0	<16.4	1.9	1.8
13-14	<11.5	1.5	1.0	<9.6	2.1	1.9
14-15	<5.2	<0.7	0.8	<15.0	2.0	2.2
15-16	135.0	2.5	1.5	<6.2	2.6	2.2
16-17	40.5	2.9	1.5	<9.8	1.8	2.9
17-18	81.6	4.0	<2.1	<10.1	1.5	3.3
18-19	74.4	2.6	<1.4	<9.5	<2.5	3.6
19-20	8.9	1.2	<0.8	<8.5	2.0	2.2
20-21	139.0	7.0	<3.0	<10.8	<2.3	3.5
21-22	160.0	7.9	<3.7	<17.6	2.3	2.9
22-23	104.0	5.1	2.2	<11.3	2.1	<4.7
23-24	"	"	"	<13.0	1.8	2.8
24-25	10.0	1.4	<0.4	14.1	1.9	1.1
25-26	"	"	"	<18.7	1.9	2.4
26-27				6.3	1.3	1.7
27-28				5.3	1.6	2.4
28-29				<12.0	1.2	<3.7
29-30				15.9	1.8	1.6
30-31				2.6	1.4	1.9
31-32				<3.5	1.0	1.0
32-33				<4.4	0.8	0.8
33-34				<4.3	1.0	0.6

Source: Weston, Inc., Roy F., 1987b, "Characterization Investigation Study, Volume 2: Chemical and Radiological Analysis of the Waste Pits," prepared for Westinghouse Materials Co. of Ohio, U.S. Dept. of Energy Feed Materials Production Center, Fernald, OH



NOTES:

1. U–234, U–235, AND U–238 ARE GIVEN IN pCi/g
2. TOTAL URANIUM GIVEN IN mg/kg
3. NA DENOTES NOT ANALYZED
4. N DENOTES NO VALUE REPORTED (NUCLIDE NOT IDENTIFIED BY GAMANAL ANALYSIS)
5. NI DENOTES THAT VALUE DID NOT EXCEED ROOM BACKGROUND LEVEL FOR NUCLIDE IDENTIFIED BY GAMANAL ANALYSIS SAMPLE SPECTRUM

SCALE

0 125 250 FEET

LEGEND:

SUBSURFACE SAMPLING LOCATION

- □ ES BORING
- △ CIS BORING
- ○ RI/FS BORING
- ------ EXTENT OF FILL
- ——— FLYASH/SOUTH FIELD BOUNDARY
- – – – OPERABLE UNIT 2 STUDY AREA
- BOUNDARY BETWEEN FLYASH PILES AND SOUTH FIELD

KVP 10/6/92 REV. 2
R02 A 5K5361 OU2 TK20 OR

FIGURE 4–13. URANIUM CONCENTRATIONS IN SUBSURFACE MEDIA SAMPLES IN THE INACTIVE FLYASH PILE STUDY AREA

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TABLE 4-28

ORGANIC COMPOUNDS DETECTED IN SUBSURFACE MEDIA
IN THE INACTIVE FLYASH PILE

Compound	Frequency of Detection	Range (mg/kg)
Volatile Compounds		
2-Butanone	2/18	0.012-0.029
2-Hexanone	2/13	0.006-0.014
4-Methyl-2-pentanone	3/13	0.001-0.007
Acetone	13/20	0.002-0.190
Carbon disulfide	2/20	0.006-0.009
Styrene	1/16	0.002
Toluene	7/14	0.003-0.110
Trichloroethene	1/12	0.006
Chlorinated Volatile Compounds		
1,1,1-Trichloroethane	10/20	0.004–0.150
Methylene chloride	18/20	0.006-0.110
Trichloroethene	1/12	0.006
Polynuclear Aromatic Hydrocarbons		
2-Methylnaphthalene	2/16	0.066–0.089
Anthracene	1/18	0.049
Benzo(b)fluoranthene	1/18	0.093
Naphthalene	2/17	0.053–0.053
Phenanthrene	2/18	0.041–0.049
Phthalate Esters		
Bis(2-Ethylhexyl)phthalate	1/18	0.620
Di-n-butyl phthalate	1/17	0.046
PCBs		
Aroclor-1242	1/13	0.005
Aroclor-1254	2/13	0.210–0.290
Other Semivolatile Compounds		
Benzoic acid	2/18	0.097-0.150
Phenol	3/18	0.430–0.480
Vinyl Acetate	2/19	0.002

NOTES: 1. Data compiled from Environmental Survey, CIS, and RI/FS sampling and analysis programs.
2. Data qualified with an "R" (i.e., rejected data) are not included.

during the RI/FS drilling were at or below background for all borings in the Inactive Flyash Pile except Boring 1710, which exhibited only trace levels (<4 ppm).

Hazardous toxicity waste characteristic thresholds (40CFR261.24) were not exceeded for any organic compound in the eight TCLP extracts or the extract from the two samples that underwent EP toxicity testing.

4.5.3.3 Metals in Surface and Subsurface Media

The RCRA metals detected at concentrations above background were arsenic (above background in 8 of 14 samples), barium (10 of 14), cadmium (9 of 14), lead (3 of 14), and silver (1 of 14) (Table 4-29). Arsenic concentrations in native soil were lower than those in fill. The highest measured concentration was 74.8 mg/kg in deep fill from Boring 1709, seven times the background level (10.3 mg/kg). Barium was above background (133 mg/kg) in shallow and deep fill, with the highest concentration at 892.0 mg/kg in deep fill from Boring 1710. Cadmium was above background (0.650 mg/kg) in both fill and native soil, with the highest concentration (4.1 mg/kg) measured in native soil, from Boring 1710. Selenium was detected above background (0.72 mg/kg) in both shallow and deep fill samples, with the highest concentration at 4.1 mg/kg in deep fill from Boring 1709.

Other inorganics detected at concentrations above background in half or more of the samples were beryllium (above background in 10 of 14 samples), copper (11 of 14), and cyanide (7 of 12). Beryllium was consistently detected above background (0.607 mg/kg) in fill samples, with the highest concentration (6.7 mg/kg) in shallow fill from Boring 1710. Copper was above background (21.2 mg/kg) in both fill and native soil; the highest concentration was 44.9 mg/kg in native soil from Boring 1711. Cyanide was above background (0.283 mg/kg) in both fill and native soil, and the highest concentration was 1.2 mg/kg in deep fill from Boring 1708.

Hazardous waste toxicity characteristic thresholds (40CFR261.24) were not exceeded for any metals in the TCLP or EP toxicity extracts.

No asbestos was detected in the Environmental Survey samples.

4.5.4 Surface Water and Sediment in the Inactive Flyash Pile Study Area

The western edge of the Inactive Flyash Pile slopes steeply towards Paddys Run. Two sediment samples (FMP-SD-53-001 and FMP-53-SD-002; henceforth to be referenced as 53-001 and 53-002) were collected as part of the CIS from a drainage between the base of the fill and Paddys Run (Weston 1987c). These were analyzed at the on-site laboratory for uranium-238, thorium-232, radium-226, cesium-137, and ruthenium-106, and are presented for comparison only (Table 4-30). Sediment

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TABLE 4-29

INORGANICS DETECTED IN SUBSURFACE MEDIA
IN THE INACTIVE FLYASH PILE

Analyte	Background Concentration (mg/kg)	Frequency of Detection	Range (mg/kg)	Frequency Above Background Concentration
Aluminum	16973	14/14	2130-9550	0/14
Antimony	0.0	4/10	8.8-16.3	4/10
Arsenic	10.3	14/14	1.7-74.8	8/14
Barium	133	14/14	13.1-892	10/14
Beryllium	0.607	13/14	1.43-6.7	10/14
Cadmium	0.650	11/14	0.65-4.1	9/14
Calcium	201722	14/14	2510-123000	0/14
Chromium	22.0	14/14	5.1-19.6	0/14
Cobalt	15.8	12/14	5.2-12.1	0/14
Copper	21.2	14/14	12.1-44.9	11/14
Cyanide	0.283	10/12	0.18-1.2	7/12
Iron	33026	14/14	4610-20100	0/14
Lead	16.6	14/14	6.4-67.1	3/14
Magnesium	59838	14/14	377–25100	0/14
Manganese	1099	14/14	22.7-780.11	0/14
Mercury	0.292	4/11	0.15-0.44	1/14
Molybdenum	8.8	12/12	3.2-9.4	3/14
Nickel	38.1	14/14	9.7-19.6	0/14
Potassium	1911	13/14	456-1430	0/14
Selenium	0.72	9/14	0.73-4.1	9/14
Silver	8.03	5/14	2.8-8.3	1/14
Sodium	235	14/14	71.9-294	3/14
Thallium	0.397	3/14	0.8-1.0	3/14
Vanadium	39.5	14/14	10.7-34.9	0/14
Zinc	81.2	14/14	9.4-102	1/14

NOTES: 1. Data compiled from Environmental Survey, CIS, and RI/FS sampling and analysis programs.
2. Data qualified with an "R" (i.e., rejected data) are not included.

TABLE 4-30

WASTE-RELATED RADIONUCLIDE CONCENTRATIONS IN SURFACE WATER AND SEDIMENT IN THE INACTIVE FLYASH PILE

		Sediment				Surface Water
		CIS Sample Location		RI/FS Sample Location and Number		RI/FS Sample Location and Number
Analyte	Background Concentration	53-001	53-002	ASIT-008 09048	ASIT-009 09049	ASIT-009 01175
Radionuclides (pCi/g, pCi/ℓ)						
Bismuth-214	1.51	NA	NA	NA	NA	NA
Cesium-137	0.711	0.50±0.2	<1.40	NA	NA	NA
Lead-210	1.33	NA	NA	NA	NA	NA
Plutonium 239/240	0.0	NA	NA	NA	NA	NA
Radium-224	0.983	NA	NA	NA	NA	NA
Radium-226	1.51	1.4±0.5	0.80±0.3	0.9±0.1	0.7±0.1	<1.0
Radium-228	1.28	NA	NA	0.9±0.1	0.7±0.1	<3.0
Strontium-90	0.0	NA	NA	NA	NA	NA
Technetium-99	0.0	NA	NA	NA	NA	NA
Thorium-228	1.56	NA	NA	NA	NA	NA
Thorium-230	2.18	NA	NA	NA	NA	NA
Thorium-232	1.36	1.10±0.6	<0.50	NA	NA	NA
Total Thorium (mg/kg, µg/ℓ)	12.4	10.0[b]	<4.5[b]	NA	NA	NA
Uranium-234	1.28	NA	NA	NA	NA	NA
Uranium-235	0.151	NA	NA	NA	NA	NA
Uranium-235/236	0.151	NA	NA	NA	NA	NA
Uranium-238	1.22	8.90±3.4	4.0±3.1	NA	NA	NA
Total Uranium (mg/kg, µg/ℓ)	3.66	26.5[c]	11.9[c]	13.9±1.8	5.4±1.1	40.0±6.0

NA = Not analyzed
[a] = Background concentration for sediment are taken as soil UTLs. No UTLs have been calculated for surface water
[b] = Total thorium for CIS samples are calculated estimates which are based on measured values of thorium-232
[c] = Total uranium for CIS samples are calculated estimates which are based on measured values of uranium-235 and uranium-238

samples were collected from two locations (ASIT-008 and ASIT-009, located at the northwestern and southwestern edge of the waste area, respectively, as shown in Figure 2-15) during RI/FS sampling activities and were analyzed for radium- 226, radium-228, and total uranium. A surface water sample was collected at ASIT-009 and was analyzed for radium-226, radium-228, total uranium, metals, and the general water quality parameters.

4.5.4.1 Radionuclides in Surface Water and Sediment

Total uranium was detected above the soil background (3.66 mg/kg) in all sediment samples (Table 4-30). Total uranium was also found to exist in the surface water sample from ASIT-009 at a level of 40 µg/ℓ.

4.5.4.2 Organic Compounds in Surface Water and Sediment

No surface water sample or sediment from the Inactive Flyash Pile was analyzed for organic constituents.

4.5.4.3 Metals in Surface Water and Sediment

Six waste-related metals were detected in the surface water sample, including lead (0.0083 mg/ℓ) and mercury (0.0008 mg/ℓ).

4.5.5 Groundwater in the Inactive Flyash Pile Study Area

A perched groundwater system is located beneath the Inactive Flyash Pile, but there is no evidence that water in this system intersects the fill. Groundwater in the Great Miami Aquifer typically flows from west to east in the Inactive Flyash Pile area and is generally derived from the Dry Fork Section of the New Haven Trough. During periods of high rainfall, Paddys Run becomes a recharge area, and contaminants in the surface water runoff from the site can be introduced into the aquifer west of the South Field (DOE 1990a).

As part of the RI/FS, a series of groundwater wells were placed to the north and south of the Inactive Flyash Pile. The wells in the vicinity of the Inactive Flyash Pile were sampled quarterly only between 1988 and 1990 (Table 4-31). Samples from all wells were analyzed for radionuclides, metals, and the general water quality parameters (Table 2-4). On one occasion, Wells 1016 and 2016 were analyzed for VOCs, SVOCs, pesticides/PCBs, dioxins, and organophosphorus pesticides.

4.5.5.1 Radionuclides in Groundwater

Uranium was consistently detected in all wells in the Inactive Flyash Pile study area, with the highest concentration of total uranium found in Well 2016, where the average concentration was approximately 20.7 µg/ℓ. The background is 0.741 µg/ℓ in the Dry Fork Section. Well 2046, which is in the South Field but is also hydraulically downgradient of the Inactive Flyash Pile, exhibits an average

TABLE 4-31

WASTE-RELATED RADIONUCLIDE CONCENTRATIONS IN GROUNDWATER IN THE INACTIVE FLYASH PILE

		RI/FS Wells, Sample Numbers and Dates Collected													
		1016[a]			1047[a]					2016[b]					
Analyte	Background Concentration[c]	03062 3/28/88	03906 2/26/89	66819 12/13/89	03102 4/20/88	03369 7/24/88	03648 10/23/88	03855 1/22/89	66830 12/12/89	03063 3/28/88	03434 8/3/88	03685 11/04/88	03883 02/07/89	04152 07/26/89	04213 03/04/90
Radionuclides: (pCi/ℓ)															
Bismuth-214	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.0/0.0	<20.0	<20.0	NA	<20.0	<20.0	<20.0	<20.0	NA	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0
Lead-210	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-239/240	0.0/0.0	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Radium-224	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226	<1/<1	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Radium-228	<3/<3	<3.0	<3.0	NA	<3.0	<3.0	<3.0	<3.4	NA	<3.0	<3.0	<3.0	<3.2	<3.0	<3.0
Strontium-90	0.0/0.0	<5.0	<5.0	NA	<5.0	<5.0	<5.0	<5.0	NA	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Technetium-99	0.0/0.0	<30.0	<30.0	<1.0	<30.0	<30.0	<43.7	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0
Thorium-228	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	1.1±0.4	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Thorium-230	<1/<1	<1.0	<1.0	1.2±0.7	<1.0	<1.0	1.0±0.4	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Thorium-232	<1/<1	<1.0	<1.0	NA	<1.0	<1.0	1.1±0.4	<1.0	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Thorium (µg/ℓ)	<9/<9	<9.1[d]	<3.0	NA	<9.1[d]	5.0±3.0	10.0±4.0	<3.0	NA	<9.1[d]	<2.0	<2.0	<3.0	<2.0	<1.9
Uranium-234	<1/0.25	<1.0	2.5±0.6	<1.0	3.7±0.9	7.4±1.1	7.3±1.2	3.7±0.6	4.0±0.8	7.7±1.5	5.3±0.8	4.6±0.7	6.6±0.9	5.1±0.8	4.3±0.7
Uranium-235	<1/0.012	NA	NA	<1.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235/236	<1/0.012	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Uranium-238	<1/0.25	<1.0	2.6±0.6	<1.0	2.5±0.7	3.2±0.6	3.6±0.7	2.1±0.4	<1.0	6.2±1.3	6.4±0.9	5.6±0.9	8.0±1.1	5.8±0.9	5.0±0.8
Total Uranium (µg/ℓ)	<3/0.74	<1.0	9.0±2.0	2.0±0.2	6.0±1.0	9.0±2.0	11.2[e]	6.0±1.0	10.3±1.1	21.0±3.0	18.0±3.0	17.0±3.0	22.0±4.0	17.0±3.0	29.4±4.0

This table is to be read horizontally
NA = Not analyzed
[a] = Perched groundwater well
[b] = Great Miami Aquifer well
[c] = Background Concentration given for perched groundwater/Dry Fork Tributary of the Great Miami Aquifer
[d] = Total thorium for RI/FS samples are calculated estimates which are based on measured values of thorium-232
[e] = Total uranium for RI/FS samples are calculated estimates which are based on measured values of uranium-235 and uranium-238

TABLE 4-31
(continued)

Analyte	Background Concentration	RI/FS Wells, Sample Numbers and Dates Collected											
		2047[b]				3016[b]					4016[b]		
		03998 01/22/89	04093 05/02/89	04160 07/28/89	04220 04/03/90	03082 04/08/88	03435 08/03/88	03686 11/04/88	03882 02/07/89	04241 03/04/90	03996 01/20/89	04090 05/01/89	66867 12/12/89
Radionuclides:(pCi/ℓ)													
Bismuth-214	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.0/0.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	NA
Lead-210	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium 239/240	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Radium-224	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Radium-228	<3/<3	<3.2	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.1	<3.0	<3.0	<3.0	NA
Strontium-90	0.0/0.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	NA
Technetium-99	0.0/0.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0	<30.0
Thorium-228	<1/<1	<1.0	<1.0	<1.0	<1.0	1.4 ± 0.7	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Thorium-230	<1/<1	<1.0	<1.0	<1.0	1.1±0.3	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.4±0.4
Thorium-232	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Total Thorium (μg/ℓ)	<9/9	<4.0	<5.0	<4.0	<1.9	<9.1[d]	<3.0	<2.0	<3.0	<1.4	<9.0	<2.0	NA
Uranium-234	<1/0.25	5.1 ± 0.9	3.2 ± 0.7	3.7 ± 0.7	4.72±0.8	5.3 ± 0.9	3.3 ± 0.6	3.3 ± 0.6	3.3 ± 0.7	3.0±0.5	<1.0	<1.0	<1.0
Uranium-235	<1/0.012	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235/236	<1/0.012	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Uranium-238	<1/0.25	4.5 ± 0.9	3.4 ±0.7	3.8 ± 0.8	4.66±0.8	4.4 ± 0.8	3.5 ± 0.6	3.2 ± 0.6	2.9 ± 0.6	2.8±0.5	<1.0	<1.0	<1.0
Total Uranium (μg/ℓ)	<3/0.74	15.0 ± 3.0	10.0 ± 2.0	9.0 ± 1.0	13.8±1.4	11.0 ± 2.0	9.0 ± 2.0	8.0 ± 1.0	7.0 ± 1.0	13.4±1.4	<1.0	<1.0	<1.0

uranium concentration of 575 µg/ℓ (as will be presented in Section 4.6.5.1). Based on uranium concentrations measured in the soils underlying the Inactive Flyash Pile soils, this waste area is a potential source of the groundwater contamination (Figure 4-14). Other potential sources are recharge from Paddys Run (DOE 1990a), the South Field, and/or other site-related sources.

4.5.5.2 Organic Compounds in Groundwater

No waste-related VOCs, SVOCs, pesticides/PCBs, or organophosphorus pesticides were detected in Wells 1016 and 2016, except for 1,1,1-trichloroethane at 0.002 mg/ℓ in Well 1016 and bis(2-ethylhexyl) phthalate at 0.004 mg/ℓ in Well 2016.

4.5.5.3 Metals in Groundwater

Waste-related metals consistently detected in one or more wells at concentrations above their applicable background concentrations include cadmium in Well 4016. This well, however, is screened in the Lower Great Miami Aquifer, and thus is not likely a receptor for contamination from the Inactive Flyash Pile.

4.5.6 Biota in the Inactive Flyash Pile Study Area

Levels of uranium (reported as the sum of uranium-234, uranium-235, and uranium-238 activities), strontium-90, and cesium-137 were reported for samples of surface soil, forb roots, and forb leaves from Location 22 (Figure 2-13) (Table 4-32) (DOE 1992b). Uranium was detected at 2.3 pCi/g in forb roots at Location 22. Terrestrial vegetation is not concentrating uranium at a higher level than the uranium concentration in the adjacent surface soils.

No samples were taken for SVOCs, pesticides/PCBs, or metals.

4.5.7 Inactive Flyash Pile Summary

Uranium, the primary contaminant in the Inactive Flyash Pile, exists at levels up to 873 mg/kg in subsurface media and 26,600 mg/kg in the surface media. The most contaminated media are at the surface and in the deepest fill, possibly a layer of contaminated soil underlying the flyash. The fact that uranium concentrations in deep samples are greater than those in overlying flyash suggests that contaminated media were placed in the area before the dumping of flyash. Another potential explanation is that uranium has migrated from flyash into underlying native soils.

Well 2046, which is in the South Field but is immediately downgradient of the Inactive Flyash Pile, has an average total uranium concentration of 576 µg/ℓ, the highest such average in the Flyash/South Field study area. Based on data presented in this report, however, a definite conclusion can not be drawn as to whether the Inactive Flyash Pile is a measurable source of uranium to the groundwater.

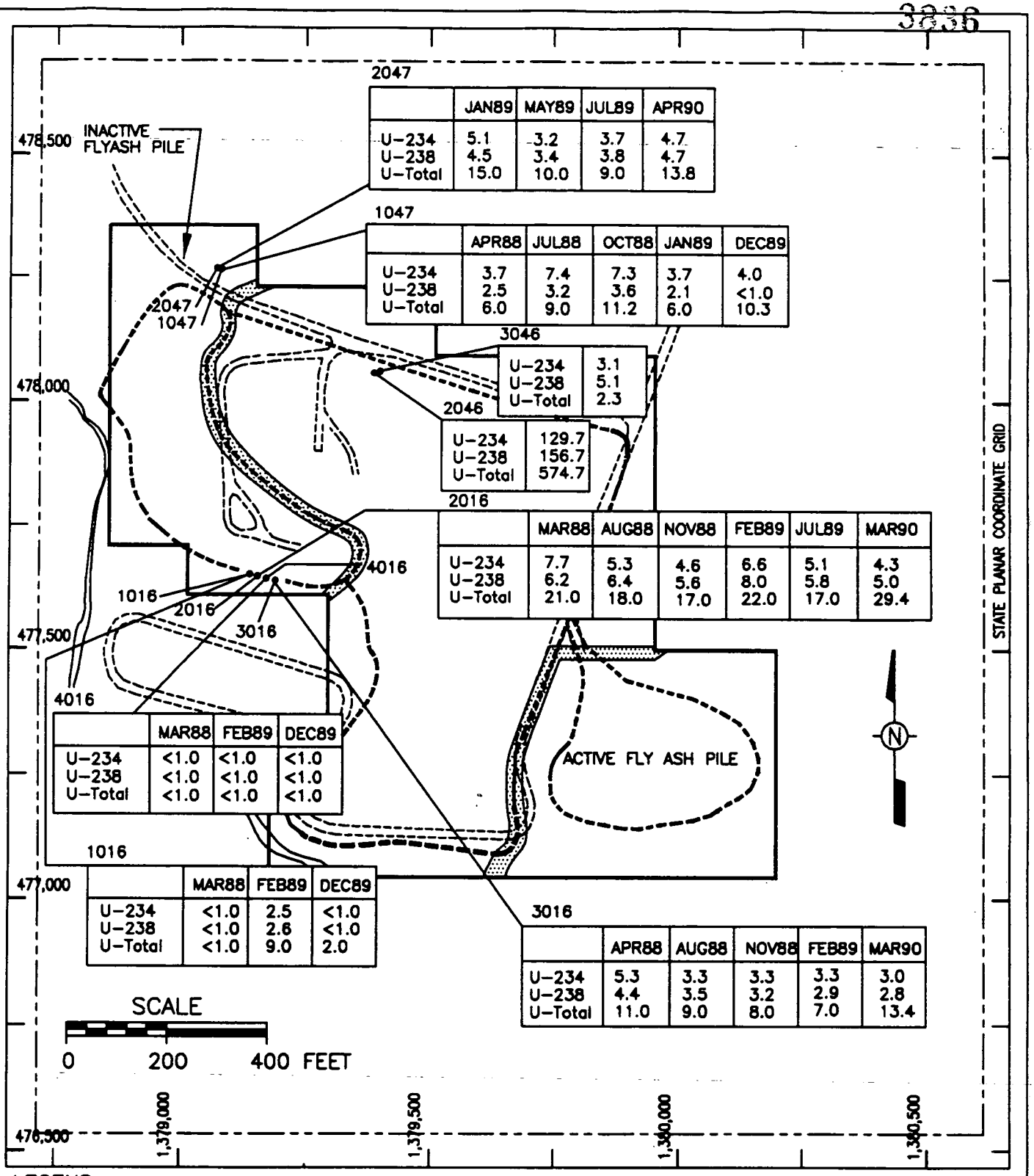

FIGURE 4-14. GROUNDWATER URANIUM CONCENTRATIONS IN THE INACTIVE FLYASH PILE STUDY AREA

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TABLE 4-32

URANIUM, CESIUM, AND STRONTIUM CONCENTRATIONS IN BIOTA IN THE INACTIVE FLYASH PILE

Location 22	Uranium[a]	Cesium-137	Strontium-90
Soil (pCi/g)	10.0	0.7	<0.5
Forb leaves (pCi/g)	<0.6	<0.3	<0.5
Forb roots (pCi/g)	2.3	<0.3	<0.5

[a] This is a sum of all uranium-234, uranium-235, and uranium-238 activities

Source: U.S. Department of Energy, 1992, "Site-Wide Characterization Report," DOE, Fernald Field Office, Fernald, OH.

Organic compounds were detected in soils both at low concentrations and low frequency. The most frequently detected compounds were methylene chloride (detected 18 times at a maximum concentration of 0.110 mg/kg), acetone (13 of 20 samples with a maximum concentration of 0.19 mg/kg), and 1,1,1-trichloroethane (10 of 20 samples with a maximum concentration of 0.15 mg/kg). Only bis(2-ethylhexyl) phthalate and 1,1,1-trichloroethane were detected in groundwater.

A number of inorganic constituents were detected in subsurface media above their respective background concentrations. The most frequent such detections were for arsenic, barium, beryllium, cadmium, copper, selenium, and cyanide. Of these, only cadmium was consistently detected above background in groundwater. The cadmium was detected in Well 4016, which is screened in the Lower Great Miami Aquifer, and thus is not likely a receptor for contamination from the Great Miami Aquifer.

The Active Flyash Pile, Inactive Flyash Pile, South Field, underlying perched groundwater units, and Great Miami Aquifer comprise a complex system of potential contaminant sources, sinks, and transport pathways. Although the complexity of this system reduces the precision to which the various sources and sinks of contamination can be characterized, the various components of the system are included in the development and implementation of the fate and transport models.

4.6 SOUTH FIELD

The analytical results for samples collected from the South Field study area are provided in Appendix G of this document. This section reports results only for waste-related constituents; i.e., analytes which were found to exceed background in at least one surface or subsurface media sample. Analytes which have been detected in groundwater, but are less than background in all surface and subsurface media samples, are considered to have originated from upgradient sources and are not discussed here.

Data tables in this section present individual sample analyses only for waste-related radionuclides. The waste-related organic and inorganic constituents are numerous but typically exhibit low frequencies of detection and low concentrations. Therefore, only summary tables for these data are given here, but the complete data set is available in Appendix G.

4.6.1 Review of Historical Data

The South Field was reportedly used as a burial site for construction rubble that may have contained low levels of radioactivity (Weston 1987b). This includes debris from the razing of the old administration building that, because of its age, may have included asbestos products. Other wastes also may have been deposited here, but no records that support this possibility are available. Some of the fill may also have been removed and deposited elsewhere within the FEMP (DOE 1988a). Flyash

may possibly be located in the South Field in the northwest and southwest perimeters bordering the Flyash Piles. Historical aerial photographs indicate disposal activity in the southeast section of the South Field as early as April 1954 (EPA 1988b).

4.6.2 Volume and Physical Characteristics of Waste

The depth of fill in the South Field may be estimated by changes in elevation during the time that waste disposal occurred. Where borings were drilled, the fill/native soil interface can be measured more accurately. Based on a review of topographic maps from 1951 and 1988 (DOE 1988b), and boring logs from the South Field (Appendix G), the maximum depth of fill is 33 feet at the southern part of the waste area (Figure 4-15). Using north-south cross-sections at 125-foot intervals across the unit, the average-end-area method was used to estimate fill volume at 109,000 cubic yards.

CIS Boring logs (Appendix G) described material found between 0 and 4 feet deep as mostly gravel, fine sand, and clay. During the RI/FS drilling, burned coal, coke, concrete and flyash were also encountered.

The South Field is currently covered with soil and vegetation. The dry density of surface soils in the South Field is approximately 95 to 100 lbs/ft^3.

4.6.3 Surface and Subsurface Media in the South Field

Within the South Field, samples were taken from surface media, shallow fill, deep fill, and native soil underlying the fill.

Surface media samples were obtained and analyzed as a part of the Environment Survey, CIS, and RI/FS. During the Environmental Survey five surface samples (FE0108SS2B, FE0109SS2B, and etc.; henceforth to be referred to as ES-108, -110, etc.) were collected and analyzed for radionuclides, VOCs, PCBs, TCLP metals, and asbestos.

As part of the CIS, 27 surface samples (FMP-SS-24-046, FMP-SL-049, FMP-SL-24-052, etc.; henceforth to be referenced as 24-046, 24-049, 24-052, etc.,) were collected and analyzed for radionuclides. Additional CIS samples were analyzed at the on-site laboratory; however, because the objective of the on-site analytical program was to serve as a screening tool, the resulting data will not be considered in this discussion of surface soil contamination.

Two surface soil samples were collected as part of the RI/FS, and these samples were analyzed for radionuclides.

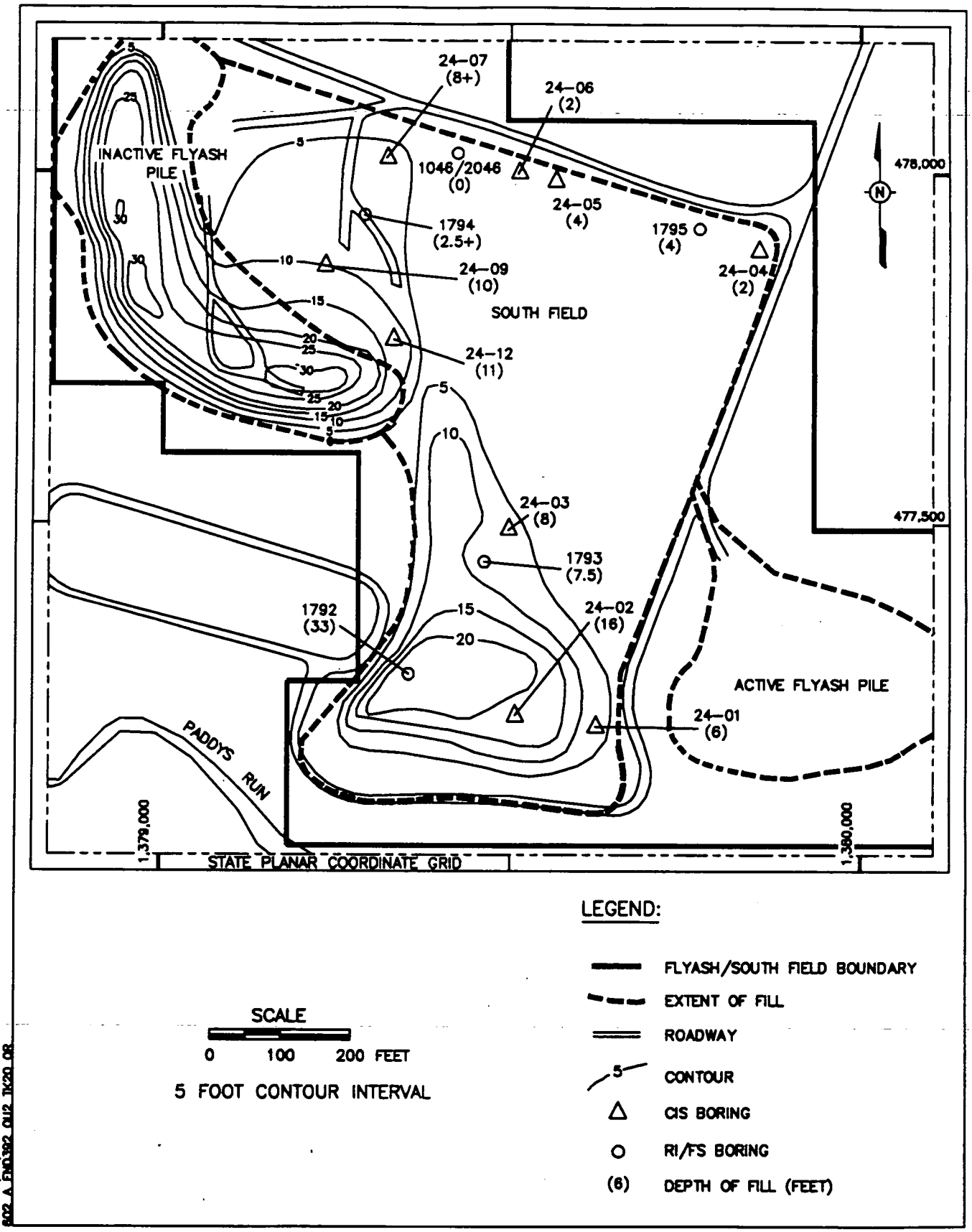

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FIGURE 4-15. DEPTH OF FILL IN THE SOUTH FIELD

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Subsurface samples were collected during the Environmental Survey, CIS, and RI/FS Investigations. During the Environmental Survey, four test pits (Test Pits 14, 15, 16, and 17) were excavated and two samples were collected from each: FE01011IS1B, FE01011IS2B, FE01012IS1B, etc. These samples were analyzed for radionuclides, VOCs, and TCLP metals.

During the CIS, 10 subsurface borings (24-01 through 24-09 and 24-12) were drilled to depths ranging from 4 feet to 20 feet. These borings were sampled at 1-foot intervals for analysis at the on-site laboratory for radium-226, thorium-232, and uranium-238. These analyses are presented as an indication of relative vertical distribution. A vertical composite was prepared from each CIS boring and was analyzed at an off-site laboratory for radionuclides, VOCs, SVOCs, PCBs, total metals, and EP toxicity metals.

Six trenches were excavated as a part of the RI/FS, with three pairs of samples collected from each pit: one pair at the north end, one in the center, and one at the south end. Each pair of samples consisted of one sample in the fill and one in the native soil below the fill, both of which were analyzed for radionuclides. An additional fill sample was collected in the center of the test pit to be analyzed for VOCs, SVOCs, pesticides/PCBs, and total metals. Trenches were numbered 1 through 6, and three boring numbers were assigned to each trench corresponding to the sample pairs. Boring numbers range from 1455 to 1472.

Subsurface samples were collected from borings drilled as part of the well installation program (1046, 1516, 1517, 1518, 2046, 3046, 2385 and 3385) and were analyzed for radionuclides. Later, additional borings were drilled or augered in the South Field. In Borings 1712 through 1715, a soil sample from approximately 2 feet deep was collected and analyzed for the full list of TCLP RCRA analytes (VOCs, SVOCs, metals, pesticides, and herbicides). Samples from Borings 1882 through 1885 were analyzed for TCLP VOCs/SVOCs. Samples from Borings 1792 through 1795 were analyzed for VOCs, SVOCs, PCBs/pesticides, dioxins/furans, organophosphorus pesticides, total metals, and the full list of TCLP RCRA analytes.

As a part of the Firing Range Removal Site Evaluation (DOE 1992c), six vertical borings and one horizontal boring were drilled into the embankment along the southeastern side of the South Field, which served as a backdrop for the Firing Range. In addition, two surface samples were collected from the area between the firing line and the embankment. Samples were analyzed for total lead, and those samples with total lead concentrations greater than 100 mg/kg were additionally analyzed for TCLP lead.

4.6.3.1 Radionuclides in Surface and Subsurface Media

Uranium, thorium, and radium are the primary contaminants in surface soils of the South Field. Total uranium was calculated at concentrations as high as 8915 mg/kg at 24-081, near the center of the South Field (Table 4-33, Figure 4-16). Each of the 34 surface soil samples had concentrations greater than background (3.66 mg/kg). These were widely scattered over the South Field. Concentrations of thorium were as high as 1182 mg/kg at 24-179, in the northwestern corner of the waste area. Thorium activity is not well correlated with uranium activity. Not correlated with either uranium or thorium was radium-226, which was measured as high as 354 pCi/g in 24-192 and at levels greater than background in 22 of 34 surface soil samples. These were also scattered throughout the waste area.

Subsurface fill samples from the South Field also exhibited elevated uranium, thorium, and radium, but at lesser concentrations than were detected in the surface soil samples (Figures 4-17 and 4-18, Tables 4-34 and 4-35). Total uranium exceeded background (3.66 mg/kg) in 16 of the RI/FS trench fill samples, with the highest concentration being 394 mg/kg in Trench 2. Six of the eight Environmental Survey fill samples had total uranium concentrations greater than background with a maximum concentration of 85 mg/kg detected in ES Test Pit 16. All 10 of the CIS boring composite samples had calculated total uranium concentrations greater than background, with 125 mg/kg calculated at Boring 24-09. The calculated total thorium in a fill sample from RI/FS Trench 1 was 31 mg/kg, which is less than three times background (12.4 mg/kg). Radium-226 concentrations exceeded background (1.5.1 pCi/g) in two of the ES test pits, three of the 10 CIS composite samples, and five of the RI/FS trench fill samples, with the highest measurement in RI/FS Trench 1 (15.7 pCi/g). The data presented above indicate that the fill exhibits its highest levels of contamination at or near the surface, and that these levels decrease with depth. This observation is supported by the CIS profile data (Table 4-35).

Native soils in the RI/FS Trenches (Figure 4-18) exhibited total uranium levels greater than background in all but one sample, with the highest measurements in Trench 2 (230 and 189 mg/kg). Total thorium and radium-226 did not exceed 16.9 mg/kg and 1.6 pCi/g, respectively, in native soil samples of the RI/FS Trenches. These data indicate that uranium has leached from fill into native soils underlying the South Field.

4.6.3.2 Organic Compounds in Surface and Subsurface Media

Because the South Field was used as a burial site for construction and demolition rubble and other debris such as coal, coke, and some flyash (Weston 1987b and Weston 1988), a wide variety of organic compounds has been detected in the samples collected from the RI/FS and CIS borings. A total of 16 samples from four RI/FS borings and six trenches were analyzed for organic compounds.

TABLE 4-33

WASTE-RELATED RADIONUCLIDE CONCENTRATIONS IN SURFACE MEDIA IN THE SOUTH FIELD

Analyte	Background Concentration	ES Samples and Depths					CIS Samples and Depths						
		108	109	110	112	115	24-046 (0.0-0.16) (ft)	24-049 (0.5-1.0) (ft)	24-052 (0.5-1.0) (ft)	24-081 (0.0-0.16) (ft)	24-094 (0.16-0.5) (ft)	24-113 (0.16-0.5) (ft)	24-116 (0.16-0.5) (ft)
Radionuclides:(pCi/g)													
Bismuth-214	1.51	1.2±0.1	0.75±0.11	3.0±0.1	0.87±0.05	0.92±0.08	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	0.74±0.07	0.46±0.07	I	0.08±0.02	0.24±0.03	0.6±0.4	<0.9	<0.5	<0.8	<0.6	<0.7	<0.9
Lead-210	1.33	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0	NA	NA	NA	NA	NA	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1
Plutonium-239/240	0.0	NA	NA	NA	NA	NA	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Radium-226	1.51	1.2±0.1	0.77±0.08	3.0±0.2	0.87±0.10	0.85±0.06	35.57±1.83	149.52±3.43	38.56±1.78	<18.67	63.02±2.19	132.57±3.57	70.61±2.7
Radium-228	1.28	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Strontium-90	0.0	NA	NA	NA	NA	NA	<0.4	<0.6	<0.6	<0.2	<0.4	<0.6	<0.9
Thorium-228	1.56	1.5±0.2	1.3±0.22	2.6±0.1	0.92±0.05	1.1±0.1	0.3±0.1	3.3±1.3	3.0±0.7	0.5±0.1	0.5±0.2	0.4±0.2	0.2±0.1
Thorium-230	2.18	NA	NA	NA	NA	NA	164.0±1.0	1070.0±30.0	2330.0±20.0	14.0±1.0	21.0±1.0	14.0±1.0	13.0±1.0
Thorium-232	1.36	1.3±0.2	1.2±0.2	2.7±0.1	0.84±0.06	1.1+0.1	0.5±0.1	4.9±1.9	4.5±0.7	0.2±0.1	0.5±0.2	0.1±0.1	0.2±0.1
Total Thorium(mg/kg)	12.4	11.8[a]	10.9[a]	24.5[a]	7.6[a]	10.0[a]	4.5[a]	44.5[a]	40.9[a]	1.8[a]	4.5[a]	0.9[a]	1.8[a]
Uranium-234	1.28	NA	NA	NA	NA	NA	15.0±1.0	79.0±1.0	28.0±1.0	2850.0±40.0	4.2±0.4	30.0±1.0	14.0±1.0
Uranium-235	0.151	N	N	N	0.3±0.02	0.79±0.03	0.6±0.1	3.6±0.3	1.2±0.2	356.0±14.0	0.2±0.1	1.8±0.2	0.7±0.1
Uranium 235/236	0.151	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-238	1.22	53.0±8.0	37.0±8.0	N	7.9±2.3	29.0±6.0	16.0±1.0	82.0±1.0	29.0±1.0	2940.0±40.0	5.4±0.4	25.0±1.0	14.0±1.0
Total Uranium(mg/kg)	3.66	8.8	57.0	7.4	16.0	58.0	47.9[b]	245.7[b]	86.9[b]	8914.6[b]	16.2[b]	75.2[b]	42.0[b]

This table is to be read horizontally

NA = Not Analyzed.

I = Nuclide identified by GAMANAL analysis of sample spectrum, but values did not exceed room background at the 95 percent confidence limit; no value reported.

N = Nuclide not identifed by GAMANAL analysis as being present in the sample; no value reported.

[a] = Total thorium for ES, CIS and RI/FS samples are calculated estimates which are based on measured values of thorium-232

[b] = Total uranium for CIS and RI/FS samples are calculated estimates which are based on measured values of uranium-235 and uranium-238

TABLE 4-33
(continued)

Analyte	Background Concentration	CIS Samples and Depths										
		24-117 (0.5-1.0) (ft)	24-121 (0.16-0.5) (ft)	24-123 (0.0-0.16) (ft)	24-133 (0.0-0.16) (ft)	24-142 (0.0-0.16) (ft)	24-151 (0.0-0.16) (ft)	24-179 (1.0-1.5) (ft)	24-183 (0.0-0.16) (ft)	24-189 (0.0-0.16) (ft)	24-192 (0.16-0.5) (ft)	24-196 (0.0-0.16) (ft)
Radionuclides: (pCi/g)												
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.3	<0.8	<0.7	<1.0	<0.5	<0.6	<0.5	<0.4	<0.7	<0.5	<0.5
Lead-210	1.33	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0	<0.3	<0.1	<0.1	<0.1	NA	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Plutonium-239/240	0.0	<0.1	<0.1	<0.1	<0.1	<0.10	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Radium-226	1.51	69.62±2.77	4.47±1.67	184.19±4.11	279.65±5.23	<4.21	49.53±2.16	<5.69	<5.41	48.39±2.25	353.6±4.65	33.99±2.0
Radium-228	1.28	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Strontium-90	0.0	<0.8	<0.3	<0.7	<0.9	<0.8	<0.3	<0.5	<0.4	<0.4	<0.6	<0.5
Thorium-228	1.56	<0.2	0.4±0.2	0.3±0.1	3.4±0.7	4.8±0.3	<0.1	129.0±4.0	34.0±2.0	0.1±0.1	0.2±0.1	0.3±0.1
Thorium-230	2.18	0.9±0.3	44.0±2.0	9.3±0.4	123.0±3.0	1.2±0.5	2.3±0.3	21.0±2.0	11.0±1.0	0.2±0.1	3.6±0.3	11.0±1.0
Thorium-232	1.36	<0.1	0.4±0.2	0.2±0.1	3.4±0.7	5.3±0.8	<0.1	130.0±4.0	37.0±2.0	<0.1	0.1±0.1	0.3±0.1
Total Thorium (mg/kg)	12.4	<0.9[a]	3.6[a]	1.8[a]	30.9[a]	48.2[a]	<0.9[a]	1181.8[a]	336.4[a]	<0.9[a]	0.9[a]	2.7[a]
Uranium-234	1.28	46.0±1.0	14.0±1.0	7.2±0.4	491.0±10.0	99.0±1.0	8.5±0.4	31.0±1.0	12.0±1.0	4.6±0.3	19.0±1.0	105.0±2.0
Uranium-235	0.151	2.0±0.2	0.6±0.1	0.3±0.1	20.0±2.0	4.2±0.3	0.4±0.1	1.4±0.2	0.7±0.1	0.2±0.1	1.1±0.2	4.4±0.3
Uranium-235/236	0.151	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-238	1.22	58.0±1.0	15.0±1.0	7.5±0.4	500.0±10.0	94±1	9.2±0.4	29.0±1.0	11.0±1.0	6.6±0.4	18.0±1.0	108.0±2.0
Total Uranium (mg/kg)	3.66	173.5[b]	44.9[b]	22.5[b]	1497.3[b]	281.7[b]	27.6[b]	87.0[b]	33.1[b]	19.7[b]	54.1[b]	323.5[b]

TABLE 4-33
(continued)

Analyte	Background Concentration	CIS Samples and Depths									RI/FS Sample Location and Depth	
		24-197 (0.16-0.5) (ft)	24-199 (0.16-0.5) (ft)	24-206 (0.16-0.5) (ft)	24-212 (0.16-0.5) (ft)	24-221 (0.0-0.16) (ft)	24-235 (0.0-0.16) (ft)	24-236 (0.16-0.4) (ft)	24-255 (0.5-1.0) (ft)	24-262 (0.5-1.0) (ft)	1046 08014 (0-1.5ft)	5001 (0-0.17ft)
Radionuclides: (pCi/g)												
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.5	<0.4	<0.8	0.3±0.2	<0.2	<0.4	<0.4	<0.6	<0.7	<0.2	0.3±0.2
Lead-210	1.33	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.6	<0.6
Plutonium-239/240	0.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.6	<0.6
Radium-226	1.51	15.43±1.11	73.92±2.66	69.04±2.85	0.71±0.36	1.5±0.75	16.7±2.0	25.26±2.14	55.48±2.17	91.38±3.0	1.3±0.3	1.2±0.2
Radium-228	1.28	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.3±0.6	<1.0
Strontium-90	0.0	<1.0	<0.4	<0.6	<0.5	<0.8	<0.5	<0.6	<0.4	<0.3	<0.5	<0.5
Thorium-228	1.56	0.4±0.1	<0.1	1.7±0.5	1.5±0.4	1.9±0.2	<0.1	8.0±0.5	0.3±0.2	0.3±0.1	1.1±0.4	0.9±0.3
Thorium-230	2.18	7.0±0.3	2.9±0.3	18.0±1.0	32.0±2.0	7.1±0.4	0.1±0.1	27.0±1.0	9.7±0.7	12.0±1.0	1.3±0.5	1.5±0.4
Thorium-232	1.36	0.4±0.1	0.1±0.1	1.5±0.5	1.3±0.4	2.4±0.2	<0.1	10.0±1.0	0.2±0.1	0.2±0.1	0.8±0.4	1.7±0.5
Total Thorium (mg/kg)	12.4	3.6[a]	0.9[a]	13.6[a]	11.8[a]	21.8[a]	<0.9[a]	90.9[a]	1.8[a]	1.8[a]	7.3[a]	15.4[a]
Uranium-234	1.28	98.0±2.0	6.3±0.4	9.0±0.5	115.0±2.0	117.0±2.0	44.0±1.0	74.0±2.0	8.3±0.5	49.0±1.0	1.7±0.5	2.6±0.6
Uranium-235	0.151	3.8±0.5	0.3±0.1	0.3±0.1	5.5±0.4	4.9±0.3	1.9±0.2	3.2±0.5	0.4±0.1	2.4±0.2	NA	NA
Uranium 235/236	0.151	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.6	<0.6
Uranium-238	1.22	102.0±2.0	5.9±0.4	9.5±0.5	129.0±2.0	124.0±2.0	42.0±1.0	69.0±2.0	8.5±0.5	57.0±1.0	2.1±0.5	2.7±0.6
Total Uranium (mg/kg)	3.66	305.1[b]	17.7[b]	28.4[b]	386.5[b]	371.3[b]	125.9[b]	206.8[b]	25.5[b]	170.8[b]	6.5[b]	6.5[b]

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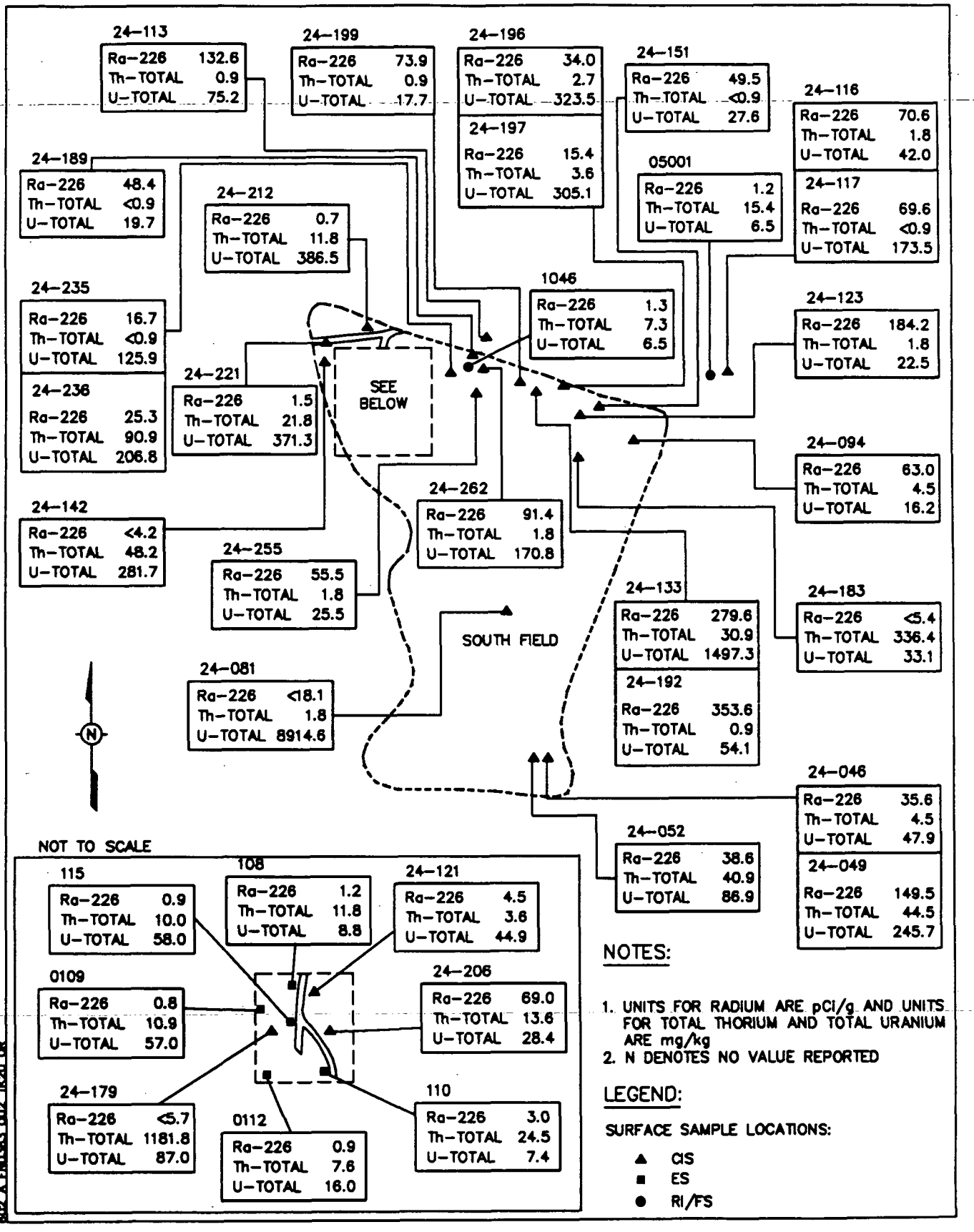

FIGURE 4-16. SURFACE MEDIA URANIUM, THORIUM, AND RADIUM CONCENTRATIONS IN THE SOUTH FIELD

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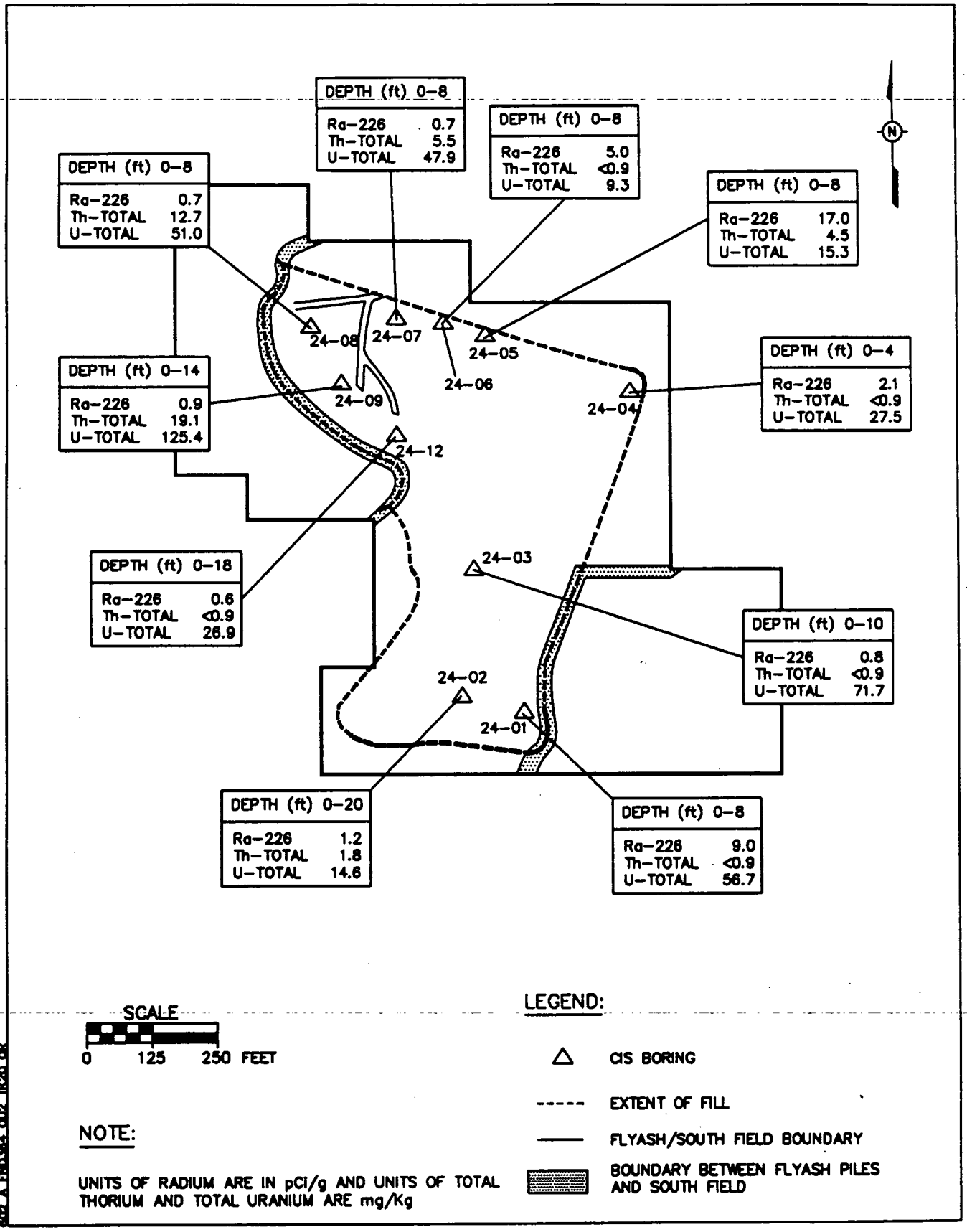

FIGURE 4–17. URANIUM, THORIUM, AND RADIUM CONCENTRATIONS IN COMPOSITE SUBSURFACE MEDIA FROM THE SOUTH FIELD

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TRENCH 1	1455		1456		1457	
	3.0 ft	3.75 ft	3.75 ft	4.25 ft	3.75 ft	4.25 ft
Ra-226	5.9	1.3	0.9	1.2	15.7	1.4
Th-230	10.3	2.1	1.4	1.8	57.3	2.2
TOTAL Th	11.6	10.7	9.3	9.4	31.0	11.6
U-234	12.6	2.4	9.4	22.1	26.4	4.1
U-238	14.6	3.1	10.6	22.6	28.1	4.4
TOTAL U	42.6	10.3	27.7	74.4	71.4	11.9

TRENCH 2	1458		1459		1460	
	4.0 ft	4.5 ft	5.0 ft	6.0 ft	3.5 ft	4.25 ft
Ra-226	1.5	1.4	1.6	1.3	1.1	1.1
Th-230	3.2	4.4	1.6	2.2	1.7	3.2
TOTAL Th	15.7	16.9	11.8	12.0	8.6	10.1
U-234	24.2	22.4	78.4	57.2	119.0	75.8
U-238	23.7	23.6	82.7	60.8	131.0	78.8
TOTAL U	76.1	59.8	228.0	189.0	394.0	230.0

TRENCH 3	1461		1462		1463	
	4.0 ft	5.0 ft	4.0 ft	5.0 ft	3.5 ft	4.5 ft
Ra-226	1.2	1.6	1.3	1.4	0.9	1.5
Th-230	4.1	2.1	3.3	2.1	4.4	2.0
TOTAL Th	9.5	12.6	9.4	11.5	6.6	10.4
U-234	4.7	1.5	5.0	4.7	19.7	1.1
U-238	5.6	1.4	6.2	4.7	61.4	1.5
TOTAL U	19.1	5.2	19.4	14.8	121.0	5.5

TRENCH 4	1464		1465		1466	
	3.75 ft	4.5 ft	3.5 ft	4.5 ft	3.0 ft	4.5 ft
Ra-226	1.2	1.4	1.1	1.3	0.8	1.6
Th-230	1.5	1.8	1.3	1.4	1.3	1.4
TOTAL Th	7.5	11.1	8.8	7.7	7.6	10.3
U-234	1.1	2.0	1.7	3.3	1.1	4.7
U-238	1.4	1.8	1.1	3.5	1.3	5.4
TOTAL U	10.8	5.0	7.3	4.3	10.6	4.7

TRENCH 5	1467		1468		1469	
	2.5 ft	3.5 ft	2.5 ft	3.5 ft	2.5 ft	3.5 ft
Ra-226	<0.3	1.6	0.9	1.6	<0.9	1.3
Th-230	1.7	2.0	1.6	1.8	1.2	1.2
TOTAL Th	6.3	10.6	7.0	10.2	4.9	8.0
U-234	3.8	1.0	3.4	1.3	2.6	1.1
U-238	4.1	1.3	3.6	1.3	3.2	1.4
TOTAL U	11.4	8.6	12.3	<4.5	10.9	5.0

TRENCH 6	1470		1471		1472	
	3.0 ft	4.0 ft	4.0 ft	5.5 ft	4.0 ft	5.0 ft
Ra-226	1.2	<0.3	1.2	<0.3	1.3	1.1
Th-230	1.9	1.6	1.2	1.9	2.9	1.6
TOTAL Th	9.7	8.1	7.7	9.1	8.1	9.5
U-234	3.8	1.5	1.5	1.0	3.5	2.1
U-238	4.0	1.6	2.1	1.4	3.6	2.1
TOTAL U	11.7	5.1	6.9	5.2	10.2	9.9

Test Pit 14

1011	2.0 ft	5.0 ft
Ra-226	3.6	0.9
Th-228	1.1	1.0
Th-232	1.2	1.4
U-238	46.0	N
U-TOTAL	71.0	2.1
Th-TOTAL	10.9	12.7

Test Pit 15

1012	1.0 ft	5.0 ft
Ra-226	1.1	1.3
Th-228	1.6	2.4
Th-232	1.5	2.5
U-238	N	20.0
U-TOTAL	15.0	56.0
Th-TOTAL	13.6	22.7

Test Pit 16

1013	1.0 ft	3.0 ft
Ra-226	1.1	1.4
Th-228	1.2	1.4
Th-232	0.8	1.3
U-238	49.0	N
U-TOTAL	85.0	2.9
Th-TOTAL	7.6	11.8

Test Pit 17

1014	2.0 ft	4.5 ft
Ra-226	1.7	1.4
Th-228	1.1	0.9
Th-232	1.3	0.9
U-238	12.0	9.0
U-TOTAL	14.0	12.0
Th-TOTAL	11.8	8.2

LEGEND:

RI/FS TRENCH TEST PIT

ES TEST PIT

NOTES:

1. ALL RESULTS EXCEPT TOTAL URANIUM AND TOTAL THORIUM GIVEN IN pCi/g
2. TOTAL URANIUM AND TOTAL THORIUM VALUES ARE GIVEN IN mg/kg
3. N DENOTES NO VALUE REPORTED
   (NUCLIDE NOT IDENTIFIED BY GAMANAL ANALYSIS)

SCALE

0 125 250 FEET

KVP 10/2/92 REV. 2
802 A DS037A 0/12 DX20 OR

FIGURE 4-18. URANIUM, THORIUM, AND RADIUM CONCENTRATIONS IN GRAB SUBSURFACE MEDIA SAMPLES FROM THE SOUTH FIELD

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TABLE 4-34
WASTE-RELATED RADIONUCLIDE CONCENTRATIONS IN SUBSURFACE MEDIA IN THE SOUTH FIELD

		ES Test Pit #14		ES Test Pit #15		ES Test Pit #16		ES Test Pit # 17	
Analyte	Background Concentration	1011IS1B 2.0 ft	1011IS2B 5.0 ft	1012IS1B 1.0 ft	1012IS2B 5.0 ft	1013IS1B 1.0 ft	1013IS2B 3.0 ft	1014IS1B 2.0 ft	1014IS2B 4.5 ft
Radionuclides: (pCi/g)									
Bismuth-214	1.51	3.2±0.1	1.0±0.1	1.1±0.1	1.2±0.1	1.1±0.1	1.4±0.1	1.7±0.1	1.5±0.1
Cesium-137	0.711	I	I	I	I	I	I	I	I
Lead-210	1.33	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-239/240	0.0	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226	1.51	3.6±0.2	0.94±0.1	1.1±0.1	1.3±0.1	1.1±0.1	1.4±0.1	1.7±0.1	1.4±0.1
Radium-228	1.28	NA	NA	NA	NA	NA	NA	NA	NA
Strontium-90	0.0	NA	NA	NA	NA	NA	NA	NA	NA
Thorium-228	1.56	1.1±0.1	1.0±0.2	1.6±0.1	2.4±0.1	1.2±0.1	1.4±0.1	1.1±0.1	0.91±0.05
Thorium-230	2.18	NA	NA	NA	NA	NA	NA	NA	NA
Thorium-232	1.36	1.2±0.3	1.4±0.2	1.5±0.1	2.5±0.2	0.84±0.05	1.3±0.1	1.3±0.1	0.9±0.06
Total Thorium (mg/kg)	12.4	10.9[a]	12.7[a]	13.6[a]	22.7[a]	7.6[a]	11.8[a]	11.8[a]	8.2[a]
Uranium-234	1.28	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235	0.151	0.83±0.02	0.14±0.02	0.16±0.01	0.3	0.63±0.01	0.07±0.01	0.19±0.01	0.15±0.01
Uranium-235/236	0.151	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-238	1.22	46.0±5.0	N	N	20.0±4.0	49.0±3.0	N	12.0±3.0	9.0±2.0
Total Uranium (mg/kg)	3.66	71.0	2.1	15.0	56.0	85.0	2.9	14.0	12.0

This table is to be read horizontally
NA = Not Analyzed
N = Nuclide not identified by GAMANAL analysis as being present in the sample; no value reported
I = Nuclide identified by GAMANAL analysis of sample spectrum, but values did not exceed room background at the 95% confidence limit; no value reported
R = Value rejected during data validation
[a] = Total thorium for ES, CIS and RI/FS samples are calculated estimates which are based on measured values of thorium-232
[b] = Total uranium for CIS and RI/FS samples are calculated estimates which are based on measured values of uranium-235 and uranium-238

TABLE 4-34
(continued)

Analyte	Background Concentration	CIS Borings, Sample Descriptions, and Depths				
		24-01 Composite 0-8ft	24-02 Composite 0-20ft	24-03 Composite 0-10ft	24-04 Composite 0-4ft	24-05 Composite 0-8ft
Radionuclides: (pCi/g)						
Bismuth-214	1.51	NA	NA	NA	NA	NA
Cesium-137	0.711	NA	NA	NA	NA	NA
Lead-210	1.33	28.0±2.0	3.0±1.0	2.0±1.0	4.0±1.0	26.0±2.0
Plutonium-238	0.0	NA	NA	NA	NA	NA
Plutonium-239/240	0.0	NA	NA	NA	NA	NA
Radium-226	1.51	9.0±1.0	1.2±0.4	0.8±0.3	2.1±0.5	17.0±1.0
Radium-228	1.28	1.6±0.8	0.9±0.6	0.6±0.4	2.2±0.7	<1.0
Strontium-90	0.0	NA	NA	NA	NA	NA
Thorium-228	1.56	0.1±0.1	0.2±0.1	<0.1	0.3±0.2	0.8±0.3
Thorium-230	2.18	9.6±0.5	0.3±0.1	0.1±0.1	0.5±0.2	10.0±1.0
Thorium-232	1.36	<0.1	0.2±0.1	<0.1	<0.1	0.5±0.2
Total Thorium (mg/kg)	12.4	<0.9[a]	1.8[a]	<0.9[a]	<0.9[a]	4.5[a]
Uranium-234	1.28	9.1±0.4	2.0±0.2	8.2±0.4	5.8±0.3	3.8±0.3
Uranium-235	0.151	0.4±0.1	0.09±0.07	0.5±0.1	0.3±0.1	0.2±0.05
Uranium-235/236	0.151	NA	NA	NA	NA	NA
Uranium-238	1.22	19.0±1.0	4.9±0.4	24.0±1.0	9.2±0.4	5.1±0.3
Total Uranium (mg/kg)	3.66	56.7[b]	14.6[b]	71.7[b]	27.5[b]	15.3[b]

TABLE 4-34
(continued)

Analyte	Background Concentration	CIS Borings, Sample Descriptions, and Depths				
		24-06 Composite 0-8ft	24-07 Composite 0-8ft	24-08 Composite 0-8ft	24-09 Composite 0-14ft	24-12 Composite 0-18ft
Radionuclides: (pCi/g)						
Bismuth-214	1.51	NA	NA	NA	NA	NA
Cesium-137	0.711	NA	NA	NA	NA	NA
Lead-210	1.33	4.0±1.0	2.0±1.0	3.0±1.0	2.0±1.0	2.0±1.0
Plutonium-238	0.0	NA	NA	NA	NA	NA
Plutonium-239/240	0.0	NA	NA	NA	NA	NA
Radium-226	1.51	5.0±1.0	0.7±0.5	0.7±0.5	0.9±0.4	0.6±0.3
Radium-228	1.28	1.0±0.6	3.0±1.0	9.0±1.0	10.0±1.0	2.0±0.6
Strontium-90	0.0	NA	NA	NA	NA	NA
Thorium-228	1.56	<0.1	0.7±0.2	1.3±0.2	1.9±0.2	<0.2
Thorium-230	2.18	0.5±0.1	1.1±0.3	0.7±0.2	0.5±0.1	<0.1
Thorium-232	1.36	<0.1	0.6±0.2	1.4±0.2	2.1±0.2	<0.1
Total Thorium (mg/kg)	12.4	<0.9[a]	5.5[a]	12.7[a]	19.1[a]	<0.9[a]
Uranium-234	1.28	2.6±0.2	15.0±1.0	14.0±1.0	15.0±1.0	6.7±0.4
Uranium-235	0.151	0.1±0.04	0.6±0.1	0.8±0.1	0.8±0.1	0.2±0.1
Uranium-235/236	0.151	NA	NA	NA	NA	NA
Uranium-238	1.22	3.1±0.2	16.0±1.0	17.0±1.0	42.0±1.0	9.0±0.4
Total Uranium (mg/kg)	3.66	9.3[b]	47.9[b]	51.0[b]	125.4[b]	26.9[b]

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TABLE 4-34
(continued)

Analyte	Background Concentration	RI/FS Test Pits, Boring Numbers, Sample Descriptions, Sample Numbers, and Depths					
		Trench #1					
		1455		1456		1457	
		Fill 55900 3.0ft	Native Soil 55901 3.75ft	Fill 55902 3.75ft	Native Soil 55903 4.25ft	Fill 55904 3.75ft	Native Soil 55905 4.25ft
Radionuclides: (pCi/g)							
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Lead-210	1.33	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Plutonium-239/240	0.0	<0.6	<0.6	1.2±0.7	<0.6	<0.6	<0.6
Radium-226	1.51	5.93±0.48	1.3±0.1	0.9±0.1	1.2±0.1	15.7±1.2	1.44±0.16
Radium-228	1.28	1.27±0.19	1.58±0.24	0.9±0.19	1.3±0.27	2.46±0.33	1.6±0.3
Strontium-90	0.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Thorium-228	1.56	1.52±0.27	1.42±0.28	1.07±0.28	1.25±0.26	2.63±0.68	1.3±0.27
Thorium-230	2.18	10.3±1.3	2.12±0.37	1.37±0.32	1.78±0.33	57.3±9.5	2.16±0.39
Thorium-232	1.36	1.29±0.24	1.19±0.25	1.03±0.27	1.05±0.23	3.44±0.82	1.29±0.27
Total Thorium (mg/kg)	12.4	11.6±2.2	10.7±2.2	9.3±2.4	9.4±2.1	31.0±7.4	11.6±2.5
Uranium-234	1.28	12.6±1.8	2.44±0.44	9.36±1.3	22.1±2.8	26.4±3.7	4.06±0.61
Uranium-235	0.151	NA	NA	NA	NA	NA	NA
Uranium-235/236	0.151	0.75±0.24	<0.6	0.67±0.21	1.1±0.25	1.66±0.42	<0.6
Uranium-238	1.22	14.6±2.0	3.1±0.52	10.6±1.4	22.6±2.8	28.1±3.9	4.41±0.65
Total Uranium (mg/kg)	3.66	42.6±6.9	10.3±2.9	27.7±4.9	74.4±8.7 R	71.4±11.0	11.9±3.2

TABLE 4-34
(continued)

Analyte	Background Concentration	RI/FS Test Pits, Boring Numbers, Sample Descriptions, Sample Numbers, and Depths					
		Trench #2					
		1458		1459		1460	
		Fill 55913 4.0ft	Native Soil 55914 4.5ft	Fill 55915 5.0ft	Native Soil 55916 6.0ft	Fill 55917 3.5ft	Native Soil 55918 4.25ft
Radionuclides: (pCi/g)							
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Lead-210	1.33	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0	<0.6	<0.6	<0.6	<0.6	<0.6	<.6
Plutonium-239/240	0.0	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Radium-226	1.51	1.48±0.17	1.41±0.15	1.6±0.16	1.3±0.1	1.1±0.1	1.1±0.1
Radium-228	2.18	<0.5 R	1.95±0.25	1.37±0.23	1.25±0.23	0.94±0.23	0.85±0.18
Strontium-90	0.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Thorium-228	1.56	1.78±0.33	2.06±0.38	1.52±0.36	1.62±0.34	1.28±0.28	1.26±0.25
Thorium-230	2.18	3.18±0.51	4.41±0.69	1.56±0.37	2.16±0.42	1.73±0.34	3.22±0.5
Thorium-232	1.36	1.74±0.32	1.87±0.36	1.31±0.33	1.33±0.3	0.95±0.23	1.12±0.23
Total Thorium (mg/kg)	12.4	15.7±2.9	16.9±3.2	11.8±3.0	12.0±2.7	8.6±2.1	10.1±2.1
Uranium-234	1.28	24.2±3.1	22.4±2.8	78.36±11.0	57.2±7.8	119.0±14.0	75.76±10.0
Uranium-235	0.151	NA	NA	NA	NA	NA	NA
Uranium-235/236	0.151	1.58±0.33	1.2±0.26	4.05±0.84	2.73±0.57	20.6±2.7	3.77±0.75
Uranium-238	1.22	23.7±3.0	23.6±2.9	82.7±12.0	60.8±8.3	131.0±16.0	78.8±11.0
Total Uranium (mg/kg)	3.66	76.1±12.0	59.8±9.2	228.0 ±35.0	189.0±20.0	394.0±60.0	230.0±35.0

TABLE 4-34
(continued)

		RI/FS Test Pits, Boring Numbers, Sample Descriptions, Sample Numbers, and Depths					
		Trench #3					
		1461		1462		1463	
Analyte	Background Concentration	Fill 55926 4.0ft	Native Soil 55927 5.0ft	Fill 55928 4.0ft	Native Soil 55929 5.0ft	Fill 55930 3.5ft	Native Soil 55931 4.5 ft
Radionuclides: (pCi/g)							
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Lead-210	1.33	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Plutonium-239/240	0.0	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Radium-226	1.15	1.2±0.1	1.6±0.1	1.3±0.1	1.4±0.1	0.9±0.1	1.5±0.1
Radium-228	1.28	1.1±0.1	1.4±0.2	0.8±0.1	1.4±0.2	0.7±0.1	1.3±0.3
Strontium-90	0.0	<0.5	<0.5	<0.5	<0.5	<5.0	<0.5
Thorium-228	1.56	1.3±0.2	1.7±0.3	1.0±0.2	1.3±0.2	5.3±0.9	1.2±0.3
Thorium-230	2.18	4.1±0.6	2.1±0.4	3.3±0.5	2.1±0.3	4.4±0.7	2.0±0.4
Thorium-232	1.36	1.0±0.2	1.4±0.3	1.0±0.2	1.3±0.2	0.7±0.2	1.2±0.2
Total Thorium (mg/kg)	12.4	9.5±2.0	12.6±2.7	9.4±2.1	11.5±2.6	6.6±2.1	10.4±2.6
Uranium-234	1.28	4.7±0.6	1.5±0.3	5.0±0.7	4.7±0.7	19.7±3.2	1.1±0.2
Uranium-235	0.151	NA	NA	NA	NA	NA	NA
Uranium-235/236	0.151	<0.6	<0.6	<0.6	<0.6	2.5±0.6	<0.6
Uranium-238	1.22	5.6±0.7	1.4±0.3	6.2±0.9	4.7±0.7	61.4±9.2	1.5±0.2
Total Uranium (mg/kg)	3.66	19.1±3.7	5.2±2.3	19.4±3.7	14.8±2.9	121.0±13.0	5.5±2.3

TABLE 4-34
(continued)

		RI/FS Test Pits, Boring Numbers, Sample Descriptions, Sample Numbers, and Depths											
		Trench #4											
		1464				1465				1466			
Analyte	Background Concentration	Fill 55939 3.75ft		Native Soil 55940 4.5ft		Fill 55941 3.5ft		Native Soil 55942 4.5ft		Fill 55943 3.0ft		Native Soil 55944 4.5ft	
Radionuclides: (pCi/g)													
Bismuth-214	1.51	NA		NA		NA		NA		NA		NA	
Cesium-137	0.711	<0.2	R	<0.2		<0.2	R	<0.2		<0.2	R	<0.2	
Lead-210	1.33	NA		NA		NA		NA		NA		NA	
Plutonium-238	0.0	<0.6		<0.6		<0.6		<0.6		<0.6		<0.6	
Plutonium-239/240	0.0	<0.6		<0.6		<0.6		<0.6		<0.6		<0.6	
Radium-226	1.51	1.2±0.1	R	1.44±0.15		1.1±0.1	R	1.3±0.1		0.8±0.1	R	1.56±0.19	
Radium-228	1.28	0.95±0.13	R	1.26±0.22		0.8±0.1	R	1.31±0.22		<0.5	R	1.46±0.27	
Strontium-90	0.0	<0.5	R	<0.5	R	<0.5		<0.5		<0.5		0.92±0.24	
Thorium-228	1.56	0.98±0.2		1.48±0.29		1.12±0.25		1.22±0.33		0.82±0.28		1.35±0.33	
Thorium-230	2.18	1.46±0.26		1.82±0.34		1.3±0.27		1.41±0.36		1.3±0.36		1.44±0.34	
Thorium-232	1.36	0.83±0.18		1.23±0.26		0.97±0.23		0.86±0.27		0.84±0.27		1.1±0.3	
Total Thorium (mg/kg)	12.4	7.5±1.6		11.1±2.3		8.8±2.0		7.7±2.4		7.6±2.6		10.3±2.7	
Uranium-234	1.28	1.1±0.2		1.96±0.32		1.68±0.32		3.27±0.47		1.1±0.2		4.71±0.67	
Uranium-235	0.151	NA		NA		NA		NA		NA		NA	
Uranium-235/236	0.151	<0.6		<0.6		0.76±0.1		<0.6		<0.6		<0.6	
Uranium-238	1.22	1.37±0.25		1.76±0.29		1.1±0.2		3.5±0.5		1.26±0.26		5.36±0.74	
Total Uranium (mg/kg)	3.66	10.8±2.1	R	5.0±2.4		7.3±2.0	R	4.3±2.7		10.6±2.1		4.7±2.7	

TABLE 4-34
(continued)

Analyte	Background Concentration	RI/FS Test Pits, Boring Numbers, Sample Descriptions, Sample Numbers, and Depths					
		Trench #5					
		1467		1468		1469	
		Fill 55952 2.5ft	Native Soil 55953 3.5ft	Fill 55954 2.5ft	Native Soil 55955 3.5ft	Fill 55956 2.5ft	Native Soil 55957 3.5ft
Radionuclides: (pCi/g)							
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Lead-210	1.33	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Plutonium-239/240	0.0	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Radium-226	1.51	<0.3	1.56±0.16	0.9±0.1	1.58±0.18	<0.9	1.3±0.1
Radium-228	1.28	1.05±0.24	1.35±0.23	0.9±0.18	<0.5	<0.7	1.39±0.2
Strontium-90	0.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Thorium-228	1.56	0.98±0.22	1.12±0.28	0.91±0.22	1.19±0.26	0.88±0.21	0.95±0.28
Thorium-230	2.18	1.7±0.31	1.99±0.4	1.61±0.31	1.82±0.35	1.2±0.25	1.19±0.32
Thorium-232	1.36	0.7±0.2	1.18±0.29	0.8±0.1	1.1±0.2	<0.6	0.89±0.27
Total Thorium (mg/kg)	12.4	6.3±1.5	10.6±2.6	7.0±1.7	10.2±2.3	4.9±1.4	8.0±2.4
Uranium-234	1.28	3.82±0.64	1.0±0.2	3.42±0.53	1.31±0.27	2.59±0.4	1.1±0.2
Uranium-235	0.151	NA	NA	NA	NA	NA	NA
Uranium-235/236	0.151	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Uranium-238	1.22	4.14±0.68	1.32±0.3	3.56±0.5	1.32±0.27	3.18±0.47	1.38±0.26
Total Uranium (mg/kg)	3.66	11.4±3.2	8.6±2.5	12.3±2.7	<4.5	10.9±2.6	5.0±2.5

TABLE 4-34
(continued)

Analyte	Background Concentration	RI/FS Test Pits, Boring Numbers, Sample Descriptions, Sample Numbers, and Depths					
		Trench #6					
		1470		1471		1472	
		Fill 55966 3.0ft	Native Soil 55967 4.0ft	Fill 55968 4.0ft	Native Soil 55969 5.5ft	Fill 55970 4.0ft	Native Soil 55971 5.0ft
Radionuclides: (pCi/g)							
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Lead-210	1.33	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Plutonium-239/240	0.0	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Radium-226	1.51	1.2±0.1	<0.3	1.2±0.1	<0.3	1.3±0.1	1.1±0.1
Radium-228	1.28	0.9±0.18	0.97±0.22	0.99±0.18	1.09±0.19	0.96±0.2	1.09±0.2
Strontium-90	0.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Thorium-228	1.56	1.1±0.23	1.05±0.24	0.87±0.25	1.24±0.27	1.0±0.2	1.07±0.23
Thorium-230	2.18	1.94±0.34	1.63±0.32	1.22±0.3	1.9±0.36	2.86±0.45	1.65±0.31
Thorium-232	1.36	1.08±0.22	0.9±0.22	0.85±0.24	1.0±0.23	0.9±0.2	1.05±0.23
Total Thorium (mg/kg)	12.4	9.7±2.0	8.1±2.0	7.7±2.1	9.1±2.1	8.1±1.8	9.5±2.0
Uranium-234	1.28	3.79±0.61	1.51±0.34	1.5±0.2	1.0±0.2	3.46±0.52	2.13±0.36
Uranium-235	0.151	NA	NA	NA	NA	NA	NA
Uranium-235/236	0.151	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Uranium-238	1.22	4.04±0.64	1.61±0.35	2.12±0.36	1.35±0.26	3.64±0.54	2.06±0.36
Total Uranium (mg/kg)	3.66	11.6±2.8	5.1±2.5	6.9±2.2	5.2±2.4	10.2±2.7	9.9±2.5

TABLE 4-34
(continued)

Analyte	Background Concentration	RI/FS Borings, Sample Descriptions, Sample Numbers, and Depths										
		1516										
		Native Soil 055371 0.0 - 0.5	Native Soil 055373 1.0 - 1.5	Native Soil 055375 2.0 - 2.5	Native Soil 055377 3.0 - 3.5	Native Soil 055379 4.0 - 4.5	Native Soil 055383 6.0 - 6.5	Native Soil 055387 8.0 - 8.5	Native Soil 055389 9.0 - 9.5	Native Soil 055391 10. - 10.5	Native Soil 055393 11. - 11.5	Native Soil 055395 12. - 12.5
Radionuclides: (pCi/g)												
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	0.2±0.1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Lead-210	1.33	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0	0.8±0.3	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Plutonium-239/240	0.0	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Radium-226	1.51	1.4±0.1	<0.3	<0.3	0.5±0.1	0.6±0.1	0.9±0.1	0.5±0.1	0.6±0.1	0.5±0.1	0.4±0.1	<0.3
Radium-228	1.28	0.9±0.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Strontium-90	0.0	<0.5	<0.5	<0.5	1.2±0.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Thorium-228	1.56	1.0±0.2	<0.6	0.7±0.1	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Thorium-230	2.18	5.6±0.8	3.1±0.4	0.8±0.1	0.8±0.1	1.0±0.2	1.4±0.2	0.7±0.1	0.7±0.1	0.8±0.2	<0.6	1.0±0.2
Thorium-232	1.36	1.1±0.2	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Total Thorium (mg/kg)	12.4	10.0±2.1	3.0±0.9	2.3±0.8	3.0±1.0	1.8±0.7	3.2±1.0	1.3±0.9	<0.9	2.5±1.2	1.9±0.8	4.7±1.3
Uranium-234	1.28	4.6±0.6	2.6±0.4	1.3±0.2	1.2±0.2	1.7±0.2	2.3±0.3	1.5±0.2	1.5±0.2	1.5±0.2	1.6±0.2	1.8±0.3
Uranium-235	0.151	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235/236	0.151	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Uranium-238	1.22	7.0±0.9	2.7±0.4	1.4±0.2	1.7±0.2	1.9±0.3	2.8±0.4	1.5±0.2	1.9±0.3	1.5±0.2	1.8±0.3	2.0±0.3
Total Uranium (mg/kg)	3.66	26.4±5.0	12.9±2.8	8.1±1.9	3.4±1.5	6.9±1.6	9.4±1.9	7.9±1.7	6.6±1.9	9.4±2.1	5.5±0.9	9.0±1.9

TABLE 4-34
(continued)

Analyte	Background Concentration	RI/FS Borings, Sample Descriptions, Sample Numbers, and Depths									
		1516					1517				
		Native Soil 055399 14. - 14.5	Native Soil 055401 15. - 15.5	Native Soil 055405 17. - 17.5	Native Soil 055407 18. - 18.5	Native Soil 055409 19. - 19.5	Native Soil 055413 0.0 - 0.5	Native Soil 055416 1.5 - 2.0	Native Soil 055419 3.0 - 3.5	Native Soil 055422 4.5 - 5.0	Native Soil 055425 6.0 - 6.5
Radionuclides: (pCi/g)											
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Lead-210	1.33	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Plutonium-239/240	0.0	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Radium-226	1.51	0.5±0.1	<0.3	0.5±0.1	0.6±0.1	<0.3	<0.3	0.7±0.1	1.8±0.2	<0.3	0.4±0.1
Radium-228	1.28	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.6±0.1	<0.8	<0.5	<0.5
Strontium-90	0.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.7±0.2	<0.5	<0.5	<0.5
Thorium-228	1.56	0.7±0.2	0.7±0.2	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Thorium-230	2.18	1.2±0.3	1.6±0.3	0.8±0.1	0.7±0.1	0.9±0.2	1.1±0.2	0.8±0.2	0.9±0.2	0.7±0.2	0.7±0.1
Thorium-232	1.36	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Total Thorium (mg/kg)	12.4	4.4±1.8	4.8±1.5	1.7±0.8	1.8±0.8	1.9±0.8	4.1±1.2	4.7±1.5	2.2±0.9	<1.4	2.0±0.8
Uranium-234	1.28	2.3±0.3	1.6±0.2	1.0±0.1	2.3±0.4	<0.6	1.1±0.2	1.0±0.2	<0.6	<0.6	<0.6
Uranium-235	0.151	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235/236	0.151	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Uranium-238	1.22	2.6±0.3	1.8±0.3	0.8±0.1	2.7±0.4	<0.6	1.5±0.2	0.8±0.1	<0.6	<0.6	0.6±0.1
Total Uranium (mg/kg)	3.66	6.7±1.9	8.6±1.9	2.6±1.3	6.3±1.6	6.8±1.7	3.0±1.8	5.8±1.6	5.9±1.6	5.1±1.3	1.8±0.4

TABLE 4-34
(continued)

Analyte	Background Concentration	RI/FS Borings, Sample Descriptions, Sample Numbers, and Depths									
		1517									
		Native Soil 055427 7.0 - 7.5	Native Soil 055429 8.0 - 8.5	Native Soil 055431 9.0 - 9.5	Native Soil 055433 10. - 10.5	Native Soil 055437 12. - 12.5	Native Soil 055440 13. - 14.0	Native Soil 055443 15. - 15.5	Native Soil 055446 16. - 17.0	Native Soil 055449 18. - 18.5	Native Soil 055451 19. - 19.5
Radionuclides: (pCi/g)											
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Lead-210	1.33	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0	<0.6	<0.6	<0.6	<0.6	1.0±0.2	<0.6	<0.6	<0.6	<0.6	<0.6
Plutonium-239/240	0.0	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Radium-226	1.51	0.5±0.1	3.9±0.5	0.6±0.1	0.5±0.1	0.5±0.1	0.4±0.1	0.4±0.1	0.5±0.1	0.5±0.1	0.6±0.1
Radium-228	1.28	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Strontium-90	0.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Thorium-228	1.56	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	1.9±0.3	<0.6	<0.6
Thorium-230	2.18	0.6±0.1	0.9±0.2	0.7±0.1	<0.6	2.0±0.4	<0.6	<0.6	<0.6	0.9±0.2	1.0±0.1
Thorium-232	1.36	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Total Thorium (mg/kg)	12.4	1.6±1.0	1.5±0.7	2.7±1.0	1.6±1.0	1.8±1.1	1.7±0.8	1.5±0.9	1.0±0.7	2.0±0.9	2.3±0.8
Uranium-234	1.28	<0.6	1.4±0.2	<0.6	0.8±0.1	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Uranium-235	0.151	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235/236	0.151	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Uranium-238	1.22	0.6±0.1	<0.6	0.6±0.1	<0.6	<0.6	<0.6	<0.6	0.6±0.1	<0.6	<0.6
Total Uranium (mg/kg)	3.66	1.8±0.4	1.2±0.3	1.9±1.5	1.5±0.4	5.9±1.6	1.4±0.4	1.8±0.5	5.3±1.4	1.5±0.4	5.6±1.5

TABLE 4-34
(continued)

Analyte	Background Concentration	RI/FS Borings, Sample Descriptions, Sample Numbers, and Depths									
		1518									
		Native Soil 055454 0.0 - 0.5	Native Soil 055456 1.0 - 1.5	Native Soil 055458 2.0 - 2.5	Native Soil 055460 3.0 - 3.5	Native Soil 055462 4.0 - 4.5	Native Soil 055464 5.0 - 5.5	Native Soil 055466 6.0 - 6.5	Native Soil 055468 7.0 - 7.5	Native Soil 055470 8.0 - 8.5	Native Soil 055472 9.0 - 9.5
Radionuclides: (pCi/g)											
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Lead-210	1.33	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Plutonium-239/240	0.0	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Radium-226	1.51	<0.3	0.7±0.1	0.5±0.1	<0.3	0.5±0.1	0.7±0.1	0.8±0.1	<0.3	0.6±0.1	0.5±0.1
Radium-228	1.28	<0.5	<0.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Strontium-90	0.0	<0.5	<0.5	<0.5	<0.7	<0.5	<0.5	<0.6	<0.5	<0.5	<0.5
Thorium-228	1.56	1.2±0.2	<0.6	<0.6	<0.6	<0.6	<0.6	0.7±0.1	0.6±0.1	<0.6	1.5±0.3
Thorium-230	2.18	1.6±0.3	0.7±0.1	0.8±0.2	0.6±0.1	0.8±0.1	1.1±0.2	1.2±0.2	1.2±0.2	0.9±0.1	0.7±0.1
Thorium-232	1.36	0.6±0.1	<0.6	<0.6	<0.6	<0.6	<0.6	0.6±0.1	<0.6	<0.6	<0.6
Total Thorium (mg/kg)	12.4	5.7±1.7	1.7±0.8	2.1±1.1	1.8±0.8	2.1±0.9	2.8±1.3	5.6±1.6	3.4±1.1	3.5±1.0	2.8±1.2
Uranium-234	1.28	1.2±0.2	<0.6	<0.6	<1.2	<0.6	0.7±0.1	0.6±0.1	0.6±0.1	<0.6	<0.6
Uranium-235	0.151	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235/236	0.151	<0.6	<0.6	<0.6	<1.2	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Uranium-238	1.22	1.2±0.2	<0.6	<0.6	<1.2	<0.6	0.9±0.1	0.9±0.1	0.6±0.1	0.6±0.1	<0.6
Total Uranium (mg/kg)	3.66	6.2±1.8	1.5±0.4	4.2±1.3	5.7±1.5	1.8±0.4	5.4±1.7	7.6±2.1	6.0±1.7	5.6±1.5	1.6±0.4

TABLE 4-34
(continued)

Analyte	Background Concentration	RI/FS Borings, Sample Descriptions, Sample Numbers, and Depths									
		1518									
		Native Soil 055474 10. - 10.5	Native Soil 055476 11. - 11.5	Native Soil 055478 12. - 12.5	Native Soil 055481 13.5 - 14.	Native Soil 055483 14.5 - 15.	Native Soil 055485 15.5 - 16.	Native Soil 055487 16.5 - 17.	Native Soil 055489 17.5 - 18.	Native Soil 055491 18.5 - 19.	Native Soil 055493 19.5 - 20.
Radionuclides: (pCi/g)											
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Lead-210	1.33	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Plutonium-239/240	0.0	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Radium-226	1.51	0.4±0.6	<0.3	0.5±0.1	0.5±0.1	<0.5	<0.3	0.5±0.1	0.6±0.1	0.4±0.1	0.6±0.1
Radium-228	1.28	<0.5	<0.5	<0.5	<0.5	<1.2	<0.5	<0.5	<0.5	<0.5	<0.5
Strontium-90	0.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Thorium-228	1.56	<0.6	5.9±0.9	<0.6	<0.6	<0.6	<0.6	<0.6	0.7±0.2	0.7±0.2	<0.6
Thorium-230	2.18	0.9±0.2	3.0±0.5	1.1±0.3	<0.6	1.0±0.2	1.1±0.2	1.0±0.3	0.9±0.2	0.9±0.2	1.1±0.3
Thorium-232	1.36	<0.6	5.6±0.9	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Total Thorium (mg/kg)	12.4	2.6±1.1	50.5±8.4	<2.4	1.3±0.8	<1.7	2.6±1.1	<1.7	4.0±1.8	4.0±1.8	2.6±1.4
Uranium-234	1.28	0.7±0.2	0.6±0.2	0.8±0.2	0.9±0.1	1.1±0.2	2.9±0.5	2.0±0.8	<0.6	<0.6	0.8±0.3
Uranium-235	0.151	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235/236	0.151	<0.6	0.9±0.2	<0.6	<0.6	0.8±0.2	<0.6	<0.6	<0.6	<0.6	<0.6
Uranium-238	1.22	0.7±0.2	0.9±0.2	0.7±0.2	0.8±0.1	0.7±0.2	<0.6	0.6±0.2	0.7±0.1	0.7±0.1	<0.6
Total Uranium (mg/kg)	3.66	<1.8	5.3±1.4	<2.8	4.6±1.3	<12.0	4.3±1.4	<2.4	5.5±1.5	1.7±1.1	5.8±1.6

TABLE 4-34
(continued)

Analyte	Background Concentration	RI/FS Borings, Sample Descriptions, Sample Numbers, and Depths							
		1046		2046		2385		3046	3385
		Native Soil 08024 15.0-16.5ft	Native Soil 08025 15.0-16.5ft	Native Soil 08950 30.0-31.5ft	Native Soil 08956 61.0-62.5ft	Native Soil 032622 4.5-6.0ft	Native Soil 032639 45.0-46.5	Native Soil 032709 100.0-101.5ft	Native Soil 032725 80.0-81.5ft
Radionuclides: (pCi/g)									
Bismuth-214	1.51	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.711	<0.2	<0.2	<0.2	NA	<0.2	<0.2	<0.2	<0.2
Lead-210	1.33	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0	<0.6	<0.6	<0.6	NA	<0.6	<0.6	<0.6	NA
Plutonium-239/240	0.0	<0.6 R	<0.6 R	<0.6	NA	<0.6	<0.6	<0.6	<0.6
Radium-226	1.51	<0.3	0.6±0.2	0.5±0.1	NA	0.9±0.1	0.65±0.09	0.49±0.06	1.7±0.3 R
Radium-228	1.28	0.5±0.1	<0.5	<0.5	NA	0.74±0.21	<0.5	<0.5	<1.0
Strontium-90	0.0	<0.5	<0.5	0.7±0.2	NA	1.34±0.28	<0.5	<0.5	<0.5
Thorium-228	1.56	<0.5	<0.6	<0.6	NA	0.72±0.23 R	<0.6 R	0.74±0.16 R	<0.6 R
Thorium-230	2.18	1.0±0.4	0.8±0.3	0.9±0.2	NA	0.74±0.23 R	<0.6 R	0.97±0.19 R	0.60±0.18 R
Thorium-232	1.36	<0.6	<0.6	<0.6	NA	0.65±0.21	<0.6	<0.6	<0.6
Total Thorium (mg/kg)	12.4	<5.5[a]	<5.5[a]	5.5[a]	NA	5.88±1.93	<1.1	3.93±1.08	4.15±1.39
Uranium-234	1.28	0.6±0.2	<0.6	<0.6	NA	0.98±0.30 R	<0.6 R	4.3±0.6 R	0.74±0.16
Uranium-235	0.151	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235/236	0.151	<0.6	<0.6	<0.6	NA	<0.6 R	<0.6 R	<0.6 R	<0.6 R
Uranium-238	1.22	0.7±0.3	<0.6	<0.6	NA	0.74±0.26	<0.6	4.23±0.58	1.05±0.21
Total Uranium (mg/kg)	3.66	2.4[b]	<0.3[b]	<3.0	16.0±3.7	2.76±0.83 R	4.63±1.76	12.7±1.8	5.8±1.1

TABLE 4-35

RADIONUCLIDE CONCENTRATIONS IN SUBSURFACE MEDIA PROFILES OF THE SOUTH FIELD

	Borings and Analytes														
	24-01			24-02			24-03			24-04			24-05		
Depth (ft)	U-238	Ra-226 (pCi/g)	Th-232	U-238	Ra-226 (pCi/g)	Th-232	U-238	Ra-226 (pCi/g)	Th-232	U-238	Ra-226 (pCi/g)	Th-232	U-238	Ra-226 (pCi/g)	Th-232
0-1	<58.2	31.5	3.4	<27.5	<3.7	7.6	17.8	0.7	1.0	<29.0	4.8	<5.9	<32.8	46.0	<7.3
1-2	"	"	"	"	"	"	"	"	"	11.1	0.9	1.4	<46.2	34.0	<7.3
2-3	9.9	2.7	<0.5	<7.6	0.6	1.4	14.3	<1.0	1.0	9.8	1.1	0.9	9.3	1.2	1.1
3-4	<14.6	0.7	1.0	"	"	"	7.8	0.8	<5.0	<8.7	1.1	1.0	<16.0	<1.2	<0.4
4-5	16.2	1.9	1.9	<16.2	1.0	1.9	6.2	0.6	<3.1				<9.3	1.7	<0.6
5-6	"	"	"	"	"	"	5.0	<1.1	0.6				<7.0	0.8	<0.4
6-7	<9.1	1.4	<2.2	<11.3	0.6	1.3	<13.5	0.8	1.2				<14.7	1.2	<0.5
7-8	<7.3	1.0	0.9	"	"	"	3.8	1.2	<0.8				<14.2	1.0	<3.8
8-9				No sample recovery			<13.0	<0.7	0.7						
9-10				No sample recovery			<10.6	0.8	0.8						
10-11				<9.8	0.5	0.6									
11-12				<12.1	0.8	<0.3									
12-13				3.7	0.8	0.8									
13-14				<8.7	1.0	1.0									
14-15				<11.2	1.0	1.7									
15-16				"	"	"									
16-17				2.7	<1.2	0.5									
17-18				<7.9	0.5	<0.3									
18-19				<9.4	0.5	0.5									
19-20				<11.1	<1.2	0.9									

This table is to be read horizontally

Source: Weston, Inc., Roy F., 1987b, "Characterization Investigation Study, Volume 2: Chemical and Radiological Analysis of the Waste Pits," prepared for Westinghouse Materials Co. of Ohio, U.S. Dept. of Energy Feed Materials Production Center, Fernald, OH.

TABLE 4-35
(continued)

	Borings and Analytes														
	24-06			24-07			24-08			24-09			24-12		
Depth (ft)	U-238	Ra-226 (pCi/g)	Th-232	U-238	Ra-226 (pCi/g)	Th-232	U-238	Ra-226 (pCi/g)	Th-232	U-238	Ra-226 (pCi/g)	Th-232	U-238	Ra-226 (pCi/g)	Th-232
0-1	<32.9	5.6	<4.6	38.6	4.5	25.2	30.0	<2.1	36.5	<39.3	<5.5	78.1	<9.0	<0.1	<2.3
1-2	<18.3	1.7	2.1	12.3	1.3	1.9	"	"	"	<41.4	<5.1	101.3	<7.6	1.1	0.7
2-3	<15.4	0.6	<0.8	15.2	0.8	1.5	No sample recovery			12.3	2.6	4.2	<9.3	0.6	0.6
3-4	<13.1	1.1	1.0	5.5	<1.3	1.0	No sample recovery			"	"	"	"	"	"
4-5	<5.0	0.6	0.5	<6.8	1.0	1.0	<11.5	<0.1	1.2	<27.4 3.9	1.9		5.3	0.9	1.1
5-6	<12.7	<0.3	<1.7	<10.0	<1.9	<1.5	<5.3	0.6	0.8	"	"		"	"	"
6-7	<8.1	0.6	0.8	<12.3	<0.8	<0.3	<8.0	0.5	1.1	"			13.2	0.7	0.9
7-8	"	"	"	"	"	"	"	"	"	22.1	1.7	6.7	22.0	1.4	2.0
8-9										"	"	"	5.9	1.2	1.0
9-10										10.7 6.3	1.2 0.9	2.6 0.8	"	"	"
10-11										<7.1	<1.8	0.9	12.8	1.0	4.3
11-12										<10.5	0.9	<1.6	"	"	"
12-13										<8.3	0.7	<2.5	6.3	0.6	1.5
13-14										<9.0	0.8	0.8	"	"	"
14-15													No sample recovery		
15-16													<5.4	<1.7	<0.3
16-17													<4.2	<0.8	0.7
17-18															
18-19															
19-20															

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Ten CIS composite boring samples were also analyzed for organics, as was one Environmental Survey Test Pit sample.

The most frequently detected compounds are low levels of acetone and methylene chloride (Table 4-36), which do not exceed 0.25 mg/kg in any sample. Another volatile compound, 2-butanone, was also detected in one-third of all samples analyzed, but at a maximum concentration of 0.012 mg/kg.

Because of the reported presence of coke and coal in the fill material, a large variety of PAHs were also detected in the RI/FS samples. The largest number of PAHs and the highest concentrations were detected in Borings 1794 and 1795, located near the northern boundary of the South Field area.

Chlorinated dioxins and furans were analyzed in 10 samples from RI/FS Borings 1792 through 1795 located near the northern waste area boundary and the southwest waste area boundary. Octachlorodibenzo-p-dioxin was detected in all of the ten samples at concentrations ranging from 0.00012 to 0.0036 mg/kg; however, the laboratory method blanks were contaminated in two cases. Tetrachlorodibenzofuran was detected in a single sample from Boring 1792 at 0.00002 mg/kg.

Aroclor-1254 was detected in four of five RI/FS trench samples at concentrations ranging from 0.13 to 1.1 mg/kg. It was detected at similar concentrations in seven of the CIS sample locations. Aroclor-1242 and Aroclor-1260 were detected less frequently and at lower concentrations (Table 4-36).

Hazardous waste toxicity characteristic thresholds (40CFR261.24) were not exceeded for any organics in the 12 TCLP extracts.

4.6.3.3 Metals in Surface and Subsurface Media

The RCRA metals detected at concentrations above background were barium (above background in 3 of 26 samples), cadmium (24 of 26), chromium (12 of 26), lead (11 of 26), mercury (4 of 26), and silver (6 of 26) (Table 4-37). Cadmium concentrations in native soil were similar to those in fill. The highest measured concentration was 5.15 mg/kg in CIS Boring 24-07, eight times the background level (0.650 mg/kg).

Other metals detected at concentrations above background in half or more of the samples were beryllium (16 of 26) and molybdenum (10 of 16). Beryllium was above background (0.607 mg/kg) in both fill and native soil samples. The highest concentration was 1.6 mg/kg in fill from Trench 5. Molybdenum was above background (8.8 mg/kg) in both fill and native soil samples, with the highest concentration (15.8 mg/kg) in shallow fill from Boring 1792.

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TABLE 4-36

ORGANIC COMPOUNDS DETECTED IN SUBSURFACE MEDIA IN THE SOUTH FIELD

Compound	Fequency of Detection	Range (mg/kg)
Volatile Compounds		
2-Butanone	9/26	0.004–0.012
2-Hexanone	2/27	0.006
4-Methyl-2-pentanone	2/27	0.001–0.003
Acetone	16/25	0.003–0.230
Toluene	3/27	0.002–0.006
Total Xylenes	2/27	0.001–0.002
Chlorinated Volatile Compounds		
Chloroform	3/27	0.003–0.007
Methylene chloride	18/27	0.002–0.110
Polynuclear Aromatic Hydrocarbons		
Anthracene	1/22	0.058
Benzo(a)anthracene	5/22	0.078–0.270
Benzo(a)pyrene	3/22	0.046–0.230
Benzo(b)fluoranthene	5/22	0.088–0.360
Benzo(g,h,i)perylene	2/22	0.045–0.100
Chrysene	5/22	0.070–0.300
Fluoranthene	7/23	0.039–0.610
Indeno(1,2,3-cd)pyrene	1/22	0.084
Phenanthrene	5/22	0.093–0.370
Pyrene	10/25	0.043–0.500
2 Methylnapthalene	1/22	0.056
Phthalate Esters		
Bis(2-ethylhexyl)phthalate	1/22	0.040
Diethyl phthalate	1/22	0.084
Di-n-octyl phalate	1/22	0.210

TABLE 4-36
(continued)

Compound	Fequency of Detection	Range (mg/kg)
PCBs		
Aroclor-1242	4/26	0.0019–0.093
Aroclor-1254	13/26	0.032–1.100
Aroclor-1260	3/26	0.15–0.420
Chlorinated Dioxins and Furans		
Octachlorodibenzo-p-dioxin	10/10	0.00012–0.0036
Tetrachlorodibenzofuran	1/10	0.00002
Other Semivolatile Compounds		
Benzoic acid	7/25	0.043–1.900

NOTES: 1. Data compiled from Environmental Survey, CIS, and RI/FS sampling and analysis programs.
2. Data qualified with an "R" (i.e., rejected data) are not included.

TABLE 4-37

INORGANICS DETECTED IN SUBSURFACE MEDIA
IN THE SOUTH FIELD

Analyte	Background Concentration (mg/kg)	Frequency of Detection	Range (mg/kg)	Frequency Above Background Concentration
Aluminum	16973	26/26	4860.00–14636.47	0/26
Antimony	0.0	9/21	7.80–29.70	9/21
Arsenic	10.3	26/26	2.90–8.10	0/26
Barium	133	25/26	48.37–198.00	3/26
Beryllium	0.607	17/26	0.77–1.60	16/26
Boron	48.9	5/7	17.10–36.00	0/7
Cadmium	0.650	24/26	0.69–5.15	24/26
Calcium	201722	26/26	3720.00–187187.03	0/26
Chromium	22.0	26/26	9.36–31.90	12/26
Cobalt	15.8	21/26	9.76–27.73	2/26
Copper	21.2	26/26	9.57–26.80	7/26
Cyanide	0.283	1/26	0.569–13.50	1/26
Iron	33026	26/26	12797.79–29200.00	0/26
Lead	16.6	26/26	10.35–1140.00	11/26
Magnesium	59838	26/26	2828.85–35300.00	0/26
Manganese	1099	26/26	303.00–1165.66	1/26
Mercury	0.292	11/26	0.12–1.22	4/26
Molybdenum	8.8	11/16	12.30–15.80	10/16
Nickel	38.1	26/26	10.22–48.32	2/26
Potassium	1911	26/26	348.48–1503.60	0/26
Silicon	1566	7/7	636.00–1530.00	0/7
Silver	8.03	12/26	2.20–16.20	6/26
Sodium	235	18/26	37.50–522.00	1/26
Thallium	0.397	2/26	0.19–0.20	0/26
Vanadium	39.5	26/26	15.08–34.10	0/26
Zinc	81.2	26/26	26.90–68.10	0/26

NOTES: 1. Data compiled from Environmental Survey, CIS, and RI/FS sampling and analysis programs.
2. Data qualified with an "R" (i.e., rejected data) are not included.

Lead was detected in sieved samples from the Firing Range embankment (collected during the Firing Range Removal Site Evaluation) at concentrations up to 2820 mg/kg (Tables 4-38 and 4-39). In addition to the subsurface samples shown in Tables 4-38 and 4-39, surface sample SP-8 and SP-9 exhibited total lead at 63.3 and 34.9 µg/kg, respectively. Twenty of the 46 boring samples exceeded background (15.0 mg/kg). Lead concentrations are highest at the surface, and diminish with depth. Based on these data, lead contamination is generally confined to the top 5 feet. Only four sieved samples, all of which were within 3.0 feet of the surface, exhibited the RCRA hazardous characteristic for lead (i.e., had lead concentrations greater than 5.0 mg/ℓ in the TCLP extract).

Except at the Firing Range, hazardous waste toxicity characteristic thresholds (40CFR261.24) were not exceeded for any metal in the TCLP of EP toxicity extracts.

No asbestos was detected in the Environmental Survey samples.

4.6.4 Surface Water and Sediment in the South Field

No surface water or sediment samples were collected in the South Field.

4.6.5 Groundwater in the South Field Study Area

A perched groundwater system is located beneath the South Field and Active Flyash Pile, but there is no evidence that water in this system intersects the field. The groundwater of the Great Miami Aquifer flows from west to east in the South Field area, and is generally derived from the Dry Fork Section of the New Haven Trough. During periods of high rainfall, Paddys Run becomes a recharge area, and contaminants in the surface water runoff from the site can be introduced into the aquifer west of the South Field (DOE 1990a).

Some of the groundwater wells within the South Field study area are downgradient of the Active Flyash Pile or the Inactive Flyash Pile, as well as the South Field, so these wells could be impacted by more than one waste area. Wells were sampled quarterly in 1988, 1989, and 1990, although any given well was typically sampled only for a one-year period. Samples were analyzed for radionuclides, VOCs, SVOCs, pesticides/PCBs, organophosphorus pesticides, metals, and the general water quality parameters.

4.6.5.1 Radionuclides in Groundwater

During all quarters of testing, uranium was consistently detected in perched groundwater above the background concentration (<3 µg/ℓ) in Well 1048, where the concentration averaged 18 µg/ℓ), Well 1516 (490 µg/ℓ), Well 1517 (350 µg/ℓ), and Well 1518 (100 µg/ℓ) (Figure 4-19, Table 4-40). In

TABLE 4-38

LEAD CONCENTRATIONS IN VERTICAL BORINGS AT THE FEMP FIRING RANGE

	Boring Numbers											
	SP-1		SP-2		SP-3		SP-4		SP-5		SP-6	
Depth Interval (ft)	Total (mg/kg)	TCLP (mg/ℓ)	Total (mg/kg)	TCLP (mg/ℓ)	Total (mg/kg)	TCLP (mg/ℓ)	Total (mg/kg)	TCLP (mg/ℓ)	Total (mg/kg)	TCLP (mg/ℓ)	Total (mg/kg)	TCLP (mg/ℓ)
0.0-0.5	665	6.9	1250	2.0	123	0.4	63.2	NA	2820	101	64.4	NA
0.0-1.0	154	1.8	2200	4.8	5.6	NA	7.7	NA	2270	21.2	31.3	NA
1.0-2.0	6.1	NA	2460 1380	8.8 9.3	4.8	NA	11.2 7.0	NA	503	1.3	35.7	NA
2.0-3.0	6.6	NA	345	1.4	5.1 17.5	NA	12.8	NA	204	2.9	17.6	NA
3.0-4.0	4.9	NA	57.4	NA	4.0	NA	7.9	NA	2.1	NA	NA	NA
4.0-5.0	5.6	NA	29.6	NA	1.6	NA	7.5	NA	11.6	NA	NA	NA

NA = Not analyzed

Source: Westinghouse Environmental Management Company

Note: 1. Samples sieved with No. 10 sieve to remove lead fragments greater than 2 mm
2. Background for lead is 16.6 mg/kg

TABLE 4-39

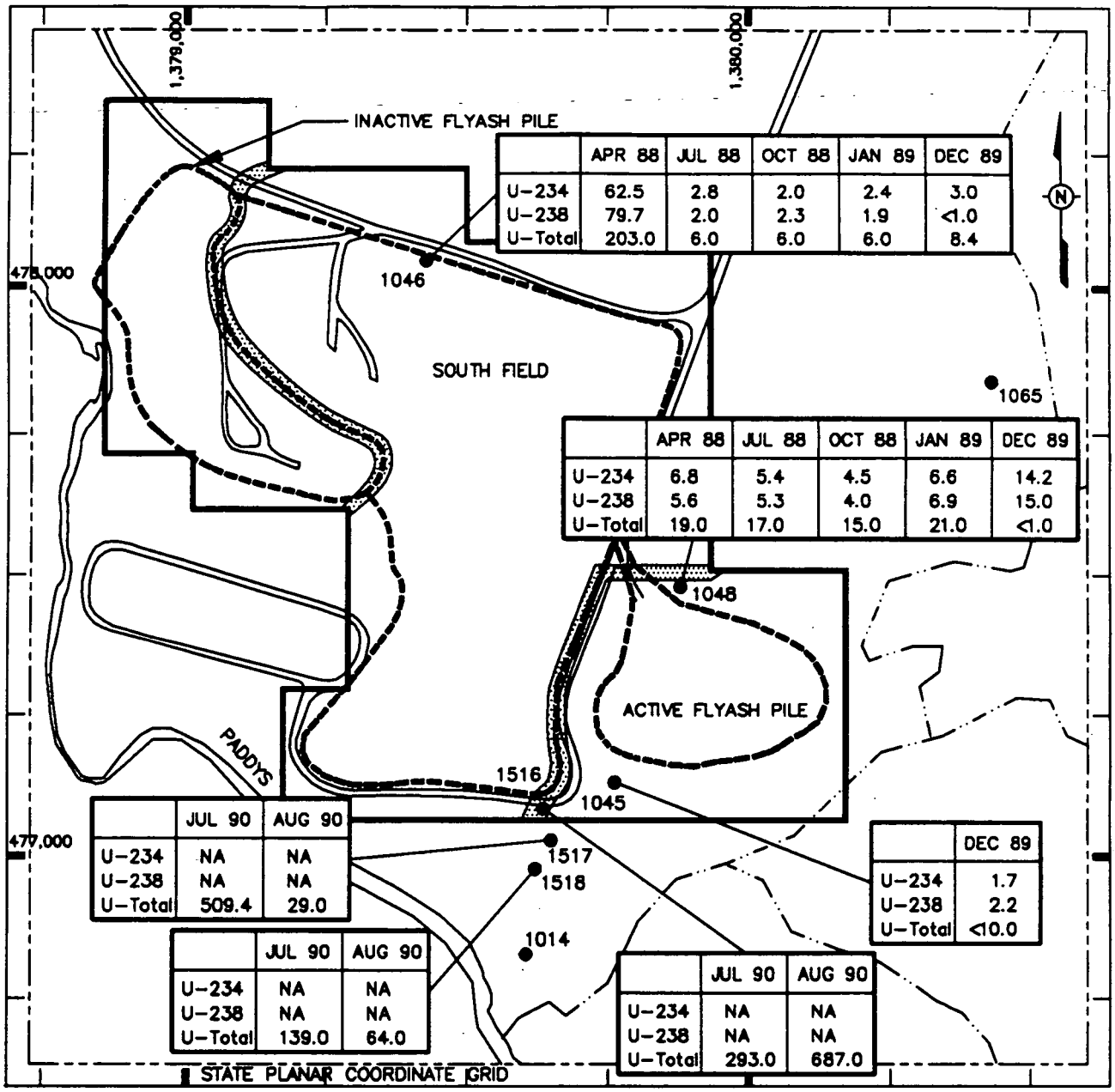
LEAD CONCENTRATIONS IN HORIZONTAL BORING AT THE FEMP FIRING RANGE

Depth (ft)	Total Lead (mg/kg)	TCLP Lead (mg/ℓ)
0-5	1020	0.27
5-10	4.8	NA
10-15	6.1	NA
15-20	4.5	NA
20-25	6.9	NA
25-30	5.3	NA
30-35	4.6	NA
35-40	7.2	NA
40-45	4.6	NA
45-50	5.5	NA

NA = Not analyzed

Source: Westinghouse Environmental Management Company

Note: 1. Samples sieved with No. 10 sieve to remove lead fragments greater than 2 mm
2. Background for lead is 16.6 mg/kg



	APR 88	JUL 88	OCT 88	JAN 89	DEC 89
U-234	62.5	2.8	2.0	2.4	3.0
U-238	79.7	2.0	2.3	1.9	<1.0
U-Total	203.0	6.0	6.0	6.0	8.4

	APR 88	JUL 88	OCT 88	JAN 89	DEC 89
U-234	6.8	5.4	4.5	6.6	14.2
U-238	5.6	5.3	4.0	6.9	15.0
U-Total	19.0	17.0	15.0	21.0	<1.0

	JUL 90	AUG 90
U-234	NA	NA
U-238	NA	NA
U-Total	509.4	29.0

	JUL 90	AUG 90
U-234	NA	NA
U-238	NA	NA
U-Total	139.0	64.0

	JUL 90	AUG 90
U-234	NA	NA
U-238	NA	NA
U-Total	293.0	687.0

	DEC 89
U-234	1.7
U-238	2.2
U-Total	<10.0

SCALE

0 125 250 FEET

NOTES:

1. U-234 AND U-238 CONCENTRATIONS ARE GIVEN IN UNITS OF pCi/L
2. U-TOTAL CONCENTRATIONS ARE GIVEN IN UNITS OF ug/L
3. NA DENOTES NOT ANALYZED

LEGEND:

- RI/FS WELL LOCATION
- EXTENT OF FILL
- FLYASH/SOUTH FIELD BOUNDARY
- BOUNDARY BETWEEN FLYASH PILES AND SOUTH FIELD
- OPERABLE UNIT 2 STUDY AREA

KVP 8/5/92 REV. 1
802 A FIG353 OU2 TK20 OR

FIGURE 4-19. GROUNDWATER URANIUM CONCENTRATIONS IN THE FLYASH/SOUTH FIELD STUDY AREA: 1000-SERIES WELLS

TABLE 4-40

WASTE-RELATED RADIONUCLIDE CONCENTRATIONS IN GROUNDWATER IN THE SOUTH FIELD/ACTIVE FLYASH PILE

		RI/FS Wells, Sample Numbers, and Dates Collected											
		1045[a]	1046[a]						1048[a]				
Analyte	Background Concentration[b]	66828 12/13/89	03089 04/13/88	03370 07/24/88	03649 10/23/88	03854 01/22/89	66829 12/12/89		03132 04/27/88	03368 07/24/88	03647 10/23/88	03856 01/22/89	66831 12/16/89
Radionuclide: (pCi/ℓ)													
Bismuth-214	0.0/0.0	NA	NA	NA	NA	NA	NA		NA	NA	NA	NA	NA
Cesium-137	0.0/0.0	NA	<20.0	<20.0	<20.0	<20.0	NA		<20.0	<20.0	<20.0	<20.0	NA
Lead-210	0.0/0.0	NA	NA	NA	NA	NA	NA		NA	NA	NA	NA	NA
Plutonium-238	0.0/0.0	NA	<1.0	<1.0	<1.0	<1.0	NA		<1.0	<1.0	<1.0	<1.0	NA
Plutonium-239/240	0.0/0.0	NA	<1.0	<1.0	<1.0	<1.0	NA		<1.0	<1.0	<1.0	<1.0	NA
Radium-226	<1/<1	NA	<1.0	<1.0	<1.0	<1.0	NA		<1.0	<1.0	<1.0	<1.0	NA
Radium-228	<3/<3	NA	<3.0	<3.0	<3.0	<3.3	NA		<3.0	<3.0	<3.0	<3.0	NA
Strontium-90	0.0/0.0	NA	<5.0	<5.0	<5.0	<5.0	NA		<5.0	<5.0	<5.0	<5.0	NA
Thorium-228	<1/<1	<1.0	1.1±0.5	<1.0	<1.0	<1.0	1.5±0.5		<1.0	<1.0	<1.0	<1.0	2.9±1.2
Thorium-230	<1/<1	<1.0	1.0±0.5	<1.0	<1.0	<1.0	7.8±0.5	R	<1.0	<1.0	<1.0	<1.0	2.8±1.1
Thorium-232	<1/<1	NA	<1.0	<1.0	<1.0	<1.0	NA		<1.0	<1.0	<1.0	<1.0	NA
Total Thorium (μg/ℓ)	<9/<9	NA	<9.1[d]	<4.0	<4.0	<4.0	NA		<9.1[d]	<4.0	5.0±3.0	4.0±2.0	NA
Uranium-234	<1/0.25	1.7±0.3	62.5±10.8	2.8±0.5	2.0±0.5	2.4±0.5	3.0±0.6		6.8±1.2	5.4±0.8	4.5±1.0	6.6±1.0	14.2±2.0
Uranium-235	<1/0.012	<1.0	NA	NA	NA	NA	NA		NA	NA	NA	NA	NA
Uranium-235/236	<1/0.012	NA	3.8±1.3	<1.0	<1.0	<1.0	NA		<1.0	<1.0	<1.0	<1.0	NA
Uranium-238	<1/0.25	2.2±0.4	79.7±13.5	2.0±0.4	2.3±0.5	1.9±0.4	<1.0		5.6±1.0	5.3±0.8	4.0±1.0	6.9±1.1	15.0±2.0
Total Uranium (μg/ℓ)	<3/0.741	10.1±1.1	203.0±32.0	6.0±1.0	6.0±1.0	6.0±1.0	8.4±0.9		19.0±3.0	17.0±3.0	15.0±3.0	21.0±4.0	<1.0

This table is to be read horizontally
NA = Not Analyzed
R = Value rejected during data validation
* = Duplicate
a = Perched groundwater wells
b = Background concentration given for perched groundwater/Great Miami Aquifer.
c = Great Miami Aquifer wells
d = Total thorium calculated, not analyzed

TABLE 4-40
(continued)

Analyte	Background Concentration[b]	RI/FS Wells, Sample Numbers, and Dates Collected						
		1516[a]		1517[a]			1518[a]	
		046938 07/17/90	046941 08/21/90	046944 07/17/90	046945* 07/17/90	046946 08/21/90	046962 07/17/90	046965 08/21/90
Radionuclide: (pCi/ℓ)								
Bismuth-214	0.0/0.0	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.0/0.0	NA	NA	NA	<20.0	NA	NA	NA
Lead-210	0.0/0.0	NA	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0/0.0	NA	NA	NA	<1.0	NA	NA	NA
Plutonium-239/240	0.0/0.0	NA	NA	NA	<1.0	NA	NA	NA
Radium-226	<1/<1	NA	NA	NA	<1.0	NA	NA	NA
Radium-228	<3/<3	NA	NA	NA	<3.0	NA	NA	NA
Strontium-90	0.0/0.0	NA	NA	NA	<5.0	NA	NA	NA
Thorium-228	<1/<1	NA	NA	NA	<1.0	NA	NA	NA
Thorium-230	<1/<1	NA	NA	NA	<1.0	NA	NA	NA
Thorium-232	<1/<1	NA	NA	NA	<1.0	NA	NA	NA
Total Thorium (µg/ℓ)	<9/<9	NA	NA	NA	3.7±2.7	NA	NA	NA
Uranium-234	<1/0.25	NA	NA	NA	NA	NA	NA	NA
Uranium-235	<1/0.012	NA	NA	NA	NA	NA	NA	NA
Uranium-235/236	<1/0.012	NA	NA	NA	NA	NA	NA	NA
Uranium-238	<1/0.25	NA	NA	NA	NA	NA	NA	NA
Total Uranium (µg/ℓ)	<3/0.741	293±46	687±106	52.8±8.7	966±141	29.9±5.9	139±20	64±9.8

TABLE 4-40
(continued)

Analyte	Background Concentration	RI/FS Wells, Sample Numbers, and Dates Collected											
		2014[c]						2045[c]					
		03064 03/28/88	03384 07/28/88	03673 11/06/88	03869 01/31/89	04151 07/26/89	04211 04/01/90	03993 01/23/89	04092 05/01/89	04129* 05/01/89	04158 07/25/89	04218 04/01/90	04266* 04/01/90
Radionuclides: (pCi/ℓ)													
Bismuth-214	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.0/0.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0
Lead-210	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Plutonium-239/240	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Radium-226	<1/<1	<1.0	<1.0	1.2±0.5	1.4±0.3	<1.0	<1.0	<1.0	<0.1	<1.0	<1.0	<1.0	1.2±0.3
Radium-228	<3/<3	<3.0	<3.0	<3.0	<3.2	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Strontium-90	0.0/0.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Thorium-228	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Thorium-230	<1/<1	1.2±0.8	<1.0	<1.0	<1.0	<1.0	<1.0	1.2±0.5	<1.0	<1.0	<1.0	<1.0	<1.0
Thorium-232	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.0±0.7
Total Thorium (μg/ℓ)	<9/<9	<9.1[d]	<4.0	<3.0	<3.0	<3.0	<2.2	5.0±3.0	<3.0	<5.0	<5.0	<4.3	9.5±6.6
Uranium-234	<1/0.25	9.5±2.1	7.7±1.2	9.8±1.4	4.2±0.8	7.0±1.0	7.1±1.0	78.9±10.3	74.7±10.6	77.6±11.6	104.0±14.0	97.0±15.0	95.3±15.0
Uranium-235	<1/0.012	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235/236	<1/0.012	1.6±0.7	<1.0	<1.0	<1.0	<1.0	<1.0	3.5±0.8	4.4±1.1	3.2±1.0	4.7±1.1	3.6±1.2	4.6±1.4
Uranium-238	<1/0.25	13.1±2.7	9.9±1.4	13.5±1.9	5.7±0.9	9.0±1.2	9.0±1.2	92.3±11.9	85.5±12.1	87.5±13.0	119.0±17.0	104.0±16.0	103.0±16.0
Total Uranium (μg/ℓ)	<3/0.741	32.0±5.0	33.0±5.0	35.0±6.0	17.0±3.0	33.0±7.0	36.0±5.1	283.0±46.0	265.0±42.0	291.0±46.0	341.0±57.0	462.0±61.0	461.0±63.0

TABLE 4-40
(continued)

Analyte	Background Concentration	RI/FS Wells, Sample Numbers, and Dates Collected							
		2046[c]				2048[c]			
		03997 02/02/89	04097 05/10/89	04159 07/28/89	04219 04/03/90	03994 02/09/89	04100 05/02/89	04162 07/26/89	04221 04/01/90
Radionuclide: (pCi/ℓ)									
Bismuth-214	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.0/0.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0
Lead-210	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Plutonium-239/240	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Radium-226	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Radium-228	<3/<3	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Strontium-90	0.0/0.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Thorium-228	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Thorium-230	<1/<1	<1.0	<1.0	<1.0	1.92±0.6	<1.0	<1.0	<1.0	<1.0
Thorium-232	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Thorium(μg/ℓ)	<9/<9	<2.0	<3.0	<6.0	<4.1	<2.0	<3.0	<6.0	<4.3
Uranium-234	<1/0.25	93.8±11.9	219.0±30.0	86.9±11.7	119.0±37.0	<1.0	<1.0	<1.0	3.4±0.7
Uranium-235	<1/0.012	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235/236	<1/0.012	4.3±0.9	9.7±1.9	3.8±0.9	11.5±3.2	<1.0	<1.0	<1.0	<1.0
Uranium-238	<1/0.25	102.0±13.0	231.0±32.0	87.7±11.8	206.0±38.0	<1.0	<1.0	<1.0	3.0±0.6
Total Uranium (μg/ℓ)	<3/0.741	309.0±51.0	851.0±136.0	232.0±39.0	907.0±124.0	<1.0	<1.0	<1.0	2.1±0.2

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TABLE 4-40
(continued)

Analyte	Background Concentration	RI/FS Wells, Sample Numbers and Dates Collected							
		2049[c]							
		03085 04/08/88	03436 08/03/88	03470 12/06/88	03687* 12/06/88	03885 02/07/89	04134 05/10/89	04164 07/30/89	04222 04/03/90
Radionuclides: (pCi/ℓ)									
Bismuth-214	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.0/0.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0
Lead-210	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Plutonium-239/240	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Radium-226	<1/<1	<1.0	<1.0	<1.0	<1.0	<0.1	<1.0	<1.0	1.2±0.2
Radium-228	<3/<3	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Strontium-90	0.0/0.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Thorium-228	<1/<1	1.5±0.7	<1.0	<1.0	<1.0	<1.0	<1.0	1.1±0.4	2.3±0.9
Thorium-230	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.3±0.7
Thorium-232	<1/<1	1.6±0.7	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.3±0.9
Total Thorium (µg/ℓ)	<9/<9	14.5[d]	<3.0	<3.0	<5.0	<2.0	<3.0	<4.0	20.8±8.5
Uranium-234	<1/0.25	50.8±8.1	3.1±0.6	1.3±0.3	1.0±0.3	2.3±0.5	42.9±5.5	83.2±11.0	NA
Uranium-235	<1/0.012	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235/236	<1/0.012	2.3±0.8	<1.0	<1.0	<1.0	<1.0	1.8±0.5	1.4±0.5	NA
Uranium-238	<1/0.25	51.4±8.1	2.8±0.6	<1.0	<1.0	2.1±0.4	47.5±6.0	89.9±11.8	NA
Total Uranium (µg/ℓ)	<3/0.741	130.0±20.0	8.0±1.0	3.0±1.0	2.0±1.0	6.0±1.0	175.0±28.0	147.0±24.0	43.3±37.9

TABLE 4-40
(continued)

Analyte	Background Concentration	RI/FS Wells, Sample Numbers, and Dates Collected								
		2065[c]								2385[c]
		03095 04/19/88	03438 08/04/88	03693 11/08/88	03538 02/02/89	03884* 02/02/89	04163 07/30/89	04168* 07/30/89	04225 04/09/90	04303 07/10/90
Radionuclide: (pCi/l)										
Bismuth-214	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.0/0.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	NA
Lead-210	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Plutonium-239/240	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Radium-226	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Radium-228	<3/<3	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<2.0
Strontium-90	0.0/0.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Thorium-228	<1/<1	<1.0	<1.0	<1.0	1.4±0.9	1.2±0.6	<1.3	<1.1	<1.0	1.2±0.3
Thorium-230	<1/<1	1.2±0.8	<1.0	<1.0	<1.1	<1.0	<1.3	<1.1	<1.0	<1.0
Thorium-232	<1/<1	<1.0	<1.0	<1.0	<1.1	<1.0	<1.3	<1.1	<1.0	52.9±8.8
Total Thorium (µg/l)	<9/<9	<9.1[d]	<7.0	<3.0	<10.0	<7.0	<12.0	<10.0	<4.5	<1.9
Uranium-234	<1/0.25	5.1±1.3	4.6±0.8	2.6±0.5	5.3±1.3	3.7±1.2	5.5±1.0	4.1±0.7	3.9±0.6	34.8±4.5
Uranium-235	<1/0.012	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235/236	<1/0.012	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.8±0.5
Uranium-238	<1/0.25	3.3±1.0	4.0±0.7	2.6±0.5	3.9±1.1	3.3±1.1	5.3±1.0	4.0±0.7	3.8±0.6	36.2±4.7
Total Uranium (µg/l)	<3/0.741	10.0±1.0	9.0±1.0	7.0±1.0	9.0±2.0	8.0±1.0	12.0±2.0	11.0±2.0	11.4±1.9	108.0±14.0

TABLE 4-40
(continued)

Analyte	Background Concentration	RI/FS Wells, Sample Numbers, and Dates Collected								
		3014[c]					3045[c]		3046[c]	
		03084 04/08/88	03385 07/28/88	03672 11/06/88	03870 01/31/89	04239 04/01/90	04198 05/23/90	04319 08/09/90	04207 06/15/90	04332 08/24/90
Radionuclide: (pCi/ℓ)										
Bismuth-214	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.0/0.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0
Lead-210	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Plutonium-239/240	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Radium-226	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.4±0.5	<1.0
Radium-228	<3/<3	<3.0	<3.0	<3.0	<3.1	<3.0	<3.0	<3.0	<3.0	<3.0
Strontium-90	0.0/0.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Thorium-228	<1/<1	2.5±0.9	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.6±0.4
Thorium-230	<1/<1	1.4±0.6	<1.0	<1.0	<1.0	1.1±0.4	<1.0	<1.0	<1.0	<1.0
Thorium-232	<1/<1	1.1±0.6	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Thorium (μg/ℓ)	<9/<9	<10.0[d]	7.0±4.0	<7.0	<3.0	<2.9	<6.7	<1.8	<3.1	<1.7
Uranium-234	<1/0.25	6.7±1.3	7.3±1.1	7.1±1.0	6.9±1.0	17.1±2.4	<1.0	4.6±0.7	<1.0	1.7±0.3
Uranium-235	<1/0.012	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235/236	<1/0.012	<1.0	<1.0	<1.0	<1.0	1.5±0.5	<1.0	<1.0	<1.0	<1.0
Uranium-238	<1/0.25	8.5±1.5	10.0±1.4	8.7±1.2	8.9±1.2	16.4±2.3	<1.0	5.1±0.8	<1.0	<1.0
Total Uranium (μg/ℓ)	<3/0.741	23.0±4.0	29.0±5.0	28.0±5.0	30.0±5.0	35.3±5.0	6.0±0.6	15.2±2.4	1.7±0.2	3.0±0.8

TABLE 4-40
(continued)

		RI/FS Wells, Sample Numbers, and Dates Collected											
		3049[c]				3065[c]			3385[c]		4014[c]		
Analyte	Background Concentration	003992 01/31/89	004091 05/01/89	004246 04/26/90	004271* 04/26/90	003995 01/25/89	004098 05/31/89	004249 04/09/90	004309 07/24/90	004363 01/10/91	003871 01/31/89	004089 05/01/89	066866 12/13/89
Radionuclide: (pCi/ℓ)													
Bismuth-214	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cesium-137	0.0/0.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	NA
Lead-210	0.0/0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Plutonium-238	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Plutonium-239/240	0.0/0.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Radium-226	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA	<1.0	<1.0	<1.0	NA
Radium-228	<3/<3	<3.4	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	NA	<3.0	<3.0	<3.0	NA
Strontium-90	0.0/0.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	NA	<5.0	<5.0	<5.0	NA
Thorium-228	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.2±0.4	<1.0	<1.0	<1.0
Thorium-230	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	2.2±0.6	<1.0	<1.0	<1.0	<1.0
Thorium-232	<1/<1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.0±0.4	<1.0	<1.0	<1.0	NA
Total Thorium (µg/ℓ)	<9/<9	<3.0	<7.0	<3.6	<3.1	<2.0	<2.0	<1.8	9.4±3.6	<2.4	<2.0	<4.0	NA
Uranium-234	<1/0.25	<1.0	<1.0	<1.0	6.0±0.9	<1.0	<1.0	<1.0	1.1±0.3	1.4±0.3	<1.0	<1.0	<1.0
Uranium-235	<1/0.012	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium-235/236	<1/0.012	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Uranium-238	<1/0.25	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Uranium (µg/ℓ)	<3/0.741	<1.0	<1.0	<1.0	1.2±0.2	<1.0	<1.0	0.8±0.5	2.3±0.8	2.9±0.3	<1.0	<1.0	<1.0

2000-series wells, uranium was consistently above background (0.741 µg/ℓ) in all wells except Well 2048 (Figure 4-20). The average concentrations for these wells are as follows: 575 µg/ℓ in Well 2046, 363 µg/ℓ in 2049, 108 µg/ℓ in 2385, 73 µg/ℓ in 2049, 31 µg/ℓ in 2014, and 11.4 µg/ℓ in 2065.

The concentration in Well 2049 appears to have a seasonal fluctuation, beginning with 130 µg/ℓ in April 1988, dropping to 2.5 µg/ℓ in December 1988, and rising to 175 µg/ℓ in May 1989. The likely source of this contamination is the storm sewer outfall ditch, which serves as a recharge zone for the Great Miami Aquifer during periods of high rainfall (Figure 3-8).

Wells 2048 (below the UTL) and 2385 (108 µg/ℓ) are among those 2000-series wells which have the least contamination, yet these wells are immediately downgradient of the most heavily uranium-contaminated soils in the South Field. The wells exhibiting the highest uranium concentrations (2046 at 575 µg/ℓ and 2045 at 363 µg/ℓ) are separated by two wells which are much less contaminated (Well 2016 at 20.7 µg/ℓ and Well 2048 at below background). Since all of these wells are screened at the same elevation, multiple sources are suspected. Well 2046, the well with the highest uranium concentration in the Flyash/South Field study area, is downgradient of uranium-contaminated soils in both the South Field and the Inactive Flyash Pile. Soils above the water table in Borings 2046 and 1046, however, did not exhibit elevated uranium. Based on these data, it is not clear that the South Field is a source of uranium contamination to the Great Miami Aquifer. Other potential sources are recharge from Paddys Rum (DOE 1990a), the Inactive Flyash Pile, and/or other site-related sources.

In 3000- and 4000- series wells, uranium was greater than background in Wells 3014 (av 29 µg/ℓ), 3045 (av 10.6 µg/ℓ), 3385 (av 2.385 µg/ℓ). Uranium was not consistently detected in Wells 3049, 3065, and 4014.

4.6.5.2 Organic Compounds in Groundwater

Organics were analyzed only in samples from Wells 1517, 2014 and 2065. Diethyl phthalate was detected in Well 2065 at 0.02 mg/ℓ. Acetone was detected in Wells 1517 (0.005 mg/ℓ) and 2014 (0.002 mg/ℓ). Bis(2-ethylhexyl)phthalate was detected in Well 2014 at a concentration of 0.002 mg/ℓ. Trichloroethene was detected at 0.007 mg/ℓ in Well 1517.

4.6.5.3 Metals in Groundwater

Waste-related metals consistently detected in one or more wells at concentrations above their applicable background concentrations include cadmium, which was detected in Wells 2065 and 3065.

4.6.6 Biota in the South Field Study Area

Levels of uranium (reported as the sum of uranium-234, uranium-235, and uranium-238 activities), strontium-90, and cesium-137 were reported for samples of surface soil, grass roots, and grass leaves

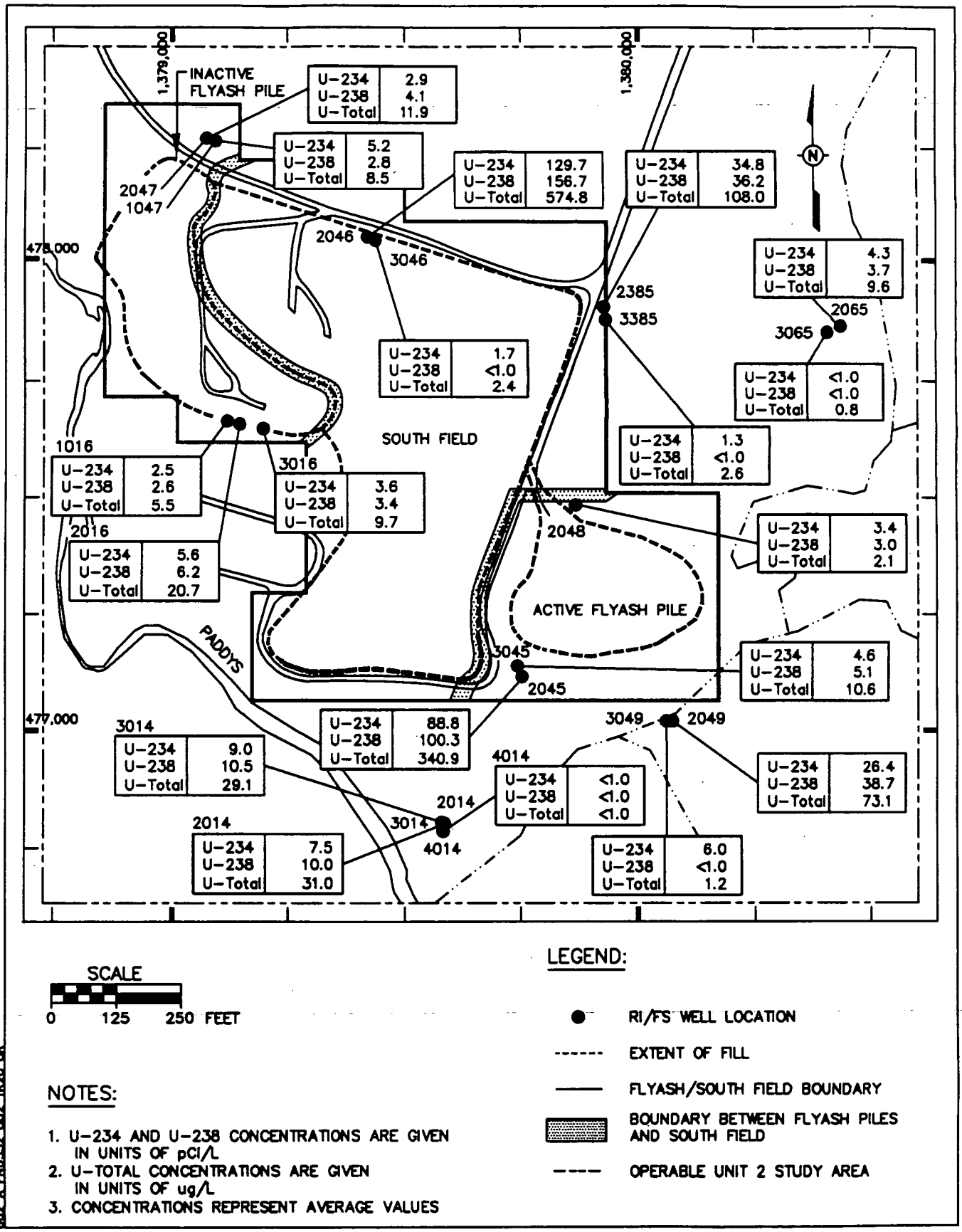

FIGURE 4-20. GROUNDWATER URANIUM CONCENTRATIONS IN THE FLYASH/SOUTH FIELD STUDY AREA: 2000-SERIES, 3000-SERIES, AND 4000-SERIES WELLS

from Location 23 (Figure 2-13; Table 4-41) (DOE 1992b). Cesium-137 was detected at 0.3 pCi/g in grass roots at Location 23. Terrestrial vegetation is not concentrating cesium-137 at a level higher than the cesium-137 concentration in the adjacent surface soil.

No SVOCs, PCBs/pesticides, or metals samples were taken at Location 23.

4.6.7 South Field Summary

Uranium, thorium, and radium are the primary contaminants in the South Field. In surface media, total uranium, total thorium, and radium-226 were measured at levels as high as 8915 mg/kg, 1182 mg/kg, and 354 pCi/g, respectively. Levels for these analytes in subsurface fill were as high as 394 mg/kg, 31 mg/kg, and 16 pCi/g, respectively, indicating that radionuclide concentrations decrease with depth. In native soils underlying the fill, maximum levels were 230 mg/kg, 16.9 mg/kg, and 1.6 pCi/g, respectively.

The presence of uranium in some native soil samples suggest that uranium is leaching from the fill into the native soil. Well 2046, the most highly uranium contaminated well, lies downgradient of the uranium bearing soils; however, Well 2046 is also downgradient of the Inactive Flyash Piles. Moreover, Well 2048, the nearest well downgradient of the most heavily uranium-contaminated fill, exhibits a total uranium less than background. Well 2385, downgradient of the South Field, was sampled only one time and exhibited a total uranium of 108 µg/ℓ. Based on the groundwater data presented in this report, no conclusion can be drawn concerning whether or not the South Field is a source of radionuclide groundwater contamination to the underlying Great Miami Aquifer. Other potential sources are the Inactive Flyash Pile, recharge from Paddys Run, and/or other site-related sources.

PAH compounds were detected primarily in soil samples at concentrations up to 0.84 mg/kg. The most frequently detected PAHs were pyrene and fluoranthene. PCB Aroclors were detected a total of 20 times at a maximum concentration of 1.1 mg/kg. Only three occurrences of phthalates and acetone, which are common laboratory contaminants, were detected in groundwater. This indicates migration of organic compounds has not occurred.

A number of inorganic constituents were detected in subsurface media above their respective background concentrations. The most frequent such detections were for cadmium, beryllium, and molybdenum. Of these, only cadmium was consistently detected above background in groundwater.

Lead was detected in surface soils in the Firing Range at concentrations up to 2820 mg/kg. Four samples exceeded the hazardous waste characteristic threshold of 5 mg/ℓ.

TABLE 4-41

URANIUM, CESIUM, AND STRONTIUM CONCENTRATIONS IN BIOTA IN THE SOUTH FIELD STUDY AREA

	Uranium[a]	Cesium-137	Strontium-90
LOCATION 23			
Soil (pCi/g)	5.3	0.3	<0.5
Grass leaves (pCi/g)	<0.6	<0.2	<0.5
Grass roots (pCi/g)	<0.6	0.3	<0.5

[a] = This is a sum of all uranium-234, uranium-235, and uranium-238 activities

Source: U.S. Department of Energy, 1992, "Site-Wide Characterization Report," DOE, Fernald Field Office, Fernald, OH.

The Active Flyash Pile, Inactive Flyash Pile, South Field, underlying perched groundwater units, and Great Miami Aquifer comprise a complex system of potential contaminant sources, sinks, and transport pathways. Although the complexity of this system reduces the precision to which the various sources and sinks of contamination can be characterized, the various components of the system are included in the development and implementation of the fate and transport models.

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5.0 CONTAMINANT FATE AND TRANSPORT

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Fate and transport models are used to predict contaminant movement from source areas to potential human or ecological receptors via a number of potential migration pathways. Used in conjunction with monitoring data, these models predict contaminant concentrations at potential exposure locations when measured contaminant concentration data are not available, such as for off-site locations and/or for future times. In this RI, models are used to predict the migration of constituents of concern via the air, surface water, and groundwater pathways.

Constituents of concern are identified for each waste area in Operable Unit 2 as discussed in the Operable Unit 2 Baseline Risk Assessment (Appendix A). This section describes the models used to simulate contaminant migration and presents the results obtained. Section 5.1 through 5.3 presents information on migration pathways, contaminant persistence, and modeling procedures that pertain to all of the Operable Unit 2 waste areas. Section 5.4 presents the results of fate and transport modeling for each of the individual waste areas. These results were used in the Baseline Risk Assessment to estimate potential risks to human health. Detailed descriptions of the technical approaches used to model environmental transport by the groundwater, surface water, and air pathways are presented in Appendix B.

5.1 POTENTIAL MIGRATION PATHWAYS

5.1.1 Air Pathway

During periods of turbulent wind conditions, particles of surface materials (e.g., contaminated soil) can become resuspended in ambient air and subject to inhalation by on-site and/or off-site human receptors. The amount of material that may be resuspended depends on wind speed and other site conditions such as soil moisture, particle size, and vegetative cover. Resuspended particles are then carried downwind to on-site and off-site receptors. Concentrations of these airborne contaminant-bearing particles at receptor locations form the basis for assessment of human exposure by the inhalation pathways, as discussed in Section 6.0 and Appendix A (Baseline Risk Assessment).

5.1.2 Surface Water Pathway

Surface water runoff is a viable transport pathway for all of the waste areas in Operable Unit 2 except the Lime Sludge Ponds. Flow from the slopes of the Flyash Piles and South Field drains into the storm sewer outfall ditch and Paddys Run. The Solid Waste Landfill is drained by a drainageway which passes through the northern part of the waste area. Surface water is not a viable transport pathway for the Lime Sludge Ponds since the ponds are contained within soil berms which isolate them from the surrounding soils.

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 attached to the soil particles are also removed and carried into the receiving surface water. Each contaminant will be present in the runoff water in two forms: (1) adsorbed to the soil particles and (2) dissolved in the water.

5.1.3. Groundwater Pathway

Rainfall infiltrates the surface and percolates through the waste and soil overlying the groundwater aquifer. The FEMP is situated above the Great Miami Aquifer, which serves as a principal source of domestic, municipal, and industrial water throughout the region. The Great Miami Aquifer is considered the primary pathway by which contaminants released from a source (waste area) are transported to a human receptor. The three major mechanisms for this migration pathway are (1) the leaching of contaminants from the soil matrix into the dissolved phase, (2) the percolation of the contaminated leachate to the underlying aquifer, and (3) the movement of water in the Great Miami Aquifer. The contaminant concentrations in leachate reaching groundwater depend on the recharge rate, the solubility of the contaminants, degradation rates, soil texture, soil hydraulic conductivity, depth to the groundwater, and a number of other chemical- and soil-specific factors. Predicted contaminant concentrations in the Great Miami Aquifer were used as the basis for the assessment of human exposure by water-dependent intake and exposure pathways as discussed in Section 6.0 and Appendix A (Baseline Risk Assessment).

5.2 PERSISTENCE OF CONTAMINANTS

The migration of contaminants from Operable Unit 2 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 (usually described by a half-life or an environmental half-life in a given media), and chemical affinity for solids or organic matter (usually described by a partitioning coefficient). These properties and how they affect contaminant behavior are described below for radionuclides, inorganics, and organics.

5.2.1 Radionuclides

Radioactive elements undergo spontaneous transformations that involve the emission of particles and radiant energy. The resulting progeny element may also be radioactive and undergo spontaneous decay or a stable element may result. The decay process can occur by various spontaneous mechanisms. Two of the more important decay modes are alpha decay and beta decay, with the latter differentiated as negatron or positron decay. The emissions consist of three different types of rays: alpha, beta, and gamma.

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. The resulting progeny product is a different element because the number of protons in the nucleus has changed. Beta decay emits particles that have the mass of an electron, but could have a positive or negative charge. In negatron decay, a neutron is transformed into a proton and an electron. The electron is then expelled from the nucleus as a negative beta particle, along with other subnuclear particles. The atomic number of the resulting progeny is thus increased by one, and the number of neutrons is decreased by one. In positron decay, a proton spontaneously transforms to a neutron with the subsequent emission of a positron (a positively charged electron) and subatomic particles. The progeny product has one less proton than its parent and an additional neutron. In each type of decay, the atom may be left in an excited state; that is, the atom has excess energy which must be released. This energy can be emitted in several ways, including the formation of a gamma ray with a discrete energy.

Most of the radioactive materials present at the FEMP originated from natural sources such as pitchblende ore or concentrates. The radioactive elements present in these materials belong to three decay chain series: the uranium series, the uranium-235 (actinium) series, and the thorium series as shown in Figures 5-1, 5-2, and 5-3. 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 activity mass decay of each nuclide is essentially equal to that of the nuclide that heads the series, leading to constant ratios of activity concentrations among the respective nuclides. This property of secular equilibrium is the case on a global basis for each series, but local concentrations can vary widely when chemical and physical forces are imposed on the series members. Activity mass ratios can be used at the site as an indicator of contaminant source. Because of the refining processes, uranium-234 is selectively leached from radiation-damaged crystal sites over the parent element, uranium-238. The various waste streams may thus have differing uranium-238/uranium-234 ratios.

The half-lives of most of the elements of concern at the FEMP are long (thousands of years or greater, e.g., uranium-238 is 4.5E+09 years) when compared to the life of the site. Exceptions are strontium-90 (with a half-life of 29 years) and cesium-137 (with a half-life of 30 years). Strontium-90 decays to the stable isotope zirconium-90. The remaining compounds of concern, heavy metals and transition metals, do not undergo nuclear transformations and their persistence on site is related to their geochemical mobility in the environment. Many reversible reactions occur which cause retardation. The partitioning coefficient (K_d) is used to derive a retardation factor (R_f) which slows down the velocity of the contaminant movement. Though the K_d formulation of the reaction term of the transport equation has numerous assumptions and uncertainties associated with them (discussed in Appendix B), it provides a practical means of incorporating the reaction process into the transport models. Radionuclide retardation in groundwater transport and their decay constants are discussed in Appendix B.

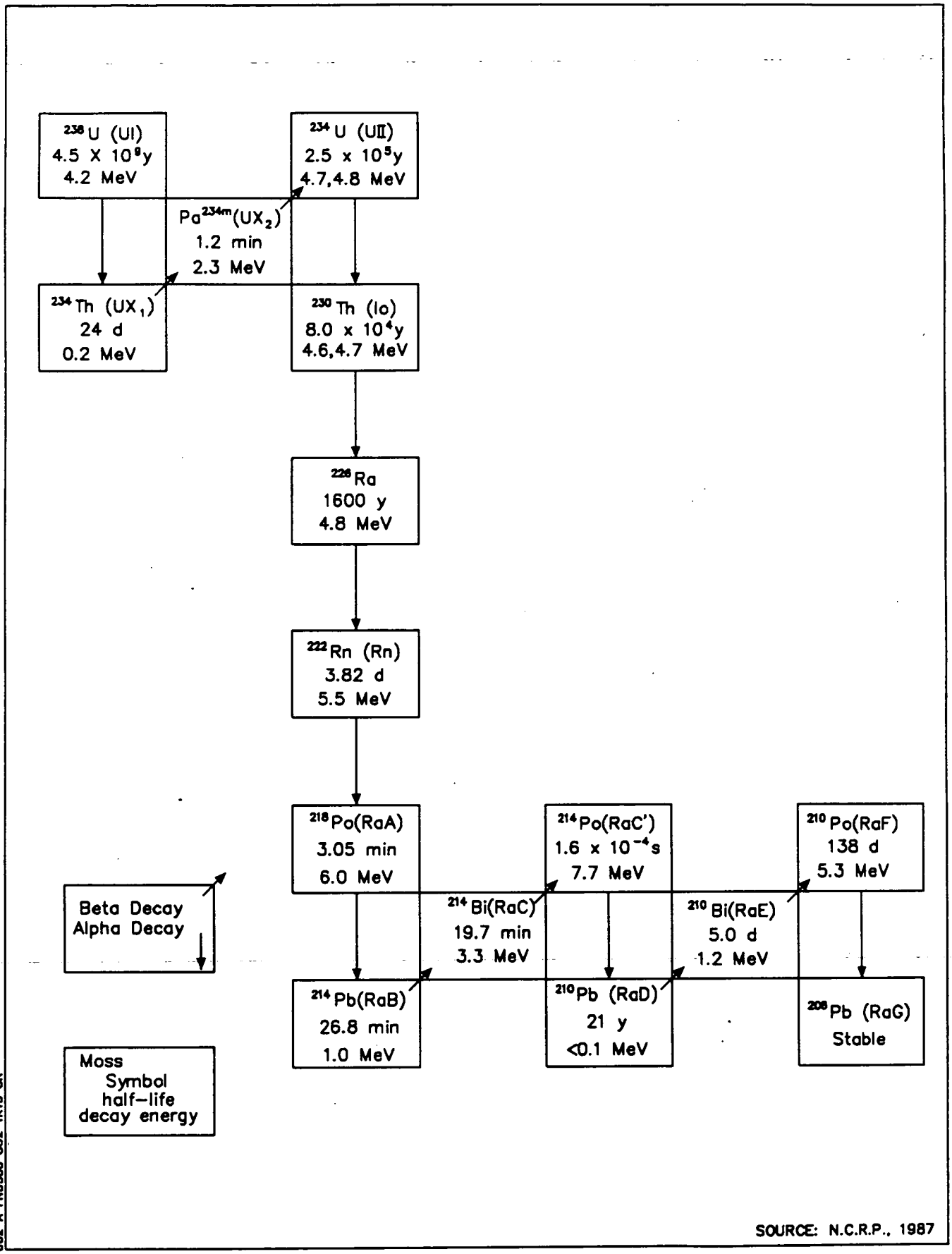

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FIGURE 5-1. PRINCIPAL DECAY SCHEME OF THE URANIUM SERIES

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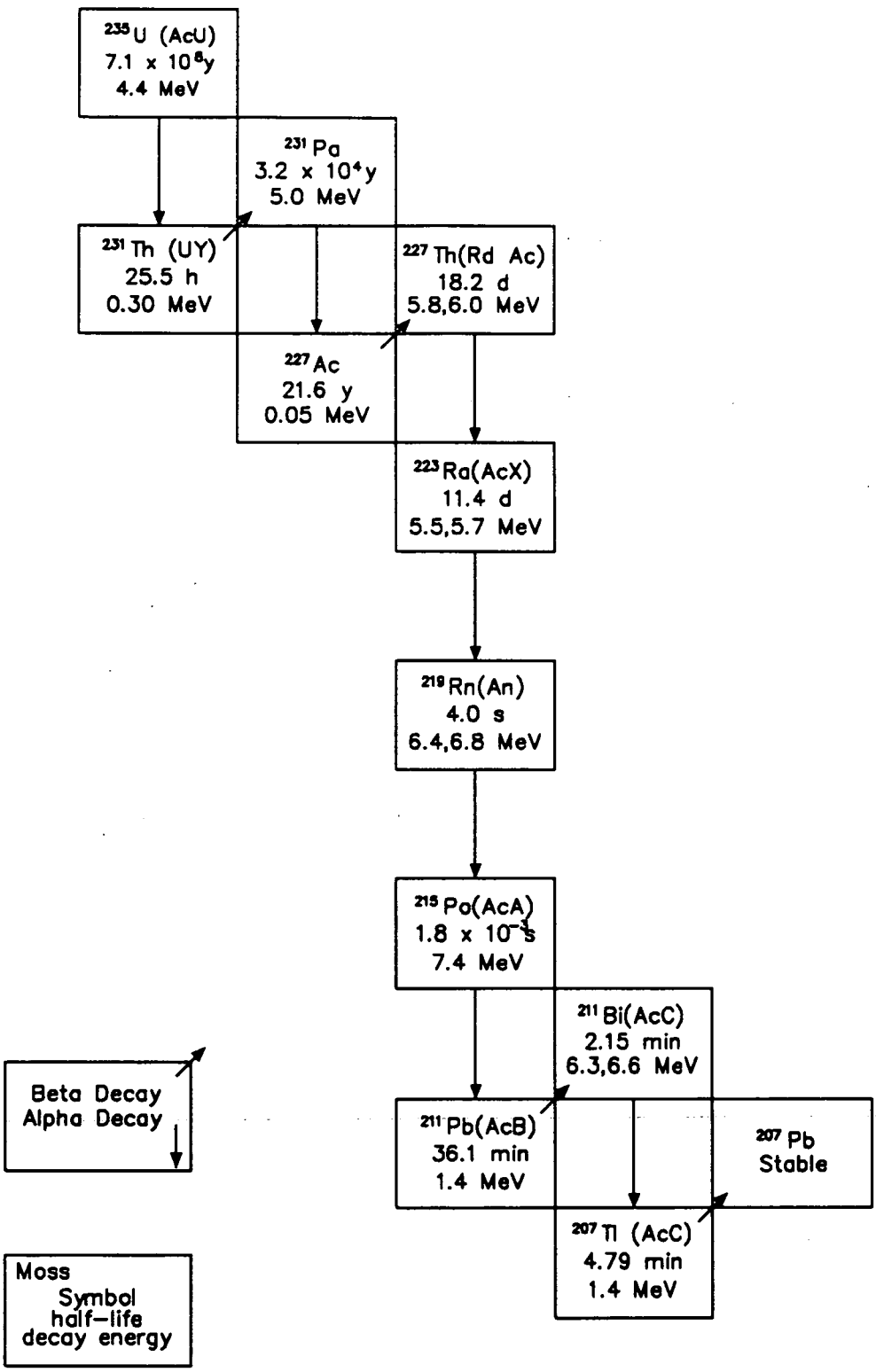

SOURCE: N.C.R.P., 1987

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FIGURE 5-2. PRINCIPAL DECAY SCHEME OF THE ACTINIUM SERIES

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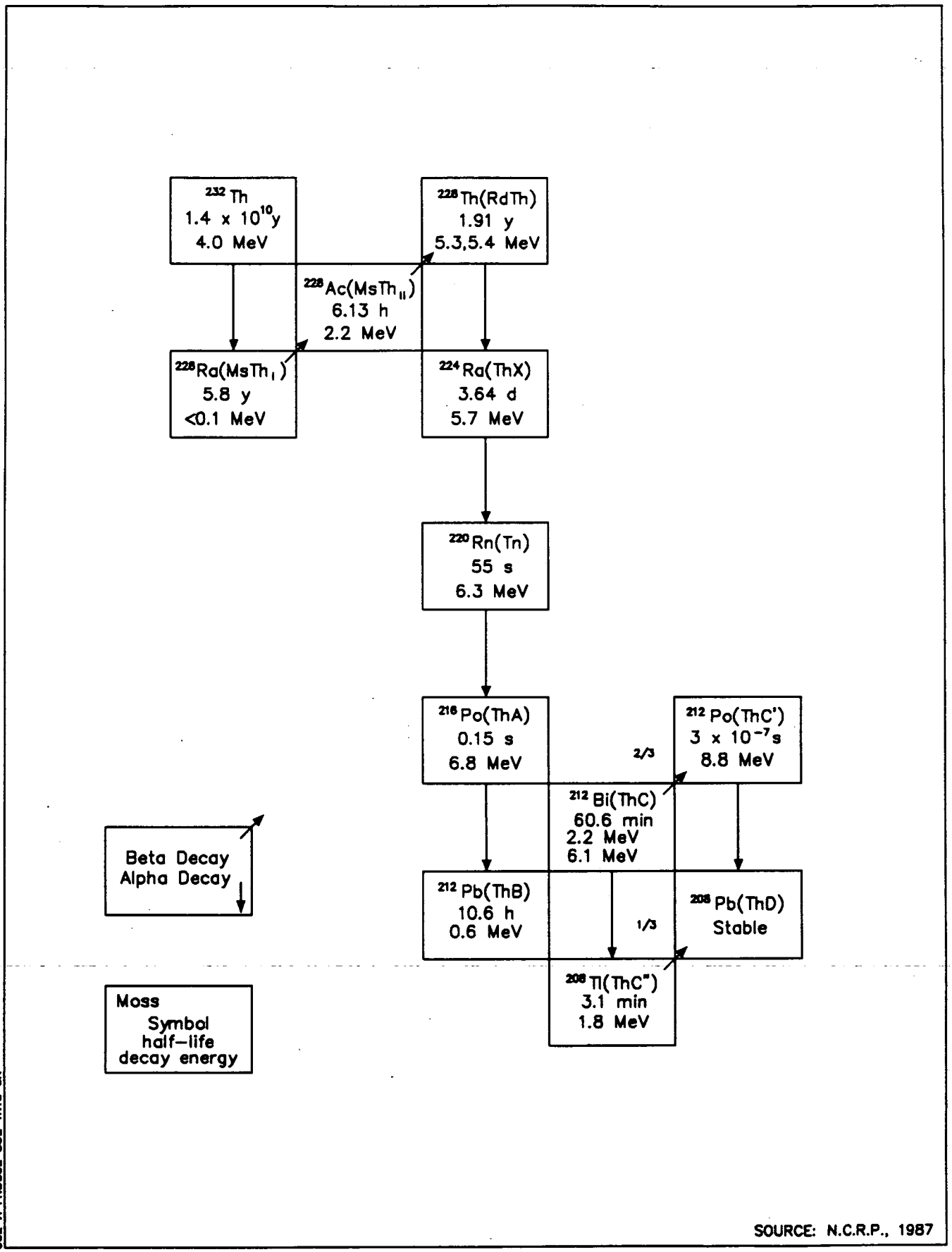

FIGURE 5-3. PRINCIPAL DECAY SCHEME OF THE THORIUM SERIES

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5.2.2 Inorganics

Inorganics do not degrade in the environment, but they may undergo speciation, which is a change in chemical form. They may also react with soils or other solid surfaces by ion exchange, adsorption, precipitation or complexation. These processes are affected by pH, oxidation-reduction conditions, and the type and amount of organic matter, clay, and hydrous oxides present. These factors are affected by the physical and biological properties of the environmental media.

Inorganic chemical form has a large impact on solubility and therefore 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. Inorganic contaminant retardation in groundwater transport is discussed in Appendix B.

5.2.3 Organics

Organic contaminants may be degraded in the environment by various processes, including hydrolysis, oxidation/reduction, photolysis, or biodegradation. Half-lives in various media can vary from minutes to years, depending on the chemical and on environmental conditions. Environmental half-lives for organic contaminants of concern for Operable Unit 2 are discussed in Appendix B.

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 soils and its transportation with the groundwater would be very limited and at a much slower rate. Retardation factors in groundwater transport are discussed further in Section 5.3.3 and Appendix B. A general overview of the relative water solubility, tendency to adsorb to solids, and contaminant mobility for different categories of organic contaminants of concern at Operable Unit 2 is presented 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 2 examples include 1,2-dichloroethane, 1,1,1-trichloroethane, toluene

- 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 2 examples include anthracene, chlorobenzene, di-n-butylphthalate

- PCBs and dioxins:
  - Low water solubility
  - Low volatility
  - High tendency to adsorb to solids
  - Generally transported while adsorbed to soil particles
  - Operable Unit 2 examples include chlordane, Aroclor-1248, octachlorodibenzo-p-dioxin

5.3 MODELING OF POTENTIAL CONTAMINANT MIGRATION

5.3.1 Air Quality Modeling and Contaminant Transport

The migration of contaminant-bearing soil particles is a two-step process. First, particles of soil or other surface media are dislodged from the surface by the wind and are entrained in the air column. Second, the suspended materia is carried and dispersed downwind. These two processes are modeled separately.

Emissions from a dust source may depend on soil characteristics, such as particle size, and climatic conditions, such as mean wind velocity and extent of precipitation. Bohn et al. (1978) empirically derived an equation, later modified by Cowherd et al. (1985), to estimate the emission rate based on (1) percent silt content of aggregate material, (2) number of dry days per year, and (3) percentage of time that wind speed exceeds 12 miles per hour at 1 foot above the ground. The use of this model is described in "A Method for Estimating Fugitive Particulate Emissions from Hazardous Waste Sites" (EPA 1987a). The estimated resuspension rate is input to the Industrial Source Complex dispersion model which projects downwind concentrations of contaminated particles in ambient air.

The Industrial Source Complex Long Term model (EPA 1987b) calculates annual average concentrations of an airborne pollutant at user-selected locations of interest, called receptor locations. It is a steady-state Gaussian plume model that is applicable in flat or gently rolling terrain. It is well suited to this application, because it allows emission rates to vary with wind speeds. Data required for input to the model include emission rates of the sources, the locations and other physical information about the sources, meteorological information that is representative of actual site conditions, and physical locations of receptors.

In this application, on-site meteorological data for 1989 was used. Receptors were located 100 meters apart, covering the entire FEMP tract. All contaminated surfaces were assumed to be dry, except on days when rainfall occurred.

Using the models described above, the average annual concentrations of resuspended particles were calculated at receptor locations encompassing the entire FEMP site. Table 5-1 lists the resuspension rate and the highest modeled on-site and off-site airborne particulate concentrations for each of the Operable Unit 2 waste areas. The resuspension model does not account for the existing surface vegetation which significantly retards resuspension on all of the Operable Unit 2 waste areas except for the North Lime Sludge Pond and the Active Flyash Pile. Therefore, the simulated resuspension rates are significantly higher than would normally be expected for the Solid Waste Landfill, South Lime Sludge Pond, Inactive Flyash Pile, and South Field. The maximum on-site concentrations listed in Table 5-1 are the maximum concentrations that appear at the nodes on a 100-meter x 100-meter grid over the FEMP site. It is possible that slightly higher concentrations may exist in the 100 meter space between adjacent grid nodes. The off-site concentrations are based on projections at locations along the FEMP boundary.

The concentration of a specific contaminant in the resuspended particles is assumed to be the same as the measured concentration of the contaminant measured in the surface media. For example, the upper confidence level (UCL) of thorium-230 activity in surface soils of the Solid Waste Landfill is 5.56×10^{-6} pCi/μg. The highest concentration of resuspended particles in on-site air from the landfill is 0.189 (μg/m^3). Accordingly, the highest concentration of thorium-230 in ambient air is $0.189 \times 5.56 \times 10^{-6} = 1.05 \times 10^{-6}$ pCi/m^3.

5.3.2 Surface Water Modeling

Contaminants in surface soils can be released from source areas and transported to surface water via precipitation runoff. During a rainfall event, some amount of the rainwater infiltrates the soil surface and some runs off the surface as shown in Figure 5-4. The amount of runoff depends on soil type, soil vegetative cover, the amount of moisture already present in the soil, the intensity and duration of rainfall, slope length, and slope steepness.

Contaminants in the surface soil can be transported via runoff either in the dissolved phase or adsorbed to soil particles. The less soluble a contaminant is in water, the more likely it will be adsorbed to soil particles. Because the water solubility of contaminants of concern in Operable Unit 2 vary widely, transport is modelled for both dissolved phase and adsorbed phase contaminants.

Paddys Run is an intermittent stream that begins north of the site and flows southward along the western edge. Natural drainage from the site flows primarily to Paddys Run. Paddys Run flows into the Great Miami river 2.4 km south of the FEMP. Some surface water drainage has been diverted

TABLE 5-1

AIRBORNE CONCENTRATIONS OF RESUSPENDED PARTICLES FROM OPERABLE UNIT 2 WASTE AREAS

Waste Areas	Area (m^2)	Area (ft^2)	Resuspension Rate (g/sec)	Highest On-Site Airborne Concentration[a] ($\mu g/m^3$)	Highest Off-Site Airborne Concentration ($\mu g/m^3$)
Solid Waste Landfill	3,930	42,300	0.394	0.189	0.00661
North Lime Sludge Pond	2,600	28,000	0.261	0.078	0.00144
South Lime Sludge Pond	2,750	29,600	0.275	0.211	0.00240
Active Flyash Pile	8,710	93,800	0.872	0.216	0.02908
Inactive Flyash Pile	12,200	131,000	1.216	0.372	0.02959
South Field	22,500	242,000	2.252	0.340	0.04231

[a] Based on projections at node points on a 100-meter grid.

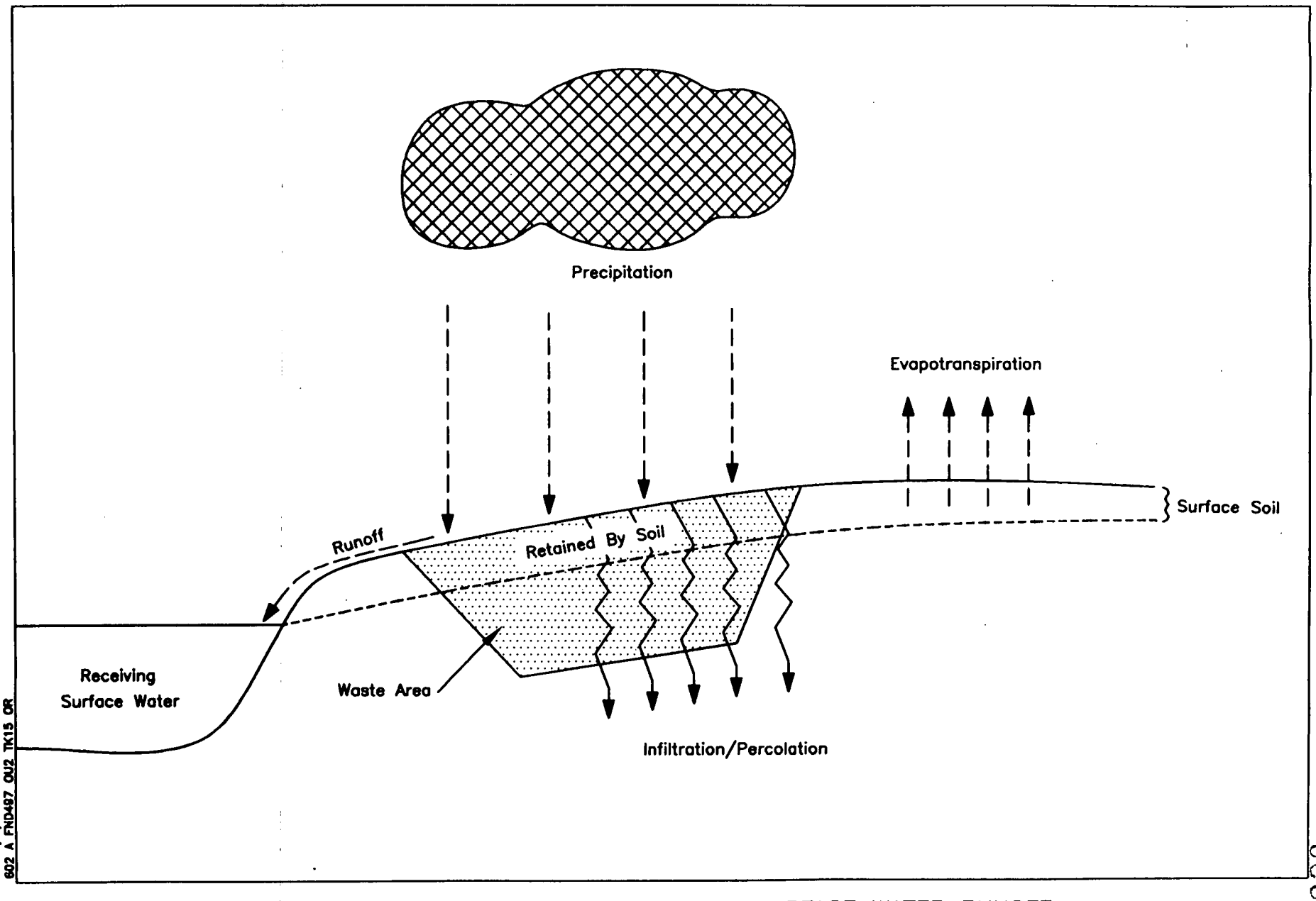

FIGURE 5-4. CONCEPTUAL MODEL OF SURFACE WATER RUNOFF

away from Paddys Run into a retention basin (WEMCO 1991). The storm sewer outfall ditch flows from the retention basin into Paddys Run.

The modeling approach used to estimate contaminant concentrations in surface water and sediment resulting from transport by surface water runoff is described here. Modeling the transport of soil by runoff requires characterization of the contaminants in the initial soil or waste source term. Two models were used to quantify the migration of contaminated soil to stream sediment from erosion by surface water runoff. The two soil loss models, obtained from the EPA Superfund Exposure Assessment Manual (EPA 1988c), are the Universal Soil Loss Equation (USLE), which calculates the annual soil loss, and the Modified Universal Soil Loss Equation (MUSLE), which calculates the soil loss for a single rainfall event. The USLE model takes the same form as MUSLE, except that USLE uses an area-dependent method to determine runoff, while MUSLE employs event-specific runoff volume and flow rate variables. Additional models were used to describe contaminant partitioning between soil and water in the runoff flow. These partitioning models provide an estimate of the contaminant concentration dissolved in water runoff and adsorbed to the soil that is carried with the runoff and deposited in the sediments of receiving surface water bodies (Haith 1980, Mills et al. 1982). The volume of runoff is also estimated in order to determine both the amount that stream flow may be increased by a runoff event, and to estimate dissolved contaminant loading. The depth of runoff is calculated as a function of the depth of rainfall and a soil water retention factor. In effect, the amount of water retained by the soil is subtracted from the total amount of rainfall and the remainder is available as runoff flow. A certain amount of rainfall, depending on soil conditions, is required before any runoff occurs. The dissolved contaminant concentration in the receiving stream is estimated by a simple dilution model with runoff concentration, runoff volume and stream flow.

A detailed description of the model assumptions, equations, and parameters can be found in Appendix B.

5.3.3 Groundwater Modeling and Transport Analysis

5.3.3.1 Principles of Contaminant Fate and Transport

The migration of water and dissolved contaminants from the waste source to the receptor involves flow through both unsaturated (vadose zone) and saturated zones (regional aquifer and perched zones). Flow in these zones is controlled by Darcy's law, which states that the volumetric flow is proportional to the product of the driving force, the material's ability to transmit water, and the cross-sectional area perpendicular to the flow direction. The driving force for the flow in both unsaturated and saturated conditions is the gradient. The gradient results from differences in elevation, pressure (saturated conditions), and matric potential (unsaturated conditions).

Generally, the unsaturated hydraulic conductivity at residual moisture content is low. Unsaturated hydraulic conductivity increases, gradually at first and then more rapidly, as the degree of saturation

increases from the residual moisture content to the saturated moisture content. Because of this relationship, unsaturated hydraulic conductivity changes with the degree of saturation, and is always less than the saturated hydraulic conductivity.

Dispersion (mixing) in groundwater is primarily caused by molecular diffusion, varying pore sizes, varying path lengths, variation in velocity gradients across the pore space, and flow splitting around matrix particles. In groundwater, dilution due to mixing occurs at a much slower rate than in surface water, and the overall magnitude of dispersion is smaller. In addition to dispersion, both attenuation and retardation should be considered in transport modeling.

Attenuation is the loss of contaminants from the plume. While the mass of the contaminant is not changed, a certain percentage of the total contaminant will be removed from the solution by geochemical reactions and will no longer be available for transport. Attenuation is used to model those processes that immobilize contaminants. These mechanisms can include hydrolysis, complexation, oxidation/reduction reactions, acid/base reactions, organic and radioactive decay, and chemical precipitation. The attenuation process is accounted for by a combination of chemical modeling to determine a solubility-constrained leachate concentration along the potential flow path and the use of decay constants for radionuclides and organic compounds.

Retardation consists of reversible reactions that slow the movement of a constituent. Two retardation mechanisms, organic retardation and cationic retardation, are generally used for modeling. Organic retardation is the sorbing of hydrophobic compounds onto organic materials in the matrix. Cationic retardation refers to positive charged ions being attracted to ionic particles within the matrix. In both cases retardation is reversible, causing the development of a plume that has a long tail of decreasing concentration. The plume will be present for extended time periods following source removal. These adsorption processes have a substantial potential to alter the migration rate of reactive solutes, and for compounds with high partitioning coefficients, may be the dominant influence on the transport process.

The partitioning coefficient (K_d) is used to derive a retardation factor (Rf). Although the K_d/Rf formulation of the reaction term of the transport equation has numerous assumptions and uncertainties associated with it, it nevertheless provides a practical means of incorporating the reaction process into transport models. K_d values for the specific constituents of concern were derived from site investigations (DOE 1992a), calculations based on octanol-water coefficients, and literature values .

5.3.3.2 Conceptual Model

The migration of contaminants from the waste (the source) to the groundwater begins with the infiltration of rainwater across the soil surface (Figure 5-5). As the water percolates through the waste, contaminants in the waste are dissolved into the water to form a leachate. At the base of the waste, this leachate is referred to as Leachate A (shown in Figure 5-5). In addition to its contaminant

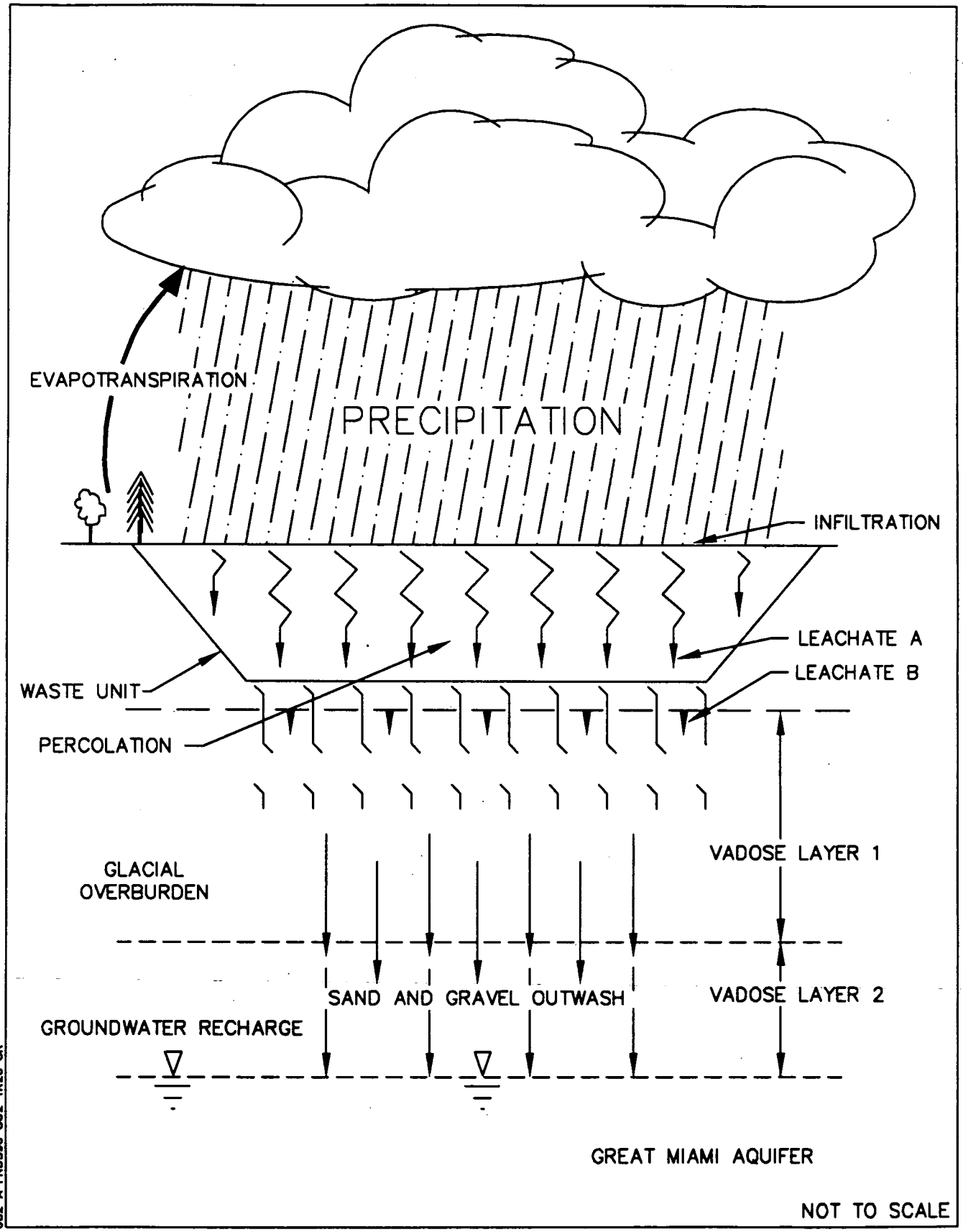

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FIGURE 5–5. CONCEPTUAL VADOSE ZONE MODEL

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concentrations, Leachate A is characterized by a number of chemical properties which affect the fate and transport of contaminants; these include pH, redox potential, mineral solubility, and reaction equilibrium. Leachate A then migrates into and reacts with the underlying glacial overburden to form a modified leachate, referred to as Leachate B. For the purpose of this modeling exercise, the effects of these reactions on the chemical properties of the leachate are instantaneous, and Leachate B is the result. It should be noted here that the concept of Leachate A and B are merely used as simplifications to the modeling process. The prediction of leachate properties is accomplished using a method which is discussed in the following section. Details on the development of leachate compositions for Operable Unit 2 waste areas can be found in Appendix B.

Fate and transport models are used to simulate the vertical transport of contaminants from the bottom of the waste area down through the vadose zone to the Great Miami Aquifer and the horizontal transport through the aquifer to the well of a potential human receptor. For modeling purposes, the vadose zone is divided into two layers, referenced in Figure 5-5 as Layer 1 and Layer 2. Layer 1 consists of the unweathered glacial overburden interbedded with glaciofluvial sand and gravel stringers. Layer 2 consists of sand and gravel outwash deposits existing above the Great Miami Aquifer. Leachate B enters the top of Layer 1 and flows through Layers 1 and 2. Root uptake, soil matrix adsorption/desorption, chemical transformation, precipitation, biological degradation, dissolution, etc., may be acting simultaneously and retard the movement of the contaminants through the soil with the percolating water. After percolating through the vadose zone, the contaminants enter the saturated zone of the Great Miami Aquifer. The aquifer is a well-sorted sand and gravel water table system consisting of glacial outwash deposits located within a 2-to 3-mile wide subterranean valley known as the New Haven Trough. This aquifer is divided by a 10- to 20-foot-thick clay aquitard at an approximate depth of 120 feet. The receptor pathway considered for this analysis is the upper part of the Great Miami Aquifer, above the clay aquitard. Appendix B presents a complete description of the conceptual model for aquifer modeling at the FEMP as well as the conceptual flow model for vadose zone modeling.

5.3.3.3 Estimating the Composition of Operable Unit 2 Waste Leachates

The six waste areas that make up the Operable Unit 2 comprise a variety of chemical and physical waste forms. The Solid Waste Landfill holds a variety of organic and inorganic waste that is mixed with native soil; the North and South Lime Sludge Ponds hold waste streams treated with lime; the Active and Inactive Flyash Piles are the sites where boiler plant flyash was disposed; and the South Field is a general disposal area for construction rubble. This complex assemblage of waste types implies that each waste area will produce a leachate of distinct composition. In most cases, this waste leachate will be produced by the interaction of percolating rainfall with the waste, and if impermeable liners and/or natural barriers underlie the waste, the leachate may pond in the waste unit. This section will summarize the site-specific data that are available to estimate the composition of leachate that may migrate from the units. The leachate compositions are used to constrain the initial contaminant

concentrations entered into the fate and transport modeling, which is used to estimate contaminant dose at identified receptors. Details on the development of leachate compositions for Operable Unit 2 waste units can be found in Appendix B. The hierarchy of the consideration for estimating the leachate for the radionuclides and inorganics is shown in Figure 5-6. The hierarchy for the estimate of leachate concentration for the organics is illustrated in Figure 5-7.

For Operable Unit 2 waste areas, the composition of waste leachate is best estimated by recovering and analyzing in situ leachate from each waste unit. In situ leachate reflects the complex chemical interactions that take place between the waste solids and contact solution in the physical disposal environment, and duplicating these conditions in laboratory tests is difficult or impossible. Surface water analyses from the North Lime Sludge Pond are the closest approximation to in-situ leachate available for the waste area. RI/FS sampling efforts have recovered surface water samples at the North Lime Sludge Pond (Appendix D), and these analyses were used in arriving at an estimate of leachate composition for Lime Sludge Ponds. Surface water samples were also obtained from the Solid Waste Landfill (Appendix C), Active Flyash Pile (Appendix E), and Inactive Flyash Pile (Appendix F) in a 1989 sampling effort. However, these samples are not considered to be representative of in situ leachate because they were obtained during rain-storm events and represent transient conditions, rather than long-term contact with the waste. Monitoring wells in Solid Waste Landfill and Inactive Flyash Pile have recently been sampled to obtain a small volume of fluid that may represent in situ leachate. However, analytical results from this recent sampling effort were not available during preparation of the RI, but will be considered in the FS for the no-treatment alternative. In summary, only surface water data from the North Lime Sludge Pond are currently available to use as estimates of in situ leachate.

An alternative to estimating the leachate composition when in situ leachate is unavailable is the TCLP developed by the Environmental Protection Agency. TCLP data are available for all Operable Unit 2 waste areas, but TCLP results produce very conservative (i.e., high) contaminant concentrations when inorganic waste is leached. This is because the acetic acid used in the TCLP procedure produces uncharacteristically low pH conditions and partially degrades to the acetate ion, which is very effective at complexing metals and enhancing their concentrations in solution. Additionally, TCLP data are generally only available for the RCRA metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver) but not for other metals of concern, such as antimony, beryllium, cobalt, copper, molybdenum, and nickel. Although radionuclides are also not analyzed routinely as part of the TCLP test, TCLP radionuclide data are available from OU2 treatability studies and these data can be used to estimate radionuclide concentrations in leachate when more appropriate data are lacking. In summary, TCLP data will be used to estimate leachate compositions when available, but will be subjected to a screening to determine if using the TCLP concentration would result in depletion of the contaminant inventory in less than 70 years (the

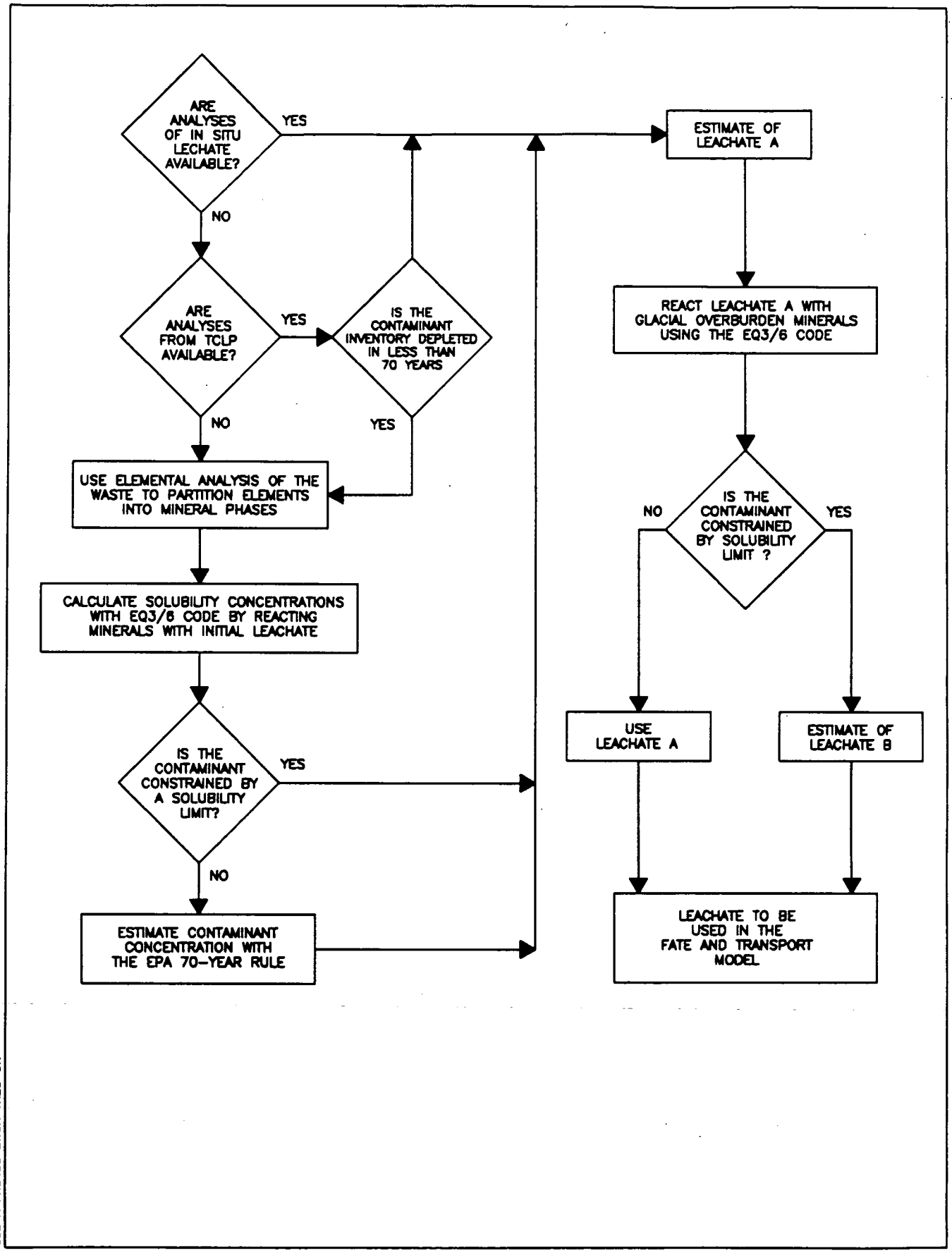

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FIGURE 5-6. ESTIMATING LEACHATE FOR RADIONUCLIDES AND INORGANICS

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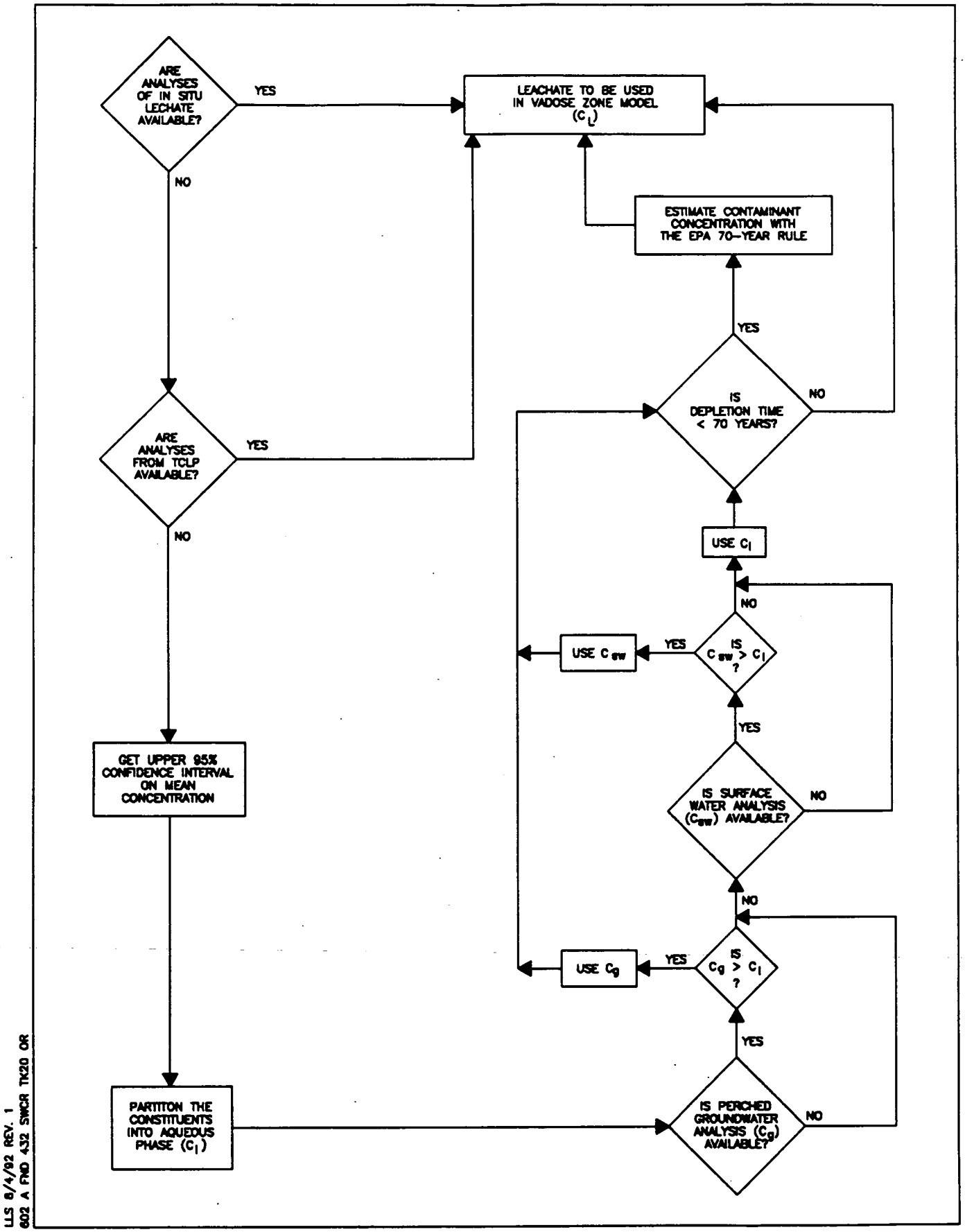

FIGURE 5-7. ESTIMATING LEACHATE FOR ORGANICS

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total contaminant inventory of any particular constituent in a waste area can be obtained by multiplying the UCL of that contaminant by the total mass of the waste area). The 70-year rule is discussed below.

When the composition of waste leachate cannot be estimated with in situ leachate or TCLP data, mineral solubility calculations (geochemical modeling) can be performed to estimate the contaminant concentration in the leachate. The concept of mineral solubility may be illustrated by placing some mineral (for example, cerussite [$PbCO_3$], which contains lead) in distilled water at 25°C. Under these conditions, the steady-state (or equilibrium) lead concentration in solution is 1.1 mg/L, which is referred to as the solubility limit for lead in distilled water contacting cerussite at 25°C. The mineral solubility calculations require data on the waste mineralogy to calculate the contaminant concentrations. If the mineralogy of the waste is not known, an elemental analysis of the waste can be used to form mineral phases that are thought to be present based on process knowledge or waste disposal records. Mineral solubility calculations are then carried out with the known or assumed mineral phases to simulate the reactions between rainwater and the minerals.

A final method for estimating the composition of leachate released from a waste unit is the EPA 70-year rule (EPA 1988c). The 70-year rule calculates the concentration of a contaminant by assuming that the total mass of the contaminant in the waste inventory will be depleted (completely leached out by the percolating water) by 70 years (a time period approximately equal to the life of a human being). This method is likely to be the most conservative (i.e., result in the greatest contaminant concentrations) for all but the most soluble elements (e.g., cesium, strontium, technetium).

In applying the best available data to the estimation of Operable Unit 2 waste leachate, (as discussed in Appendix B), waste leachate may be estimated by using data from several sources. For instance, the Active Flyash Pile lacks data on in situ leachate, but TCLP analyses are available. As noted above, the TCLP results are screened to determine if their use would result in depletion of the contaminant inventory in less than 70 years. For the contaminants of concern in Active Flyash Pile, TCLP data are available for arsenic, lead, mercury, selenium, silver, radium, strontium-90, thorium, and uranium, and the leachate composition for these contaminants are estimated with TCLP data. At this point, we are left with estimating the remaining constituents of concern with mineral solubility calculations or the 70-year rule. Mineral solubility calculations are investigated first by assessing the available information on waste mineralogy. Elemental analyses of the waste and process knowledge was used to estimate the waste minerals that may be present in flyash. Flyash is generated from the combustion of coal, and many metals present in the coal are converted to oxide compounds during the combustion process (e.g., nickel oxide). Other metals will tend to react with the sulfate that is produced from the oxidation of sulfur to form sulfate minerals (e.g., radium sulphate). In this way, the mineralogy of the flyash is estimated and the mineral solubility calculations are carried out with the appropriate mineral phases.

In summary, site-specific data are used to estimate leachate compositions that are needed for fate and transport modeling to assess the contaminant concentration at identified receptors. The leachate compositions are estimated using a combination of in situ leachate recovered from the waste unit, TCLP data, mineral solubility calculations, or the EPA 70-year rule. Constraining the leachate compositions with site-specific data and the methods outlined above provides the most defensible estimates of contaminant concentrations in leachate that migrate from Operable Unit 2 waste areas.

5.3.3.4 Groundwater Transport Modeling

Vertical migration is characterized by the bulk movement of water through the geological strata underlying the source. As contaminated leachate percolates from the source of contamination through the vadose zone and aquifer (phreatic zone), its continued movement is dependent on the physical and chemical characteristics of these zones. Predicted contaminant concentrations in groundwater are then used in the water-dependent intake and exposure model equations.

Transport in the Vadose Zone

This phase of contaminant transport includes the bulk migration of water and dissolved materials from source areas at Operable Unit 2 to the Great Miami Aquifer through the unsaturated zone, also known as the vadose zone. Downward movement of water, driven by gravitational potential, capillary potential, and other components of the total fluid potential, is the prime mover of contaminants through the vadose zone.

Leachate B, i.e., the results of geochemical modeling, were used as the initial concentrations for radionuclides and inorganics, and the EPA 70-year rule for other constituents of concern. Each layer in the conceptual flow system is analyzed separately, with the concentrations from the upper layer acting as the input concentrations to the lower layer. The models assume vertical flow through unsaturated soils. The depletion of the waste source over time, radioactive decay, and biodegradation are taken into account in the vadose zone modeling.

The models selected to evaluate flow in the vadose zone are ST1D (IT 1990) and ODAST (Javendel et al. 1984). ST1D, a one-dimensional analytical solution, was used for the initial screening of constituents for mobility in the unsaturated zone. ODAST, another one-dimensional analytical solution, was used to model the fate and transport for constituents which exceed the selection criteria. These procedures are based on the solution originally developed by Ogata and Banks (1961), and they calculate 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. The ODAST code can account for retardation of contaminants, source changes, and decay. ST1D and ODAST have been extensively verified against STRIP1B (Batu 1989).

Infiltration rates through the surface of the waste areas were used in calculating the total times for source depletion and the vertical seepage velocities in vadose zone models. Infiltration rates were estimated using the Hydrologic Evaluation of Landfill Performance (HELP) model (EPA 1984), which is a deterministic quasi-two-dimensional model. The HELP mode considers four levels of surface cover. They are bare ground, poor grass, fare grass, and excellent grass. The covers used in the Operable Unit 2 waste areas are fare grass for the Solid Waste Landfill, fare grass for the South Lime Sludge Pond, bare ground for the Active Flyash pile, fare grass for the Inactive Flyash pile and South Field. The HELP model is an EPA-approved model suitable for estimating flow through both unsaturated and saturated zones for different layers in a porous medium. The model computes surface runoff by the U.S. Soil Conservation Service curve number method using the default values of runoff curve numbers. HELP also predicts evapotranspiration using the modified Penman method (EPA 1984), which incorporates the effect of site-specific values of temperature, solar radiation, and evaporation coefficients. The amount of precipitation, minus surface runoff and surface water evaporation, percolates through the soil layer producing soil moisture storage, vertical leakage, and lateral drainage flow. The HELP model can not represent the effect of steady state ponded water condition on the topmost layer of the media, as currently exists in the North Lime Sludge Pond. Therefore, for this waste area, a steady state analytical solution of the variably saturated (i.e. unsaturated-saturated) flow equation was used to estimate the percolation rates through the glacial overburden and the unsaturated sand and gravel layer.

Transport in the Aquifer

This phase of contaminant transport involves the advective and diffusive migration of water and dissolved materials from one part of the Great Miami Aquifer to another. As contaminated leachate percolates from the vadose zone into the saturated zone of the aquifer, its continued movement is dependent on physical and chemical characteristics of the aquifer. The physical properties of the aquifer influence the bulk movement of water, and the chemical and physical properties influence the ease with which the aquifer allows the migration of specific contaminants.

The Sandia Waste Isolation Flow and Transport (SWIFT III) model for groundwater flow and solute transport (Geotrans 1987) was used to analyze contaminant transport in the Great Miami Aquifer. The SWIFT III code is a fully transient three-dimensional, finite-difference model which solves coupled equations that describe water flow and transport in geologic media.

The model, applied at the FEMP since 1988, has been extensively calibrated against known uranium concentrations in groundwater. The SWIFT III code and its verification and application are fully outlined in the "Flow and Solute Transport Computer Code Verification Report" (IT 1990), along with the input parameters used. The groundwater flow process incorporated into the calibrated SWIFT-III model is considered independent of the type of the contaminant present in the aquifer. For this reason, the model calibrated against uranium can be used for the prediction of the movement of the other

contaminants in the aquifer. The magnitude of uncertainty for the contaminants depends on the uncertainty in the estimation of attenuation and retardation parameters. The groundwater modeling performed for Operable Unit 2 risk analysis was done using output values from vadose zone modeling. The loading rates of each compound were used to calculate the expected maximum concentrations which would occur in the Great Miami Aquifer.

Detailed descriptions of groundwater model applications and assumptions, model parameters, sensitivity analysis, and uncertainty in modeling results can be found in Appendix B.

5.4 MODELING RESULTS AND DISCUSSION

Operable Unit 2 consists of six unlined waste disposal areas used for the disposal of flyash, spent lime, sanitary waste, and construction rubble from facility operations. The primary characteristics of these waste areas are that they involve large volumes of waste, of which only small percentages are hazardous chemicals and/or radionuclides.

Analytical data from these waste areas were compiled and screened to identify the constituents of concern through different media (air, surface water, and groundwater), based upon risk assessment guidelines as discussed in the Risk Assessment Work Plan Addendum (DOE 1992a). Fate and transport modeling was performed on these constituents of concern and the modeling results were then used in the Baseline Risk Assessment to estimate the human health risk.

5.4.1 Solid Waste Landfill

5.4.1.1 Air Quality Results

Airborne concentrations for contaminants originating from the Solid Waste Landfill were calculated at receptor locations based on (1) average annual concentrations of resuspended particles originating from the waste area (Table 5-1), and (2) contaminant concentrations in subsurface soils in the waste area.

The highest on-site annual concentrations of resuspended radionuclides and inorganic and organic compounds are 2.29E-05 pCi/m^3 (uranium-238), 2.89E-05 µg/m^3 (barium), and 1.04E-07 µg/m^3 (fluoranthene), respectively (Table 5-2). The highest off-site annual concentrations of resuspended radionuclides and inorganic and organic compounds are 8.00E-07 pCi/m^3 (uranium-238), 1.01E-06 µg/m^3 (barium), and 3.62E-09 µg/m^3 (fluoranthene), respectively. The concentration of airborne uranium-238 resuspended from the Solid Waste Landfill is shown in Figure 5-8.

Since the resuspension model does not account for surface vegetation, (which significantly retards resuspension at the Solid Waste Landfill, the simulated resuspension rates are significantly higher than actually occurs. The maximum on-site concentrations listed in Table 5-2 are the maximum concentrations that appear at the nodes on a 100-meter x 100-meter grid over the FEMP site. It is possible that

TABLE 5-2

HIGHEST ANNUAL AVERAGE CONCENTRATIONS OF RESUSPENDED CONTAMINANTS FROM THE SOLID WASTE LANDFILL

Resuspended Particles	Highest On-site[a] Airborne Concentration[b]	Highest Off-site Airborne Concentration[b]
Radionuclides (pCi/m^3)		
Plutonium-238	1.89E-08	6.61E-10
Radium-224	3.84E-07	1.34E-08
Radium-226	1.95E-07	6.81E-09
Radium-228	2.95E-07	1.03E-08
Strontium-90	1.15E-07	4.02E-09
Thorium-228	7.58E-07	2.65E-08
Thorium-230	1.05E-06	3.68E-08
Thorium-232	3.86E-07	1.35E-08
Uranium-234	9.54E-06	3.33E-07
Uranium-235/236	3.16E-07	1.10E-08
Uranium-238	2.29E-05	8.00E-07
Inorganics (µg/m^3)		
Antimony	2.50E-06	8.73E-08
Barium	2.89E-05	1.01E-06
Beryllium	1.84E-07	6.44E-09
Cadmium	1.00E-06	3.51E-08
Chromium	6.91E-06	2.42E-07
Cobalt	3.08E-06	1.08E-07
Copper	4.88E-06	1.71E-07
Lead	5.78E-06	2.02E-07
Molybdenum	3.15E-06	1.10E-07
Silver	2.25E-06	7.88E-08
Thallium	1.14E-07	4.00E-09
Vanadium	8.51E-06	2.98E-07
Organics (µg/m^3)		
1,1-Dichloroethane	1.13E-09	3.96E-11
2,4-Dimethylphenol	4.54E-08	1.59E-09
Acenaphthene	5.03E-08	1.76E-09
Anthracene	5.46E-08	1.91E-09
Benzoic acid	2.08E-08	7.27E-10
bis(2-Ethylhexyl) phthalate	6.35E-08	2.22E-09
Di-n-butyl phthalate	2.27E-08	7.92E-10
Di-n-octyl phthalate	6.62E-08	2.30E-09

TABLE 5-2
(continued)

Resuspended Particles	Highest On-site[a] Airborne Concentration[b]	Highest Off-site Airborne Concentration[b]
Organics ($\mu g/m^3$)		
Fluoranthene	1.04E-07	3.62E-09
Fluorene	5.07E-08	1.77E-09
n-Nitrosodiphenylamine(1)	1.27E-08	4.42E-10
Naphthalene	2.65E-08	9.25E-10
Phenol	1.15E-08	4.02E-10

[a] Based on projections at node points on a 100-meter grid.
[b] Concentrations are based on subsurface soil values.

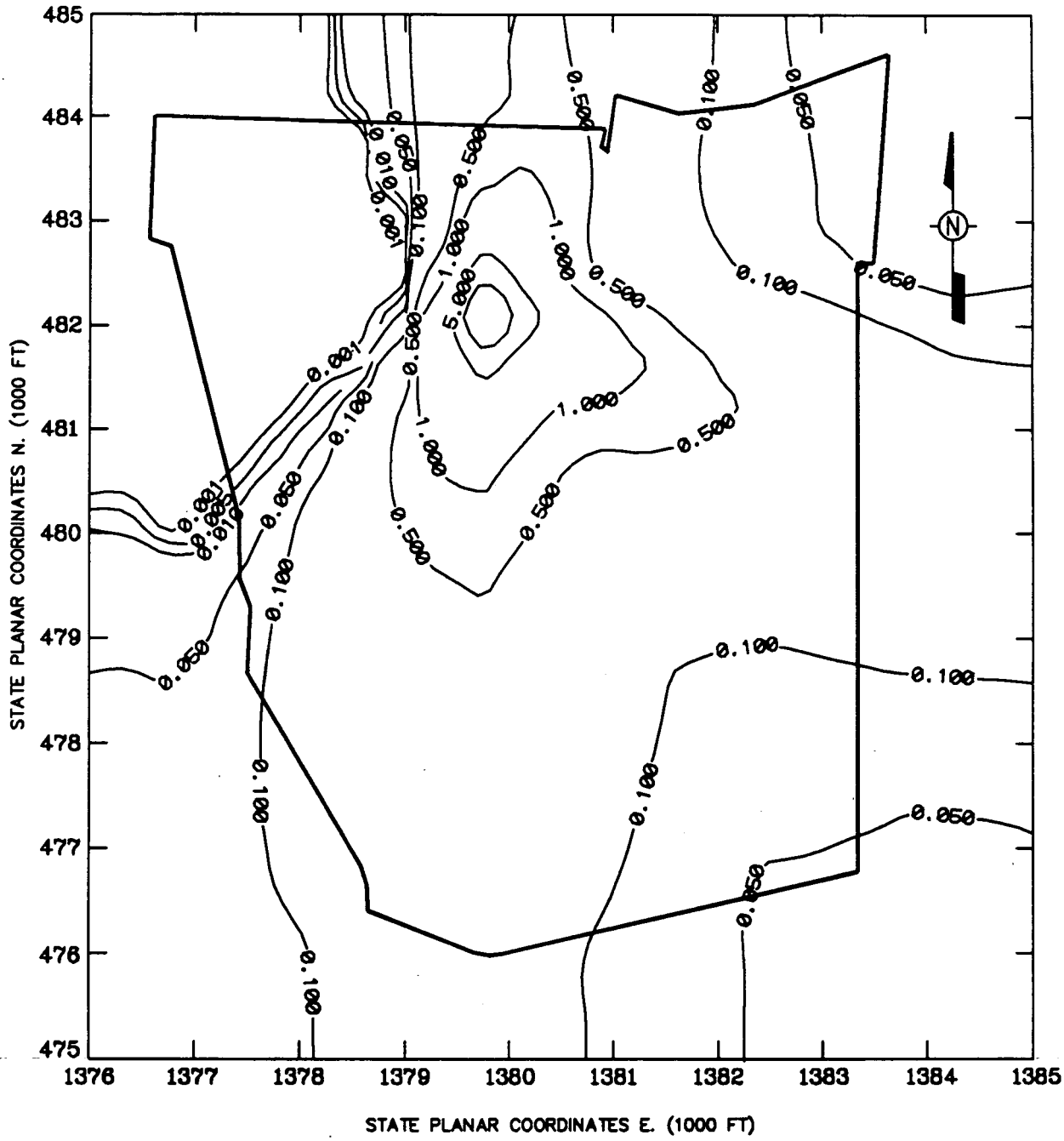

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FIGURE 5-8. RADIOACTIVITY OF AIRBORNE U-238 RESUSPENDED FROM OU-2 SOLID WASTE LANDFILL

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slightly higher concentrations may exist in the 100 meter space between adjacent grid nodes. The off-site concentrations are based on projections at locations along the FEMP boundary.

5.4.1.2 Surface Water Results

Table 5-3 presents the results of surface water modeling for the Solid Waste Landfill based upon a single storm event (6.4 cm in 24 hours) (Hershfield 1961) using the MUSLE model. The model shows that the small mass of contaminants that partition into the water, combined with a dilution flow in Paddys Run of 0.2 to 4.0 ft^3/sec (Dames and Moore 1985a), results in low surface water concentrations from the Solid Waste Landfill, usually much less than parts per billion, however, the highest modeled concentration, for uranium-238, was 420 µg/ℓ. These concentrations remain only through the duration of the storm. When rainfall and runoff cease, surface water concentrations are likely to return to non-detectable levels, as indicated by the surface water sampling results.

Modeled sediment concentrations resulting from a single runoff event are comparable to the source term soil concentrations for the Solid Waste Landfill. For example, the modeled sediment concentration for uranium-238 was 340 mg/kg, compared to 359 mg/kg in the soil source term. Sediment concentrations would be expected to decrease following the rainfall event because of dispersion through sediment transport and gradual mixing with sediment from other sources.

5.4.1.3 Groundwater Results

The groundwater fate and transport modeling results are summarized in Table 5-4 for the constituents of concern that will reach the Great Miami Aquifer within 1000 years from the Solid Waste Landfill. The simulation time period of 1000 years was selected based on the Risk Assessment Work Plan Addendum (DOE 1992a). The table also presents the arrival time for the constituents to reach the aquifer, the maximum loading concentration, the maximum concentrations of the constituents that would be expected in the aquifer within 1000 years and the time required for the constituents to reach the maximum value. It also presents the predicted maximum concentration at the FEMP boundary due to loading from the Solid Waste Landfill. Screening levels have been developed based on a 10^{-7} lifetime risk of cancer, presented in Appendix A, and provide a basis for understanding the risk to human health from the ingestion of water from the Great Miami Aquifer at the hypothetical receptor location. The constituents projected to be above the screening levels in the Great Miami Aquifer directly beneath the Solid Waste Landfill are the uranium isotopes uranium-234, uranium-235, and uranium-238. None of the constituents are projected to exceed screening levels at the FEMP boundary. Contour plots were made for uranium at different time periods (Appendix B). As an example, Figure 5-9 depict a plume of uranium in groundwater beneath the Solid Waste Landfill and moving towards the southeastern boundary of the FEMP. The plots show the future concentration profiles predicted by the SWIFT-III model at the time of maximum loading concentration at the boundary between the vadose zone and the Great Miami Aquifer.

TABLE 5-3

CONTAMINANT LOADING TO SURFACE WATER FROM THE SOLID WASTE LANDFILL

Constituent	Chemical Data: Partition Coefficient, Kd (ml/g)	Chemical Data: Concentration in Waste Area, Ci (mg/kg)	Results: Total Annual Loading to Stream, Tl (g/yr)	Results: Concentration in Surface Water During Storm Event, Cw (mg/ℓ)	Results: Concentration in Sediment, Cs (mg/kg)
Radionuclides					
Plutonium-238	1.70E+03	5.84E-09	2.36E-09	7.54E-15	5.84E-09
Radium-224	6.96E+02	1.26E-11	5.28E-12	3.98E-17	1.26E-11
Radium-226	6.96E+02	1.04E-06	4.36E-07	3.28E-12	1.04E-06
Radium-228	6.96E+02	5.73E-09	2.40E-09	1.81E-14	5.73E-09
Strontium-90	1.00E+01	4.42E-09	9.88E-09	9.63E-13	4.38E-09
Thorium-228	5.80E+03	4.89E-09	1.93E-09	1.85E-15	4.89E-09
Thorium-230	5.80E+03	2.75E-04	1.09E-04	1.04E-10	2.75E-04
Thorium-232	5.80E+03	1.86E+01	7.36E+00	7.04E-06	1.86E+01
Uranium-234	1.80E+00	8.07E-03	8.28E-02	9.42E-06	7.72E-03
Uranium-235	1.80E+00	7.73E-01	7.93E+00	9.02E-04	7.39E-01
Uranium-238	1.80E+00	3.59E+02	3.68E+03	4.19E-01	3.43E+02
Inorganics					
Antimony	2.50E+02	1.32E+01	6.17E+00	1.16E-04	1.32E+01
Barium	1.14E+03	1.53E+02	6.30E+01	3.00E-04	1.50E+02
Beryllim	1.30E+02	9.75E-01	4.00E-01	1.60E-06	9.70E-01
Cadmium	5.00E+02	5.31E-00	2.30E+00	2.30E-05	5.30E+00
Chromium	1.50E+03	3.66E+01	1.50E+01	5.40E-05	3.70E+01
Cobalt	5.50E+02	1.63E+01	6.90E+00	6.50E-05	1.60E+01
Copper	1.25E+02	2.58E+01	1.40E+01	4.50E-04	2.60E+01
Lead	3.00E+03	3.06E+01	1.20E+01	2.20E-05	3.10E+01
Molybdenum	9.00E+01	1.67E+01	9.99E+00	4.07E-04	1.67E+01
Silver	1.80E+02	1.19E+01	5.91E+00	1.45E-04	1.19E+01
Thallium	1.50E+03	6.05E-01	2.40E-01	8.90E-07	6.00E-01
Organics					
1,1-Dichloroethane	1.18E+00	6.00E-03	9.06E-02	1.04E-05	5.61E-03
1,2-Dichloroethane	5.40E-01	3.00E-03	9.08E-02	1.06E-05	2.60E-03
1,2-Dichloroethene	2.36E+00	4.00E-03	3.20E-02	3.60E-06	3.87E-03
1,4-Dioxane	7.28E-03	1.29E+01	2.69E+03	3.17E-01	1.05E+00
2-Butanone	3.47E-02	5.00E-03	7.98E-01	9.42E-05	1.49E-03
2-Chlorophenol	2.71E+00	4.90E-02	3.46E-01	3.86E-05	4.76E-02
2-Hexanone	4.59E-01	1.00E-03	3.47E-02	4.06E-06	8.49E-04
2-Methylnaphthalene	1.39E+02	9.30E-02	4.89E-02	1.47E-06	9.29E-02
2-Methyl phenol	1.71E+00	9.60E-02	1.03E+00	1.18E-04	9.16E-02
2,4-Dimethyl phenol	5.04E+00	2.40E-01	9.65E-01	1.03E-04	2.36E-01
4-Chloro-3-methylphenol	2.41E+01	5.50E-02	6.38E-02	4.99E-06	5.48E-02
4-Methyl-2-Pentanone	2.36E-01	1.00E-03	5.89E-02	6.92E-06	7.42E-04

TABLE 5-3
(continued)

Constituent	Chemical Data: Partition Coefficient, Kd (ml/g)	Chemical Data: Concentration in Waste Area, Ci (mg/kg)	Results: Total Annual Loading to Stream, Tl (g/yr)	Results: Concentration in Surface Water During Storm Event, Cw (mg/ℓ)	Results: Concentration in Sediment, Cs (mg/kg)
4-Methyl phenol	1.52E+00	3.60E-01	4.31E+00	4.93E-04	3.42E-01
Acenaphthene	1.59E+02	2.66E-01	1.35E-01	3.67E-06	2.66E-01
Acetone	1.09E-02	2.60E-02	5.21E+00	6.15E-04	3.06E-03
Anthracene	5.36E+02	2.89E-01	1.23E-01	1.18E-06	2.89E-01
Total PCBs	2.47E+04	2.00E+00	7.88E-01	1.78E-07	2.00E+00
Benzoic acid	1.42E+00	1.10E-01	1.40E+00	1.61E-04	1.04E-01
Bis(2-Ethylhexyl)phthalate	3.83E+03	3.36E-01	1.33E-01	1.93E-07	3.36E-01
Chlorobenzene	1.33E+01	3.00E-03	5.36E-03	4.94E-07	2.98E-03
Chloromethane	1.56E-01	6.00E-03	4.71E-01	5.55E-05	3.93E-03
Dibenzofuran	2.53E+02	2.46E-01	1.15E-01	2.14E-06	2.46E-01
Diethyl phthalate	1.75E+01	3.05E-01	4.43E-01	3.82E-05	3.04E-01
Di-n-butyl phthalate	3.03E+03	1.20E-01	4.78E-02	8.71E-08	1.20E-01
Di-n-octyl phthalate	3.03E+07	3.50E-01	1.37E-01	2.54E-11	3.50E-01
Ethylbenzene	2.68E+01	4.00E-03	4.33E-03	3.27E-07	3.99E-03
Fluoranthene	4.09E+03	5.48E-01	2.17E-01	2.94E-07	5.48E-01
Fluorene	2.87E+02	2.68E-01	1.22E-01	2.05E-06	2.68E-01
Methylene chloride	3.41E-01	1.30E-02	5.76E-01	6.75E-05	1.05E-02
Naphthalene	4.40E+01	1.40E-01	1.14E-01	6.97E-06	1.40E-01
N-Nitrosodiphenyl amine	2.59E+01	6.70E-02	7.43E-02	5.67E-06	6.68E-02
Octachlorodibenzo-p-dioxin	2.70E+04	5.00E-05	1.97E-05	4.07E-12	5.00E-05
Pentachlorophenol	1.95E+03	1.29E+00	5.19E-01	1.45E-06	1.29E+00
Phenol	5.52E-01	6.10E-02	1.81E+00	2.11E-04	5.31E-02
Total PAHs	1.83E+04	6.76E+00	2.66E+00	8.12E-07	6.76E+00
Pyrene	2.90E+03	1.15E+00	4.57E-01	8.69E-07	1.15E+00
Pyridine	8.56E-02	3.00E-03	3.34E-01	3.93E-05	1.53E-03
Styrene	2.77E+01	2.00E-03	2.12E-03	1.58E-07	1.99E-03
Tetrachloroethene	6.49E+00	4.00E-03	1.29E-02	1.34E-06	3.95E-03
Toluene	9.38E+00	2.00E-03	4.71E-03	4.64E-07	1.98E-03
Total Xylenes	2.11E+01	6.00E-03	7.62E-03	6.23E-07	5.98E-03

TABLE 5-4

SUMMARY OF CONSTITUENTS OF CONCERN WHICH WILL REACH THE AQUIFER IN 1000 YEARS FROM SOLID WASTE LANDFILL

Constituents	Time of Arrival to the Aquifer (years)	Time of Maximum Loading Concentration (years)	Maximum Loading Concentration (mg/ℓ)	Maximum Concentration in the Aquifer (mg/ℓ)	Maximum Concentration at the FEMP Boundary (mg/ℓ)	Screening Levels (mg/ℓ)
Radionuclides						
Strontium-90	280	440	1.4E-17	2.8E-19	3.4E-21	3.91E-13
Uranium-234	100	140	9.3E-06	1.9E-07	2.2E-09	1.95E-08
Uranium-235	100	140	8.9E-04	1.8E-05	2.1E-07	5.64E-05
Uranium-238	100	140	4.1E-01	8.2E-03	1.0E-04	2.08E-04
Organics						
1,4-Dioxane	10	10	3.8E-03	7.6E-05	9.1E-07	-
2-Chlorophenol	90	130	1.4E-03	2.7E-05	3.4E-07	3.65E-02
2-Hexanone	25	35	1.6E-05	3.3E-07	3.8E-09	-
4-Chloro-3-Methylphenol	740	1000	5.1E-05	1.0E-06	1.2E-08	-
Benzoic acid	60	70	7.1E-04	1.4E-05	1.7E-07	2.92E+01

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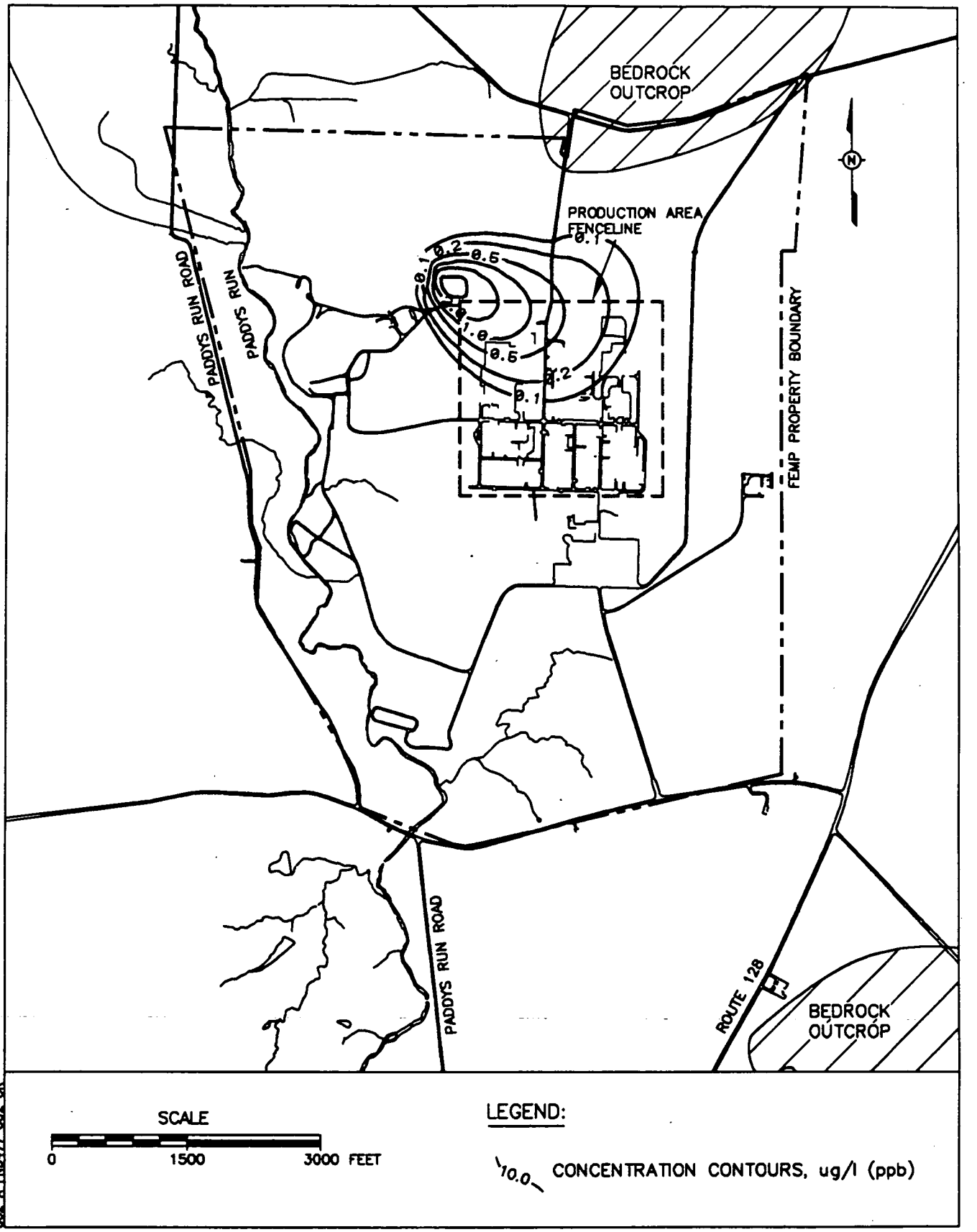

FIGURE 5-9. PROJECTED CONCENTRATION OF URANIUM IN GROUNDWATER BENEATH FEMP AFTER 140 YEARS DUE TO LOADING FROM SOLID WASTE LANDFILL

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5.4.2 North Lime Sludge Pond

5.4.2.1 Air Quality Results

The results of air quality modeling from North Lime Sludge Pond are presented in Table 5-5. This table lists the projected highest airborne concentrations for the radionuclides and inorganic and organic compounds that are of potential concern at the North Lime Sludge Pond.

The highest on-site annual concentrations of resuspended radionuclides and inorganic and organic compounds are 3.45E-05 pCi/m^3 (thorium-230) 2.20E-06 μg/m^3 (chromium), 2.18E-07 μg/m^3 (butyl benzyl phthalate), respectively. The highest off-site annual concentrations of resuspended radionuclides and inorganic and organic compounds are 6.36E-07 pCi/m^3 (thorium-230), 4.06E-08 μg/m^3 (chromium), and 4.03E-09 μg/m^3 (butyl benzyl phthalate), respectively. The concentration of airborne uranium-238 resuspended from the North Lime Sludge Pond is shown in Figure 5-10.

The maximum on-site concentrations listed in Table 5-5 are the maximum concentrations that appear at the nodes on a 100-meter x 100-meter grid over the FEMP site. It is possible that slightly higher concentrations may exist in the 100-meter space between adjacent grid nodes. The off-site concentrations are based on projections at locations along the FEMP boundary.

5.4.2.2 Surface Water Results

The North Lime Sludge Pond is contained within a soil berm which isolates it from the surrounding soils; thus, this waste area is not considered a source of contaminants to the surface waters which drain the site. No surface water pathway modeling was conducted.

5.4.2.3 Groundwater Results

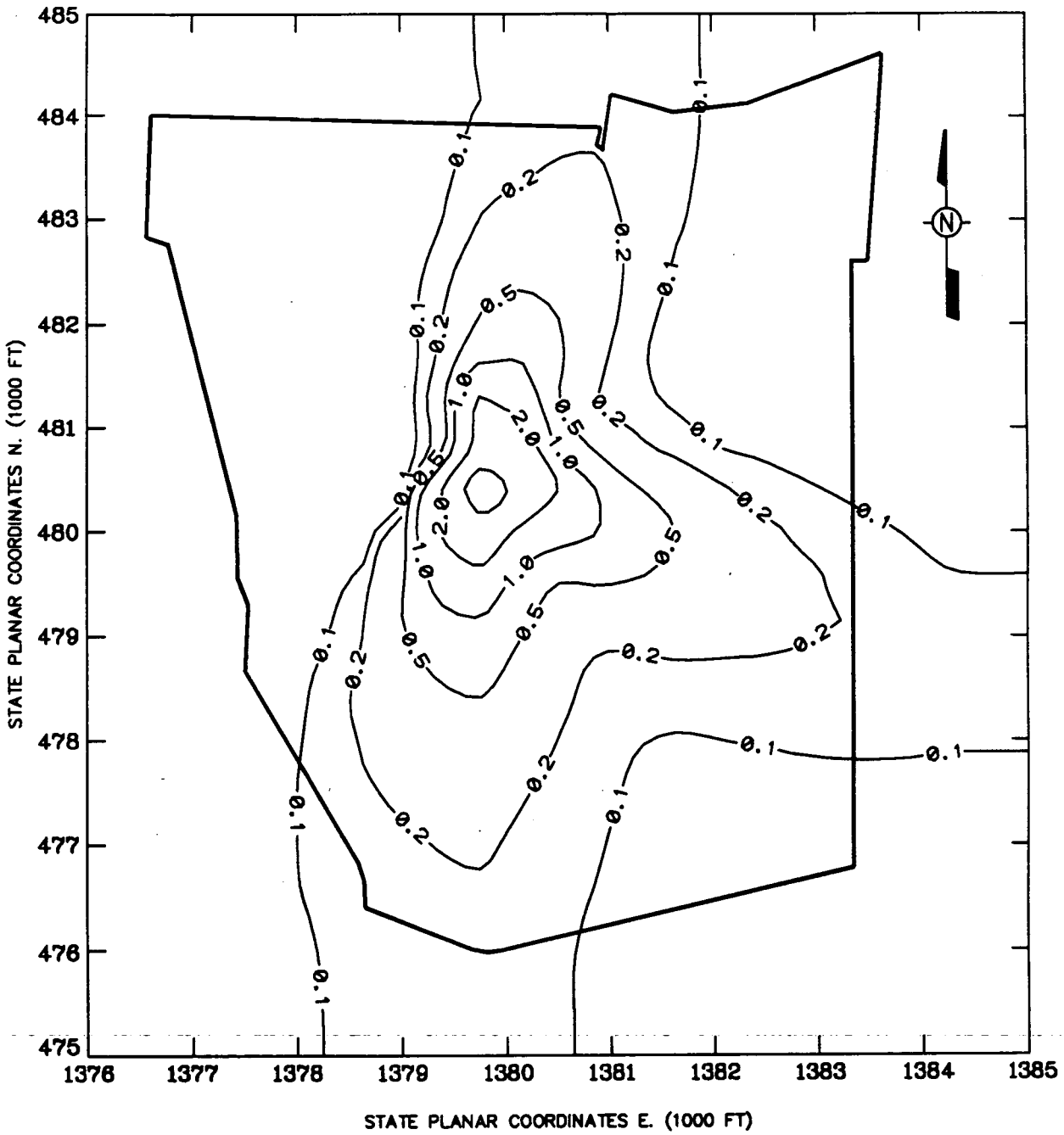
The groundwater fate and transport modeling results are summarized in Table 5-6 for the constituents of concern that will reach the Great Miami Aquifer in 1000 years from the North Lime Sludge Pond. The table also presents the arrival time for the constituents to reach the aquifer, the maximum loading concentration, the maximum concentrations of the constituents that would be expected in the aquifer within 1000 years, and the time required for the constituents to reach the maximum value. It also presents the predicted maximum concentration at the FEMP boundary due to loading from the North Lime Sludge Pond. Screening levels have been developed based on a 10^{-7} lifetime risk of cancer, presented in Appendix A, and provide a basis for understanding the risk to human health from the ingestion of water from the Great Miami Aquifer at the hypothetical receptor location. The only constituent projected to be above the screening level in the Great Miami Aquifer directly beneath the North Lime Sludge Pond is uranium-238. None of the constituents is projected to exceed screening levels at the FEMP boundary. Contour plots were made for uranium at different time periods (Appendix B). As an example, Figure 5-11 depicts a plume of uranium in groundwater beneath the

TABLE 5-5

HIGHEST ANNUAL AVERAGE CONCENTRATIONS OF RESUSPENDED CONTAMINANTS FROM THE NORTH LIME SLUDGE POND

Resuspended Particles	Highest On-site[a] Airborne Concentration[b]	Highest Off-site Airborne Concentration[b]
Radionuclides (pCi/m^3)		
Cesium-137	3.82E-08	7.05E-10
Lead-210	3.43E-06	6.33E-08
Neptunium-237	2.89E-08	5.33E-10
Plutonium-238	1.33E-08	2.45E-10
Plutonium-239/240	1.80E-08	3.33E-10
Radium-226	1.26E-06	2.33E-08
Technetium-99	5.16E-07	9.54E-09
Thorium-228	1.33E-06	2.44E-08
Thorium-230	3.45E-05	6.36E-07
Thorium-232	1.41E-06	2.59E-08
Uranium-234	8.81E-06	1.62E-07
Uranium-235/236	3.67E-07	6.78E-09
Uranium-238	9.75E-06	1.80E-07
Inorganics(μg/m^3)		
Antimony	1.72E-06	3.18E-08
Beryllium	5.93E-08	1.09E-09
Cadmium	3.12E-07	5.76E-09
Chromium	2.20E-06	4.06E-08
Cyanide	1.33E-07	2.45E-09
Mercury	2.34E-08	4.32E-10
Silver	1.72E-06	3.17E-08
Thallium	3.98E-08	7.34E-10
Organics(μg/m^3)		
1,1,2-Trichloro-1,1,2-trifluoroethane	6.32E-09	1.17E-10
Aroclor-1248	9.36E-08	1.73E-09
bis(2-Ethylhexyl) phthalate	2.42E-08	4.47E-10
Butyl benzyl phthalate	2.18E-07	4.03E-09
Chlordane	9.36E-08	1.73E-09
Di-n-butyl phthalate	9.36E-09	1.73E-10
Phenol	4.76E-08	8.79E-10

[a] Based on projections at node points on a 100-meter grid.
[b] Concentrations are based on subsurface soil values.



LEGEND:

0.500 — AIRBORNE CONCENTRATION, ATTOCURIES PER CUBIC METER OF AIR
(1 ATTOCURIE = 1.0E-6 PICOCURIES)

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FIGURE 5-10. RADIOACTIVITY OF AIRBORNE U-238 RESUSPENDED FROM OU-2 NORTH LIME SLUDGE POND

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TABLE 5-6

SUMMARY OF CONSTITUENTS OF CONCERN WHICH WILL REACH THE AQUIFER IN 1000 YEARS FROM NORTH LIME SLUDGE POND

Constituents	Time of Arrival to the Aquifer (years)	Time of Maximum Loading Concentration (years)	Maximum Loading Concentration (mg/ℓ)	Maximum Concentration in the Aquifer (mg/ℓ)	Maximum Concentration at the FEMP Boundary (mg/ℓ)	Screening Levels (mg/ℓ)
Radionuclides						
Strontium-90	200	300	7.2E-17	2.9E-18	7.9E-20	3.91E-13
Uranium-234	60	100	2.1E-07	8.2E-09	2.3E-10	1.95E-08
Uranium-235	60	100	5.6E-05	2.2E-06	6.2E-08	5.64E-05
Uranium-238	60	100	9.0E-03	3.6E-04	9.9E-06	2.08E-05
Inorganics						
Mercury	260	460	7.5E-05	3.0E-06	8.3E-08	2.19E-03
Cyanide	10	10	4.4E-04	1.8E-05	4.8E-07	1.46E-01
Organics						
2-Hexanone	15	20	5.2E-04	2.1E-05	6.2E-07	–
Carbon Disulfide	70	80	2.7E-08	1.1E-09	3.0E-11	7.30E-01

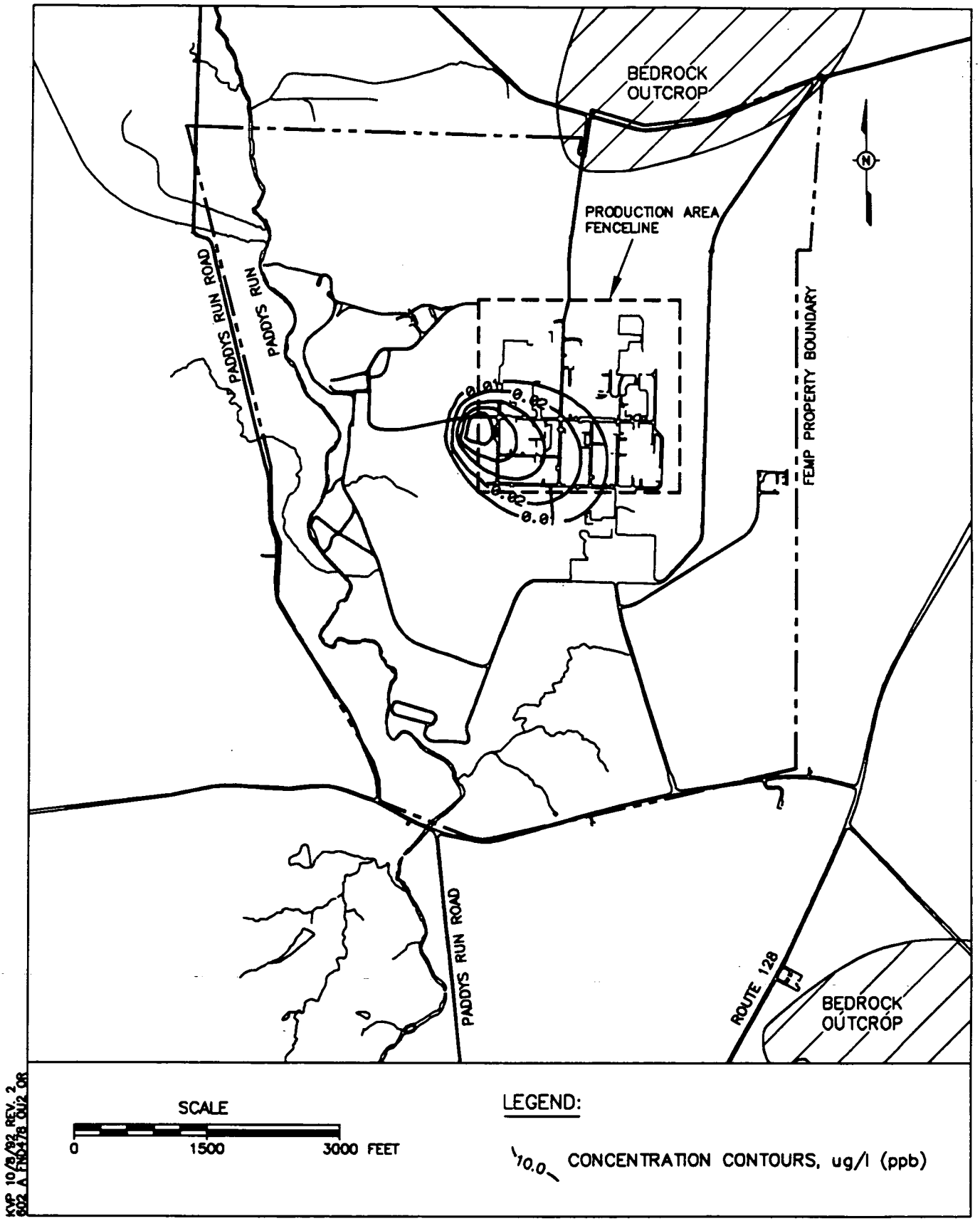

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FIGURE 5–11. PROJECTED CONCENTRATION OF URANIUM IN GROUNDWATER BENEATH FEMP AFTER 100 YEARS DUE TO LOADING FROM NORTH AND SOUTH LIME SLUDGE PONDS

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North and South Lime Sludge Ponds and moving towards the southeastern boundary of the FEMP. The plots show the future concentration profiles predicted by the SWIFT-III model at the time of maximum loading concentration at the boundary between the vadose zone and the Great Miami Aquifer.

5.4.3 South Lime Sludge Pond

5.4.3.1 Air Quality Results

The results of air quality modeling from the South Lime Sludge Pond are presented in Table 5-7. This table lists the projected highest airborne concentrations for the radionuclides and inorganic and organic compounds that are of potential concern at the South Lime Sludge Pond.

The highest on-site annual concentrations of resuspended radionuclides and inorganic and organic compounds are 9.33E-05 pCi/m^3 (thorium-230), 5.95E-06 μg/m^3 (chromium), and 6.54E-08 μg/m^3 (bis [2-ethylhexyl] phthalate), respectively. The highest off-site annual concentrations of resuspended radionuclides and inorganic and organic compounds are 1.06E-06 pCi/m^3 (thorium-230), 6.77E-08 μg/m^3 (Chromium), and 7.44E-10 μg/m^3 (bis [2-ethylhexyl] phthalate), respectively. The activity concentration of airborne uranium-238 resuspended from the South Lime Sludge Pond is shown in Figure 5-12.

Since the resuspension model does not account for surface vegetation (which significantly retards resuspension at the South Lime Sludge Pond), the simulated resuspension rates are significantly higher than actually occurs. The maximum on-site concentrations listed in Table 5-7 are the maximum concentrations that appear at the nodes on a 100-meter x 100-meter grid over the FEMP site. It is possible that slightly higher concentrations may exist in the 100-meter space between adjacent grid nodes. The off-site concentrations are based on projections at locations along the FEMP boundary.

5.4.3.2 Surface Water Results

The South Lime Sludge Pond is contained within a soil berm which isolates it from the surrounding soils; thus, this waste area is not considered a source of contaminants to the surface waters which drain the site. No surface water pathway modeling was conducted.

5.4.3.3 Groundwater Results

The groundwater fate and transport modeling results are summarized in Table 5-8 for the constituents of concern that will reach the Great Miami Aquifer in 1000 years from the South Lime Sludge Pond. The table also presents the arrival time for the constituents to reach the aquifer, the maximum loading concentration, the maximum concentrations of the constituents that would be expected in the aquifer within 1000 years, and the time required for the constituents to reach the maximum value. It also presents the predicted maximum concentration at the FEMP boundary due to loading from the South Lime Sludge Pond. Screening levels have been developed based on a 10^{-7} lifetime risk of cancer,

TABLE 5-7

HIGHEST ANNUAL AVERAGE CONCENTRATIONS OF RESUSPENDED CONTAMINANTS FROM THE SOUTH LIME SLUDGE POND

Resuspended Particles	Highest On-site[a] Airborne Concentration[b]	Highest Off-site Airborne Concentration[b]
Radionuclides (pCi/m^3)		
Cesium-137	1.03E-07	1.18E-09
Lead-210	9.28E-06	1.06E-07
Neptunium-237	7.81E-08	8.87E-10
Plutonium-238	3.59E-08	4.07E-10
Plutonium-239/240	4.86E-08	5.53E-10
Radium-226	3.40E-06	3.87E-08
Technetium-99	1.40E-06	1.59E-08
Thorium-228	3.58E-06	4.07E-08
Thorium-230	9.33E-05	1.06E-06
Thorium-232	3.80E-06	4.33E-08
Uranium-234	2.38E-05	2.70E-07
Uranium-235/236	9.94E-07	1.13E-08
Uranium-238	2.64E-05	3.01E-07
Inorganics (µg/m^3)		
Antimony	4.66E-06	5.31E-08
Beryllium	1.60E-07	1.82E-09
Cadmium	8.44E-07	9.60E-09
Chromium	5.95E-06	6.77E-08
Cyanide	3.59E-07	4.07E-09
Mercury	6.33E-08	7.20E-10
Silver	4.64E-06	5.27E-08
Thallium	1.08E-07	1.22E-09
Organics (µg/m^3)		
Benzoic acid	3.38E-08	3.84E-10
bis(2-Ethylhexyl) phthalate	6.54E-08	7.44E-10
Di-n-butyl phthalate	1.54E-08	1.76E-10
Phenol	1.88E-08	2.13E-10

[a] Based on projections at node points on a 100-meter grid.
[b] Concentrations are based on subsurface soil values.

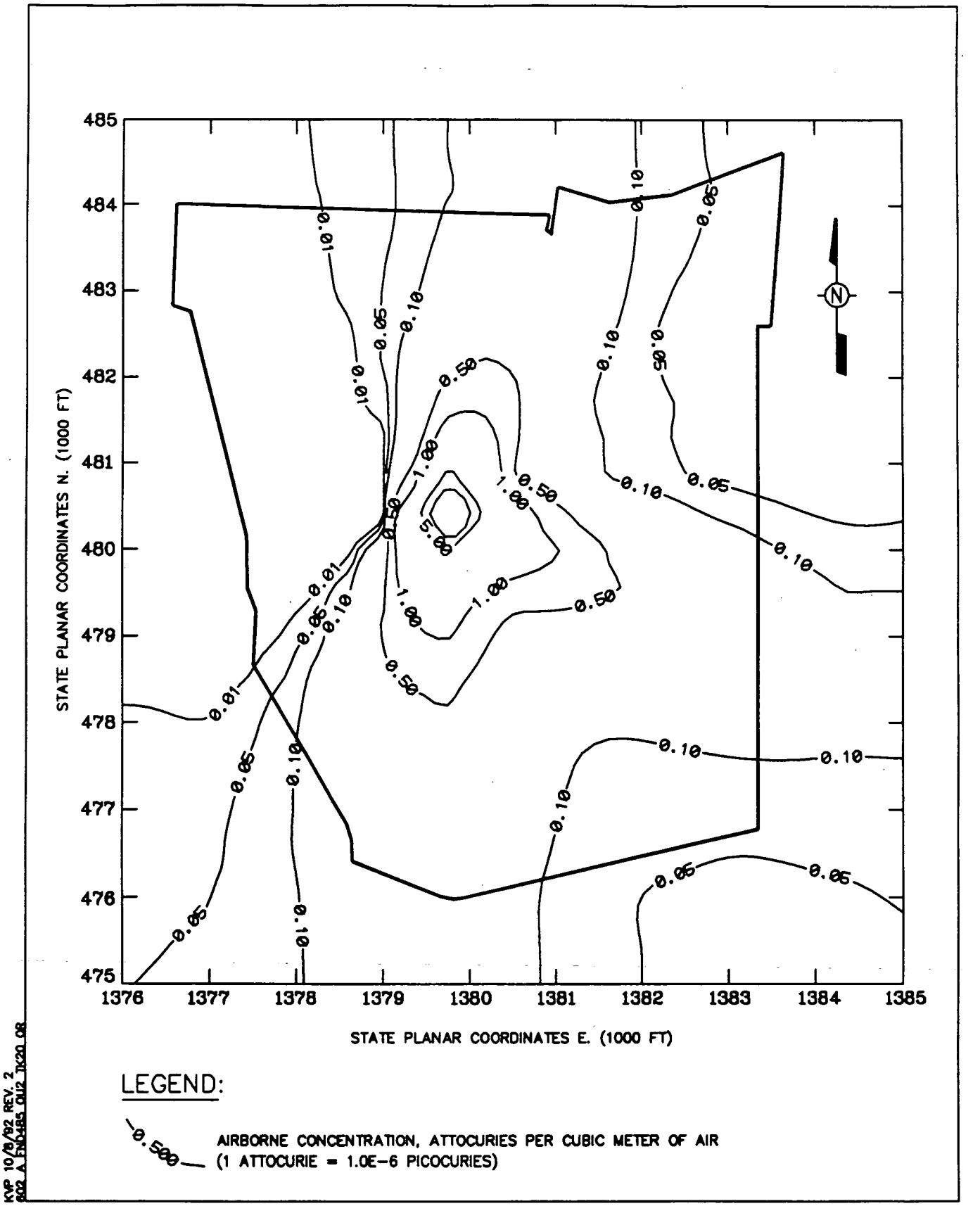

FIGURE 5-12. RADIOACTIVITY OF AIRBORNE U-238 RESUSPENDED FROM OU-2 SOUTH LIME SLUDGE POND

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TABLE 5-8

SUMMARY OF CONSTITUENTS OF CONCERN WHICH WILL REACH THE AQUIFER IN 1000 YEARS FROM SOUTH LIME SLUDGE POND

Constituents	Time of Arrival to the Aquifer (years)	Time of Maximum Loading Concentration (years)	Maximum Loading Concentration (mg/ℓ)	Maximum Concentration in the Aquifer (mg/ℓ)	Maximum Concentration at the FEMP Boundary (mg/ℓ)	Screening Levels (mg/ℓ)
Radionuclides						
Strontium-90	240	380	5.0E-17	2.0E-18	5.3E-20	3.91E-13
Uranium-234	60	100	2.2E-07	8.5E-09	2.3E-10	1.95E-08
Uranium-235	60	100	6.0E-05	2.3E-06	6.2E-08	5.64E-05
Uranium-238	60	100	9.5E-03	3.7E-04	9.9E-06	2.08E-04
Inorganics						
Mercury	300	540	8.8E-05	3.4E-06	9.2E-08	2.19E-03
Cyanide	10	10	1.1E-03	4.2E-05	1.2E-06	1.46E-01
Organics						
2-Hexanone	20	25	5.9E-04	2.3E-05	6.2E-07	–
Benzoic acid	40	60	6.3E-05	2.4E-06	6.6E-08	2.92E+01

presented in Appendix A, and provide a basis for understanding the risk to human health from the ingestion of water from the Great Miami Aquifer at the hypothetical receptor location. The only constituents projected to be above the screening level in the Great Miami Aquifer directly beneath the South Lime Sludge Pond is the uranium-238. None of the constituents is projected to exceed screening levels at the FEMP boundary.

Contour plots were made for uranium at different time periods (Appendix B). As an example, Figure 5-11 depict a plume of uranium in groundwater beneath the South Lime Sludge Pond and is moving towards the southeastern boundary of the FEMP. The plots show the future concentration profiles predicted by the SWIFT-III model at the time of maximum loading concentration at the boundary between the vadose zone and the Great Miami Aquifer.

5.4.4 Active Flyash Pile

5.4.4.1 Air Quality Results

The results of air quality modeling from the Active Flyash Pile are presented in Table 5-9. This table lists the projected highest airborne concentrations for the radionuclides and inorganic and organic compounds that are of potential concern at the Active Flyash Pile.

The highest on-site annual concentrations of resuspended radionuclides and inorganic and organic compounds are 2.14E-06 pCi/m^3 (uranium-234), 1.08E-04 μg/m^3 (barium), and 8.53E-08 μg/m^3 (di-n-octyl phthalate), respectively. The highest off-site annual concentrations of resuspended radionuclides and inorganic and organic compounds are 2.89E-07 pCi/m^3 (uranium-234), 1.46E-05 μg/m^3 (barium), 1.15E-08 μg/m^3 (di-n-octyl phthalate), respectively. The concentration of airborne uranium-238 resuspended from the Active Flyash Pile is shown in Figure 5-13.

The maximum on-site concentrations listed in Table 5-9 are the maximum concentrations that appear at the nodes on a 100-meter x 100-meter grid over the FEMP site. It is possible that slightly higher concentrations may exist in the 100-meter space between adjacent grid nodes. The off-site concentrations are based on projections at locations along the FEMP boundary.

5.4.4.2 Surface Water Results

Table 5-10 presents the results of surface water modeling from the Active Flyash Pile based upon a single storm event (6.4 cm in 24 hours) (Hershfield 1961) using the MUSLE model. The model shows that the small mass of contaminants that partition into the water, combined with a dilution flow in Paddys Run of 0.2 to 4.0 ft^3/s (Dames and Moore 1985a), results in low surface water concentrations from the Active Flyash Pile, usually much less than parts per billion. The highest modeled concentration, for uranium-238, was 83 μg/L. These concentrations remain only through the duration

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TABLE 5-9

HIGHEST ANNUAL AVERAGE CONCENTRATIONS OF RESUSPENDED CONTAMINANTS FROM THE ACTIVE FLYASH PILE

Resuspended Particles	Highest On-site[a] Airborne Concentration[b]	Highest Off-site Airborne Concentration[b]
Radionuclides (pCi/m^3)		
Lead-210	3.52E-07	4.74E-08
Radium-224	8.08E-07	1.09E-07
Radium-226	8.38E-07	1.13E-07
Radium-228	6.91E-07	9.29E-08
Strontium-90	4.02E-07	5.41E-08
Thorium-228	7.73E-07	1.04E-07
Thorium-230	8.62E-07	1.16E-07
Thorium-232	5.96E-07	8.09E-08
Uranium-234	2.14E-06	2.89E-07
Uranium-235/236	1.45E-07	1.95E-08
Uranium-238	1.47E-06	1.98E-07
Inorganics (µg/m^3)		
Antimony	6.72E-06	9.07E-07
Arsenic	1.44E-05	1.93E-06
Barium	1.08E-04	1.46E-05
Beryllium	9.73E-07	1.31E-07
Cadmium	2.48E-07	3.34E-08
Chromium	5.21E-06	7.01E-07
Copper	1.17E-05	1.58E-06
Lead	7.34E-06	9.88E-07
Molybdenum	3.42E-06	4.61E-07
Selenium	2.20E-06	2.97E-07
Thallium	2.42E-07	3.25E-08
Zinc	2.00E-05	2.69E-06
Organics (µg/m^3)		
2-Chlorophenol	1.04E-08	1.39E-09
2-Methylnapthalene	3.46E-08	4.65E-09
4-Chloro-3-methylphenol	1.25E-08	1.69E-09
4-Nitrophenol	1.04E-08	1.39E-09
Benzoic acid	1.58E-08	2.12E-09
bis(2-Ethylhexyl) phthalate	8.23E-08	1.11E-08
Di-n-butyl phthalate	1.49E-08	2.01E-09
Di-n-octyl phthalate	8.53E-08	1.15E-08

TABLE 5-9
(continued)

Resuspended Particles	Highest On-site[a] Airborne Concentration[b]	Highest Off-site Airborne Concentration[b]
Organics ($\mu g/m^3$)		
Napthalene	1.77E-08	2.38E-09
Phenanthrene	1.56E-08	2.09E-09
Phenol	1.25E-08	1.69E-09

[a] Based on projections at node points on a 100-meter grid.
[b] Concentrations are based on subsurface soil values.

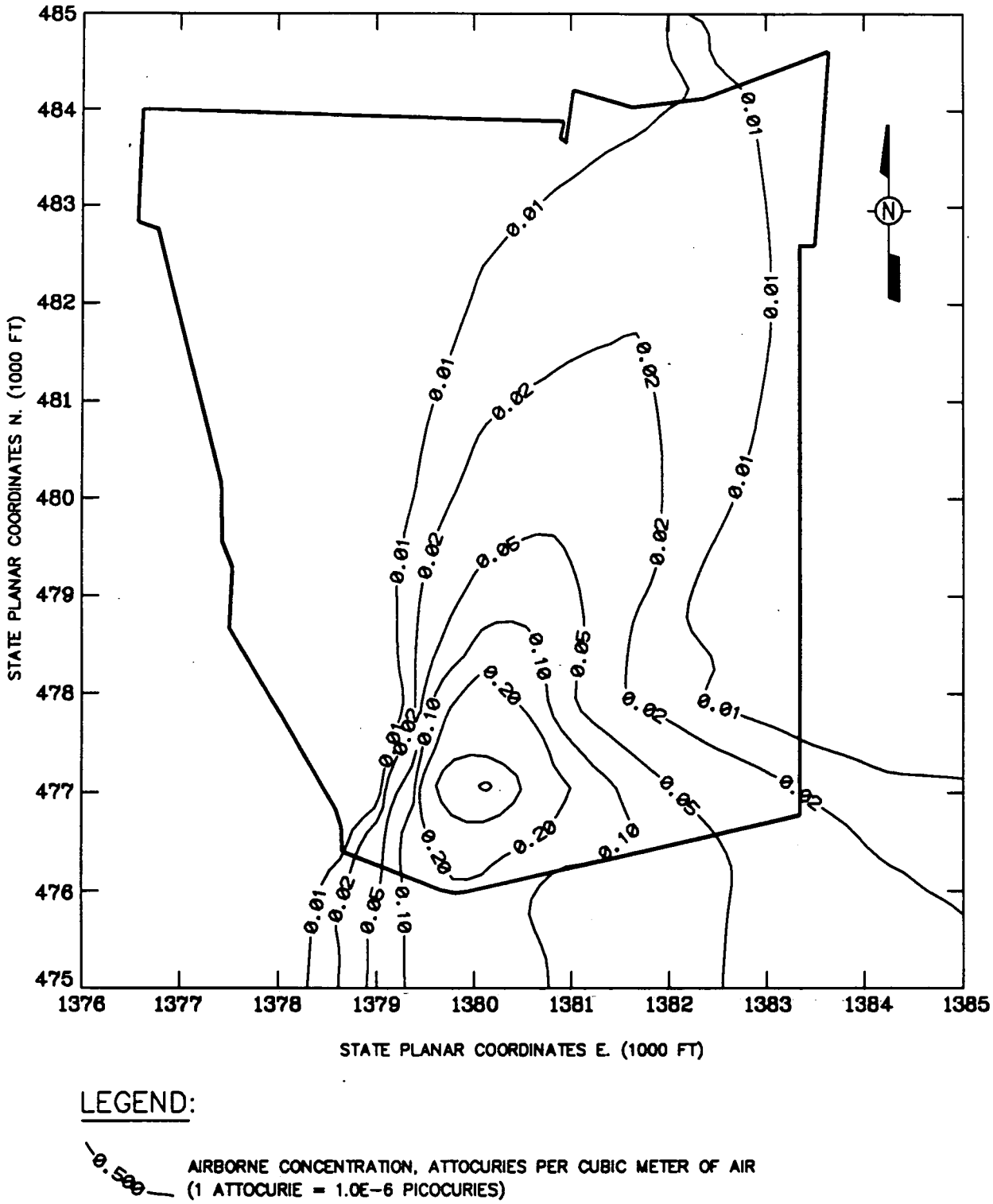

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FIGURE 5-13. RADIOACTIVITY OF AIRBORNE U-238 RESUSPENDED FROM OU-2 ACTIVE FLYASH PILE

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TABLE 5-10

CONTAMINANT LOADING TO SURFACE WATER FROM THE ACTIVE FLYASH PILE

	Chemical Data		Results		
Constituent	Partition Coefficient, Kd (ml/g)	Concentration in Waste Area, Ci (mg/kg)	Total Annual Loading to Stream, Tl (g)	Concentration in Surface Water During Storm Event, Cw (mg/ℓ)	Concentration in Sediment, Cs (mg/kg)
Radionuclides					
Lead-210	3.00E+03	2.13E-08	8.87E-07	5.55E-14	2.13E-08
Radium-224	6.96E+02	2.32E-11	9.70E-10	2.61E-16	2.32E-11
Radium-226	6.96E+02	3.92E-06	1.64E-04	4.40E-11	3.92E-06
Radium-228	6.96E+02	1.17E-08	4.90E-07	1.32E-13	1.17E-08
Strontium-90	1.00E+01	1.34E-08	6.88E-07	1.03E-11	1.32E-08
Thorium-228	5.80E+03	4.37E-09	1.82E-07	5.88E-15	4.36E-09
Thorium-230	5.80E+03	1.97E-04	8.22E-03	2.66E-10	1.97E-04
Thorium-232	5.80E+03	2.52E+01	1.05E+03	3.39E-05	2.51E+01
Uranium-234	1.80E+00	1.59E-03	1.47E-01	6.47E-06	1.49E-03
Uranium-235	1.80E+00	3.07E-01	2.85E+01	1.25E-03	2.89E-01
Uranium-238	1.80E+00	2.03E+01	1.88E+03	8.26E-02	1.90E+01
Inorganics					
Antimony	2.50E+02	3.11E+01	1.31E+03	9.71E-04	3.11E+01
Arsenic	2.00E+02	6.65E+01	2.80E+03	2.60E-03	6.60E+01
Barium	1.14E+03	5.00E+02	2.10E+04	3.40E-03	5.00E+02
Beryllium	1.30E+03	4.50E+00	1.88E+02	2.71E-05	4.50E+00
Cadmium	5.00E+02	1.15E+00	4.80E+01	1.80E-05	1.10E+00
Chromium	1.50E+03	2.41E+01	1.00E+03	1.30E-04	2.40E+01
Copper	1.25E+02	5.44E+01	2.30E+03	3.40E-03	5.40E+01
Lead	3.00E+03	3.40E+01	1.40E+03	8.80E-05	3.40E+01
Molybdenum	9.00E+01	1.58E+01	6.77E+02	1.37E-03	1.58E+01
Selenium	7.40E+02	1.02E+01	4.26E+02	1.08E-04	1.02E+01
Thallium	1.50E+03	1.12E+00	4.70E+01	5.80E+06	1.10E+00
Zinc	2.40E+03	9.26E+01	3.90E+03	3.00E+04	9.30E+01
Organics					
1,1,1-Trichloroethane	5.65E+00	1.30E+00	7.62E+01	1.76E-03	1.27E+00
1,1,2-Trichloroethane	2.87E+00	4.90E-02	3.65E+00	1.28E-04	4.71E-02
1,2-Dichloroethane	5.40E-01	2.00E-03	3.83E-01	2.38E-05	1.65E-03
2-Butanone	3.47E-02	4.00E-03	2.78E+00	2.08E-04	9.24E-04
2-Chlorophenol	2.71E+00	4.80E-02	3.67E+00	1.33E-04	4.60E-02
2-Methylnaphthalene	1.39E+02	1.60E-01	6.77E+00	9.01E-06	1.60E-01

TABLE 5-10
(continued)

Constituent	Chemical Data: Partition Coefficient, Kd (ml/g)	Chemical Data: Concentration in Waste Area, Ci (mg/kg)	Results: Total Annual Loading to Stream, Tl (g)	Results: Concentration in Surface Water During Storm Event, Cw (mg/ℓ)	Results: Concentration in Sediment, Cs (mg/kg)
4-Chloro-3-methylphenol	2.41E+01	5.80E-02	2.65E+00	1.87E-05	5.77E-02
4-Methyl-2-Pentanone	2.36E-01	1.50E-02	4.81E+00	3.34E-04	1.01E-02
4-Nitrophenol	1.56E+00	4.80E-02	4.81E+00	2.24E-04	4.47E-02
Acetone	1.09E-02	1.70E-02	1.39E+01	1.05E-03	1.47E-03
Total PCBs	2.47E+04	3.80E-02	1.58E+00	1.20E-08	3.80E-02
Benzene	2.59E+00	2.00E-03	1.56E-01	5.78E-06	1.91E-03
Benzoic acid	1.42E+00	7.30E-02	7.70E+00	3.71E-04	6.75E-02
Bis(2-Ethylhexyl)phthalate	3.83E+03	3.81E-01	1.59E+01	7.77E-07	3.81E-01
Carbondisulfide	2.78E+00	5.00E-03	3.78E-01	1.35E-05	4.80E-03
Di-n-butyl phthalate	3.03E+03	6.90E-02	2.87E+00	1.78E-07	6.90E-02
Di-n-octyl phthalate	3.03E+07	3.95E-01	1.64E+01	1.02E-10	3.95E-01
Methylene chloride	3.41E-01	4.10E-02	1.05E+01	7.02E-04	3.06E-02
Naphthalene	4.40E+01	8.20E-02	3.60E+00	1.45E-05	8.18E-02
Phenol	5.52E-01	5.80E-02	1.09E+01	6.79E-04	4.80E-02
Total PAHs	1.83E+04	7.20E-02	3.00E+00	3.07E-08	7.20E-02

storm. When rainfall and runoff cease, surface water concentrations are likely to return to nondetectable steady-state conditions, as indicated by surface water sampling.

Modeled sediment concentrations resulting from a single runoff event are comparable to the source term soil concentrations for the Active Flyash Pile. For example, the modeled Uranium-238 sediment concentration was 19 mg/kg, compared to 20 mg/kg in the soil source term. Sediment concentrations would be expected to decrease following the rainfall event because of dispersion through sediment transport and gradual mixing with sediment from other sources.

5.4.4.3 Groundwater Results

The groundwater fate and transport modeling result are summarized in Table 5-11 for the constituents of concern that will reach the Great Miami Aquifer within 1000 years from the Active Flyash Pile. The table also presents the arrival time for the constituents to reach the aquifer, the maximum loading concentration, the maximum concentrations of the constituents that would be expected in the aquifer within 1000 years and the time required for the constituents to reach the maximum value. It also presents the predicted maximum concentration at the FEMP boundary due to loading from the Active Flyash Pile. Screening levels have been developed, based on 10^{-7} lifetime risk of cancer, presented in Appendix A, and provide a basis for understanding the risk to human health from the ingestion of water from the Great Miami Aquifer at the hypothetical receptor location. The constituents projected to be above the screening levels in the Great Miami Aquifer directly beneath the Active Flyash Pile are the uranium isotopes uranium-234, uranium-235 and uranium-238, and molybdenum. None of the constituents is projected to exceed screening levels at the FEMP boundary. Contour plots were made for uranium at different time periods (in Appendix B). As an example, Figure 5-14 depict a plume of uranium in groundwater beneath the Active Flyash Pile and moving towards the southeastern boundary of the FEMP. The plots show the future concentration profiles predicted by the SWIFT-III model at the time of maximum concentration at the boundary between the vadose zone and the Great Miami Aquifer.

5.4.5 Inactive Flyash Pile

5.4.5.1 Air Quality Results

The results of air quality modeling from the Inactive Flyash Pile are presented in Table 5-12. This table lists the projected highest airborne concentrations for the radionuclides, organic, and inorganic compounds that are of potential concern at the Inactive Flyash Pile.

The highest on-site annual concentrations of resuspended radionuclides and inorganic and organic compounds are 1.89E-04 pCi/m^3 (uranium-238), 1.63E-04 µg/m^3 (barium), and 1.21E-07 µg/m^3 (bis [2-ethylhexyl] phthalate), respectively. The highest off-site annual concentrations of resuspended radionuclides and inorganic and organic compounds are 1.50E-05 pCi/m^3 (uranium-238), 1.30E-05

TABLE 5-11

SUMMARY OF CONSTITUENTS OF CONCERN WHICH WILL REACH THE AQUIFER IN 1000 YEARS FROM ACTIVE FLYASH PILE

Constituents	Time of Arrival to the Aquifer (years)	Time of Maximum Loading Concentration (years)	Maximum Loading Concentration (mg/ℓ)	Maximum Concentration in the Aquifer (mg/ℓ)	Maximum Concentration at the FEMP Boundary (mg/ℓ)	Screening Levels (mg/ℓ)
Radionuclides						
Strontium-90	100	220	3.9E-13	1.4E-14	2.8E-15	3.91E-13
Uranium-234	60	160	2.1E-07	7.4E-09	1.5E-09	1.95E-08
Uranium-235	60	160	4.1E-05	1.4E-06	3.0E-07	5.64E-05
Uranium-238	60	160	2.7E-03	9.4E-05	2.0E-05	2.08E-04
Inorganics						
Barium	640	1000	3.2E-04	1.1E-05	2.3E-06	5.11E-01
Molybdenum	320	800	9.5E-02	2.5E-03	2.5E-04	3.65E-02
Organics						
2-Chlorophenol	40	90	2.2E-03	7.8E-05	1.6E-05	3.65E-02
4-Chloro-3-Methylphenol	340	760	3.2E-04	1.1E-05	2.3E-06	–
Benzoic acid	25	50	5.4E-03	1.9E-04	3.9E-05	2.92E+01
Carbon disulfide	50	90	2.2E-04	7.5E-06	1.9E-06	7.30E-01

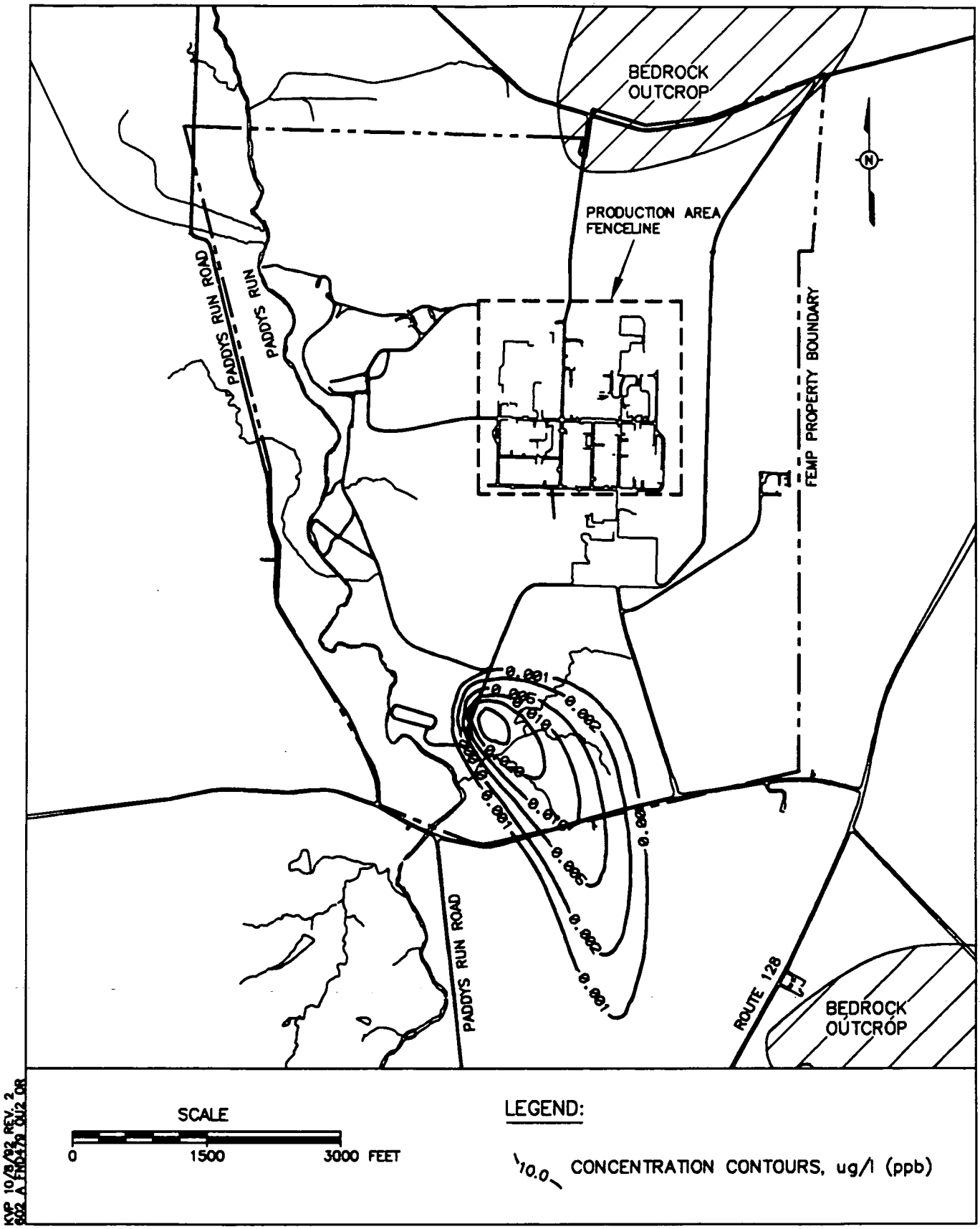

FIGURE 5-14. PROJECTED CONCENTRATION OF URANIUM IN GROUNDWATER BENEATH FEMP AFTER 160 YEARS DUE TO LOADING FROM ACTIVE FLYASH PILE

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TABLE 5-12

HIGHEST ANNUAL AVERAGE CONCENTRATIONS OF RESUSPENDED CONTAMINANTS FROM THE INACTIVE FLYASH PILE

Resuspended Particles	Highest On-site[a] Airborne Concentration[b]	Highest Off-site Airborne Concentration[b]
Radionuclides (pCi/m^3)		
Plutonium-239/240	2.27E-07	1.81E-08
Radium-226	9.19E-06	7.30E-07
Technetium-99	1.30E-05	1.04E-06
Thorium-228	1.32E-06	1.06E-07
Thorium-230	9.56E-06	7.61E-07
Thorium-232	1.08E-06	8.58E-08
Uranium-234	9.45E-05	7.51E-06
Uranium-235/236	3.38E-05	2.69E-06
Uranium-238	1.89E-04	1.50E-05
Inorganics (µg/m^3)		
Antimony	3.93E-06	3.12E-07
Arsenic	2.68E-05	2.14E-06
Barium	1.63E-04	1.30E-05
Beryllium	1.98E-06	1.57E-07
Cadmium	7.73E-07	6.15E-08
Copper	1.14E-05	9.05E-07
Cyanide	3.20E-07	2.55E-08
Lead	1.17E-05	9.32E-07
Selenium	9.03E-07	7.18E-08
Thallium	1.80E-07	1.43E-08
Organics (µg/m^3)		
Aroclor-1254	7.81E-08	6.21E-09
Benzo(a)anthracene	4.09E-08	3.25E-09
Benzo(a)pyrene	4.84E-08	3.85E-09
Benzo(b)fluoranthene	9.04E-08	7.18E-09
Benzo(k)fluoranthene	8.52E-08	6.77E-09
Benzoic acid	5.58E-08	4.44E-09
bis(2-Ethylhexyl) phthalate	1.21E-07	9.62E-09
Chrysene	5.58E-08	4.44E-09
Fluoranthene	3.50E-08	2.78E-09
Phenol	7.07E-08	5.62E-09
Pyrene	4.46E-08	3.55E-09

[a] Based on projections at node points on a 100-meter grid.
[b] Concentrations are based on subsurface soil values.

$\mu g/m^3$ (barium), and 9.62E-09 $\mu g/m^3$ (bis [2-ethylhexyl] phthalate). The concentration of airborne uranium-238 resuspended from the Inactive Flyash Pile is shown in Figure 5-15.

Since the resuspension model does not account for surface vegetation (which significantly retards resuspensions at the Inactive Flyash Pile), the simulated resuspension rates are significantly higher than actually occurs. The maximum on-site concentrations listed in Table 5-12 are the maximum concentrations that appear at the nodes on a 100-meter x 100-meter grid over the FEMP site. Slightly higher concentrations may exist in the 100-meter space between adjacent grid nodes. The off-site concentrations are based on projections at locations along the FEMP boundary.

5.4.5.2 Surface Water Results

Table 5-13 presents the results of surface water modeling from the Inactive Flyash Pile, based upon a single storm event (6.4 cm in 24 hours) (Hershfield 1961), using the MUSLE model. The model shows that the small mass of contaminants that partition into the water, combined with a dilution flow in Paddys Run of 0.2 to 4.0 ft^3/s (Dames and Moore 1985a), results in low surface water concentrations from the Inactive Flyash Pile, usually much less than parts per billion. The highest modeled concentration, for uranium-238, was 440 $\mu g/L$. These concentrations remain only through the duration of the storm. At the point that rainfall ceases and runoff ceases, surface water concentrations are likely to return to nondetectable steady-state conditions, as indicated by surface water sampling.

Modeled sediment concentrations resulting from a single runoff event are comparable to the source term soil concentrations for the Inactive Flyash Pile. For example, the modeled uranium-238 sediment concentration was 139 mg/kg, compared to 152 mg/kg in the soil source term. Sediment concentrations would be expected to decrease following the rainfall event because of dispersion through sediment transport and gradual mixing with sediment from other sources.

5.4.5.3 Groundwater Results

The groundwater fate and transport modeling results are summarized in Table 5-14 for the constituents of concern that will reach the Great Miami Aquifer within 1000 years from the Inactive Flyash Pile. The table also presents the arrival time for the constituents to reach the aquifer, the maximum loading concentration, the maximum concentrations of the constituents that would be expected in the aquifer within 1000 years, and the time required for the constituents to reach the maximum value. It also presents the predicted maximum concentration at the FEMP boundary due to loading from the Inactive Flyash Pile. Screening levels have been developed based on a 10^{-7} lifetime risk of cancer, presented in Appendix A, and provide a basis for understanding the risk to human health from the ingestion of water from the Great Miami Aquifer at the hypothetical receptor location. The constituents projected to be above the screening levels in the Great Miami Aquifer directly beneath the Inactive Flyash Pile are the uranium isotopes uranium-234, uranium-235 and uranium-238, and neptunium-237. Only uranium

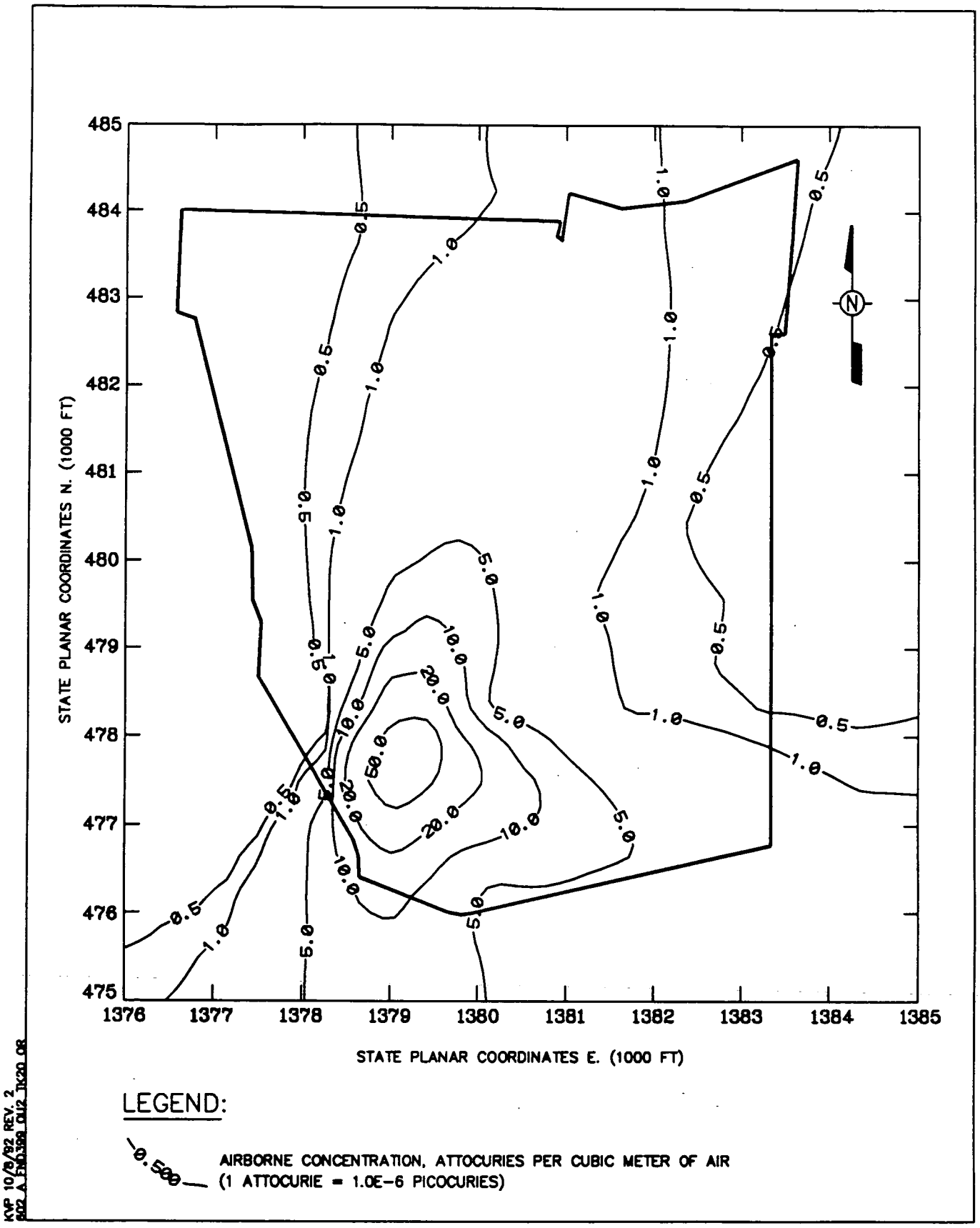

FIGURE 5-15. RADIOACTIVITY OF AIRBORNE U-238 RESUSPENDED FROM OU-2 INACTIVE FLYASH PILE

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TABLE 5-13

CONTAMINANT LOADING TO SURFACE WATER FROM THE INACTIVE FLYASH PILE

	Chemical Data		Results		
Constituent	Partition Coefficient, Kd (ml/g)	Concentration in Waste Area, Ci (mg/kg)	Total Annual Loading to Stream, Tl (g)	Concentration in Surface Water During Storm Event, Cw (mg/ℓ)	Concentration in Sediment, Cs (mg/kg)
Radionuclides					
Neptunium-237	5.50E+01	5.32E-04	1.56E-03	5.51E-08	5.30E-04
Lead-210	3.00E+03	8.04E-08	1.53E-07	1.53E-13	8.04E-08
Radium-224	6.96E+02	2.17E-11	4.27E-11	1.78E-16	2.17E-11
Radium-226	6.96E+02	6.47E-06	1.27E-05	5.31E-11	6.47E-06
Radium-228	6.96E+02	8.63E-09	1.70E-08	7.08E-14	8.63E-09
Strontium-90	1.00E+01	4.70E-09	3.55E-08	2.64E-12	4.62E-09
Thorium-228	5.80E+03	3.24E-09	6.14E-09	3.19E-15	3.24E-09
Thorium-230	5.80E+03	8.99E-04	1.70E-03	8.85E-10	8.99E-04
Thorium-232	5.80E+03	2.22E+01	4.20E+01	2.19E-05	2.22E+01
Uranium-234	1.80E+00	1.25E-02	3.89E-01	3.62E-05	1.14E-02
Uranium-235	1.80E+00	4.54E+00	1.41E+02	1.32E-02	4.15E+00
Uranium-238	1.80E+00	1.52E+02	4.73E+03	4.40E-01	1.39E+02
Inorganics					
Antimony	2.50E+02	1.06E+01	2.23E+01	2.41E-04	1.06E+01
Arsenic	2.00E+02	7.21E+01	1.60E+02	2.10E-03	7.20E+01
Barium	1.14E+03	4.30E+02	0.50E+02	2.10E-03	7.20E+01
Beryllium	1.30E+03	5.31E+00	1.02E+01	2.33E-05	5.31E+00
Cadmium	5.00E+02	2.08E+00	4.20E+00	2.40E-05	2.10E+00
Copper	1.25E+02	3.06E+01	7.20E+01	1.40E-03	3.10E+01
Cyanide	4.29E-02	8.60E-01	2.34E+02	2.30E-02	1.73E-01
Lead	3.00E+03	3.15E+01	6.00E+01	6.00E-05	3.10E-01
Selenium	7.40E+02	2.43E+00	4.76E+00	1.87E-05	2.43E+00
Thallium	1.50E+03	4.03E-01	9.30E-01	1.80E-06	4.80E-01
Organics					
1,1,1-Trichloroethane	5.65E+00	5.40E-02	6.37E-01	5.30E-05	5.24E-02
2-Butanone	3.47E-02	1.10E-02	3.11E+00	3.06E-04	1.86E-03
2-Hexanone	4.59E-01	3.00E-03	2.80E-01	2.72E-05	2.19E-03
2-Methylnaphthalene	1.39E+02	8.90E-02	2.05E-01	3.66E-06	8.89E-02
4-Methyl-2-Pentanone	2.36E-01	2.00E-03	2.88E-01	2.81E-05	1.16E-03
Acetone	1.09E-02	1.33E-01	4.25E+01	4.19E-03	8.01E-03
Anthracene	5.36E+02	4.90E-02	9.76E-02	5.22E-07	4.90E-02

TABLE 5-13
(continued)

Constituent	Chemical Data: Partition Coefficient, Kd (ml/g)	Chemical Data: Concentration in Waste Area, Ci (mg/kg)	Results: Total Annual Loading to Stream, Tl (g)	Results: Concentration in Surface Water During Storm Event, Cw (mg/ℓ)	Results: Concentration in Sediment, Cs (mg/kg)
Total PCBs	2.47E+04	2.16E-01	4.07E-01	4.99E-08	2.16E-01
Benzoic acid	1.42E+00	1.50E-01	5.72E+00	5.39E-04	1.34E-01
Bis(2-Ethylhexyl)phthalate	3.83E+03	3.25E-01	6.17E-01	4.84E-07	3.25E-01
Carbon disulfide	2.78E+00	4.00E-03	8.58E-02	7.75E-06	3.77E-03
Di-n-butyl phthalate	3.03E+03	4.60E-02	8.75E-02	8.68E-08	4.60E-02
Fluoranthene	4.09E+03	9.40E-02	1.78E-01	1.31E-07	9.40E-02
Methylene chloride	3.41E-01	8.00E-03	9.17E-01	8.93E-05	5.33E-03
Naphthalene	4.40E+01	5.30E-02	1.69E-01	6.84E-06	5.28E-02
Total PAHs	1.83E+04	9.11E-01	1.72E+00	2.84E-07	9.11E-01
Phenol	5.52E-01	1.90E-01	1.55E+01	1.50E-03	1.45E-01
Pyrene	2.90E+03	1.20E-01	2.28E-01	2.36E-07	1.20E-01
Styrene	2.77E+01	2.00E-03	7.91E-03	4.10E-07	1.99E-03
Toluene	9.38E+00	1.70E-02	1.35E-01	1.02E-05	1.67E-02
Trichloroethene	6.49E+00	3.00E-03	3.16E-02	2.57E-06	2.92E-03
Vinyl Acetate	1.39E-01	2.00E-03	3.77E-01	3.69E-05	8.97E-04

TABLE 5-14

SUMMARY OF CONSTITUENTS OF CONCERN WHICH WILL REACH THE AQUIFER IN 1000 YEARS FROM INACTIVE FLY ASH PILE

Constituents	Time of Arrival to the Aquifer (years)	Time of Maximum Loading Concentration (years)	Maximum Loading Concentration (mg/ℓ)	Maximum Concentration in the Aquifer (mg/ℓ)	Maximum Concentration at the FEMP Boundary (mg/ℓ)	Screening Levels (mg/ℓ)
Radionuclides						
Neptunium-237	240	660	3.6E-07	1.6E-08	3.0E-09	1.26E-08
Strontium-90	100	200	9.9E-16	3.2E-17	2.2E-18	3.91E-13
Uranium-234	60	120	2.9E-05	9.2E-07	6.4E-08	1.95E-08
Uranium-235	60	120	1.0E-02	3.3E-04	2.3E-05	5.64E-05
Uranium-238	60	120	3.5E-01	1.1E-02	7.8E-04	2.08E-04
Inorganics						
Cyanide	5	5	2.0E-03	6.4E-05	4.4E-06	1.46E-01
Organics						
2-Hexanone	15	20	3.8E-06	1.2E-07	8.4E-09	–
Benzoic acid	25	35	1.7E-05	5.3E-07	3.7E-08	2.92E+01
Carbon disulfide	40	80	1.0E-04	3.2E-06	2.2E-07	7.30E-01

isotopes are projected to exceed screening levels at the FEMP boundary. Contour plots were made for uranium at different time periods (Appendix B). As an example, Figure 5-16 depict a plume of uranium in groundwater beneath the Inactive Flyash Pile and moving towards the southeastern boundary of the FEMP. The plots show the future concentration profiles predicted by the SWIFT-III model at the time of maximum loading concentration at the boundary between the vadose zone and the Great Miami Aquifer.

5.4.6 South Field

5.4.6.1 Air Quality Results

The results of air quality modeling from the South Field are presented in Table 5-15. This table lists the projected highest airborne concentrations for the radionuclides and inorganic and organic compounds that are of potential concern at the South Field.

The highest on-site annual concentrations of resuspended radionuclides and inorganic and organic compounds are 2.43E-04 pCi/m^3 (thorium-230), 2.24E-04 µg/m^3 (manganese), and 2.65E-07 µg/m^3 (Aroclor-1254), respectively. The highest off-site annual concentrations of resuspended radionuclides and inorganic and organic compounds are 3.03E-05 pCi/m^3 (thorium-230), 2.78E-05 µg/m^3 (manganese), and 3.30E-08 µg/m^3 (Aroclor-1254). The concentration of airborne uranium-238 resuspended from the South Field is shown in Figure 5-17.

Since the resuspension model does not account for surface vegetation (which significantly retards resuspension at the South Field), the simulated resuspension rates are significantly higher than actually occurs. The maximum on-site concentrations listed in Table 5-15 are the maximum concentrations that appear at the nodes on a 100-meter x 100-meter grid over the FEMP site. It is possible that slightly higher concentrations may exist in the 100-meter space between adjacent grid nodes. The off-site concentrations are based on projections at locations along the FEMP boundary.

5.4.6.2 Surface Water Results

Table 5-16 presents the results of surface water modeling from the South Field, based upon a single storm event (6.4 cm in 24 hours) (Hershfield 1961), using the MUSLE model. The model shows that the small mass of contaminants that partition into the water, combined with a dilution flow in Paddys Run of 0.2 to 4.0 ft^3/s (Dames and Moore 1985a), results in low surface water concentrations from the South Field, usually much less than parts per billion. The highest modeled concentration, for uranium-238, was 385 µg/ℓ. These concentrations remain only through the duration of the storm. At the point that rainfall ceases and runoff ceases, surface water concentrations are likely to return to the nondetectable steady-state conditions indicated by surface water sampling.

Modeled sediment concentrations resulting from a single runoff event are comparable to the source term soil concentrations for the South Field. For example, the modeled sediment concentration for

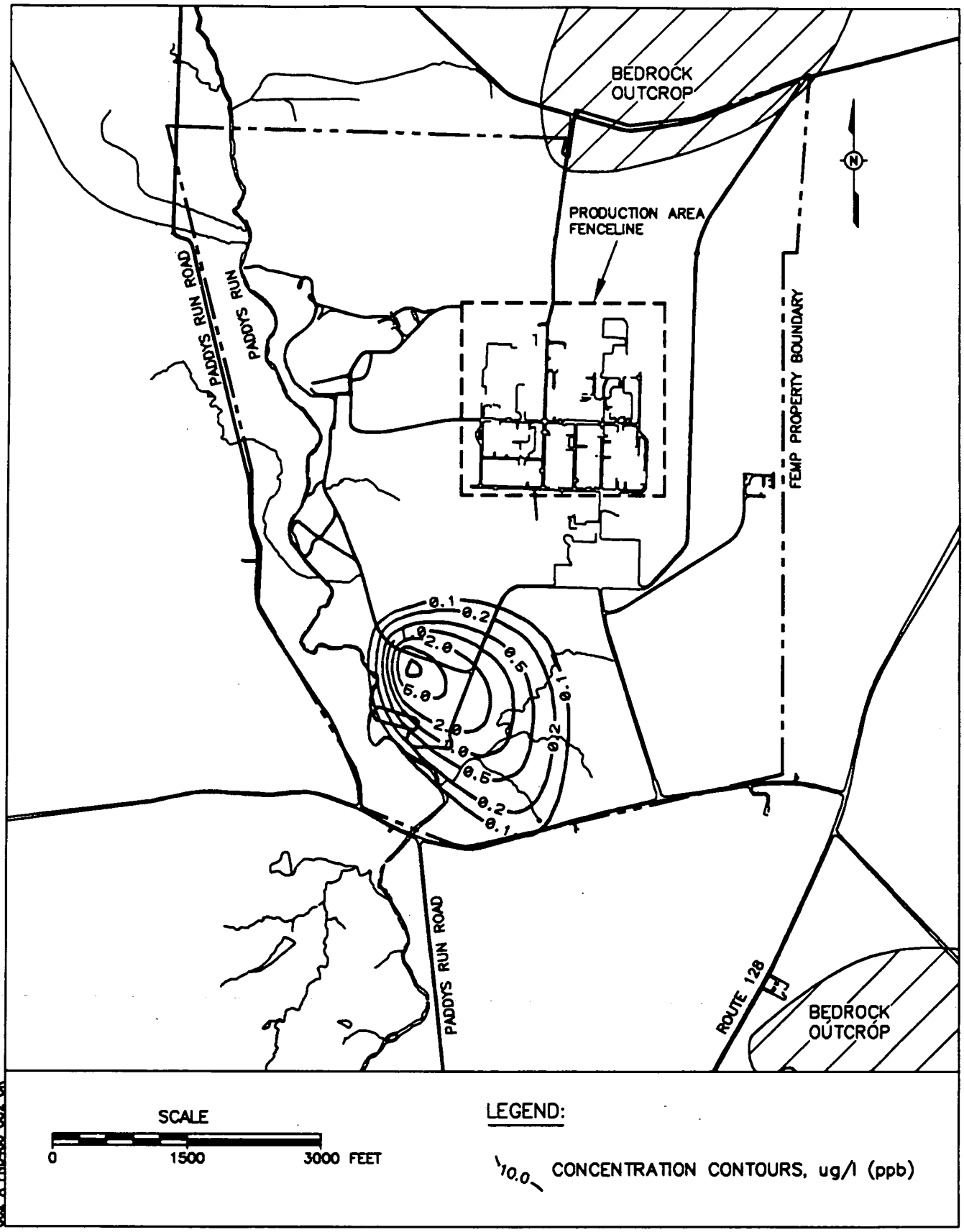

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FIGURE 5–16. PROJECTED CONCENTRATION OF URANIUM IN GROUNDWATER BENEATH FEMP AFTER 120 YEARS DUE TO LOADING FROM INACTIVE FLYASH PILE

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TABLE 5-15

HIGHEST ANNUAL AVERAGE CONCENTRATIONS OF RESUSPENDED CONTAMINANTS FROM THE SOUTH FIELD

Resuspended Particles	Highest On-site[a] Airborne Concentration[b]	Highest Off-site Airborne Concentration[b]
Radionuclides (pCi/m^3)		
Radium-226	1.20E-04	1.49E-05
Thorium-228	6.15E-06	7.67E-07
Thorium-230	2.43E-04	3.03E-05
Thorium-232	8.36E-06	1.04E-06
Uranium-234	8.94E-05	1.11E-05
Uranim-235/236	4.76E-06	5.91E-07
Uranium-238	8.84E-05	1.10E-05
Inorganics (µg/m^3)		
Antimony	6.30E-06	7.85E-07
Cadmium	1.17E-06	1.46E-07
Chromium	8.95E-06	1.11E-06
Lead	2.85E-05	3.54E-06
Manganese	2.24E-04	2.78E-05
Molybdenum	4.16E-06	5.16E-07
Silver	2.92E-06	3.63E-07
Organics (µg/m^3)		
2-Methylnapthalene	1.90E-08	2.37E-09
Anthracene	1.97E-08	2.45E-09
Aroclor-1242	3.16E-08	3.93E-09
Aroclor-1254	2.65E-07	3.30E-08
Aroclor-1260	5.10E-08	6.35E-09
Benzo(a)anthracene	6.70E-08	8.33E-09
Benzo(a)pyrene	7.82E-08	9.75E-09
Benzo(b)fluoranthene	7.65E-08	9.53E-09
Benzo(g,h,i)perylene	3.40E-08	4.23E-09
Benzoic acid	5.10E-08	6.35E-09
Bis(2-ethylhexyl) phthalate	1.36E-08	1.69E-09
Chloroform	1.02E-09	1.27E-10
Chrysene	6.90E-08	8.60E-09
Diethylphthalate	2.86E-08	3.55E-09
Fluoranthene	1.40E-07	1.75E-08
Indeno(1,2,3-cd)pyrene	2.86E-08	3.55E-09

TABLE 5-15
(continued)

Resuspended Particles	Highest On-site[a] Airborne Concentration[b]	Highest Off-site Airborne Concentration[b]
Organics ($\mu g/m^3$)		
Phenanthrene	7.34E-08	9.13E-09
Pyrene	1.13E-07	1.40E-08
Octachlorodibenzo-p-dioxin	2.21E-07	2.75E-08

[a] Based on projections at node points on a 100-meter grid.
[b] Concentrations are based on subsurface soil values.

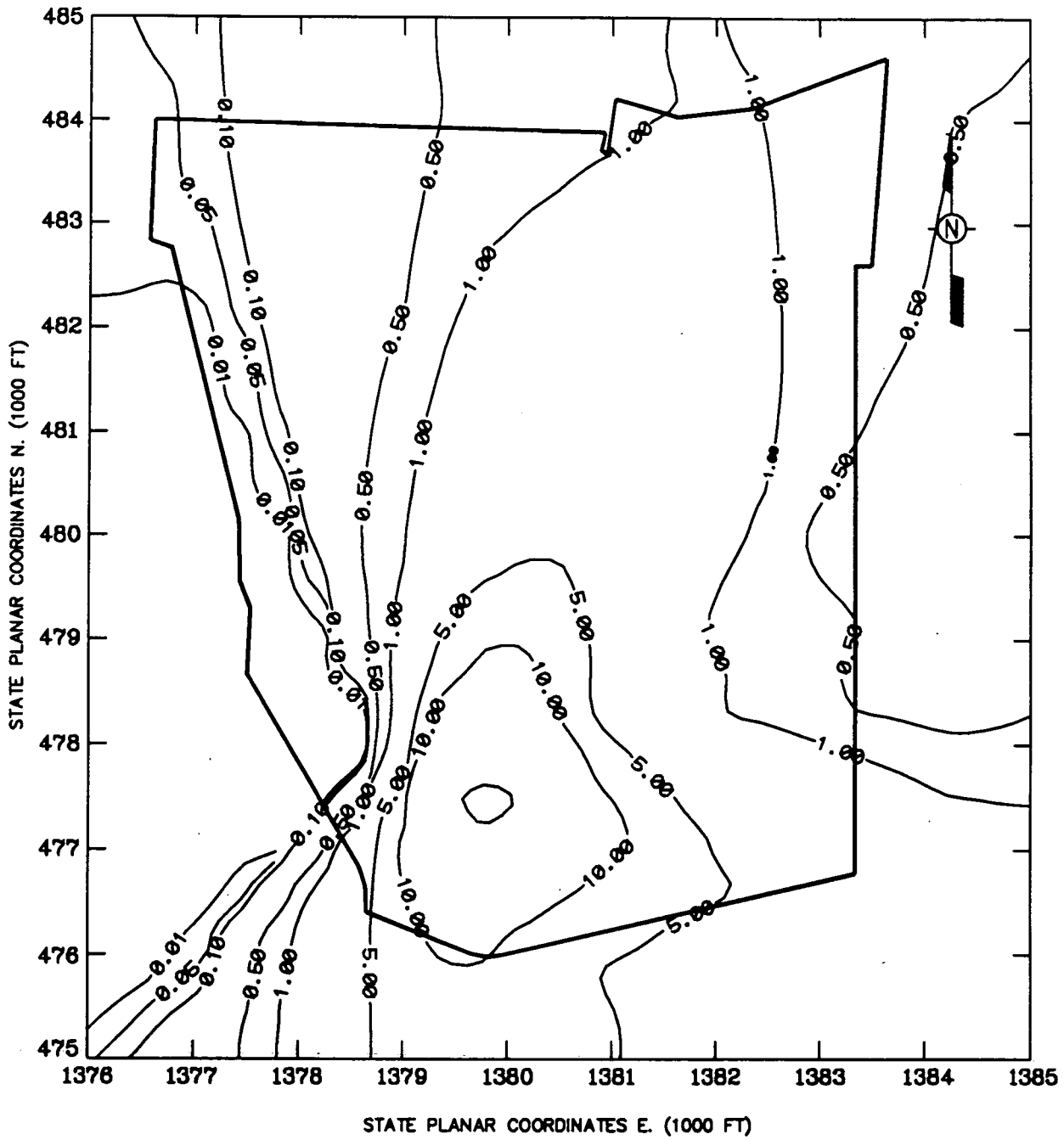

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FIGURE 5-17. RADIOACTIVITY OF AIRBORNE U-238 RESUSPENDED FROM OU-2 SOUTH FIELD

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TABLE 5-16

CONTAMINANT LOADING TO SURFACE WATER FROM THE SOUTH FIELD

Constituent	Chemical Data: Partition Coefficient, Kd (ml/g)	Chemical Data: Concentration in Waste Area, Ci (mg/kg)	Results: Total Annual Loading to Stream, Tl (g)	Results: Concentration in Surface Water During Storm Event, Cw (mg/ℓ)	Results: Concentration in Sediment, Cs (mg/kg)
Radionuclides					
Lead-210	3.00E+03	2.64E-07	1.00E-06	7.71E-13	2.64E-07
Plutonium-239/240	1.70E+03	5.37E-06	2.05E-05	2.77E-11	5.37E-06
Radium-226	6.96E+02	2.68E-06	1.05E-05	3.37E-11	2.68E-06
Radium-228	6.96E+02	6.65E-09	2.60E-08	8.37E-14	6.65E-09
Strontium-90	1.00E+01	4.51E-09	6.48E-08	3.91E-12	4.47E-09
Thorium-228	5.80E+03	3.06E-09	1.16E-08	4.62E-15	3.06E-09
Thorium-230	5.80E+03	2.30E-04	8.68E-04	3.47E-10	2.30E-04
Thorium-232	5.80E+03	1.62E+01	6.12E+01	2.45E-05	1.62E+01
Uranium-234	1.80E+00	3.17E-03	1.92E-01	1.47E-05	3.02E-03
Uranium-235	1.80E+00	2.93E-01	1.77E+01	1.36E-03	2.79E-01
Uranium-238	1.80E+00	8.30E+01	5.02E+03	3.85E-01	7.91E+01
Inorganics					
Antimony	2.50E+02	1.85E+01	7.76E+01	6.49E-04	1.85E+01
Beryllium	130E+03	1.21E+00	4.60E+00	8.10E+06	1.20E+00
Cadmium	5.00E+02	3.45E+00	1.40E+01	6.00E-05	3.50E+00
Chromium	1.50E+03	2.63E+01	1.00E+02	1.50E-04	2.60E+01
Lead	3.00E+03	8.38E+01	3.18E+02	2.44E-04	8.38E+01
Molybdenum	9.00E+01	1.22E+01	6.05E+01	1.19E-03	1.22E+01
Silver	1.80E+02	8.59E+00	3.74E+01	4.17E-04	8.58E+00
Organics					
2-Methylnaphthalene	1.39E+02	5.60E-02	2.54E-01	3.53E-06	5.60E-02
4-Methyl-2-Pentanone	2.36E-01	3.00E-03	1.00E+00	8.11E-05	2.18E-03
Anthracene	5.36E+02	5.80E-02	2.29E-01	9.47E-07	5.80E-02
Total PCBs	2.47E+04	1.02E+00	3.85E+00	3.63E-07	1.02E+00
Benzoic acid	1.42E+00	1.50E-01	1.12E+01	8.71E-04	1.41E-01
Bis(2-Ethylhexyl)phthalate	3.83E+03	4.00E-02	1.51E-01	9.14E-08	4.00E-02
Chloroform	1.79E+00	3.00E-03	1.83E-01	1.40E-05	2.86E-03
Diethyl phthalate	1.75E+01	1.95E-01	1.92E+00	9.73E-05	1.94E-01
Di-n-octyl phthalate	3.03E+07	8.40E-02	3.16E-01	2.43E-11	8.40E-02
Fluoranthene	4.09E+03	4.13E-01	1.56E+00	8.83E-07	4.13E-01
Methylene chloride	3.41E-01	9.00E-03	2.28E+00	1.84E-04	7.15E-03
Octachlorodibenzo-p-dioxin	2.70E+04	6.50E-01	2.44E+00	2.11E-07	6.50E-01
Total PAHs	1.83E+04	1.26E+00	4.72E+00	6.01E-07	1.25E+00
Pyrene	2.90E+03	3.32E-01	1.26E+00	1.00E-06	3.32E-01

Uranium-238 was 79 mg/kg, compared to 83 rainfall event because of dispersion through sediment transport and gradual mixing with sediment from other sources.

5.4.6.3 Groundwater Results

The groundwater fate and transport modeling results are summarized in Table 5-17 for the constituents of concern that will reach the Great Miami Aquifer within 1000 years from the South Field. The table also presents the arrival time for the constituents to reach the aquifer, the maximum loading concentration, the maximum concentrations of the constituents that would be expected in the aquifer within 1000 years, and the time required for the constituents to reach the maximum value. It also presents the predicted maximum concentration at the FEMP boundary due to loading from the South Field. Screening levels have been developed based on a 10^{-7} lifetime risk of cancer, are presented in Appendix A, provide a basis for understanding the risk to human health from the ingestion of water from the Great Miami Aquifer at the hypothetical receptor location. The constituents projected to be above the screening levels at the Great Miami Aquifer directly beneath the South Field are the uranium isotopes uranium-234 and uranium-238. Only uranium-238 is projected to exceed screening levels at the FEMP boundary. Contour plots were made for uranium at different time periods (Appendix B). As an example, Figure 5-18 depicts a plume of uranium in groundwater beneath the South Field. The plots show the future concentration profiles predicted by the SWIFT-III model at the time of maximum concentration at the boundary between the vadose zone and the Great Miami Aquifer.

5.4.7 Summary

5.4.7.1 Air

Radionuclides and inorganic and organic compounds resuspended by turbulent winds can become dispersed over a wide area, both within and outside of the FEMP site. The highest on-site annual concentrations of resuspended radionuclides and inorganic and organic compounds from Operable Unit 2 waste areas are thorium-230 at 2.43E-04 pCi/m^3, manganese at 2.24E-04 μg/m^3, and Aroclor-1254 at 2.65E-07 μg/m^3, all from the South Field.

The highest off-site annual concentrations as predicted by modeling of resuspended radionuclides and inorganic and organic compounds are considerably lower than the predicted on-site annual concentrations. The highest off-site annual concentrations of resuspended radionuclides and inorganic and organic compounds are thorium-230 at 3.03E-05 pCi/m^3 and manganese at 2.78E-05 at μg/m^3 and aroclor-1254 at 3.30E-08 μg/m^3 from the South Field.

As discussed in preceding sections, the air dispersion modeling does not account for surface vegetation, which significantly retards the resuspension of particles from all Operable Unit 2 waste areas except the Active Flyash Pile and the North Lime Sludge Pond.

TABLE 5-17

SUMMARY OF CONSTITUENTS OF CONCERN WHICH WILL REACH THE AQUIFER IN 1000 YEARS FROM SOUTH FIELD

Constituents	Time of Arrival to the Aquifer (years)	Time of Maximum Loading Concentration (years)	Maximum Loading Concentration (mg/ℓ)	Maximum Concentration in the Aquifer (mg/ℓ)	Maximum Concentration at the FEMP Boundary (mg/ℓ)	Screening Levels (mg/ℓ)
Radionuclides						
Strontium-90	40	100	3.8E-12	1.6E-13	8.0E-15	3.91E-13
Uranium-234	20	80	9.8E-07	4.4E-07	1.1E-08	1.95E-08
Uranium-235	20	80	9.1E-05	4.1E-05	1.1E-06	5.64E-05
Uranium-238	20	80	2.6E-02	1.2E-02	3.0E-04	2.08E-04
Inorganics						
Antimony	520	1000	1.3E-03	6.8E-05	1.3E-05	2.92E-03
Cadmium	140	440	8.9E-03	4.3E-04	7.0E-05	3.65E-03
Cobalt	680	1000	3.0E-05	1.5E-06	3.0E-07	1.90E-02
Lead	440	1000	3.1E-04	1.6E-05	3.1E-06	5.03E-03
Molybdenum	120	340	8.5E-02	3.9E-03	1.0E-04	3.65E-02
Organics						
Benzoic acid	10	20	1.1E-02	5.7E-04	1.1E-04	2.92E+01
2-Methylnaphthalene	680	1000	2.8E-09	1.5E-10	2.8E-11	–

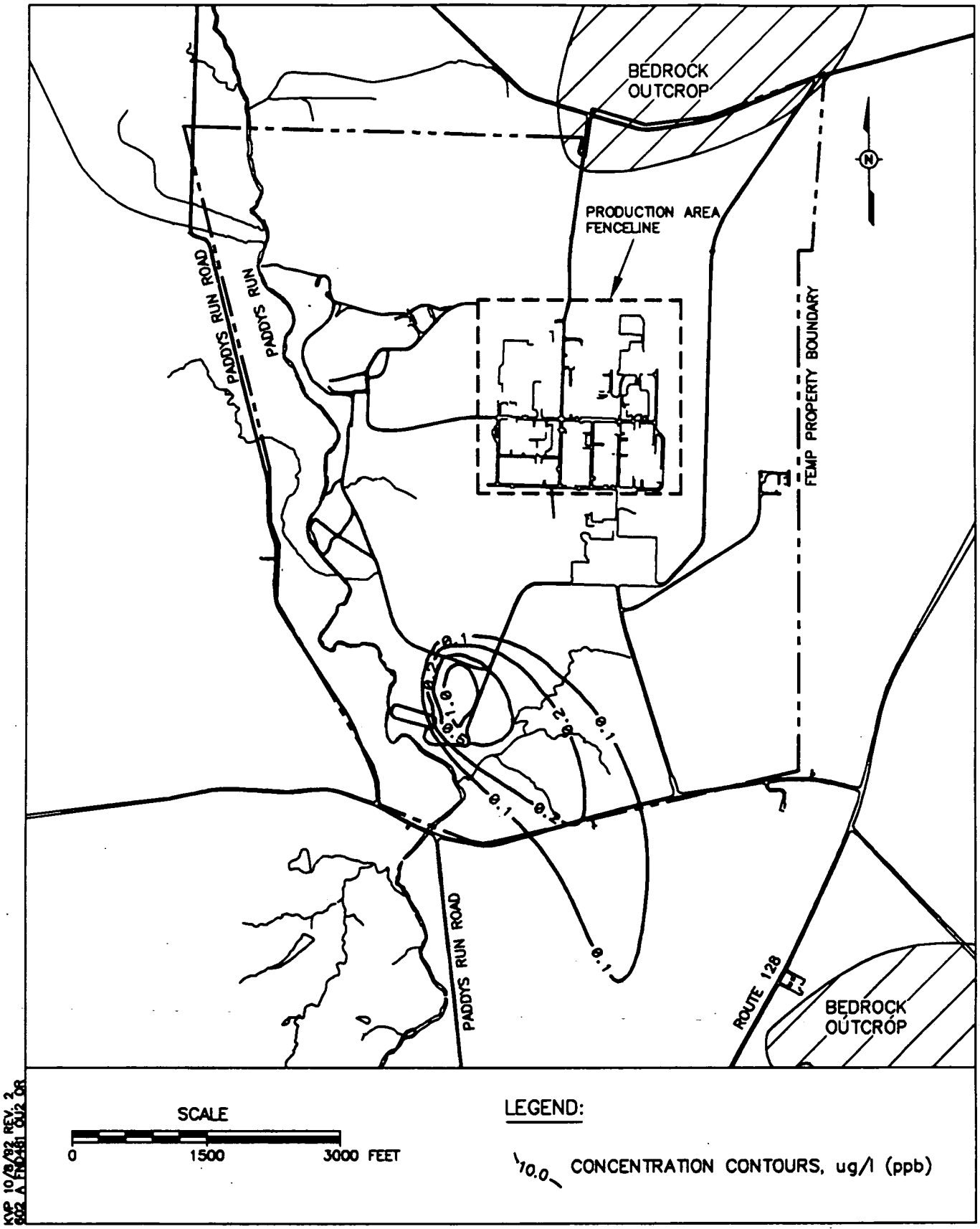

FIGURE 5–18. PROJECTED CONCENTRATION OF URANIUM IN GROUNDWATER BENEATH FEMP AFTER 150 YEARS DUE TO LOADING FROM SOUTH FIELD

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5.4.7.2 Surface Water

The USLE model can be used to estimate the amount of soil loss due to runoff, but these estimates cannot be used to predict chemical concentrations in the receiving water body. Instead, MUSLE output was used to estimate concentrations in Paddys Run. Results from MUSLE suggest that under normal rainfall conditions, runoff does not occur from the waste areas due to water retention by the soils. Results of surface water sampling of the storm sewer outfall ditch and Paddys Run indicate contaminant levels are within background levels.

Runoff does occur, however, during major rainfall events in the wet season. Results of modeling a single storm event (6.4 cm in 24 hours) (Hershfield 1961) using MUSLE show that the small mass of contaminants that partition into the water, combined with a dilution flow in Paddys Run of 0.2 to 4.0 ft^3/s (Dames and Moore 1985a), results in low surface water concentrations from each of the four sources. This concentration remains only through the duration of the storm. At the point that rainfall ceases and runoff ceases, surface water concentrations are likely to return to the nondetectable steady-state conditions indicated by surface water sampling. Estimated sediment concentrations following a runoff event were comparable to soil concentrations in the source areas. These concentrations are also likely to decrease following the rainfall event, due to gradual mixing with sediment from other sources.

These results suggest that surface water runoff is not a major transport pathway from the waste areas of Operable Unit 2.

5.4.7.3 Groundwater

The uranium isotopes are the major constituents of concern for the groundwater pathway. It may be observed that the predicted uranium loading concentrations for the Solid Waste Landfill, Inactive Flyash Pile and the South Field are higher than for the Lime Sludge Ponds and the Active Flyash Pile. Other radionuclide contaminants from Operable Unit 2 that are projected to reach the Great Miami Aquifer with concentrations above the screening level are neptunium-237 from the Inactive Flyash Pile, and strontium-90, molybdenum and cadmium from the South Field. No organic compounds are projected to reach the Great Miami Aquifer above the screening levels.

In general, contaminants with low retardation factors reach the Great Miami Aquifer earlier than the contaminants with high retardation factors. Uranium is projected to arrive in the aquifer at times ranging from 20 years (from the South Field, where the unweathered till layer is nonexistent) to 100 years (from the Solid Waste Landfill, where the unweathered till is 20 feet thick). A majority of the organic compounds (retardation factor greater than 100) do not reach the aquifer within 1000 years. The organic compounds which are highly soluble (low retardation factors) will reach the aquifer, but due to utilization of biodegradation rates, the concentration of these organic compounds are significantly reduced (several orders of magnitude lower than their detection values) and are reported as not

reaching the aquifer. Only the organic constituents with concentrations above 10^{-6} ppb are reported in the summary tables (Tables 5-4, 5-6, 5-8, 5-11, 5-14, and 5-17). It should be noted here that the actual retardation factors and especially the organic decay rates at the FEMP may not closely follow the assumed literature values (used for contaminant fate and transport modeling) particularly over the long term. Deviations from assumed literature values may significantly affect contaminant fate predictions.

The contaminants that reach the aquifer are diluted and move laterally towards the boundary. The maximum concentrations at the FEMP boundary that exceed the screening levels are the uranium isotopes from the Inactive Flyash Pile and the South Field.

6.0

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6.0 BASELINE RISK ASSESSMENT

This section presents a summary of the results of the baseline risk assessment for each of the Operable Unit 2 waste areas. A complete summary of the methods used and detailed calculations of the risk assessment are presented in Appendix A. This section addresses the salient features of the risk assessment, along with a summary of the results. Section 6.1 summarizes the methods used to evaluate the risks. Sections 6.2 through 6.6 present the results of the baseline risk assessment for each off the Operable Unit 2 waste areas.

6.1 METHODS

The baseline risk assessment was performed in accordance with available EPA guidance and follows the guidelines for performing risk assessments at the FEMP, as described in the Risk Assessment Work Plan Addendum (DOE 1992). In some instances, procedures deviated from the Risk Assessment Work Plan Addendum when it was necessary to incorporate new information and/or new guidance that was not available at the time the Risk Assessment Work Plan Addendum was developed. In most instances, deviations are noted in the text of the Appendix. Significant deviations from the Risk Assessment Work Plan Addendum include:

- Two land-use scenarios have been added: (a) future land use with passive access controls and (b) future land use without access controls (which addresses an on-property resident) using typical average exposures instead of reasonable maximum exposures

- Radiation cancer slope factors were updated by EPA in Spring 1992, and differ from those presented in the Risk Assessment Work Plan Addendum.

- The outline of the report deviates slightly in order to accommodate the five discreet waste areas of Operable Unit 2.

Major stages of the risk assessment process for the FEMP include (Figure 6-1):

- Selection of chemicals of concern
- Fate and transport modeling and exposure modeling
- Toxicity assessment
- Development of unit risk factors
- Risk characterization
- Uncertainty analysis

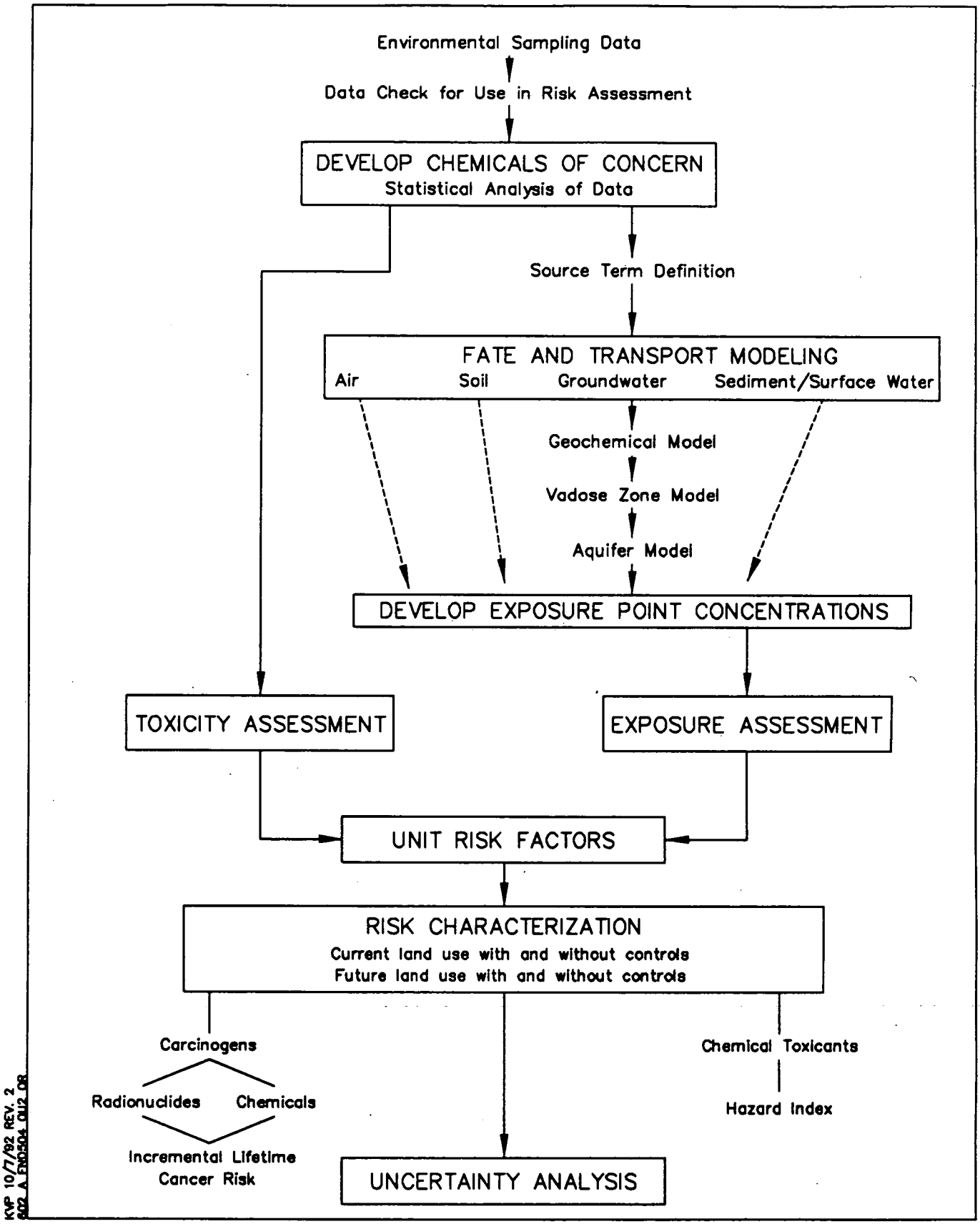

FIGURE 6–1. FEMP RISK ASSESSMENT PROCESS

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6.1.1 Chemicals of Concern

Radionuclides and hazardous chemicals of concern for each waste area were identified using statistical methods outlined in the Risk Assessment Work Plan Addendum and summarized in Appendix A. In summary, a chemical was excluded as a chemical of concern if (1) site-related concentrations were less than background concentrations, (2) a chemical was an essential human nutrient (e.g., sodium), or (3) a chemical was infrequently detected (e.g., less than 5 percent of the time).

6.1.2 Exposure Assessment

The exposure assessment was performed for both current and future potential land-use scenarios. The development of exposure scenarios is the first step toward understanding the context in which the risk assessment results can be used. The scenarios represent various combinations of data, parameters, and pathways, all based on assumptions about land use. The scenarios can help risk managers make an assessment of the impact of possible land control decisions.

The Risk Assessment Work Plan Addendum requires that, at a minimum, the following three exposure scenarios be addressed:

- Current land use with active access controls (Scenario 1)
- Current land use without access controls (Scenario 2)
- Future land use without access controls, assuming a reasonable maximum exposure (RME) (Scenario 5)

In addition to the minimum required scenarios, two additional scenarios have been included in the Operable Unit 2 risk assessment. These scenarios are:

- Future land use with passive access controls (Scenario 3)
- Future land use without access controls, assuming a typical average exposure (Scenario 4)

Current land use with active access controls describes the current situation at the FEMP, with the security fence in place and active controls that minimize or preclude trespassing. The receptors for this scenario include an infrequent trespasser and an off-property resident.

Current land use without access controls describes the hypothetical situation that the DOE would lose control of the property in the near future. This scenario assumes that no changes would occur to the property that would involve capital expenditures, such as building a house. The receptors for this

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scenario include a child who plays on the property frequently and an off-property resident who has cattle that graze on FEMP property.

Future land use without access controls describes the worst-case scenario in which all access controls are assumed to be gone and a farmer would reside and farm on the waste area. This scenario provides an upper-bound estimate of the risk distribution and is designed to ensure that the calculated future risk, with any given set of assumptions and parameters, would not be likely to exceed the reasonable maximum exposure (RME) risk. The receptor for this scenario is an on-property resident farmer.

Future land use with passive access controls is a scenario in which the government is assumed to retain ownership of the property but employs access controls which are less extensive than are currently in place. A fence remains around the site and the public is assumed to be off-property. This scenario provides the vehicle for including future risks to the nearest off-property receptor. The receptors associated with this pathway include a child who infrequently trespasses on the waste areas, and an off-property resident farmer.

The second additional scenario has been added in response to new guidance from the EPA suggesting that all risk assessments provide an evaluation of the central tendency of the risk range, using the best information available to describe the average situation (EPA 1992a, EPA 1992b). This scenario is used to provide an estimate of risk closer to the average risks for the resident farmer scenario. This scenario is currently being developed and will require additional review. The receptors for this scenario are located at the same location as the RME receptor. Exposure pathways quantified in the risk assessment for each scenario are identified in Table 6-1 and are discussed in more detail in Appendix A. The approximate location of Operable Unit 2 receptors via soil, air and groundwater are on Figure 6-2. The parameters associated with each soil pathway for each land-use scenario are listed in Table 6-2. Soil pathways are found to dominate the total risk.

6.1.3 Toxicity Assessment

Two human health hazards are identified in the toxicity assessment: cancer induction and chemical toxicity. Chemical toxicity includes numerous health effects such as kidney damage, liver disease, or eye irritation. For both types of health hazards, dose-response data from human and animal studies are used to determine the potency of the individual radionuclides and chemicals. For cancer induction it is assumed that no dose threshold exists, such that for any dose of a carcinogen there exists a possibility,

TABLE 6-1

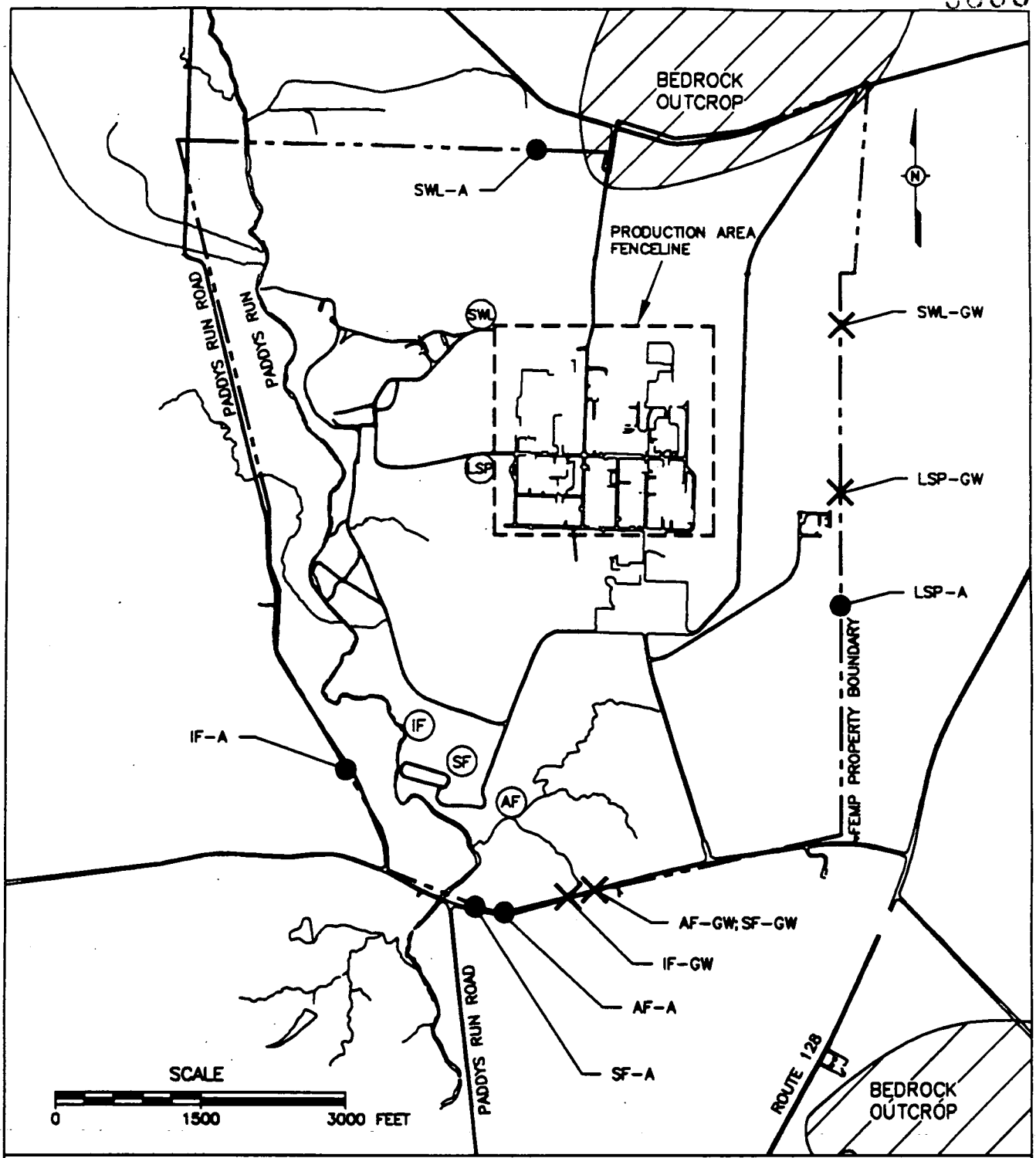
POTENTIAL PATHWAYS QUANTITATIVELY EVALUATED IN ASSESSMENT OF LONG-TERM RISKS ASSOCIATED WITH OPERABLE UNIT 2

Exposure Pathways			Solid Waste Landfill				Lime Sludge Ponds				Active Flyash Pile				Inactive Flyash Pile				South Field			
Source	Pathway	Exposure Media of Mechanism	1[a]	2[b]	3[c]	4/5[d]	1	2	3	4/5	1	2	3	4/5	1	2	3	4/5	1	2	3	4/5
Soil	Surface soil	Ingestion	C[e]	C	C	RF[f]	C	C	C	RF	C	C	C	RF	C	C	C	RF	C	C	C	RF
Soil	Root uptake	Vegetables				RF				RF				RF				RF				RF
Soil	Root uptake	Beef & Milk		OF[g]		RF										OF		RF		OF		RF
Soil	Ingestion by livestock	Beef & Milk		OF		RF										OF		RF		OF		RF
Soil	Surface soil**	Dermal contact	C	C	C	RF	C	C	C	RF	C	C	C	RF	C	C	C	RF	C	C	C	RF
Soil	Penetrating external radiation	Irradiation	C	C	C	RF	C	C	C	RF	C	C	C	RF	C	C	C	RF	C	C	C	RF
Soil/GW[h]	Drinking water	Direct ingestion			OF	RF			OF	RF			OF	RF			OF	RF			OF	RF
Soil/GW	Irrigation - root uptake, deposition	Vegetables			OF	RF			OF	RF			OF	RF			OF	RF			OF	RF
Soil/GW	Irrigation - root uptake, deposition	Beef & Milk			OF	RF			OF	RF			OF	RF			OF	RF			OF	RF
Soil/GW	Stock water	Beef & Milk			OF	RF			OF	RF			OF	RF			OF	RF			OF	RF
Soil/Air	Emission of gases to air	Inhalation																				
Soil/Air	Particulate emissions	Inhalation[i]	OF	OF	OF	RF	OF	OF	OF	RF	OF	OF	OF	RF	OF	OF	OF	RF	OF	OF	OF	RF
Soil/Air	Foliar deposition	Vegetables																				

TABLE 6-1
(continued)

Exposure Pathways			Solid Waste Landfill				Lime Sludge Ponds				Active Flyash Pile				Inactive Flyash Pile				South Field			
Source	Pathway	Exposure Media of Mechanism	1[a]	2[b]	3[c]	4/5[d]	1	2	3	4/5	1	2	3	4/5	1	2	3	4/5	1	2	3	4/5
Soil/SW[j]	Partitioning to sediment	Ingestion																				
Soil/SW	Partitioning to sediment	Dermal contact																				
Soil/SW	Drinking water	Direct ingestion																				
Soil/SW	Bioaccumulation	Fish																				
Soil/SW	Irrigation - root uptake, deposition	Vegetables																				
Soil/SW	Recreation	Incidental ingestion																				
Soil/SW	Recreation	Dermal contact																				

(a) 1 = Current land use with active access controls
(b) 2 = Current land use without access controls
(c) 3 = Future land use with passive access controls
(d) 4 = Future land use without access controls - typical average exposure; 5 = Future land use without access controls - reasonable maximum exposure
(e) C = Child
(f) RF = Resident farmer
(g) OF = Off-property farmer
(h) GW = Groundwater
(i) Quantified for radionuclides only
(j) SW = Surface water



NOTES:

SF - SOUTH FIELD
IF - INACTIVE FLYASH PILE
AF - ACTIVE FLYASH PILE
SWL - SOLID WASTE LANDFILL
LSP - LIME SLUDGE PONDS
GW - GROUNDWATER
A - AIR

LEGEND:

SWL — ON-SITE RESIDENT FARMER RECEPTOR LOCATION

● — OFF-SITE RESIDENT MAXIMUM RECEPTOR VIA THE AIR PATHWAY

X — OFF-SITE RESIDENT MAXIMUM RECEPTOR VIA THE GROUNDWATER PATHWAY.

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FIGURE 6-2. OPERABLE UNIT 2 RECEPTOR LOCATIONS

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TABLE 6-2

PARAMETERS USED TO DESCRIBE EXPOSURE TO SOILS FOR OPERABLE UNIT 2 CHEMICALS OF CONCERN

	Current Land Use		Future Land Use			
				Without Access Controls On-property Resident		
Pathway/ Parameter[a]	With Active Access Controls Off-property Resident/ Trespassing Child[b] (Scenario 1)	Without Access Controls Off-property Resident/Child[c] Playing On-property (Scenario 2)	With Passive Access Controls Off-property Resident/ Trespassing Child[d] (Scenario 3)	Typical Average Exposure Resident Farmer[e] (Scenario 4)	Reasonable Maximum Exposure Resident Farmer[f] (Scenario 5)	Reference(s)/ Justification
Ingestion of Soil						
Cs	UCL in surface soil	UCL in surface soil	UCL in surface soil	UCL in surface soil	UCL in surface soil	DOE 1992a
Age	6-17 years	6-17 years	6-17 years	9 years during adulthood	1-70 years	Assumption
IR	100 mg/day	100 mg/day	100 mg/day	10 mg/day	109 mg/day	EPA 1991a
FI	0.1	0.1	0.1	1	1	Assumption
EF	4 days/year	120 days/year	40 days/year	350 days/year	350 days/year	Assumption
ED	12 years	12 years	12 years	9 years	70 years	EPA 1989a
BW	43 kg	43 kg	43 kg	70 kg	70 kg	EPA 1989a
AT-Noncancer	12 y x 365 d	12 y x 365 d	12 y x 365 d	9 y x 365 d	70 y x 365 d	EPA 1989a
AT-Cancer	70 y x 365 d	70 y x 365 d	70 y x 365 d	70 y x 365 d	70 y x 365 d	EPA 1989a
Ingestion of Vegetables[g]						
Cv	NA	NA	NA	Equation provided in Work Plan Addendum	Equation provided in Work Plan Addendum	DOE 1992a
Age	NA	NA	NA	9 years during adulthood	1-70 years	Assumption
IR	NA	NA	NA	0.305 kg/day	0.305 kg/day	EPA 1991a
FI	NA	NA	NA	0.40	0.40	EPA 1991a
EF	NA	NA	NA	350 days/year	350 days/year	EPA 1991a
ED	NA	NA	NA	9 years	70 years	Assumption
BW	NA	NA	NA	70 kg	70 kg	EPA 1991a
AT-Noncancer	NA	NA	NA	9 yr x 365 d	70 yr x 365 d	EPA 1989a
AT-Cancer	NA	NA	NA	70 yr x 365 d	70 yr x 365 d	EPA 1989a

TABLE 6-2
(continued)

Pathway/ Parameter[a]	Current Land Use: With Active Access Controls Off-property Resident/ Trespassing Child[b] (Scenario 1)	Current Land Use: Without Access Controls Off-property Resident/Child[c] Playing On-property (Scenario 2)	Future Land Use: With Passive Access Controls Off-property Resident/ Trespassing Child[d] (Scenario 3)	Future Land Use, Without Access Controls On-property Resident: Typical Average Exposure Resident Farmer[e] (Scenario 4)	Future Land Use, Without Access Controls On-property Resident: Reasonable Maximum Exposure Resident Farmer[f] (Scenario 5)	Reference(s)/ Justification
Ingestion of Beef[h]						
Cb	NA	See Equation A.2-15	NA	Equation provided in Work Plan Addendum	Equation provided in Work Plan Addendum	DOE 1992a
Age	NA	1-70 years	NA	9 years during adulthood	1-70 years	Assumption
IR	NA	0.10 kg/day	NA	0.10 kg/day	0.10 kg/day	EPA 1991a
FI	NA	0.75	NA	0.75	0.75	EPA 1991a fraction
EF	NA	350 days/year	NA	350 days/year	350 days/year	EPA 1991a
ED	NA	70 years	NA	9 years	70 years	EPA 1991a
BW	NA	70 kg	NA	70 kg	70 kg	EPA 1991a
AT-Noncancer	NA	70 yr x 365 d	NA	9 yr x 365 d	70 yr x 365 d	EPA 1989a
AT-Cancer	NA	70 yr x 365 d	NA	70 yr x 365 d	70 yr x 365 d	EPA 1989a
Ingestion of Milk[h]						
Cm	NA	See Equation A.2-15	NA	Equation provided in Work Plan Addendum	Equation provided in Work Plan Addendum	DOE 1992a
Age	NA	1-70 years	NA	9 years during adulthood	1-70 years	Assumption
IR	NA	0.4 L/day	NA	0.4 L/day	0.4 L/day	EPA 1991a
FI	NA	0.75	NA	0.75	0.75	EPA 1991a
EF	NA	350 days/year	NA	350 days/year	350 days/year	EPA 1991a
ED	NA	70 years	NA	9 years	70 years	Assumption
BW	NA	70 kg	NA	70 kg	70 kg	EPA 1991a
AT-Noncancer	NA	70 yr x 365 d	NA	9 yr x 365 d	70 yr x 365 d	EPA 1989a
AT-Cancer	NA	70 yr x 365 d	NA	70 yr x 365 d	70 yr x 365 d	EPA 1989a

TABLE 6-2
(continued)

Pathway/ Parameter[a]	Current Land Use: With Active Access Controls Off-property Resident/ Trespassing Child[b] (Scenario 1)	Current Land Use: Without Access Controls Off-property Resident/Child[c] Playing On-property (Scenario 2)	Future Land Use: With Passive Access Controls Off-property Resident/ Trespassing Child[d] (Scenario 3)	Future Land Use, Without Access Controls On-property Resident: Typical Average Exposure Resident Farmer[e] (Scenario 4)	Future Land Use, Without Access Controls On-property Resident: Reasonable Maximum Exposure Resident Farmer[f] (Scenario 5)	Reference(s)/ Justification
Dermal Contact						
Cs	UCL in surface soil	UCL in surface soil	UCL in surface soil	UCL in surface soils	UCL in surface soils	DOE 1992a
Age	6-17 years	6-17 years	6-17 years	9 years during adulthood	1-70 years	Assumption
SA	1350 cm^2	1350 cm^2	1350 cm^2	1930 cm^2	1930 cm^2	EPA 1991a
AF	1.45 mg/cm^2	1.45 mg/cm^2	1.45 mg/cm^2	1.45 mg/cm^2	1.45 mg/cm^2	EPA 1989a
ABS	Chemical-specific	Chemical-specific	Chemical-specific	Chemical-specific	Chemical-specific	EPA 1992
EF	4 days/year	120 days/year	40 days/year	350 days/year	350 days/year	EPA 1991a
ED	12 years	12 years	12 years	9 years	70 years	EPA 1991a
BW	43 kg	43 kg	43 kg	70 kg	70 kg	EPA 1991a
AT-Noncancer	12 y x 365 d	12 y x 365 d	12 y x 365 d	9 y x 365 d	70 y x 365 d	EPA 1989a
AT-Cancer	70 y x 365 d	70 y x 365 d	70 y x 365 d	70 y x 365 d	70 y x 365 d	EPA 1989a
Inhalation of Fugitive Dust[i]						
Ca	see Section 5 of the RI Report	see Section 5 of the RI Report	see Section 5 of the RI Report	see Section 5 of the RI Report	see Section 5 of the RI Report	DOE 1992a
Age	1-70 years	1-70 years	1-70 years	9 years during adulthood	1-70 years	Assumption
IR	0.833 m^3/hr	0.833 m^3/hr	0.833 m^3/hr	0.833 m^3/hr	0.833 m^3/hr	EPA 1991a
ET x EF	2000 hrs/yr	2000 hrs/yr	2000 hrs/yr	2000 hrs/yr	2000 hrs/yr	Time spent = 40 hrs/wk, 50 wks/yr
ED	70 years	70 years	70 years	9 years	70 years	Assumption
BW	70 kg	70 kg	70 kg	70 kg	70 kg	EPA 1991a
AT-Noncancer	70 y x 365 d	70 y x 365 d	70 y x 365 d	9 y x 365 d	70 y x 365 d	EPA 1989a
AT-Cancer	70 y x 365 d	70 y x 365 d	70 y x 365 d	70 y x 365 d	70 y x 365 d	EPA 1989a

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TABLE 6-2
(continued)

Pathway/ Parameter[a]	Current Land Use: With Active Access Controls Off-property Resident/ Trespassing Child[b] (Scenario 1)	Current Land Use: Without Access Controls Off-property Resident/Child[c] Playing On-property (Scenario 2)	Future Land Use: With Passive Access Controls Off-property Resident/ Trespassing Child[d] (Scenario 3)	Future Land Use, Without Access Controls On-property Resident: Typical Average Exposure Resident Farmer[e] (Scenario 4)	Future Land Use, Without Access Controls On-property Resident: Reasonable Maximum Exposure Resident Farmer[f] (Scenario 5)	Reference(s)/ Justification
External Penetrating Radiation						
DR	Radionuclide-specific	Radionuclide-specific	Radionuclide-specific	Radionuclide-specific	Radionuclide-specific	DOE 1992a
Age	6-17 years	6-17 years	6-17 years	9 years during adulthood	1-70 years	Assumption
ET inside	0	0	0	18.3 hours/day	18.3 hours/day	
ET outside	2 hours/day	2 hours/day	2 hours/day	5.7 hours/day	5.7 hours/day	Assumption
EF	4 days/year	120 days/year	40 days/year	350 days/year	350 days/year	EPA 1991a
ED	12 years	12 years	12 years	9 years	70 years	EPA 1991a
SF inside	0	0	0	0.5	0.5	
SF outside	0	0	0	0	0	NRC 1977

[a] Model parameters are described in the Risk Assessment Work Plan Addendum. Parameters are C_x = concentration in media "x"; IR = ingestion rate; FI = fraction ingested from source; EF = exposure frequency; ED = exposure duration; BW = body weight; AT-Noncancer = average time for noncarcinogens; AT-Cancer = averaging time for carcinogens; SA = surface area exposed; AF = adherence factor; ABS = absorption factor; DR = dose rate; SF = shielding factor.

[b] This scenario describes current conditions of active access controls at the site. The RME is an off-property farmer, who, as a child, trespasses on the site.

[c] This scenario describes current conditions if all access controls are lost. This scenario assumes that no capital improvement will take place on-property. This scenario assumes a child will routinely play on-property. For inhalation exposures the resident is an adult off-property.

[d] This scenario describes a potential future situation where passive controls (e.g. fences) would remain to limit access to the property. It is assumed that controls will be "passive" and less effective than the active controls in the "Current Land Use with Active Access Controls" scenario. In addition, off-property groundwater exposures are considered in this pathway.

[e] This scenario describes potential future land use assuming a resident will live and farm on-property. It provides a description of the "central tendency of the future land use risk distribution (EPA, 1992d). However, for various parameters a value describing central tendency is not known and values for "high end" analysis must be used.

[f] This scenario reflects current regulatory guidance on a future land use "reasonable maximum exposure" as described in EPA, 1989a. This scenario assumes that a resident will live and farm on-property. Conceptually, it describes the "high end" (EPA, 1992d) of the potential risk distribution.

[g] This pathway applies to scenarios involving an on-property resident.

[h] This pathway applies to scenarios that allow cattle access to the Operable Unit 2 waste areas.

[i] The assumed receptor for this pathway is off-property. This is assumed since the large exposure frequency, exposure time and exposure duration indicates the receptor would be at a farm or residence.

however small, of contracting cancer. Incremental cancer risks are expressed in terms of probability that a given receptor (person) will contract cancer due to anticipated exposures. For example, if the receptor has an additional 1 chance in 10,000 of contracting cancer due to these exposures, the probability is expressed as a 10^{-4} (1/10,000) risk. Intakes calculated in the exposure assessment are used in conjunction with the slope of the dose-response data to determine the incremental lifetime cancer risk (ILCR). Toxicity data for the Operable Unit 2 risk assessment were taken from the Integrated Risk Information System (EPA 1992c) and the updated Health Effects Assessment Summary Table (EPA 1992d).

For chemical toxicants, data suggest that a dose threshold exists below which no toxic effect will be seen. This threshold is used to develop an acceptable intake level. To determine if Operable Unit 2 contaminants may cause toxic effects, the estimated intake (calculated from the exposure assessment) is compared to the acceptable intake. If the ratio of estimated intake to the acceptable intake is greater than 1, the site-related intake may cause toxic effects. This ratio is called the hazard index (HI).

6.1.4 Risk Characterization

Risk characterization combines the results of the exposure assessment and the toxicity information to quantitatively estimate the degree of hazard associated with exposure to chemicals of concern. In evaluating the risk characterization results to summarize in this chapter, an estimated ILCR of 10^{-4} and an HI of 1 were used as levels for triggering additional discussion. The ranges of generally acceptable risk under CERCLA are an ILCR of 10^{-4} to 10^{-6} and an HI of less than 1. Because of the extreme conservatism in calculating risks (e.g., the use of the resident farmer scenario), the lower level of 10^{-6} was not used as the trigger to summarize the results. Many of the risks were greater than this level, thus 10^{-6} would not act as an effective screen. The 10^{-4} level is used as a trigger for discussion. It is not assumed to be the point of departure from an acceptable risk level, which is generally assumed to be the 10^{-6} level. An HI of 0.2 is often used as a trigger for toxic effects since this value helps account for potential intake from other sources. However, an HI of 1 was chosen as the trigger for discussion in order to concentrate on major issues.

6.2 RESULTS

6.2.1 General Overview

In general, estimated cancer risks associated with the scenarios involving continued access controls are in the range of acceptable. However, for the scenarios that assume access control will be lost, several ILCRs are greater than 10^{-4} and some HIs are greater than 1.

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In almost all cases where estimated upper-bound risks are greater than 10^{-4}, systematic uncertainties associated with the current risk assessment methods appear to contribute significantly to the high risk values. A significant uncertainty is the external radiation slope factor used to calculate risk via external radiation exposure. In some waste areas, concentrations of radium-228 and thorium-228 only slightly above background are estimated to cause risks in the range of 10^{-3} to 10^{-4}. This is anticipated since lifetime risks from average natural background radiation exposures in the U.S. calculated by the same methods are approximately 10^{-2}.

An uncertainty that contributes to high risk results for the Solid Waste Landfill, the Inactive Flyash Pile, and South Field surface soils is the existence of anomalous detections in the characterization data sets. Some of these detections are identified as statistical outliers, which may indicate the presence of pockets of contamination. The risks associated with the use of these data are likely overestimated since the current method for calculating source terms assumes that the statistics are based on random sampling. It is also believed that surface soil sampling methods have resulted in a radiological data set which is biased high, since CIS sampling locations were generally chosen as the locations having the highest field radiation measurements.

Another potential systematic error in the risk assessment is the use of high biotransfer factors between soil and plants and between plants and farm foodstuff. This applies primarily to inorganic constituents, since the transfer factors used in the evaluation assume that the metals are in relatively soluble complexes. In all waste areas, metals are estimated to have the potential to produce toxic effects, even though they are only slightly above background values.

In some of the Operable Unit 2 waste areas, PCBs, PAHs, and dioxins were detected. In all cases with positive detection of these three chemical groups, corresponding risks were high for the following reasons:

- PAHs for which no toxicity data are available are evaluated using toxicity data for benzo(a)pyrene, one of the most carcinogenic PAHs. This assumption normally leads to an overestimation of the carcinogenicity of total PAHs.

- The carcinogenicity of all PCBs is assumed to be equal to the carcinogenicity of Aroclor-1260, since dose-response data for other isomers are inconclusive. Only Aroclor-1260 has shown statistically significant increases in tumors.

- The carcinogenicity of dioxins and furans other than the 2,3,7,8-isomers are determined using the EPA's revised 1989 toxicity equivalency factors (TEFs). These TEFs are based

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on the assumption that all dioxins and furans are carcinogenic, an assumption which has not been proven to date.

Underlying all estimated risks associated with the future land use resident farmer is the fact that it is a hypothetical worst-case scenario that does not necessarily reflect future realities. Access controls that eliminate contact with the waste effectively eliminate soil pathway risks to the resident farmer. However, since contaminants migrate, these controls may not eliminate risks via air and water transport pathways. For this reason, Scenario 3, which evaluates groundwater risks to the off-property farmer, has been added. Future groundwater risk estimates, however, are not without their own uncertainties, primarily stemming from assumptions about the geochemical form of the contaminants in the waste areas.

Results for the individual waste areas are summarized in the following sections. ILCRs and HIs for each of the waste areas are presented for the soil pathways. Risk characterization information for groundwater is presented in Appendix A. In general, risks from groundwater exposure pathways were found to be several orders of magnitude lower than risks from soil exposure pathways, and thus are not summarized here.

6.2.2 Solid Waste Landfill

For the Solid Waste Landfill, exposure point concentrations for contamination in surface soil for current exposure scenarios and future exposure scenarios are the upper 95 percent confidence limit on the mean (UCL) concentrations determined from subsurface soil boring results. The UCLs for soil are presented in Appendix A. The exposure point concentrations for groundwater are calculated using fate and transport modeling as presented in Appendix B. Exposure point concentrations are multiplied by chemical-specific, pathway-specific unit risk factors and unit toxicity factors to determine ILCRs and HIs for the Solid Waste Landfill.

Risk estimates based on the UCL soil concentrations of the carcinogens are shown in Table 6-3. These results represent the total risk from all pathways evaluated for each scenario. Supporting information on the risks associated with the individual pathways is presented in Attachment III of Appendix A.

Calculated risks from uranium-238, thorium-228, radium-226, and radium-228 and their short-lived progeny exceed 1×10^{-4} for the RME scenario for future land use without access controls. As noted in Attachment III, the majority of these calculated risks are due to external radiation exposures.

TABLE 6-3

TOTAL INCREMENTAL LIFETIME CANCER RISK ASSOCIATED WITH ALL SOIL PATHWAYS AT THE SOLID WASTE LANDFILL

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Chemical of Concern	Current Land Use: With Active Access Controls Off-property Resident/ Trespassing Child (Scenario 1)	Current Land Use: Without Access Controls Off-property Resident/Child Playing On-property (Scenario 2)	Future Land Use: With Passive Access Controls Off-property Resident/ Trespassing Child (Scenario 3)	Future Land Use, Without Access Controls On-property Resident: Typical Average Exposure Resident Farmer (Scenario 4)	Future Land Use, Without Access Controls On-property Resident: Reasonable Maximum Exposure Resident Farmer (Scenario 5)
Pathway / Receptor[a]					
Ingestion of Soil	C	C	C	RF	RF
Ingestion of Vegetables	--	--	--	RF	RF
Ingestion of Beef	--	OF	--	RF	RF
Ingestion of Milk	--	OF	--	RF	RF
Dermal Contact	C	C	C	RF	RF
Inhalation of Fugitive Dust	OF	OF	OF	RF	RF
External Penetrating Radiation	C	C	C	RF	RF
Radionuclides					
Pu-238	1.4E-11	3.4E-10	1.1E-10	1.1E-09	6.2E-08
Ra-226 + 5 dtrs	6.8E-08	2.6E-06	6.8E-07	3.3E-05	2.6E-04
Ra-228 + 1 dtr	4.5E-08	2.0E-06	4.5E-07	2.2E-05	1.7E-04
Sr-90 + dtr	1.1E-11	3.2E-05	1.1E-10	6.2E-06	4.8E-05
Th-228 + 7 dtrs	2.5E-07	7.4E-06	2.5E-06	1.2E-04	9.3E-04
Th-230	1.7E-10	3.6E-09	5.6E-10	7.8E-09	2.6E-07
Th-232	5.8E-11	1.2E-09	1.9E-10	2.5E-09	9.0E-08
U-234	1.4E-09	3.6E-06	5.0E-09	1.7E-06	1.5E-05
U-235 + 1 dtr	5.2E-09	2.9E-07	5.2E-08	2.6E-06	2.0E-05
U-238 + 2 dtrs	6.1E-08	1.9E-05	5.7E-07	3.5E-05	2.8E-04
Hazardous Chemicals					
Beryllium	7.14E-09	3.46E-06	7.14E-08	2.97E-06	2.88E-05
1,2-Dichloroethane	3.47E-11	1.16E-09	3.47E-10	1.42E-07	1.11E-06
1,4-Dioxane	1.80E-08	5.47E-07	1.80E-07	2.06E-03	1.61E-02
Aroclor-1242	6.85E-08	2.00E-05	6.85E-07	1.88E-04	1.47E-03
Aroclor-1248	5.70E-08	1.39E-04	5.70E-07	3.71E-05	2.95E-04
Aroclor-1254	1.51E-08	1.07E-04	1.51E-07	1.86E-05	1.46E-04
Aroclor-1260	6.16E-08	2.79E-04	6.16E-07	4.96E-05	3.92E-04
Benzo(a)pyrene	3.16E-06	2.74E-03	3.16E-05	7.68E-04	6.01E-03
Bis(2-ethylhexyl) phthalate	5.98E-10	9.12E-08	5.98E-09	6.74E-08	5.30E-07
Chloromethane	9.92E-12	3.08E-10	9.92E-11	1.93E-07	1.50E-06
Heptachlorodibenzo-p-dioxin	3.47E-08	1.01E-03	3.47E-07	1.41E-04	1.09E-03
Heptachlorodibenzofuran	2.04E-08	5.96E-04	2.04E-07	8.27E-05	6.43E-04
Methylene chloride	4.98E-12	1.68E-10	4.98E-11	1.54E-07	1.20E-06
Octachlorodibenzo-p-dioxin	9.53E-09	2.75E-04	9.53E-08	3.87E-05	3.00E-04
Octachlorodibenzofuran	3.79E-09	1.11E-04	3.80E-08	1.54E-05	1.20E-04

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TABLE 6-3
(Continued)

	Current Land Use		Future Land Use		
				Without Access Controls On-property Resident	
Chemical of Concern	With Active Access Controls Off-property Resident/ Trespassing Child (Scenario 1)	Without Access Controls Off-property Resident/Child Playing On-property (Scenario 2)	With Passive Access Controls Off-property Resident/ Trespassing Child (Scenario 3)	Typical Average Exposure Resident Farmer (Scenario 4)	Reasonable Maximum Exposure Resident Farmer (Scenario 5)
Pentachlorophenol	1.97E-08	2.19E-06	1.97E-07	2.64E-06	2.07E-05
Tetrachloroethene	8.68E-13	1.64E-10	8.68E-12	5.91E-08	1.98E-07

[a] C = Child; OF = Off-site farmer; RF = Resident farmer

Calculated risks from uranium-238 in the Solid Waste Landfill for all considered exposure pathways for each exposure scenario are given in Table A.3-4. Approximately 75 percent of the risk from uranium-238 and its two short-lived progeny is from the external radiation exposure pathway from surface soil.

Only U-234 and U-238 reach the aquifer in concentrations greater than the groundwater screening levels. The risks from U-234 and U-238 isotopes via groundwater exposure pathways are approximately 10^{-6} or less.

Results for chemical carcinogens show that exposures assuming the continuance of access controls to be in the range of 10^{-5} (for total PAHs, which are represented by benzo(a)pyrene) to 10^{-11}. Conservatism is associated with the estimated risk for the total PAHs due to the assumption that all PAHs are as carcinogenic as benzo(a)pyrene.

Estimates based on the loss of access controls are higher, ranging from 10^{-7} to 10^{-2} for 1,4-dioxane. Dioxane is structurally related to dioxins and furans.

In addition to risks associated with octachorodibenzo-p-dioxin (OCDD), risks for PCBs, PAHs and heptachlorodibenzo-p-dioxin are estimated to be greater than 10^{-4}.

Table 6-4 lists the estimated potential for toxic effects associated with potential exposures to contaminants in the Solid Waste Landfill. The values on the table represent the total HI for a chemical across all pathways evaluated under each scenario.

HIs for all scenarios are less than 1, with the exception of several metals for the future land use resident farmer scenario, including antimony, cadmium, lead and silver. These inorganic chemicals have relatively small reference doses (RfDs), suggesting that they are more potent than most of the organics.

Note that very little difference exists between the HIs for the resident farmer "typical average" and "reasonable maximum" exposure. The only parameter differences between the "typical average" and "reasonable maximum" exposure are exposure frequency (in days/year), exposure duration (in years) and soil ingestion rates. For chemical toxicants, conceptually and mathematically, exposure duration in the numerator of the intake equation is canceled by the averaging time (in days) in the

TABLE 6-4

TOTAL HAZARD INDEX FOR POTENTIAL TOXIC EFFECTS ASSOCIATED WITH ALL SOIL PATHWAYS AT THE SOLID WASTE LANDFILL

	Current Land Use		Future Land Use		
				Without Access Controls On-property Resident	
Chemical of Concern	With Active Access Controls Off-property Resident/ Trespassing Child (Scenario 1)	Without Access Controls Off-property Resident/Child Playing On-property (Scenario 2)	With Passive Access Controls Off-property Resident/ Trespassing Child (Scenario 3)	Typical Average Exposure Resident Farmer (Scenario 4)	Reasonable Maximum Exposure Resident Farmer (Scenario 5)
Pathway / Receptor[a]					
Ingestion of Soil	C	C	C	RF	RF
Ingestion of Vegetables	--	--	--	RF	RF
Ingestion of Beef	--	OF	--	RF	RF
Ingestion of Milk	--	OF	--	RF	RF
Dermal Contact	C	C	C	RF	RF
Inhalation of Fugitive Dust	OF	OF	OF	RF	RF
External Penetrating Radiation	C	C	C	RF	RF
Hazardous Chemicals					
Antimony	3.28E-04	2.71E-01	3.28E-03	5.00E+01	5.00E+01
Barium	2.17E-05	1.55E-02	2.17E-04	1.30E-01	1.33E-01
Beryllium	1.94E-06	2.09E-04	1.94E-05	1.08E-03	1.34E-03
Cadmium	1.75E-05	3.54E-01	1.75E-04	2.11E+00	2.12E+00
Chromium	7.27E-05	6.16E-02	7.27E-04	1.23E-01	1.33E-01
Cobalt	6.22E-05	1.82E-01	6.22E-04	2.73E-01	2.81E-01
Copper	6.93E-06	1.21E-01	6.93E-05	4.33E-01	4.34E-01
Lead	4.41E-04	1.10E-01	4.41E-03	1.11E+00	1.17E+00
Molybdenum	3.32E-05	2.79E-01	3.32E-04	7.41E-01	7.46E-01
Silver	2.37E-05	2.14E+00	2.37E-04	2.68E+00	2.68E+00
Thallium	8.59E-05	2.58E-01	8.59E-04	2.72E-01	2.84E-01
Uranium	3.22E-04	7.12E-02	3.22E-03	3.24E-01	3.68E-01
Vanadium	6.39E-05	1.28E-02	6.39E-04	4.98E-02	5.85E-02
1,1-Dichloroethane	1.48E-09	6.39E-08	1.48E-08	3.59E-04	3.59E-04
2,4-Dimethylphenol	8.90E-06	2.74E-04	8.90E-05	3.16E-02	3.16E-02
2-Butanone	7.42E-08	2.23E-06	7.42E-07	4.58E-03	4.58E-03
2-Chlorophenol	7.27E-06	2.23E-04	7.27E-05	3.68E-02	3.68E-02
Acenaphthene	2.30E-06	8.15E-05	2.30E-05	1.69E-03	1.70E-03
Acetone	1.93E-07	5.80E-06	1.93E-06	2.32E-02	2.32E-02
Anthracene	2.87E-07	1.35E-05	2.87E-06	1.88E-04	1.89E-04
Benzoic acid	2.04E-08	6.22E-07	2.04E-07	1.49E-04	1.49E-04
Bis(2-ethylhexyl) phthalate	1.25E-05	6.36E-04	1.25E-04	1.87E-03	1.89E-03
Chlorobenzene	3.71E-10	2.49E-08	3.71E-09	2.22E-05	2.22E-05
Di-n-butyl phthalate	8.90E-07	4.28E-05	8.90E-06	1.41E-04	1.42E-04

TABLE 6-4
(Continued)

Chemical of Concern	Current Land Use: With Active Access Controls Off-property Resident/ Trespassing Child (Scenario 1)	Current Land Use: Without Access Controls Off-property Resident/Child Playing On-property (Scenario 2)	Future Land Use: With Passive Access Controls Off-property Resident/ Trespassing Child (Scenario 3)	Future Land Use, Without Access Controls On-property Resident: Typical Average Exposure Resident Farmer (Scenario 4)	Future Land Use, Without Access Controls On-property Resident: Reasonable Maximum Exposure Resident Farmer (Scenario 5)
Di-n-octyl phthalate	1.30E-05	8.19E-01	1.30E-04	8.19E-01	8.19E-01
Dichlorodifluoromethane	2.14E-06	6.54E-05	2.14E-05	1.06E-02	1.05E-02
Diethyl phthalate	2.83E-07	8.87E-06	2.83E-06	4.96E-04	4.97E-04
Ethylbenzene	9.89E-09	7.97E-07	9.89E-08	3.92E-04	3.93E-04
Fluoranthene	1.02E-05	5.28E-04	1.02E-04	1.51E-03	1.53E-03
Fluorene	3.48E-06	1.29E-04	3.48E-05	1.88E-03	1.89E-03
Methylene chloride	6.46E-08	1.98E-06	6.46E-07	2.66E-03	2.66E-03
Naphthalene	2.60E-06	1.12E-04	2.60E-05	2.77E-03	2.77E-03
Pentachlorophenol	3.19E-05	1.14E-03	3.19E-04	5.70E-03	5.76E-03
Phenol	7.54E-08	2.28E-06	7.54E-07	9.59E-04	9.59E-04
Pyrene	2.84E-05	1.36E-03	2.84E-04	4.54E-03	4.59E-03
Pyridine	2.22E-06	6.67E-05	2.22E-05	1.20E-04	1.24E-04
Styrene	7.42E-09	2.35E-07	7.42E-08	1.01E-05	1.01E-05
Tetrachloroethene	9.89E-09	5.66E-07	9.89E-08	8.97E-04	3.88E-04
Toluene	2.47E-10	1.53E-08	2.47E-09	1.80E-05	9.69E-06
Total Xylenes	7.42E-11	5.57E-09	7.42E-10	3.40E-06	2.91E-06

[a] C = Child; OF = Off-property farmer; RF = Resident farmer

denominator. The reason is that for chemical toxicants, the daily exposure is of concern. For carcinogens, the exposure duration is mathematically distributed across an entire lifetime, thus the change in exposure duration makes a difference in the unit risk factors for the two scenarios.

The change in the soil ingestion rate changes the unit toxicity factor for the soil ingestion pathway. However, since for many chemicals the soil ingestion pathway contributes little to total risk, and vegetable and meat ingestion dominate the total risk, the change in contribution from the soil ingestion pathway does not effect the total HI.

6.2.3 Lime Sludge Ponds

Exposure point concentrations for current scenarios and future scenarios are UCL concentrations determined from surface soil and subsurface soil data for radionuclides and from subsurface soil data for hazardous chemicals. The exposure point concentrations for groundwater are calculated using fate and transport modeling.

Exposure point concentrations are multiplied by chemical-specific, pathway-specific unit risk factors and unit toxicity factors to determine ILCRs and HIs, respectively. ILCRs for soil pathways for current and potential future exposure scenarios are given in Table 6-5.

Several radionuclides contribute risks exceeding 1×10^{-4}. The estimated risks from thorium-228 and radium-226 and their short-lived progeny dominate the total risk, contributing approximately 85 percent of the total risk from all radionuclides and all soil pathways. These risks are due primarily to the external radiation exposures from thorium-228 and radium-226 progeny in surface soil (as shown in Attachment A.III to Appendix A.)

Only uranium-238 reaches the aquifer in concentrations exceeding the groundwater screening level. The risk from this radionuclide via groundwater exposure pathways is less than 10^{-6}.

Four chemical carcinogens were determined to be chemicals of concern for the Lime Sludge Ponds. All four were only detected during CIS sampling. Risks associated with these chemicals are highly uncertain because their presence was not confirmed by RI/FS sampling, and because the two most potent carcinogens, Aroclor-1248 (PCB) and chlordane, were detected in one sample analyzed for these compounds.

TABLE 6-5

TOTAL INCREMENTAL LIFETIME CANCER RISK ASSOCIATED WITH ALL SOIL PATHWAYS AT THE LIME SLUDGE PONDS

Chemical of Concern	Current Land Use: With Active Access Controls Off-property Resident/ Trespassing Child (Scenario 1)	Current Land Use: Without Access Controls Off-property Resident/Child Playing On-property (Scenario 2)	Future Land Use: With Passive Access Controls Off-property Resident/ Trespassing Child (Scenario 3)	Future Land Use, Without Access Controls On-property Resident: Typical Average Exposure Resident Farmer (Scenario 4)	Future Land Use, Without Access Controls On-property Resident: Reasonable Maximum Exposure Resident Farmer (Scenario 5)
Pathway / Receptor[a]					
Ingestion of Soil	C	C	C	RF	RF
Ingestion of Vegetables	--	--	--	RF	RF
Ingestion of Beef	--	OF	--	RF	RF
Ingestion of Milk	--	OF	--	RF	RF
Dermal Contact	C	C	C	RF	RF
Inhalation of Fugitive Dust	OF	OF	OF	RF	RF
External Penetrating Radiation	C	C	C	RF	RF
Radionuclides					
Cs-137 + dtr	1.2E-08	3.6E-07	1.2E-07	6.0E-06	4.7E-05
Np-237 + dtr	1.8E-09	5.5E-08	1.8E-08	1.2E-06	9.5E-06
Pb-210 + 2 dtrs	1.4E-08	4.2E-07	1.4E-07	1.0E-04	8.5E-04
Pu-238	1.8E-11	4.9E-10	1.7E-10	1.7E-09	9.6E-08
Pu-239/240	2.7E-11	7.5E-10	2.5E-10	2.6E-09	1.4E-07
Ra-226 + 5 dtrs	1.1E-06	3.4E-05	1.1E-05	5.6E-04	4.4E-03
Sr-90 + dtr	6.2E-12	1.9E-10	6.2E-11	1.2E-06	9.6E-06
Tc-99	5.3E-12	1.6E-10	5.2E-11	6.2E-06	4.8E-05
Th-228 + 7 dtrs	1.0E-06	3.1E-05	1.0E-05	5.1E-04	4.0E-03
Th-230	6.6E-09	9.4E-08	3.4E-08	5.4E-07	1.8E-05
Th-232	2.5E-10	3.4E-09	1.2E-09	1.8E-08	6.6E-07
U-234	2.0E-09	3.7E-08	1.3E-08	3.8E-06	3.5E-05
U-235 + 1 dtr	1.4E-08	4.2E-07	1.4E-07	6.9E-06	5.4E-05
U-238 + 2 dtrs	5.6E-08	1.6E-06	5.4E-07	3.1E-05	2.5E-04
Hazardous Chemicals					
Aroclor-1248	5.57E-09	2.69E-06	5.57E-08	2.32E-06	2.25E-05
Beryllium	1.21E-07	2.95E-04	1.21E-06	7.89E-05	6.26E-04
Bis(2-ethylhexyl) phthalate	5.45E-10	8.31E-08	5.45E-09	6.14E-08	4.83E-07
Chlordane	1.98E-07	1.86E-05	1.98E-06	1.45E-05	1.17E-04
Methylene chloride	6.75E-11	2.28E-09	6.75E-10	2.08E-06	1.62E-05

[a] C = Child; OF = Off-site farmer; RF = Resident farmer

Once again, risks associated with the land-use scenarios involving access controls are lower than the scenarios assuming loss of controls, by as much as three to four orders of magnitude. For the pesticides, which tend to accumulate in plants, the vegetable ingestion scenario contributes significantly to the total risk for the future on-site scenarios. Since Aroclor-1248 has not been identified as a carcinogen (it is evaluated using the cancer slope factor for Aroclor-1260), the conservatism associated with these estimates is potentially great. The vegetable ingestion pathway also contributes significantly to the estimated beryllium risks.

Table 6-6 shows the results of the characterization of potential toxic effects associated with chemicals of concern in the Lime Sludge Ponds. HIs greater than 1 have been estimated for several chemical toxicants for the future on-property resident, including antimony, cadmium, silver, mercury, 2-butanone, and chlordane. For the land-use scenarios involving off-property residents, mercury and silver have HIs greater than 1.

6.2.4 Active Flyash Pile

For the Active Flyash Pile, exposure point concentrations for contamination in surface soil for current exposure scenarios and future exposure scenarios are the UCL concentrations determined from subsurface soil boring results. The UCLs for soil are presented in Appendix A. The exposure point concentrations for groundwater are calculated using fate and transport modeling. Exposure point concentrations are multiplied by (1) chemical-specific, pathway-specific unit risk factors and (2) unit toxicity factors to determine ILCRs and HIs for the Active Flyash Pile.

ILCRs for soil pathways are summarized in Table 6-7. The detailed results of the risk assessment are presented in Attachment III of Appendix A. The risks from thorium-228, radium-228, and radium-226, and their short-lived progeny exceed 1×10^{-4}. As noted previously, the majority of this risk is from the external radiation exposure pathway.

No contaminants are determined to reach the groundwater in concentrations exceeding the screening level.

Table 6-7 also lists six chemical carcinogens that were detected in the Active Flyash Pile. These are: Aroclor-1260 (PCB), beryllium, dichloroethylene (DCE), benzene, methylene chloride and bis (2-ethylhexyl) phthalate (the last two are common laboratory contaminants). Aroclor-1260, DCE and benzene were detected once each, and therefore the presence of these contaminants is uncertain.

TABLE 6-6

TOTAL HAZARD INDEX FOR POTENTIAL TOXIC EFFECTS ASSOCIATED WITH ALL SOIL PATHWAYS AT THE LIME SLUDGE PONDS

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Chemical of Concern	Current Land Use: With Active Access Controls Off-property Resident/ Trespassing Child (Scenario 1)	Current Land Use: Without Access Controls Off-property Resident/Child Playing On-property (Scenario 2)	Future Land Use: With Passive Access Controls Off-property Resident/ Trespassing Child (Scenario 3)	Future Land Use, Without Access Controls On-property Resident: Typical Average Exposure Resident Farmer (Scenario 4)	Future Land Use, Without Access Controls On-property Resident: Reasonable Maximum Exposure Resident Farmer (Scenario 5)
Pathway / Receptor[a]					
Ingestion of Soil	C	C	C	RF	RF
Ingestion of Vegetables	--	--	--	RF	RF
Ingestion of Beef	--	OF	--	RF	RF
Ingestion of Milk	--	OF	--	RF	RF
Dermal Contact	C	C	C	RF	RF
Inhalation of Fugitive Dust	OF	OF	OF	RF	RF
External Penetrating Radiation	C	C	C	RF	RF
Hazardous Chemicals					
Antimony	5.49E-04	4.54E-01	5.49E-03	8.36E+01	8.36E+01
Beryllium	1.51E-06	1.63E-04	1.51E-05	8.39E-04	1.05E-03
Cadmium	1.32E-05	2.67E-01	1.32E-04	1.59E+00	1.60E+00
Chromium	5.61E-05	4.75E-02	5.61E-04	9.46E-02	1.02E-01
Mercury	9.94E-06	5.95E+00	9.94E-05	6.43E+00	6.43E+00
Silver	4.37E-05	3.94E+00	4.37E-04	4.94E+00	4.95E+00
Thallium	7.24E-05	2.18E-01	7.24E-04	2.30E-01	2.39E-01
Uranium	2.79E-05	6.18E-03	2.79E-04	2.81E-02	3.19E-02
Cyanide	8.45E-07	2.53E-05	8.45E-06	4.54E-05	1.61E-04
1,1-Dichloroethane	7.42E-10	3.20E-08	7.42E-09	1.79E-04	1.79E-04
1,1,2-Trichloro-1,2,2-trifluoroethane	2.00E-08	6.13E-07	2.00E-07	9.86E-05	9.86E-05
2-Butanone	2.67E-05	8.04E-04	2.67E-04	1.65E+00	1.65E+00
Acetone	1.24E-06	3.72E-05	1.24E-05	1.49E-01	1.49E-01
Bis(2-ethylhexyl) phthalate	1.13E-05	5.78E-04	1.13E-04	1.70E-03	1.72E-03
Butyl benzyl phthalate	1.04E-05	4.18E-04	1.04E-04	2.24E-03	2.25E-03
Carbon disulfide	2.22E-09	1.09E-07	2.22E-08	3.29E-04	3.30E-04
Chlordane	1.48E-02	6.07E-01	1.48E-01	1.48E+00	1.50E+00
Di-n-butyl phthalate	8.78E-07	4.24E-05	8.78E-06	1.39E-04	1.40E-04
Methylene chloride	8.72E-07	2.67E-05	8.72E-06	3.59E-02	3.59E-02
Phenol	4.52E-06	1.37E-04	4.52E-05	5.74E-02	5.75E-02
Toluene	2.47E-09	1.53E-07	2.47E-08	1.80E-04	9.69E-05

[a] C = Child; OF = Off-property farmer; RF = Resident farmer

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TABLE 6-7

TOTAL INCREMENT LIFETIME CANCER RISK ASSOCIATED WITH ALL SOIL PATHWAYS AT THE ACTIVE FLYASH PILE

	Current Land Use		Future Land Use		
				Without Access Controls On-property Resident	
Chemical of Concern	With Active Access Controls Off-property Resident/ Trespassing Child (Scenario 1)	Without Access Controls Off-property Resident/Child Playing On-property (Scenario 2)	With Passive Access Controls Off-property Resident/ Trespassing Child (Scenario 3)	Typical Average Exposure Resident Farmer (Scenario 4)	Reasonable Maximum Exposure Resident Farmer (Scenario 5)
Pathway / Receptor[a]					
Ingestion of Soil	C	C	C	RF	RF
Ingestion of Vegetables	--	--	--	RF	RF
Ingestion of Beef	--	OF	--	RF	RF
Ingestion of Milk	--	OF	--	RF	RF
Dermal Contact	C	C	C	RF	RF
Inhalation of Fugitive Dust	OF	OF	OF	RF	RF
External Penetrating Radiation	C	C	C	RF	RF
Radionuclides					
Pb-210 + 2 dtrs	5.4E-10	1.6E-08	5.2E-09	3.7E-06	3.2E-05
Ra-226 + 5 dtrs	2.6E-07	7.7E-06	2.6E-06	1.2E-04	9.7E-04
Ra-228 + 1 dtr	1.0E-07	3.1E-06	1.0E-06	5.0E-05	3.9E-04
Sr-90 + dtr	3.3E-11	9.9E-10	3.3E-10	6.6E-06	5.1E-05
Th-228 + 7 dtrs	2.2E-07	6.6E-06	2.2E-06	1.1E-04	8.3E-04
Th-230	4.2E-10	1.2E-09	6.6E-10	4.9E-09	1.6E-07
Th-232	2.8E-10	7.6E-10	4.3E-10	2.8E-09	1.0E-07
U-234	9.5E-10	3.4E-09	1.7E-09	2.6E-07	2.4E-06
U-235 + 1 dtr	1.8E-09	5.3E-08	1.8E-08	8.7E-07	6.8E-06
U-238 + 2 dtrs	4.0E-09	8.5E-08	2.9E-08	1.6E-06	1.3E-05
Hazardous Chemicals					
1,1-Dichloroethene	5.09E-12	4.40E-10	5.09E-11	1.39E-06	1.08E-05
Aroclor-1260	3.84E-09	1.74E-05	3.84E-08	3.09E-06	2.44E-05
Benzene	2.46E-13	3.35E-11	2.46E-12	2.83E-08	2.20E-07
Bis(2-ethylhexyl) phthalate	6.78E-10	1.03E-07	6.78E-09	7.64E-08	6.02E-07
Beryllium	3.30E-08	1.60E-05	3.30E-07	1.37E-05	1.33E-04
Methylene chloride	1.57E-11	5.31E-10	1.57E-10	4.86E-07	3.78E-06

[a] C = Child; OF = Off-site farmer; RF = Resident farmer

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Estimated risks associated with beryllium range from 10^{-8} under current land-use conditions to 10^{-4} for the on-property farmer. Much of the risk is contributed by the food ingestion pathways. Calculated HIs for the toxicants in the Active Flyash Pile are presented in Table 6-8. For all land-use scenarios for all chemicals, estimated HIs greater than 1 include antimony, arsenic, lead, and zinc under the most conservative scenario. As seen with many calculations performed for the Operable Unit 2 risk assessment, the food ingestion pathways contribute the greatest risks from these metals.

The HIs associated with trichloroethane (TCA) are well below 1. This is a consequence of the relatively low toxic potency of TCA compared to the potency of many metals and the low detected soil concentrations.

6.2.5 Inactive Flyash Pile

Exposure point concentrations for current scenarios and future scenarios for the Inactive Flyash Pile are UCL concentrations determined from surface soil and subsurface soil data for radionuclides and from subsurface soil data for hazardous chemicals. The exposure point concentrations for groundwater are calculated using fate and transport modeling. Exposure point concentrations are multiplied by (1) chemical-specific, pathway-specific unit risk factors and (2) unit toxicity factors to determine ILCRs and HIs, respectively. ILCRs for soil pathways are summarized in Table 6-9. The detailed results of the risk assessment are presented in Attachment III of Appendix A. The risks from uranium-238, uranium-235, uranium-234, thorium-228, radium-226, and their short-lived progeny exceed 1×10^{-4}. Additionally, the risk from technetium-99 exceeds 1×10^{-4}. The pathways that contribute the majority of the risk from technetium-99 are ingestion of beef, milk, and home-grown vegetables. The risk appears to be inordinately high when compared to other radionuclides, due to the high biotransfer factor from soil.

The highest risks from exposures via groundwater pathways are from uranium-234 and uranium-238. The total future risk from these radionuclides via groundwater pathways is approximately 1×10^{-5}.

Table 6-9 also lists the risks associated with chemical carcinogens detected in the Inactive Flyash Pile. Seven chemical carcinogens were detected in the Inactive Flyash Pile, including beryllium, aroclor-1242 and 1254 (from CIS), benzo(a)pyrene (total PAHs), methylene chloride, trichloroethene and bis (2-ethylhexyl) phthalate. Both PCBs are evaluated using the Aroclor-1260 slope factor, and the benzo(a)pyrene (B(a)P) risk estimate is derived from the UCL of all detected PAHs for which no toxicity data exist. Risks are relatively low for land-use scenarios involving continued access controls.

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TABLE 6-8

TOTAL HAZARD INDEX FOR POTENTIAL TOXIC EFFECTS ASSOCIATED WITH ALL SOIL PATHWAYS AT THE ACTIVE FLYASH PILE

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	Current Land Use		Future Land Use		
				Without Access Controls On-property Resident	
Chemical of Concern	With Active Access Controls Off-property Resident/ Trespassing Child (Scenario 1)	Without Access Controls Off-property Resident/Child Playing On-property (Scenario 2)	With Passive Access Controls Off-property Resident/ Trespassing Child (Scenario 3)	Typical Average Exposure Resident Farmer (Scenario 4)	Reasonable Maximum Exposure Resident Farmer (Scenario 5)
Pathway / Receptor					
Ingestion of Soil	C	C	C	RF	RF
Ingestion of Vegetables	--	--	--	RF	RF
Ingestion of Beef	--	OF	--	RF	RF
Ingestion of Milk	--	OF	--	RF	RF
Dermal Contact	C	C	C	RF	RF
Inhalation of Fugitive Dust	OF	OF	OF	RF	RF
External Penetrating Radiation	C	C	C	RF	RF
Hazardous Chemicals					
Antimony	7.73E-04	6.38E-01	7.73E-03	1.18E+02	1.18E+02
Arsenic	2.20E-03	8.31E-01	2.20E-02	4.62E+00	4.92E+00
Barium	7.06E-03	5.05E-02	7.11E-04	4.26E-01	4.35E-01
Beryllium	8.95E-06	9.65E-04	8.95E-05	4.97E-03	6.19E-03
Cadmium	3.78E-06	7.66E-02	3.77E-05	4.57E-01	4.58E-01
Chromium	4.79E-05	4.06E-02	4.79E-04	8.09E-02	8.75E-02
Copper	1.46E-05	2.54E-01	1.46E-04	9.13E-01	9.15E-01
Lead	5.92E-04	1.22E-01	4.89E-03	1.23E+00	1.30E+00
Molybdenum	3.15E-05	2.65E-01	3.15E-04	7.04E-01	7.08E-01
Selenium	2.03E-05	7.37E-02	2.03E-04	1.59E-01	1.62E-01
Thallium	1.59E-04	4.78E-01	1.59E-03	5.04E-01	5.25E-01
Uranium	5.34E-05	1.18E-02	5.34E-04	5.39E-02	6.12E-02
Zinc	4.60E-06	2.53E+00	4.60E-05	3.28E+00	3.28E+00
1,1,1-Trichloroethane	3.66E-07	1.99E-05	3.57E-06	3.50E-02	3.51E-02
1,1-Dichloroethene	5.49E-09	2.18E-07	5.49E-08	2.01E-03	2.01E-03
2-Butanone	5.94E-08	1.79E-06	5.93E-07	3.67E-03	3.67E-03
2-Chlorophenol	7.12E-06	2.18E-04	7.12E-05	3.60E-02	3.60E-02
4-Methyl-2-pentanone	2.22E-07	6.72E-06	2.22E-06	4.56E-03	4.56E-03
Acetone	1.26E-07	3.79E-06	1.26E-06	1.51E-02	1.52E-02
Benzoic acid	1.35E-08	4.13E-07	1.35E-07	9.86E-05	9.87E-05
Bis(2-ethylhexyl) phthalate	1.41E-05	7.20E-04	1.41E-04	2.13E-03	2.15E-03
Carbon disulfide	4.61E-09	6.05E-08	1.24E-08	1.83E-04	1.83E-04
Di-n-butyl phthalate	5.12E-07	2.46E-05	5.12E-06	8.09E-05	8.18E-05
Di-n-octyl phthalate	1.46E-05	9.24E-01	1.46E-04	9.25E-01	9.24E-01
Methylene chloride	2.04E-07	6.24E-06	2.04E-06	8.39E-03	8.39E-03
Naphthalene	1.52E-06	6.66E-05	1.52E-05	1.62E-03	1.63E-03
Phenol	7.17E-08	2.17E-06	7.17E-07	9.12E-04	9.12E-04
Toluene	3.71E-09	2.29E-07	3.71E-08	2.71E-04	1.46E-04

* C = Child; OF = Off-property farmer; RF = Resident farmer

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TABLE 6-9

TOTAL INCREMENTAL LIFETIME CANCER RISK ASSOCIATED WITH ALL SOIL PATHWAYS AT THE INACTIVE FLYASH PILE

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Chemical of Concern	Current Land Use		Future Land Use		
				Without Access Controls On-property Resident	
	With Active Access Controls Off-property Resident/ Trespassing Child (Scenario 1)	Without Access Controls Off-property Resident/Child Playing On-property (Scenario 2)	With Passive Access Controls Off-property Resident/ Trespassing Child (Scenario 3)	Typical Average Exposure Resident Farmer (Scenario 4)	Reasonable Maximum Exposure Resident Farmer (Scenario 5)
Pathway / Receptor[a]					
Ingestion of Soil	C	C	C	RF	RF
Ingestion of Vegetables	--	--	--	RF	RF
Ingestion of Beef	--	OF	--	RF	RF
Ingestion of Milk	--	OF	--	RF	RF
Dermal Contact	C	C	C	RF	RF
Inhalation of Fugitive Dust	OF	OF	OF	RF	RF
External Penetrating Radiation	C	C	C	RF	RF
Radionuclides					
Pu-239/240	1.8E-10	3.1E-09	1.0E-09	1.0E-08	5.6E-07
Ra-226 + 5 dtrs	3.2E-06	1.2E-04	3.2E-05	1.6E-03	1.2E-02
Tc-99	1.1E-10	9.2E-03	1.1E-09	1.3E-03	1.0E-02
Th-228 + 7 dtrs	2.2E-07	6.6E-06	2.2E-06	1.1E-04	8.4E-04
Th-230	2.8E-09	2.0E-08	4.7E-09	4.1E-08	1.3E-06
Th-232	3.0E-10	1.7E-09	4.5E-10	3.2E-09	1.1E-07
U-234	7.0E-08	4.2E-04	4.9E-07	2.0E-04	1.8E-03
U-235 + 1 dtr	3.2E-06	1.8E-04	3.2E-05	1.6E-03	1.2E-02
U-238 + 2 dtrs	2.0E-06	6.3E-04	1.9E-05	1.2E-03	9.5E-03
Hazardous Chemicals					
Beryllium	8.36E-08	1.88E-05	3.89E-07	1.62E-05	1.57E-04
Aroclor-1242	6.96E-10	1.77E-07	6.06E-09	1.66E-06	1.30E-05
Aroclor-1254	2.44E-08	1.50E-04	2.12E-07	2.60E-05	2.04E-04
Benzo(a)pyrene	6.45E-07	5.51E-04	6.36E-06	1.54E-04	1.21E-03
Bis(2-ethylhexyl) phthalate	5.87E-10	8.82E-08	5.78E-09	6.52E-08	5.13E-07
Methylene chloride	3.18E-12	1.03E-10	3.07E-11	9.47E-08	7.37E-07
Trichloroethene	2.04E-13	2.64E-11	1.40E-12	9.51E-09	3.20E-08

[a] C = Child; OF = Off-site farmer; RF = Resident farmer

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Scenarios that include food ingestion pathways (e.g. scenarios involving the loss of access controls) all show risks in the range of 10^{-4} to 10^{-5} for beryllium, benzo(a)pyrene, and PCBs. The "heavy" organic compounds such as semivolatiles and pesticides, have higher biotransfer\bioaccumulation factors than VOCs leading to higher risk estimates for food ingestion pathways for the semivolatiles and pesticides.

Table 6-10 presents the HIs for chemicals toxicants detected in the Inactive Flyash Pile. All estimated HIs for current land use are less than 1. HIs greater than 1 appear only for the future on-property farmer scenario for three chemicals: antimony, arsenic and copper. As with the Active Flyash Pile, although TCA is frequently detected, HIs for TCA are low for all scenarios.

6.2.6 South Field

Exposure point concentrations for current scenarios and future scenarios for the South Field are UCL concentrations determined from surface soil and subsurface soil data for radionuclides and from subsurface soil data for hazardous chemicals. The exposure point concentrations for groundwater are calculated using fate and transport modeling. Exposure point concentrations are multiplied by (1) chemical-specific, pathway-specific unit risk factors and (2) unit toxicity factors to determine ILCRs and HIs, respectively.

ILCRs for soil pathways are summarized in Table 6-11. The detailed results of the risk assessment are presented in Attachment III of Appendix A. The risks from uranium-238, uranium-235, thorium-228, radium-228, and radium-226, and their short-lived progeny exceed 10^{-4}. The risk from radium-226 and its short-lived progeny is 9×10^{-2} and nearly all of this risk is from external radiation exposure.

Only uranium-234 and uranium-238 are determined to reach the aquifer in concentrations exceeding the screening level. The total risk from those isotopes and their short-lived progeny via groundwater exposure pathways is approximately 1×10^{-5}.

Table 6-11 also lists the ILCRs associated with hazardous chemicals. Six chemical carcinogens were detected in the South Field, including PCBs, benzo(a)pyrene (total PAHs), methylene chloride and OCDD. The estimated risks for PCBs, PAHs and OCDD for land-use scenarios with no access controls are greater than 10^{-4}. PCBs, PAHs, and dioxins represent chemicals with extreme conservatism included into the toxicity assessment.

TABLE 6-10

TOTAL HAZARD INDEX FOR POTENTIAL TOXIC EFFECTS ASSOCIATED WITH ALL SOIL PATHWAYS AT THE INACTIVE FLYASH PILE

	Current Land Use		Future Land Use		
				Without Access Controls On-property Resident	
Chemical of Concern	With Active Access Controls Off-property Resident/ Trespassing Child (Scenario 1)	Without Access Controls Off-property Resident/Child Playing On-property (Scenario 2)	With Passive Access Controls Off-property Resident/ Trespassing Child (Scenario 3)	Typical Average Exposure Resident Farmer (Scenario 4)	Reasonable Maximum Exposure Resident Farmer (Scenario 5)
Pathway / Receptor[a]					
Ingestion of Soil	C	C	C	RF	RF
Ingestion of Vegetables	--	--	--	RF	RF
Ingestion of Beef	--	OF	--	RF	RF
Ingestion of Milk	--	OF	--	RF	RF
Dermal Contact	C	C	C	RF	RF
Inhalation of Fugitive Dust	OF	OF	OF	RF	RF
External Penetrating Radiation	C	C	C	RF	RF
Hazardous Chemicals					
Antimony	2.62E-04	2.17E-01	2.62E-03	3.99E+01	4.00E+01
Arsenic	2.39E-03	9.01E-01	2.39E-02	5.01E+00	5.33E+00
Barium	6.22E-05	5.04E-02	6.22E-04	3.72E-01	3.81E-01
Beryllium	1.06E-05	1.14E-03	1.06E-04	5.86E-03	7.31E-03
Cadmium	6.83E-06	1.39E-01	6.83E-05	8.26E-01	8.29E-01
Copper	8.22E-06	1.43E-01	8.22E-05	5.13E-01	5.14E-01
Lead	4.54E-04	1.13E-01	4.54E-03	1.14E+00	1.20E+00
Selenium	4.82E-06	1.75E-02	4.82E-05	3.79E-02	3.86E-02
Thallium	6.86E-05	2.06E-01	6.86E-04	2.17E-01	2.27E-01
Uranium	2.71E-04	6.00E-02	2.71E-03	2.73E-01	3.10E-01
Cyanide	4.27E-07	1.28E-05	4.27E-06	2.30E-05	8.13E-05
1,1,1-Trichloroethane	1.48E-08	8.25E-07	1.48E-07	1.46E-03	1.46E-03
2-Butanone	1.63E-07	4.91E-06	1.63E-06	1.01E-02	1.01E-02
4-Methyl-2-pentanone	2.97E-08	8.97E-07	2.97E-07	6.09E-04	6.09E-04
Acetone	9.86E-07	2.97E-05	9.86E-06	1.19E-01	1.19E-01
Anthracene	4.87E-08	2.30E-06	4.87E-07	3.18E-05	3.21E-05
Benzoic acid	2.78E-08	8.47E-07	2.78E-07	2.03E-04	2.03E-04
Bis(2-ethylhexyl) phthalate	1.21E-05	6.14E-04	1.21E-04	1.81E-03	1.83E-03
Carbon disulfide	9.89E-10	5.10E-08	9.89E-09	1.46E-04	1.47E-04
Di-n-butyl phthalate	3.41E-07	1.65E-05	3.41E-06	5.40E-05	5.45E-05
Fluoranthene	1.74E-06	9.06E-05	1.74E-05	2.58E-04	2.62E-04
Methylene chloride	3.98E-08	1.21E-06	3.98E-07	1.64E-03	1.64E-03
Naphthalene	9.83E-07	4.30E-05	9.83E-06	1.05E-03	1.05E-03
Phenol	2.35E-07	7.12E-06	2.35E-06	2.98E-03	2.99E-03
Pyrene	2.97E-06	1.41E-04	2.97E-05	4.75E-04	4.80E-04

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TABLE 6-10
(Continued)

Chemical of Concern	Current Land Use: With Active Access Controls Off-property Resident/ Trespassing Child (Scenario 1)	Current Land Use: Without Access Controls Off-property Resident/Child Playing On-property (Scenario 2)	Future Land Use: With Passive Access Controls Off-property Resident/ Trespassing Child (Scenario 3)	Future Land Use, Without Access Controls On-property Resident: Typical Average Exposure Resident Farmer (Scenario 4)	Future Land Use, Without Access Controls On-property Resident: Reasonable Maximum Exposure Resident Farmer (Scenario 5)
Styrene	7.42E-09	2.35E-07	7.42E-08	1.01E-05	1.01E-05
Toluene	2.10E-09	1.30E-07	2.10E-08	1.53E-04	8.24E-05
Vinyl acetate	1.48E-09	4.45E-08	1.48E-08	7.97E-08	8.24E-08

[a] C = Child; OF = Off-site farmer; RF = Resident farmer

TABLE 6-11

TOTAL INCREMENTAL LIFETIME CANCER RISK ASSOCIATED WITH ALL SOIL PATHWAYS AT THE SOUTH FIELD

	Current Land Use		Future Land Use		
				Without Access Controls On-property Resident	
Chemical of Concern	With Active Access Controls Off-property Resident/ Trespassing Child (Scenario 1)	Without Access Controls Off-property Resident/Child Playing On-property (Scenario 2)	With Passive Access Controls Off-property Resident/ Trespassing Child (Scenario 3)	Typical Average Exposure Resident Farmer (Scenario 4)	Reasonable Maximum Exposure Resident Farmer (Scenario 5)
Pathway / Receptor[a]					
Ingestion of Soil	C	C	C	RF	RF
Ingestion of Vegetables	--	--	--	RF	RF
Ingestion of Beef	--	OF	--	RF	RF
Ingestion of Milk	--	OF	--	RF	RF
Dermal Contact	C	C	C	RF	RF
Inhalation of Fugitive Dust	OF	OF	OF	RF	RF
External Penetrating Radiation	C	C	C	RF	RF
Radionuclides					
Ra-226 + 5 dtrs	2.3E-05	9.0E-04	2.3E-04	1.1E-02	8.9E-02
Ra-228 + dtr	4.1E-08	1.8E-06	4.1E-07	2.0E-05	1.6E-04
Th-228 + 7 dtrs	1.1E-06	3.3E-05	1.1E-05	5.4E-04	4.2E-03
Th-230	1.1E-07	4.9E-07	1.5E-07	9.4E-07	3.0E-05
Th-232	3.5E-09	1.8E-08	5.1E-09	3.1E-08	1.1E-06
U-234	3.6E-08	2.1E-05	5.7E-08	1.0E-05	9.0E-05
U-235 + 1 dtr	4.3E-08	2.4E-06	4.2E-07	2.1E-05	1.6E-04
U-238 + 2 dtrs	1.8E-07	3.9E-05	1.2E-06	7.3E-05	5.9E-04
Hazardous Chemicals					
Beryllium	8.84E-09	4.28E-06	8.84E-08	3.68E-06	3.57E-05
Aroclor-1242	9.39E-09	2.75E-06	9.39E-08	2.58E-05	2.01E-04
Aroclor-1254	7.87E-08	5.58E-04	7.87E-07	9.65E-05	7.59E-04
Aroclor-1260	1.51E-08	6.86E-05	1.51E-07	1.22E-05	9.65E-05
Benzo(a)pyrene	7.74E-07	4.04E-04	7.74E-06	1.88E-04	1.47E-03
Bis(2-ethylhexyl) phthalate	7.12E-11	7.81E-09	7.12E-10	8.02E-09	6.32E-08
Chloroform	7.76E-14	5.47E-12	7.76E-13	1.11E-08	8.61E-08
Methylene chloride	3.45E-12	1.09E-10	3.45E-11	1.06E-07	8.29E-07
Octachlorodibenzo-p-dioxin	2.29E-09	6.69E-05	2.29E-08	9.28E-06	7.22E-05
Tetrachlorodibenzofuran	6.86E-10	2.01E-05	6.86E-09	2.79E-06	2.55E-05

[a] C = Child; OF = Off-site farmer; RF = Resident farmer

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Table 6-12 provides estimated HIs for chemical toxicants detected in the South Field. As with the other Operable Unit 2 waste areas, the land-use scenario involving the loss of access controls indicates the potential for toxic effect to occur to the hypothetical resident farmer. Effects associated with metals dominate the total toxic effect. The HI for antimony is greater than 1, while HI for several chemicals, including molybdenum, silver, total uranium and a phthalate are approaching 1. For the land-use scenarios involving continued controls, HIs range from 0.00000002 (benzoic acid) to 0.005 (antimony).

TABLE 6-12

TOTAL HAZARD INDEX FOR POTENTIAL TOXIC EFFECTS ASSOCIATED WITH ALL SOIL PATHWAYS AT THE SOUTH FIELD

	Current Land Use		Future Land Use		
				Without Access Controls On-property Resident	
Chemicals of Concern	With Active Access Controls Off-property Resident/ Trespassing Child (Scenario 1)	Without Access Controls Off-property Resident/Child Playing On-property (Scenario 2)	With Passive Access Controls Off-property Resident/ Trespassing Child (Scenario 3)	Typical Average Exposure Resident Farmer (Scenario 4)	Reasonable Maximum Exposure Resident Farmer (Scenario 5)
Pathway / Receptor[a]					
Ingestion of Soil	C	C	C	RF	RF
Ingestion of Vegetables	--	--	--	RF	RF
Ingestion of Beef	--	OF	--	RF	RF
Ingestion of Milk	--	OF	--	RF	RF
Dermal Contact	C	C	C	RF	RF
Inhalation of Fugitive Dust	OF	OF	OF	RF	RF
External Penetrating Radiation	C	C	C	RF	RF
Hazardous Chemicals					
Antimony	4.61E-04	3.80E-01	4.61E-03	7.01E+01	7.02E+01
Cadmium	1.14E-05	2.30E-01	1.14E-04	1.37E+00	1.38E+00
Chromium	5.23E-05	4.43E-02	5.23E-04	8.83E-02	9.55E-02
Lead	1.21E-03	3.00E-01	1.21E-02	3.03E+00	3.20E+00
Manganese	6.54E-05	8.41E-02	6.54E-04	8.99E-01	9.08E-01
Molybdenum	2.43E-05	2.04E-01	2.43E-04	5.44E-01	5.74E-01
Silver	1.71E-05	1.54E+00	1.71E-04	1.93E+00	1.93E+00
Uranium	1.62E-04	3.58E-02	1.62E-03	1.63E-01	1.85E-01
4-Methyl-2-pentanone	4.45E-08	1.34E-06	4.45E-07	9.13E-04	9.13E-04
Acetone	8.16E-08	2.45E-06	8.16E-07	9.80E-03	9.80E-03
Anthracene	5.76E-08	2.72E-06	5.76E-07	3.77E-05	3.80E-05
Benzoic acid	2.78E-08	8.47E-07	2.78E-07	2.03E-04	2.03E-04
Beryllium	2.40E-06	2.58E-04	2.40E-05	1.33E-03	1.66E-03
Bis(2-ethylhexyl) phthalate	1.48E-06	7.57E-05	1.48E-05	2.23E-04	2.26E-04
Chloroform	7.42E-09	3.38E-07	7.42E-08	1.41E-03	1.41E-03
Di-n-octyl phthalate	7.23E-06	4.57E-01	7.23E-05	4.56E-01	4.56E-01
Diethyl phthalate	7.79E-08	2.45E-06	7.79E-07	1.36E-04	1.37E-04
Fluoranthene	7.66E-06	3.98E-04	7.66E-05	1.14E-03	1.15E-03
Methylene Chloride	4.47E-08	1.37E-06	4.47E-07	1.84E-03	1.84E-03
Pyrene	8.21E-06	3.92E-04	8.21E-05	1.31E-03	1.33E-03
Total Xylenes	2.47E-11	1.86E-09	2.47E-10	1.13E-06	9.69E-07

[a] C = Child; OF = Off-property farmer; RF = Resident farmer

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7.0 SUMMARY

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The FEMP is a 1050-acre site in a rural area of Hamilton and Butler counties in Ohio. An RI/FS is being conducted at the site in response to CERCLA, as amended by SARA. This RI addresses contamination in Operable Unit 2, which consists of five solid waste disposal areas at the site: the Solid Waste Landfill, Lime Sludge Ponds, Active Flyash Pile, Inactive Flyash Pile, and South Field.

The specific objectives for the RI were enumerated in Section 1.0. To provide data to address these objectives, environmental sampling programs were conducted as a part of the RI/FS. Additional data collected during the Environmental Survey and the CIS were also evaluated. Sampling and analysis, as well as the collection of other site data, have been described in Section 2.0. The data were used to characterize the five waste areas which comprise Operable Unit 2, as well as the environmental setting within which they reside.

A description of the site and relevant environmental conditions have been presented in Section 3.0. This section, in conjunction with the SWCR, includes sufficient data on which to base an EIS, as required by NEPA. Section 4.0 describes the nature and extent of contamination in Operable Unit 2 waste areas, as well as the surrounding environmental media, including underlying native soils, groundwater, drainage sediments, surface water, and biota.

Evaluations of potential contaminant migration pathways (air, surface water, and underground) are presented in Section 5.0, as are the results of fate and transport modeling to predict the migration of contaminants from the waste areas to potential human and environmental receptors. The Baseline Risk Assessment, as described in Section 6.0, addresses potential risks to human health associated with contaminants migrating from the waste areas. Risks are quantified for five land-use scenarios:

- Current land use with active access controls (Scenario 1)
- Current land use without access controls (Scenario 2)
- Future land use with passive access controls (Scenario 3)
- Future land use without access controls assuming a typical average exposure (Scenario 4)
- Future land use without access controls assuming a reasonable maximum exposure (Scenario 5)

For Scenarios 1 and 3, it is assumed that the government maintains access control at the property boundary. For Scenarios 2, 4, and 5, it is assumed that the government does not maintain access control at the property boundary.

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The following sections provide summaries of the nature and extent of contamination, fate and transport modeling, and baseline risk assessment for each of the Operable Unit 2 waste areas.

7.1 SOLID WASTE LANDFILL

7.1.1 Nature and Extent of Contamination

Uranium, the most important waste-related contaminant in the Solid Waste Landfill, is present in both the surface media and the subsurface fill. The highest levels of uranium in soils appear to be scattered throughout the surface and subsurface media of the waste area, with no clear pattern emerging. Thorium and radium are also present, but at levels only slightly above background. Uranium concentrations in surface soils outside the Solid Waste Landfill boundary are similar to those inside, indicating that the contamination is widespread and is derived from sources outside the waste area boundary.

Uranium concentrations in native soils underlying the fill are above background, but are much less than those in the overlying fill. However, uranium concentrations in perched groundwater and in the Great Miami Aquifer are only slightly above background, and the 2000-series well in the study area with the highest uranium concentration is upgradient of the site. This indicates that contaminants have not migrated from the waste area via the aquifer.

A number of organic compounds were detected in soils at low concentrations and generally at low frequencies of occurrence. These included 1,4-dioxane, chlorinated dioxins and furans, PAHs, and PCBs. Of the waste-related constituents, only acetone, methylene chloride, and di-n-butyl phthalate were present in the groundwater. Acetone and methylene chloride are common laboratory contaminants.

A number of inorganic constituents were detected in subsurface media above their respective background concentrations. The most frequent such detections were for cadmium, chromium, silver, antimony, beryllium, and molybdenum. Molybdenum was detected in one perched groundwater well.

7.1.2 Fate and Transport Modeling

Results of air dispersion modeling indicate that the highest on-site and off-site airborne radionuclide concentrations are for uranium and thorium. The highest airborne organic concentrations are for fluoranthene, and the highest airborne inorganic concentrations are for barium.

Surface water modeling indicates that uranium and thorium are the leading radionuclides in terms of (1) total annual loading, (2) concentration in surface water runoff during the one-year, 24-hour storm, and (3) sediment concentration. The leading organic constituent for annual loading and storm water concentration is 1,4-dioxane. Total PAHs (as a group), total PCBs, and pentachlorophenol are the most elevated organic constituents of stream sediment. Barium is the leading inorganic constituent for

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annual loading and stream sediment, and copper is the most elevated inorganic contaminant in stormwater concentration.

The uranium isotopes are the only constituents of concern for which groundwater concentrations are projected to exceed screening levels during the next 1000 years. (Screening levels were based on a 10^{-7} cancer risk.) Uranium is not expected to exceed the screening levels at the FEMP boundary. Strontium-90, benzoic acid, and 2-chlorophenol were projected to reach the aquifer, but not to exceed their respective screening levels. Screening levels are not available for 1,4-dioxane, 2-hexanone, and 4-chloro-3-methlyphenol, which are also projected to reach the aquifer.

7.1.3 Risk Assessment

For the Solid Waste Landfill, risks associated with the groundwater and surface water pathways were found to be relatively small when compared with those of the soil pathways. The elevated risks associated with the soil pathway derive from the following constituents:

- Scenario 1: no constituents for which ILCR $>10^{-4}$ or HI>1.0
- Scenario 2: PCBs, PAHs, dioxins/furans, and silver
- Scenario 3: no constituents for which ILCR $>10^{-4}$ or HI>1.0
- Scenario 4: thorium, 1,4-dioxane, Aroclor-1242, PAHs, dioxin, antimony, cadmium, lead, and silver
- Scenario 5: uranium, thorium, radium, 1,4-dioxane, PCBs, PAHs, dioxins/furans, antimony, cadmium, lead, and silver

In summary, no elevated risks are associated with the scenarios which assume access controls are maintained.

7.2 LIME SLUDGE PONDS

7.2.1 Nature and Extent of Contamination

Uranium and thorium are the most important waste-related constituents in the Lime Sludge Ponds. Other than the Lime Sludge Ponds, another potential source is the K-65 slurry line, which lies immediately south of the South Lime Sludge Pond. Radium and lead-210 are also present above background, but at lower frequencies.

Subsurface samples exhibited uranium and thorium activities that were approximately 10 to 100 times less than those of surface media and were below or only slightly above background. This indicates that there is substantial vertical attenuation of uranium and thorium by soils in this area. Perched groundwater analyses indicate elevated uranium levels in Wells 1041 and 1042, which are adjacent to the South Lime Sludge Pond. Uranium in Well 1041 is only slightly above background, and the

source of uranium in Well 1042 is uncertain. Subsurface sampling does not indicate that waste-related radioactive constituents have migrated from the waste area.

Low levels of VOCs were detected in subsurface samples collected from both pond areas, with 2-butanone being present at the highest single concentration. SVOCs detected in soils included phthalate esters and a single occurrence of Chlordane and Aroclor-1248. Of the waste-related organic compounds, only acetone, 2-hexanone, methylene chloride, and 4-methyl-2-pentanone were detected in groundwater. Acetone and methylene chloride are common laboratory contaminants.

Chromium was detected in 3 of 8 subsurface media samples above its background concentration but was not detected above background in groundwater.

7.2.2 Fate and Transport Modeling

Results of air dispersion modeling indicate that the highest on-site and off-site airborne radionuclide concentrations are for thorium. The highest airborne organic concentrations are for butyl benzyl phthalate, and the highest airborne inorganic concentrations are for chromium.

The uranium isotopes are the only constituents of concern for which the groundwater concentrations are projected to exceed the screening levels (i.e., the 10^{-7} cancer risk concentration) during the next 1000 years. Uranium is not expected to exceed the screening levels at the FEMP boundary. Strontium-90, carbon disulfide, benzoic acid, mercury, and cyanide are projected to reach the aquifer, but not to exceed their respective screening levels. A screening level is not available for 2-hexanone, which is also projected to reach the aquifer.

7.2.3 Risk Assessment

For the Lime Sludge Ponds, risks associated with the groundwater and surface water pathways were found to be relatively small when compared with those of the soil pathways. The elevated risks associated with the soil pathway derive from the following constituents:

- Scenario 1: no constituents for which ILCR>10^{-4} or HI>1.0
- Scenario 2: beryllium, mercury, and silver
- Scenario 3: no constituents for which ILCR>10^{-4} or HI>1.0
- Scenario 4: thorium, radium, lead-210, chlordane, 2-butanone, antimony, cadmium, mercury, and silver
- Scenario 5: uranium, thorium, radium, lead-210, chlordane, 2-butanone, antimony, beryllium, cadmium, mercury, and silver

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In summary, no elevated risks are associated with the scenarios which assume access controls are maintained.

7.3 ACTIVE FLYASH PILE

7.3.1 Nature and Extent of Contamination

Uranium and thorium are the most important waste-related constituents of the Active Flyash Pile, but the concentrations of these are low when compared to other Operable Unit 2 waste areas. Radium is also present, but a concentrations only slightly above background. Analyses of underlying native soil samples do not indicate that radionuclides have migrated from the waste into the soil. However, elevated uranium levels were measured in the sediments in drainage leading away from the waste area, indicating migration via the surface water pathway. Other potential sources of this sediment contamination include the South Field and surface soils north of the Active Flyash Pile.

Organic compounds were detected in subsurface media from the Active Flyash Pile at low concentrations and low frequencies, with acetone, methylene chloride and 1,1,1-trichloroethane being the most common.

A number of inorganic constituents were detected in subsurface medial above their respective background concentrations. The most frequent such detections were for arsenic, antimony, beryllium, copper, lead, molybdenum, selenium, and thallium.

7.3.2 Fate and Transport Modeling

Results of air dispersion modeling indicate that the highest on-site and off-site radionuclide concentrations are for uranium. The highest airborne organic concentrations are for di-n-octyl phthalate, and the highest airborne inorganic concentrations are for barium.

Surface water modeling indicates that uranium and thorium are the leading radionuclides in terms of (1) total annual loading; (2) concentration in surface water runoff during the one-year, 24-hour storm; and (3) sediment concentration. Of the organic constituents-of-concern, 1,1,1-trichloroethane is the leading compound for all three categories. Barium is the leading inorganic contaminant for annual loading and sediment concentration; thallium is the leading inorganic contaminant for storm water concentration.

No constituents of concern for groundwater are projected to exceed the screening level (i.e., the 10^{-7} cancer risk) for groundwater during the next 1000 years. Uranium, strontium-90, barium, molybdenum, 2-chlorophenol, benzoic acid, and carbon disulfide are expected to reach groundwater, but not at concentrations exceeding their respective screening levels. A screening level is not available for 4-chloro-3-methylphenol, which is also projected to reach the aquifer.

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7.3.3 Risk Assessment

For the Active Flyash Pile, risks associated with the groundwater and surface water pathways were found to be relatively small when compared with those of the soil pathways. The elevated risks associated with the soil pathway derive from the following constituents:

- Scenario 1: no constituents for which ILCR $>10^{-4}$ or HI>1.0
- Scenario 2: zinc
- Scenario 3: no constituents for which ILCR $>10^{-4}$ or HI>1.0
- Scenario 4: thorium, radium, antimony, arsenic, lead, and zinc
- Scenario 5: thorium, radium, antimony, arsenic, beryllium, lead, and zinc

In summary, no elevated risks are associated with the scenarios which assume access controls are maintained.

7.4 INACTIVE FLYASH PILE

7.4.1 Nature and Extent of Contamination

Uranium, the most important contaminant in the Inactive Flyash Pile, exists at levels up to 26,600 mg/kg in surface soils and 873 mg/kg in subsurface soils. The most contaminated samples were collected from the surface and from the deepest fill. The fact that uranium concentrations in deep soil samples are greater than those in overlying flyash suggests that contaminated soils may have been placed in the area prior to the dumping of flyash. Another possibility is that uranium has leached from the flyash and then has precipitated from the leachate when it has encountered the underlying native soil. Thorium and radium are also present but typically at levels only slightly above background. Technetium was detected in two samples, one of which was at a relatively high concentration.

Well 2046, which is in the South Field but is immediately downgradient of the Inactive Flyash Pile, exhibits a uranium concentration higher than any other well in the Flyash/South Field study area. Based on data presented in this report, however, no conclusion can be drawn as to whether the Inactive Flyash Pile is a source of this contamination. Other potential sources are the South Field, recharge from Paddys Run, and/or other site-related sources.

Organic compounds were detected in soils at low concentrations and low frequency, with methylene chloride, acetone, and 1,1,1-trichloroethane being the most common. Also present were PCBs, and PAHs. Bis(2-ethylhexyl) phthalate and 1,1,1-trichloroethane were the only waste-related organic compound detected in groundwater. Acetone, methylene chloride, and bis(2-ethylhexyl), phthalate are common laboratory contaminants.

A number of inorganic constituents were detected in subsurface media above their respective background concentrations. The most frequent such detections were for arsenic, barium, beryllium,

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cadmium, copper, selenium, and cyanide. Of these, only cadmium was consistently detected above background in groundwater, but this was in Well 4016 in the Lower Great Miami Aquifer.

7.4.2 Fate and Transport Modeling

Results of air dispersion modeling indicate that the highest on-site and off-site radionuclide concentrations are for uranium. The highest airborne organic concentrations are for bis (2-ethylhexyl) phthalate; the highest inorganic concentrations is for barium.

Surface water modeling indicates that uranium is the leading radionuclide in terms of (1) total annual loading, (2) concentration in surface water runoff during the one-year, 24-hour storm, and sediment concentration. Acetone is the leading organic constituent for annual loading and stormwater concentration. Total PAHs (as a group) and bis (2-ethylhexyl) phthalate are the most elevated organic constituents of stream sediment. Cyanide is the leading inorganic constituent for annual loading and stormwater concentration, whereas arsenic and barium are the most elevated inorganic contaminants in stream sediment.

The isotopes of uranium and neptunium-237 are projected to reach groundwater at concentrations greater than their respective screening levels (i.e., the 10^{-7} cancer risk) during the next 1000 years. Uranium is projected to reach the FEMP boundary at concentrations exceeding the screening levels. Strontium-90, cyanide, benzoic acid, and carbon disulfide are expected to reach groundwater but not at concentrations exceeding their respective screening levels. A screening level is not available for 2-hexanone, which is also projected to reach the aquifer.

7.4.3 Risk Assessment

For the Inactive Flyash Pile, risks associated with the groundwater and surface water pathways were found to be relatively small when compared with those of the soil pathways. The elevated risks associated with the soil pathway derive from the following constituents:

- Scenario 1: no constituents for which ILCR $>10^{-4}$ or HI>1.0
- Scenario 2: uranium, radium, technetium, Aroclor-1254, and PAHs
- Scenario 3: no constituents for which ILCR $>10^{-4}$ or HI>1.0
- Scenario 4: uranium, thorium, radium, technetium, PAHs, antimony, arsenic, and lead
- Scenario 5: uranium, thorium, radium, technetium, Aroclor-1254, PAHs, antimony, arsenic, beryllium, and lead

In summary, no elevated risks are associated with the scenarios which assume access controls are maintained.

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7.5 SOUTH FIELD

7.5.1 Nature and Extent of Contamination

Uranium, thorium, and radium are the important contaminants in the South Field. Concentrations for these analytes were highest in the surface soils, and decreased with increasing depth. The presence of uranium in some native soil samples indicates that uranium has leached from the fill into the native soil, but most native soil samples exhibited radionuclide concentrations less than (or just slightly above) background. Groundwater samples collected from one of the closest downgradient wells exhibited uranium concentrations less than background. Based on the data presented in this report, no conclusion can be drawn as to whether the South Field is a source of radionuclide contamination to the underlying Great Miami Aquifer. Other potential sources are the Inactive Flyash Pile, recharge from Paddys Run, and/or other site-related sources.

Organic compounds were detected at low frequencies and low concentrations. These included PAHs, PCBs, and dioxins. The most frequently detected PAH was pyrene. PCB Aroclors were detected a total of 20 times, but at low concentrations. Only three occurrences of phthalate and acetone were detected in groundwater, indicating that migration of organic compounds from the fill into groundwater has not occurred.

A number of inorganic constituents were detected in subsurface media above their respective background concentrations. The most frequent such detections were for cadmium, beryllium, and molybdenum. Of these, only cadmium was consistently detected above background in groundwater.

Lead was detected in surface soils at the Firing Range at very high concentrations. Four samples exceeded the hazardous waste characteristic threshold.

7.5.2 Fate and Transport Modeling

Results of air dispersion modeling indicate that the highest on-site and off-site radionuclide concentrations in air are for thorium and radium. The highest airborne organic concentrations are for Aroclor-1254. The highest airborne inorganic concentrations are for manganese.

Surface water modeling indicates that uranium is the leading radionuclide in terms of (1) total annual loading, (2) concentration in surface water runoff during the one-year, 24-hour storm, and (3) sediment concentration. Benzoic acid is the leading organic constituent for annual loading and storm water concentration, whereas total PAHs (as a group), total PCBs (as a group), and octachlorodibenzo-p-dioxin are the most elevated organic contaminants in stream sediment. Lead is the leading inorganic constituent for annual loading and stream sediment concentration, and beryllium is the most elevated inorganic contaminant in storm water.

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The isotopes of uranium are projected to exceed screening levels (i.e., the 10^{-7} cancer risk) in groundwater within the next 1000 years. In addition, uranium-238 is projected to reach the FEMP boundary at concentrations exceeding the screening levels. Strontium-90, antimony, cadmium, cobalt, lead, molybdenum, and benzoic acid are also expected to reach groundwater, but not to exceed the screening levels. No screening level is available for 2-methylnapthalene, which is also expected to reach the aquifer.

7.5.3 Risk Assessment

- Scenario 1: no constituents for which I LCR $>10^{-4}$ or HI>1.0
- Scenario 2: radium, Aroclor-1254, PAHs, and silver
- Scenario 3: radium
- Scenario 4: thorium, radium, PAHs, antimony, cadmium, lead, and silver
- Scenario 5: uranium, thorium, radium, PCBs, PAHs, antimony, cadmium, lead, and silver

In summary, with the exception of radium, no elevated risks are associated with the scenario which assume access controls are maintained.

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