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REMEDIAL INVESTIGATION REPORT FOR OPERABLE UNIT 4 TASK 6 REPORT OCTOBER 1990

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TASK 6 REPORT

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO

REMEDIAL INVESTIGATION and FEASIBILITY STUDY

October 1990

U.S. DEPARTMENT OF ENERGY
OAK RIDGE OPERATIONS OFFICE

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FINAL

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LIST OF ACRONYMS

AEC	Atomic Energy Commission
AMS	Aerial Measuring System
ARARs	applicable or relevant and appropriate requirements
ASI	Advanced Sciences, Inc.
ASTM	American Society for Testing and Materials
BNI	Bechtel National, Inc.
CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CIS	Characterization Investigation Study
COE	U.S. Army Corps of Engineers
DCG	Derived Concentration Guides
DOE	U.S. Department of Energy
EIS	Environmental Impact Statement
EMR	Environmental Monitoring Report
EP	Extraction Procedure
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FFA	Federal Facility Agreement
FFCA	Federal Facilities Compliance Agreement
FIDLER	Field Instrument for the Detection of Low Energy Radiation
FMPC	Feed Materials Production Center
ft^3/s	cubic feet/second
ft^2/day	square feet/day
gpd	gallons per day
gpm	gallons per minute
HI	hazard index
HSL	Hazardous Substance List
ISP	Interim Stabilization Project
IT	IT Corporation
keV	kiloelectron volt
kg	kilograms
LLD	lower limit of detection

LIST OF ACRONYMS
(Continued)

LOOW	Lake Ontario Ordnance Works
MAC	maximum allowable concentration
MCL	maximum contaminant level
MCW	Mallinckrodt Chemical Works
MEI	maximally exposed individual
µg/g	microgram/gram
µg/kg	microgram/kilogram
µg/l	microgram/liter
µR/hr	microroentgen per hour
mg/kg	milligrams/kilogram
mg/l	milligram/liter
msl	mean sea level
mtu	metric tons of uranium
ND	Not Detected
NLO	National Lead (Company) of Ohio
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
O&M	Operations and Maintenance
ODH	Ohio Department of Health
OEPA	Ohio Environmental Protection Agency
ORAU	Oak Ridge Associated Universities
OVA	Organic vapor analyzer
PCB	polychlorinated biphenyls
pCi/g	picocuries/gram
pCi/L	picocuries/liter
PIC	Pressurized Ionization Chamber
ppb	parts per billion
ppm	parts per million
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
REI	reasonably exposed individual
RfD	reference dose

LIST OF ACRONYMS
(Continued)

RGTS	radon gas treatment system
RI/FS	Remedial Investigation/Feasibility Study
RME	Reasonable Maximum Exposure
SARA	Superfund Amendments and Reauthorization Act
SOWC	Southwest Ohio Water Company
TBC	to be considered
TBP	tributyl phosphate
TCLP	Toxicity Characteristic Leaching Procedure
TOC	total organic carbon
TOX	total organic halogens
USC	Unified Soils Classification
USGS	U.S. Geological Survey
USLE	Universal Soil Loss Equation
WLM	working level month
WMCO	Westinghouse Materials Company of Ohio
yd^3	cubic yards

EXECUTIVE SUMMARY

The Feed Materials Production Center (FMPC) is a contractor-operated federal facility for the production of pure uranium for the U.S. Department of Energy (DOE). The FMPC is located on 1050 acres in a rural area approximately 20 miles northwest of downtown Cincinnati, Ohio. On March 9, 1985, the U.S. Environmental Protection Agency (EPA) issued a Notice of Noncompliance letter to DOE identifying EPA's major concerns about potential environmental impacts associated with the FMPC's past and present operations. On July 18, 1986, a Federal Facilities Compliance Agreement (FFCA) was jointly signed by DOE and EPA. The FFCA was primarily intended to ensure that environmental impacts associated with past and present activities at the FMPC are thoroughly investigated so that appropriate remedial actions can be assessed and implemented. To achieve consistency with the operable unit concept and the current commitments of the Remedial Investigation/Feasibility Study (RI/FS) program without modifying the underlying objectives, the 1986 FFCA was amended by a Federal Facility Consent Agreement (Consent Agreement) under Section 120 and 106A of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The Consent Agreement was signed April 9, 1990 and became effective on June 29, 1990. Notice of the intent to conduct the RI/FS was given to the public in the Federal Register, May 15, 1990. A separate RI/FS - National Environmental Policy Act (NEPA) process was embarked upon at this time pursuant to the same Notice of Intent.

In response to the FFCA, an RI/FS was initiated pursuant to CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA). A site-wide RI/FS Work Plan based on the requirements of the FFCA was submitted to EPA in December 1986; final EPA approval was received in May 1988. The Work Plan established the site-wide objectives and overall technical approach for the collection and evaluation of RI data.

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

- Operable Unit 1 - Waste Storage Area
- Operable Unit 2 - Solid Waste Units
- Operable Unit 3 - Production Area and Suspect Areas
- Operable Unit 4 - K-65 Silos and Metal Oxide Silos
- Operable Unit 5 - Environmental Media

The operable unit concept was introduced after completion of the Work Plan. No individual operable unit plans were developed. Therefore, the objectives and methods for completing the RI for each operable unit were based on the overall technical approach stipulated in the RI/FS Work Plan.

This RI Report addresses Operable Unit 4 - the K-65 silos and the metal oxide silos. For the purposes of the RI/FS, Operable Unit 4 was defined as those special facilities with waste characteristics requiring the potential application of singular technologies to effect final remediation. Specifically, Operable Unit 4 consists of the K-65 silos (Silos 1 and 2) and the metal oxide silos (Silos 3 and 4), piping and tanks that lie beneath the silos, and the earthen embankment that provides structural support to Silos 1 and 2. Production and waste disposal records indicate that Silo 4 was never used for production-related activities or for waste storage or disposal. Radiological and chemical analysis of standing rain water contained in the silo indicates the presence of uranium below levels of concern. No further action will be considered for Silo 4 other than removing the water as part of the facility upgrade program.

The FS for Operable Unit 4 is considering remedial actions for the silo structures, the waste stored in the silos, and the adjoining soil berms. Any contaminated underlying soils or perched water will also be addressed during the Operable Unit 4 FS.

It became apparent during the RI data evaluation for Operable Unit 4 that the full impacts of Operable Unit 4 on the surrounding environment could not be determined by constraining the evaluation to only the silos. Therefore, an Operable Unit 4 study area was established to allow effective evaluation of remedial alternatives. The Operable Unit 4 study area is bounded by the following Ohio state plane coordinates: North 479300-481100 and East 1377950-1379150.

RI data relevant to Operable Unit 4 were evaluated by breaking the operable unit into its component elements. The elements evaluated during the RI were:

- Waste material in the silos
- Physical structure of the silos
- Soil embankments or berms (Silos 1 and 2)
- Glacial overburden beneath the silos
- Operable Unit 4 study area
- Regional environment

The RI field program began in July 1987. The specific media that were scheduled for sampling and analysis during the RI were:

- K-65 and metal oxide silo contents
- K-65 silo berms
- K-65 and metal oxide silo subsoils
- Surface soils
- Subsurface soils
- Surface water and sediments
- Groundwater
- Biological resources

Sampling and analysis programs for the K-65 silo berms and the K-65 and metal oxide silo subsoils are ongoing as this report is being prepared. No data are presently available from these programs. A partial sampling of the contents of the K-65 silo was completed in 1989 by Westinghouse Materials Company of Ohio (WMCO). A resampling effort by Advanced Sciences, Inc./IT Corporation (ASI/IT), which is directed toward obtaining a representative core sample of the silo contents, is ongoing at this time. Future revisions to this report will contain the data from these sampling programs when they become available.

Historic analyses of the K-65 silo residues indicated that approximately 11,200 kilograms of uranium [0.71 percent uranium-235 (U-235)] are present in the residues. Analytical results of residue samples taken in July 1988 indicated that the uranium concentration was 1400 parts per million (ppm) in Silo 1 and 1800 ppm in Silo 2. In addition, approximately 1.6 to 3.7 kilograms of radium were estimated to be in the K-65 silo residues.

Data from the sampling effort conducted in 1989 for Silos 1 and 2 indicate that the concentration of radium-226 (Ra-226) in Silo 1 ranges from 89,280 picocuries/gram (pCi/g) to 192,600 pCi/g; in Silo 2 it ranges from 657 to 145,300 pCi/g. Thorium-230 (Th-230) concentrations in Silo 1 range from 10,569 to 43,771 pCi/g and from 8365 to 40,124 pCi/g in Silo 2. The concentration of lead-210 (Pb-210) in Silo 1 ranges from 48,980 to 181,100 pCi/g and from 77,940 to 399,200 pCi/g in Silo 2. Total uranium concentrations in Silo 1 range from 1189 to 2753 ppm and from 137 to 3717 ppm in Silo 2.

The radium content of Silo 3 was previously estimated at between 15 and 23 curies. The material stored in Silo 3 was also estimated to contain 20 tons of uranium. The quantity of thorium was unknown.

The results of the Silo 3 core sample analysis from the 1989 sampling effort indicate Ra-226 concentrations range from 467 to 6435 pCi/g, comparatively lower than the results from Silos 1 and 2. Th-230 concentrations in Silo 3 range from 21,010 to 71,650 pCi/g, which are almost twice as high as the Th-230 concentrations observed in the K-65 silos. Total uranium was present in Silo 3 in concentrations ranging from 738 to 4554 ppm.

No additional data concerning the silo structures were obtained during the RI. The structural data generated in two previous studies, Camargo Associates, Ltd. (1986) and Bechtel National, Inc. (BNI 1990) are current and deemed appropriate. These studies independently concluded that no life expectancy could be assigned to the K-65 silo domes because of their deteriorated condition.

BNI's subsequent Engineering Evaluation/Cost Analysis (EE/CA) explored options for the K-65 Removal Action. Conducted in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40CFR300.415), this study found that a tornado-induced structural failure of both silos could result in an initial uncontrolled release of approximately 66 curies of radon-222 and some K-65 residues. Furthermore, a spontaneous failure of either silo would result in a release of 33 curies of radon. In both cases, radon release would increase following the initial release until corrective action could be implemented by FMPC personnel. Hence, due to the substantial risk associated with the silos, remedial action should not be undertaken at the silos without providing additional structural support for the silos.

The area around Operable Unit 4 and the FMPC boundary fenceline has been monitored for direct exposure to penetrating radiation (gamma radiation). During 1988, the boundary monitoring station exhibiting the highest average radiation exposure rate was the station directly west of Operable Unit 4 at a distance of 340 meters, along the western FMPC site boundary. The dose equivalent rate measurement for this location was an annual average of 15.3 microrem/hour (µrem/hr). The maximum was 23.53 µrem/hr, and the minimum was 11.56 µrem/hr. Natural background radiation for the area surrounding the FMPC has been estimated to range from 10 to 12 µrem/hr.

The 1988 results of routine radon measurements collected as part of the FMPC environmental monitoring program indicate that annual average background radon concentrations range from 0.50 to 1.25 picocuries/ liter (pCi/L). Off-site monitoring stations positioned at private residences near the FMPC recorded annual average concentrations ranging from 1.13 to 1.65 pCi/L. FMPC boundary fenceline monitoring stations recorded concentrations ranging from 0.6 to 1.65 pCi/L, with the measurement of 1.65 pCi/L being recorded along the FMPC boundary just west of the silos.

The Ohio Department of Health (ODH) established 16 outdoor radon monitoring stations around the FMPC: 12 locations along the FMPC site boundary and 4 control locations distant from the FMPC. Analyses of the detectors located at the site boundary closest to the K-65 silos and those located distant from the FMPC do not reveal consistent significant differences in measured radon concentrations.

There are no data available on the nature and extent of any contamination that may be present in the K-65 silo berms. Radon may be diffusing through the silo walls and decaying to Pb-210 and polonium-210 (Po-210), which accumulate in the berms. The berm sampling and analysis program being conducted as part of the RI will address the potential accumulation of Pb-210 and Po-210 decay.

Surface soil samples collected within the Operable Unit 4 study area during the RI contained uranium, thorium, and radium. The maximum isotopic concentrations for these radionuclides were: 20.8 pCi/g for U-238; 6.9 pCi/g for U-234; 4.3 pCi/g for Th-230; 1.7 pCi/g for Th-232; and 4.2 pCi/g for Ra-226. There were no conclusive data to suggest that these radionuclides were present as a result of releases from Operable Unit 4 as opposed to releases associated with general operations at the FMPC.

Subsurface soil samples collected within the Operable Unit 4 study area during the RI were submitted for full radiological analysis. Observed uranium isotopic concentrations were within background range and did not exceed 1.4 pCi/g for U-238, except for one sample that contained 15.0 pCi/g. Thorium concentrations were less than 1.8 pCi/g with the exception of two samples that contained 3.8 and 4.8 pCi/g. Radium was within background range and did not exceed 1.5 pCi/g. There were also isolated detections of technetium-99 (Tc-99), which did not exceed 3.6 pCi/g. Based on these data, there was no evidence of subsurface soil contamination directly associated with Operable Unit 4. National Lead Company of Ohio, Inc. (NLO) conducted a slant boring sampling beneath the silos in 1983. The presence of uranium and radium in the soil ranged in concentrations from 0.77 to 9.66 pCi/g uranium and 0.68 to 1.2 pCi/g radium. Samples were collected at a depth of 5 to 20 feet below land surface. However, these data were insufficient to determine the full nature and extent of contamination below the silos. Therefore, a final evaluation of subsurface soil contamination within the Operable Unit 4 study area cannot be conducted until the data are available from the slant boring program. This program is designed to collect soil samples from directly beneath the silos.

Surface water samples were collected from drainageways within the Operable Unit 4 study area during the RI. These samples contained elevated uranium concentrations ranging from 5 to 2219 micrograms/liter (µg/L). The highest observed uranium concentration was collected from the downstream sampling location closest to the K-65 silos. Concentrations of uranium in a water sample collected from Paddys Run downstream of the K-65 silos ranged from 5 to 29 µg/L. Radium was not detected in any of the surface water samples collected within the Operable Unit 4 study area.

Sediment samples collected from drainageways within the Operable Unit 4 study area during the RI contained uranium concentrations ranging from 1.0 to 30.3 ppm. The highest observed uranium concentration was collected from the downstream sampling location closest to the K-65 silos. This location corresponded with the surface water sample also containing the highest uranium concentration. Sediment samples collected from Paddys Run downstream of the K-65 silos contained uranium concentrations ranging from 1.0 to 3.0 ppm.

Although both surface water and sediment samples collected within the Operable Unit 4 study area contain elevated concentrations of uranium, it is not possible to verify the source. Currently, there are no data to suggest that the K-65 silos or Metal Oxide Silo 3 are sources of this contamination. This can only be confirmed by analyzing samples from the slant boring program to determine if the silos are leaking or if the glacial overburden beneath the silos has received enough spillage from past operations to become a contaminant source. Historically, surface water runoff from the Pilot Plant area flowed through drainageways in the vicinity of Operable Unit 4. These potentially contaminated surface waters may have been the source of contamination observed within the Operable Unit 4 study area. It is also possible that surface water contamination present within the Operable Unit 4 study area originated from the waste pits. Regardless, a planned storm water runoff removal action will control and treat runoff from the Waste Storage Area, which includes Operable Unit 4.

Groundwater samples were collected from wells within the Operable Unit 4 study area during the RI. Samples were collected from 1000-, 2000-, and 3000-series wells, which are screened respectively in the glacial overburden; at the water table within the Great Miami Aquifer; and at approximately the central part of the Great Miami Aquifer, just above the clay interbed. Uranium concentrations were highest in samples collected from the 1000-series wells. Radium was not consistently detected in groundwater samples collected within the Operable Unit 4 study area.

Therefore, no conclusion can be drawn that the K-65 silos are the source of groundwater contamination until the results from the slant boring program become available.

The highest observed uranium concentrations, which ranged from 196 to 276 µg/L, were in samples collected from Well 1032. This well is located between the silos and Paddys Run. Data from Well 1032 are not considered representative of contamination originating from Operable Unit 4 because this well was placed in a former construction rubble pile. This rubble pile will be addressed as a suspect area under Operable Unit 3.

The concentration of total uranium at the surface of the Great Miami Aquifer, based on analysis of samples from the 2000-series wells, ranged from less than 1 to 27 µg/L. These data do not necessarily suggest that the silos are the source of the observed contamination. The concentration of total uranium measured at deeper levels in the Great Miami Aquifer (3000-series wells) ranged from less than 1 to 4 µg/L, with the exception of 1 sample out of 16, which contained 10 µg/L. Like the 2000-series wells, no conclusions could be drawn to link this contamination to the silos. In an effort to resolve the uncertainty concerning the source of the uranium that is present in samples from the Great Miami Aquifer, two new 2000-series wells, Wells 2032 and 2033, were installed. Well 2032 was installed on the west side of the silos in February 1990. Well 2033 was installed on the east side of the silos in June 1990. These wells were placed adjacent to the corresponding 1000-series wells. Analysis of samples from these wells will allow monitoring of any downward movement of uranium into the Great Miami Aquifer and facilitate the assessment of water movement between the glacial overburden, Paddys Run, and the Great Miami Aquifer. Data from the slant boring program will also be essential in evaluating Operable Unit 4 as a source of the observed uranium contamination.

The investigation of biological resources conducted during the RI determined that there is uptake of radionuclides by both plants and animals within the FMPC. Food chain relationships were established; however, none of the data from this study can be directly related to releases from Operable Unit 4.

The principal environmental concerns associated with Operable Unit 4 are direct radiation emitted from the materials in the silos and the release of radon gas from the silos. The RI concluded that there is radionuclide contamination present within the Operable Unit 4 study area; however, the origin of this contamination cannot be traced to determine if it is the result of K-65 silo leakage or from deposition of radionuclides from other FMPC operations. Data from the slant boring and

berm sampling programs are needed to establish whether there is contamination present in the glacial overburden beneath the silos. If the glacial overburden is not contaminated, there are no other data to conclusively show that releases to the environment from Operable Unit 4, other than direct radiation and radon gas, extend beyond the immediate boundary of Operable Unit 4.

The resampling and analysis of the K-65 silo contents must also be completed to fully characterize the materials in the silos. These data are required to complete the engineering evaluations of remedial alternatives being conducted under the FS.

The following investigative activities are also planned to supplement the site-wide RI/FS data and may provide data applicable to Operable Unit 4:

- Collect surface water and sediment samples from Paddys Run as planned. These data will aid in identifying the source of elevated uranium concentrations detected in surface water and sediment samples.
- Attempt to collect samples of the occasional groundwater seepage emanating from the banks of Paddys Run. These samples would provide a cost-effective means of acquiring data that might provide some additional insight into contaminant migration pathways within the Operable Unit 4 study area.

Based on the existing RI data, Operable Unit 4 represents a potential, but as yet unconfirmed, source of contamination to groundwater and other environmental media. The FS has formulated remedial action objectives to achieve the overall goal of protecting public health and the environment by isolating, removing, or treating the source of contamination. There are a number of response actions that are being considered to achieve these objectives. These remedial action alternatives, in addition to the no-action alternative, include both waste removal and nonremoval actions. The nonremoval alternatives range from simple containment of the waste to in situ stabilization coupled with containment technologies, postremoval actions, and waste disposal actions. The postremoval actions include waste stabilization, contaminant separation, on-property disposal in an engineered disposal facility, or off-site disposal. These remedial action alternatives will satisfy the established remedial action objectives and are being evaluated under the Operable Unit 4 FS.

1.0 INTRODUCTION

The Feed Materials Production Center (FMPC) is a contractor-operated federal facility for the production of pure uranium metals for the U.S. Department of Energy (DOE). The FMPC site is located on 1050 acres in a rural area approximately 20 miles northwest of downtown Cincinnati, Ohio. The Production Area is limited to an approximate 136-acre tract near the center of the FMPC site. The villages of Fernald, New Baltimore, Ross, New Haven, and Shandon are all located within a few miles of the plant (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 about potential environmental impacts associated with the FMPC's past and present operations. Between April 1985 and July 1986, conferences were held between DOE and EPA representatives to discuss the issues and to identify the steps DOE proposed to take to achieve and maintain environmental compliance.

On July 18, 1986, a Federal Facilities Compliance Agreement (FFCA) was jointly signed by DOE and EPA pertaining to environmental impacts associated with the FMPC. The FFCA was entered into pursuant to Executive Order 12088 (43CFR47707) 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 FMPC are thoroughly and adequately investigated so that appropriate remedial response actions could be formulated, assessed, and implemented. On April 9, 1990, DOE and EPA Region V amended the 1986 FFCA by a Federal Facility Consent Agreement (Consent Agreement) to achieve consistency with the operable unit concept and the current commitments of the Remedial Investigation/Feasibility Study (RI/FS) program without modifying the underlying objectives. The Consent Agreement, pursuant to CERCLA Section 120 and 106(a), became effective June 29, 1990. Notice of the intent to conduct the Operable Unit 4 RI/FS was published in the May 15, 1990 Federal Register. A separate RI/FS - National Environmental Policy Act (NEPA) process was embarked upon at this time pursuant to the same Notice of Intent.

In response to the FFCA, an RI/FS was initiated pursuant to CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA). All RI/FS activities are being conducted in conformance with EPA's "Guidance for Conducting Remedial Investigations and Feasibility Studies

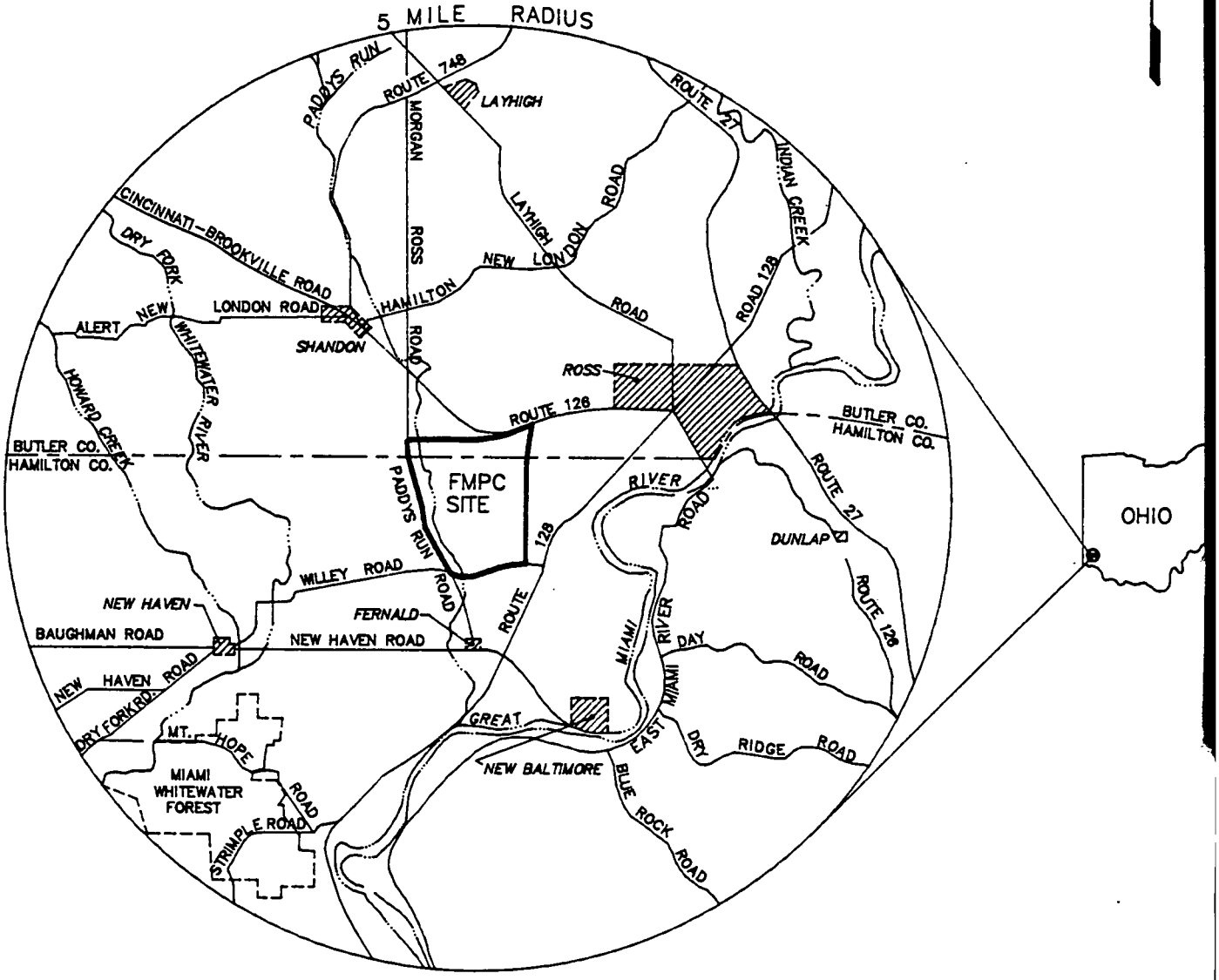

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FIGURE 1-1. FIVE-MILE RADIUS MAP, FEED MATERIALS PRODUCTION CENTER

Under CERCLA" (EPA 1988a). The RI/FS for the FMPC was initially designed to address the entire site and to focus on various environmental media that could be affected by past and present operations at the FMPC. The purpose of the RI is to determine the nature and extent of any release, or threat of release, of hazardous or radioactive substances and to gather the necessary data to support the evaluation of remedial action alternatives in the FS.

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 prepared for the site-wide RI/FS 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 also involved preparing a number of detailed plans to establish specific procedures to be followed in the completion of the RI/FS for the FMPC. These plans included the following:

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

The Sampling Plan, which was submitted in March 1988 in conjunction with the RI/FS Work Plan, contained objectives, sampling locations, and sampling procedures for the following:

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

The Work Plan identified 27 units of the FMPC 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 accommodate separate schedules for each operable unit. This allowed the remedial action process to proceed to completion for the most well-defined or problematic units, while data collection and analysis continued for other units.

There are five operable units:

- Operable Unit 1 - Waste Storage Area
- Operable Unit 2 - Solid Waste Units
- Operable Unit 3 - Production Area and Suspect Areas
- Operable Unit 4 - K-65 Silos and Metal Oxide Silos
- Operable Unit 5 - Environmental Media

Because the Work Plan, and more specifically the Sampling Plan, were developed prior to the formulation of the operable units for the FMPC, there were no specific operable unit sampling plans prepared. Areas covered by Operable Units 1 through 4 (Figure 1-2) are considered sources for possible contamination of the underlying Great Miami Aquifer. 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 to define the vertical and lateral extent of contamination within the boundary of that operable unit.

The RI report for Operable Unit 5 will address the Great Miami Aquifer, which underlies the source operable units; surface water drainages that may carry contamination from those operable units; and 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 analysis of its various sources.

The scope of work for the RI at the FMPC 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.
- Characterize the occurrence of chemical or radiological substances in aquatic and terrestrial organisms both on and off site.
- Conduct health risk assessments and environmental impact studies to assess the risk associated with any confirmed contamination at or originating from the site.

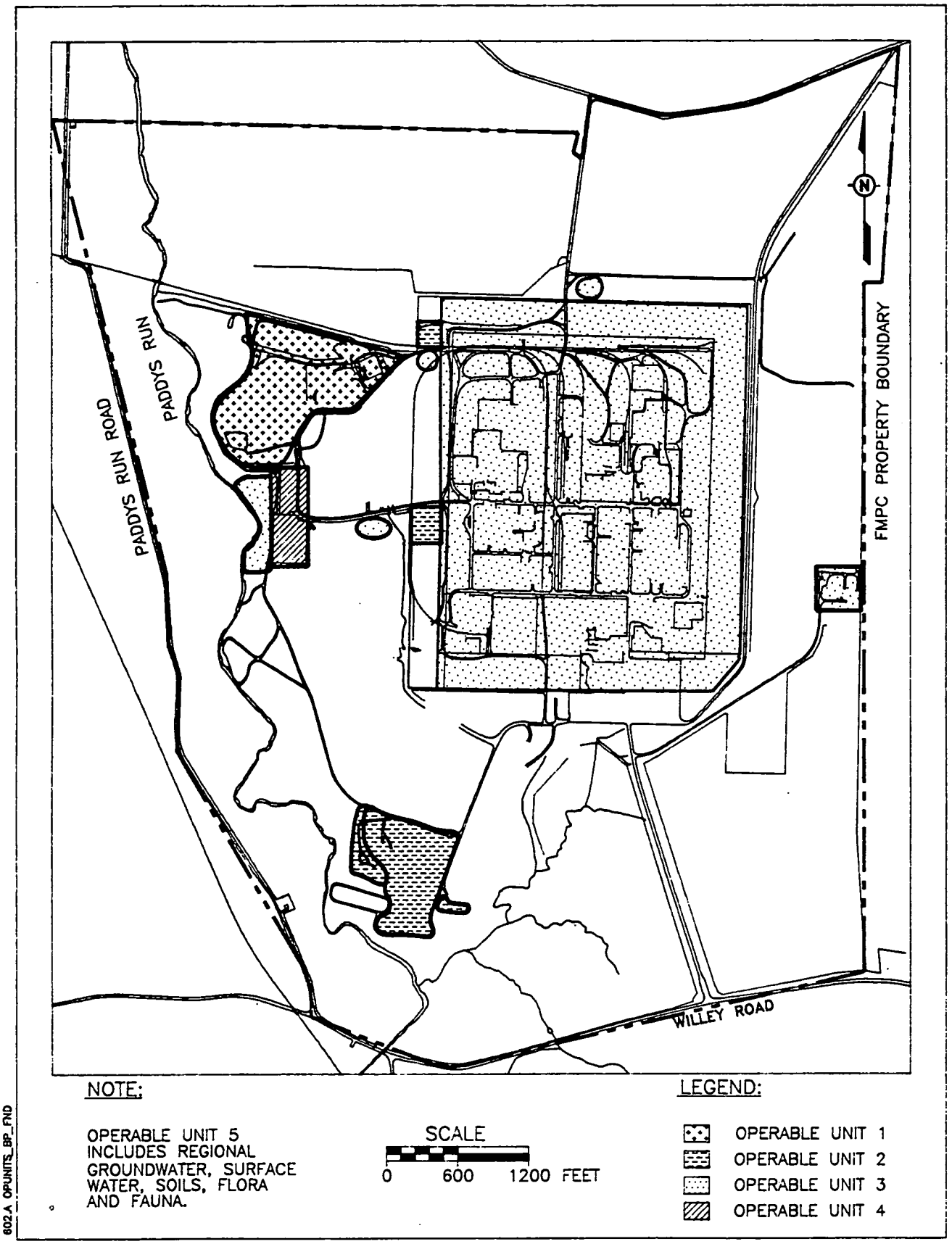


FIGURE 1–2. SOURCE OPERABLE UNITS

- 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

The RI field program began in July 1987. The FS will subsequently utilize the RI data to select, screen, and analyze remedial action alternatives. The nine criteria specified in the RI/FS guidance document (EPA 1988) will be utilized during the FS for the evaluation and eventual selection of remedial alternatives.

1.1 PURPOSE OF REPORT

This RI report serves to document the data collection and analysis phase of the RI/FS for Operable Unit 4. The evaluation considered data relevant to Operable Unit 4 that were obtained during previous investigations as well as data obtained during the RI. The evaluation of these data was directed toward achieving the following three primary objectives:

- Defining the nature and extent of contamination originating from Operable Unit 4
- Quantifying the risk to human health and the environment associated with Operable Unit 4 contamination
- Supporting the evaluation of remedial alternatives being conducted under the FS for Operable Unit 4

For the purposes of the RI/FS, Operable Unit 4 is defined as the two K-65 silos (Silos 1 and 2) and the metal oxide silos (Silos 3 and 4). This includes the silo contents and associated underground tanks and piping lying directly beneath the silos. For Silos 1 and 2, Operable Unit 4 extends to the toe of the earthen embankment that provides structural support to the silos. Piping and transfer lines associated with Operable Unit 4 that fall outside the boundaries addressed above will be remediated as part of another operable unit.

Silo 4 was included as a component of Operable Unit 4 to satisfy a requirement of the FFCA that all waste storage facilities be accounted for under the site-wide RI/FS. However, production and waste disposal records indicate that Silo 4 was never used for production-related activities or for waste storage or disposal. Currently there is standing water in Silo 4. Radiological and chemical analyses of water samples collected from Silo 4 on June 9, 1989 indicate that there are detectable levels of uranium isotopes and inorganic chemicals. The low concentrations of these materials in Silo 4 are consistent with the likely scenario that their presence is due to resuspension of materials

from the nearby waste storage pits, subsequent atmospheric transport and deposition onto the silo dome, and percolation of rain water into the silo. Several alternatives including the no-action alternative are being considered for Silo 4 under the FS.

The FS for Operable Unit 4 is currently considering remedial actions only for the physical structures of Silos 1, 2, 3, and 4; the stored waste in these silos; and the soil berms adjoining Silos 1 and 2. The decant sump, piping beneath the the silos, and any contaminated underlying soils or perched water will also be incorporated into the remedial action program for Operable Unit 4. However, the eventual need for remedial action for Operable Unit 4 will at least partially depend on the past or potential release of contaminants into the environment and any associated public health risk. Consequently, even though the remedial action will be geographically constrained to the immediate area of the silos, the RI and associated risk assessment had to be extended to the surrounding environmental media.

An Operable Unit 4 study area was defined for the purpose of evaluating data from surrounding environmental media during the RI and risk assessment. The study area to be considered for Operable Unit 4 is bounded the following State of Ohio plane coordinates: North 479300-481100 and East 1377950-1379150. The study area is shown in Figure 1-3. This study area was established to allow effective evaluation of remedial alternatives.

The data evaluation for Operable Unit 4 began by focusing on the contents of the K-65 silos and systematically expanding outward to incorporate a site-wide perspective. Figure 1-4 is a pictorial representation of the approach taken during the evaluation of RI data, highlighting the sequence of going from most specific to most general. This figure establishes six discrete elements to be considered during the evaluation of Operable Unit 4.

Operable Unit 4 was subdivided into the following four discrete elements with waste characteristics requiring the potential application of singular technologies to effect final remediation:

- The K-65 silos (Silos 1 and 2) and the Metal Oxides Silo 3
- The materials contained inside Silos 1, 2, and 3
- The glacial overburden beneath the silos
- The earthen berm surrounding Silos 1 and 2

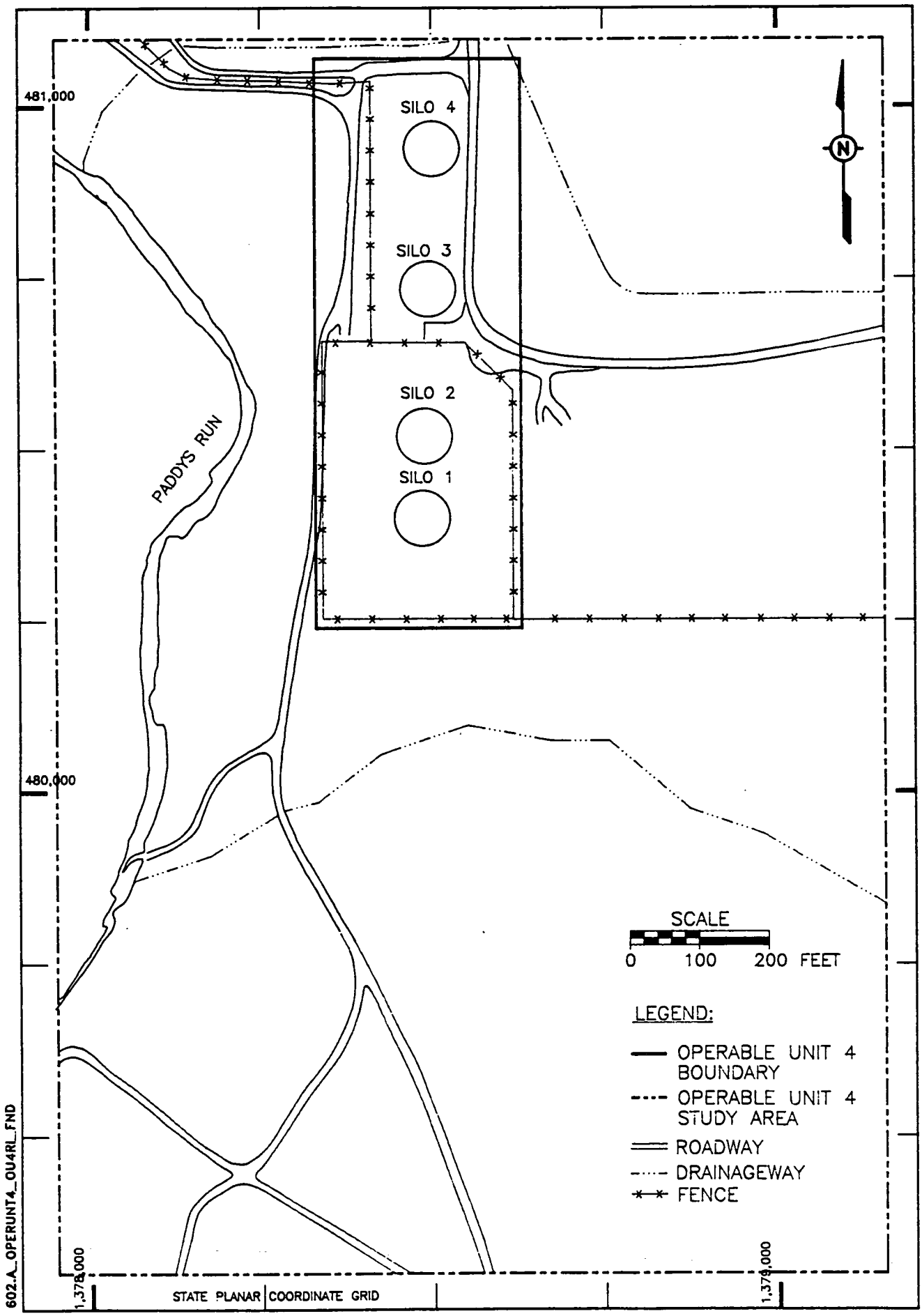
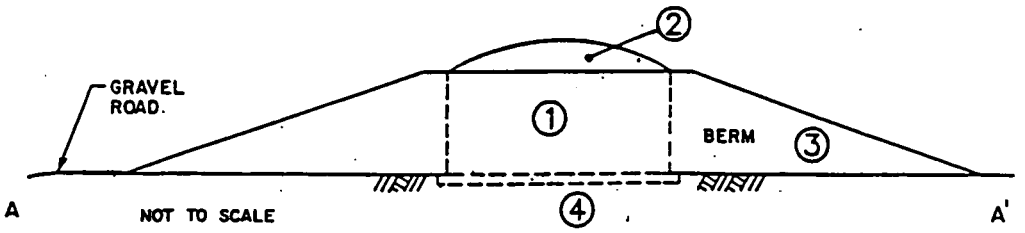
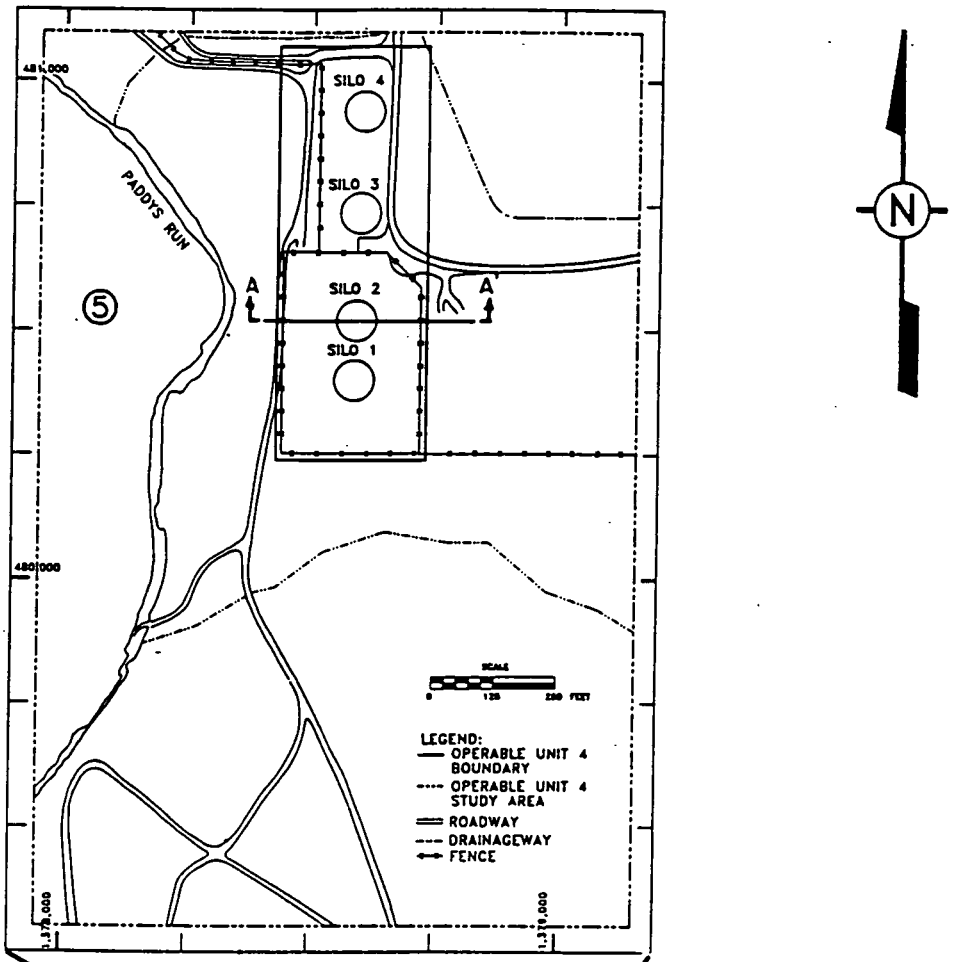


FIGURE 1-3. OPERABLE UNIT 4 STUDY AREA



TYPICAL K-65 SILO CROSS-SECTION



OPERABLE UNIT 4 STUDY AREA

LEGEND:

① WASTE MATERIALS IN SILOS

② PHYSICAL STRUCTURE OF THE SILOS

③ SOIL BERMS (SILOS 1 & 2)

④ GLACIAL OVERBURDEN BENEATH THE SILOS

⑤ OU4 STUDY AREA

⑥ REGIONAL ENVIRONMENT

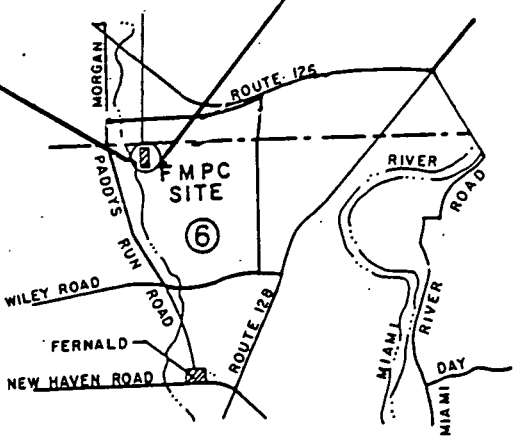


FIGURE 1-4. OPERABLE UNIT 4 RI ELEMENTS

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Moving outside the boundary of Operable Unit 4, local and regional impacts associated with Operable Unit 4 were evaluated by extending the data evaluation to:

- The Operable Unit 4 study area
- The regional environment

The Operable Unit 4 study area was defined to concentrate on that region of the FMPC that is most likely to be affected by any contamination originating from Operable Unit 4. This study area includes Operable Unit 4 and its surrounding environs.

The regional environment was the most general element evaluated because it is applicable to each of the five operable units. A regional perspective is necessary to assess risks related to Operable Unit 4 and to evaluate remedial alternatives.

Table 1-1 summarizes the data evaluation approach applied during the RI to the six designated elements related to Operable Unit 4. Each of the six elements addressed during the RI, and its relationship to Operable Unit 4, is discussed below.

Waste Material in Silos (Element 1)

The waste materials in the silos required complete characterization as part of the RI. Issues that could not be fully addressed without a detailed physical, chemical, and radiological characterization of the silo contents included:

- Applicability of remediation technologies
- Disposal options
- Quantification of source term
- Leachability and release potential
- Selection and confirmation of indicator parameters to monitor releases of silo materials

It is necessary to address these issues to ensure selection of the most appropriate remedial actions for Operable Unit 4.

Physical Structure of the Silos (Element 2)

The RI addressed the physical condition of the silos because of the potential for release of contamination associated with failure of the silo structure. Specific issues related to the physical integrity of the silos include:

TABLE 1-1

OPERABLE UNIT 4 DATA EVALUATION MATRIX

Element Number	OU4 RI Element	Applicability to OU4 RI/FS	Related Issues	Type of Data Required	Data Sources
1	Waste Materials in Silos	Support to Feasibility Study (FS)	• Applicability of process technologies • Compaction/consolidation/cohesion • Disposal options	• Chemical/radiological composition • Engineering properties	• National Lead of Ohio/ Westinghouse Materials Company of Ohio (NLO/WMCO) sampling • ASI/IT[a] silo sampling program[b]
		Support to risk assessment	• Quantification of source term • Leachability/release potential • Confirmation of indicator parameters	• Chemical/radiological composition • Water content	• NLO/WMCO sampling • ASI/IT silo sampling program[b]
2	Physical Structure of Silos	Support to FS	• Long-term structural integrity • Areas requiring structural improvements	• Engineering analysis	• Camargo study • Betchel study
		Support to risk assessment	• Potential for silo failure/effects	• Probabilistic risk assessment	• University of Cincinnati study • WMCO decant tank sampling
			• Leakage potential through bottom	• Evidence of release	• ASI/IT slant boring program[b] • Original silo drawings
3	Soil Berms (Silos 1 and 2)	Nature and extent of contamination	• Potential buildup of Pb-210 and Po-210	• Direct sampling and analysis	• ASI/IT berm sampling program[b]
		Support to FS	• Volume of material requiring action • Treatment/disposal requirements	• Chemical/radiological distribution	• ASI/IT berm sampling program[b]
		Support to risk assessment	• Contaminated soil release to Paddys Run • Potential for vertical migration	• Chemical/radiological distribution	• ASI/IT berm sampling program[b]

Table 1-1. (Continued)

Element Number	OU4 RI Element	Applicability to OU4 RI/FS	Related Issues	Type of Data Required	Data Sources
4	Glacial Overburden Beneath Silos	Nature and extent of contamination	• Contamination of underlying soils	• Direct sampling and analysis	• ASI/IT slant boring program
		Support to FS	• Volume of material requiring action • Treatment/disposal requirements	• Chemical/radiological distribution	• ASI/IT slant boring program[b]
		Support to risk assessment	• Potential for vertical migration	• Chemical/radiological distribution • Current evidence of release	• ASI/IT slant boring program[b] • Remedial Investigation (RI) groundwater sampling program
			• Other possible sources of contamination	• Information on previous spills/ releases	• NLO 1953 memo
5	Operable Unit 4 Study Area	Nature and extent of contamination	• Direct evidence of release from silos (overall issue to be addressed under OU5)	• Local distribution patterns of uranium and radium in soils, sub-surface soils, and groundwater	• RI radiation measurements • RI groundwater sampling program • RI soils sampling program • RI subsurface soils sampling program • ASI/IT slant boring program[b] • Characterization Investigation Study (CIS) program • Suspect area investigation under OU3[b]
		Support to FS	• (To be addressed under OU5)		
		Support to risk assessment	• Definition of migration pathways/patterns • Worker safety during remediation	• Groundwater elevation data • Direct radiation/radon measurements	• RI groundwater sampling program • WMCO Environmental Monitoring Report (EMR) • Monsanto-Mound Report

Table 1-1. (Continued)

Element Number	OU4 RI Element	Applicability to OU4 RI/FS	Related Issues	Type of Data Required	Data Sources
6	Regional Environment	Nature and extent of contamination	• Direct evidence of release from silos	• Regional distribution patterns of uranium and radium in groundwater, surface water, and sediments	• RI groundwater sampling program • RI surface water and sediment sampling program • WMCO EMR
		Support to risk assessment	• Risk to off-site receptors	• Direct radiation/radon measurements	• WMCO EMR • Ohio Department of Health (ODH) study
				• Potential for radon release	• WMCO measurement program at silos
			• Long-term migration potential from silo releases	• Regional groundwater flow patterns	• SWIFT-III Model • Vadose zone model • RI groundwater sampling program
		Support to meet National Environmental Policy Act (NEPA) of 1969 requirements	Environmental resources potentially impacted (e.g., wetlands)	Compilation/evaluation of environmental resources	• Feed Material Production Center (FMPC) upgrade Environmental Impact Statement (EIS) • RI biological resources program

Advanced Sciences, Inc./International Technology Corporation.
Data/information not yet available.

- Areas of the silo requiring structural support or repair
- Environmental impacts associated with silo failure
- Potential for leakage from the bottom of the silos
- Long-term structural integrity

Each of these issues will affect the evaluation and selection of remedial alternatives.

Soil Berms (Silos 1 and 2) (Element 3)

The soil berms were included in the RI because of the potential for contamination resulting from silo leakage. Another concern associated with the soil berms is the possible accumulation of lead-210 (Pb-210) and polonium-210 (Po-210) resulting from the decay of radon-222 (Rn-222) gas migrating from the silos through the berm soils. Specific issues being addressed during the RI are:

- The volume of soil requiring remediation
- Requirements for treatment or disposal of any contaminated soils
- The potential for downward migration of contaminants that might be present in the berms
- Potential for release of contaminants to Paddys Run

Each of these issues is being considered during the evaluation of remedial alternatives for Operable Unit 4.

Glacial Overburden Beneath the Silos (Element 4)

The glacial overburden beneath the silos is being evaluated to determine if it has been contaminated by any materials that might have leaked from the silos. Specific issues addressed during this evaluation include:

- The volume of soil requiring remediation
- Requirements for treatment or disposal of any contaminated soils
- The potential for downward migration of contaminants that might be present in the glacial overburden
- Possible sources of contamination other than the silos

The presence of contamination below the silos would have a significant impact on the evaluation of remedial alternatives for Operable Unit 4.

Operable Unit 4 Study Area (Element 5)

The Operable Unit 4 study area was evaluated for any evidence or indication of releases from Operable Unit 4. The environs immediately adjacent to and surrounding Operable Unit 4 are the

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most likely to have been impacted if a release occurred. Specific issues addressed during this evaluation included:

- Definition of migration pathways and patterns
- Worker safety during remediation
- Radon emissions
- Direct evidence of release from silos
- Nearby environmental resources that could be impacted (ambient air, groundwater, surface water, and soils)

These issues must be considered during the evaluation of potential remedial alternatives for Operable Unit 4.

Regional Environment (Element 6)

The regional environment is defined as that region lying outside the Operable Unit 4 study area. The bounds of the regional environment extend as far as necessary to evaluate data relevant to Operable Unit 4 or to assess impacts from Operable Unit 4. Although the RI for Operable Unit 4 was directed specifically at this operable unit, it was necessary to consider the regional environment. Issues related to Operable Unit 4 that were addressed by employing a regional perspective included:

- Radon emissions
- Risk to off-site receptors
- Long-term migration potential for materials released from the silos
- Regional environmental resources that could potentially be impacted (e.g. ambient air, groundwater, or wetlands)

Any evidence of regional environmental impact directly related to Operable Unit 4 may be addressed under the FS for Operable Unit 5 or another operable unit if it is deemed more appropriate.

This RI Report for Operable Unit 4 addresses each of these six elements of the investigation. The issues associated with each element are also addressed to the extent that the data will allow. Those issues for which no data are available will be addressed in studies that are planned as part of the RI but have not yet been conducted.

1.2 SITE BACKGROUND

This section provides general site-wide background information on the FMPC and the surrounding area. It includes a description of the FMPC, a site history, and a discussion of previous site investigations. More specific information for this operable unit is supplied in Section 1.3.

1.2.1 Site Description and History

The Atomic Energy Commission (AEC), predecessor to DOE, established the FMPC 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 Maintenance (O&M) Contractor. This contractual relationship lasted with AEC, and eventually 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 5 years.

A Pilot Plant was completed in 1951 and was the first operational facility at the FMPC; a Metals Fabrication Plant (Plant 6) began operations in 1952. Two Metals Production Plants (Plants 5 and 6), the Green Salt Plant (Plant 4), Recovery Plant (Plant 8), Sampling Plant (Plant 1), and the Refinery (Plants 2 and 3) began operations in 1953. The Hex Plant (Plant 7) and the Special Products Plant (Plant 9) were operational in 1954. A diagram of the existing FMPC layout is provided in Figure 1-5.

Production peaked in 1960 at approximately 10,000 metric tons of uranium (mtu) per year. A product decline began in 1964 and reached a low of about 1230 mtu in 1975. During the 1970s, consideration was given to closing the FMPC; therefore, capital improvements and staffing were minimized. The staffing level, which peaked at 2891 in 1956, slowly declined from 662 in 1972 to 538 in 1979. In 1981, the FMPC 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. Uranium metal production ceased in the summer of 1989 to focus plant resources on the restoration program. Currently, the FMPC metal production remains in an inactive status; however, the environmental studies and restoration activities continue.

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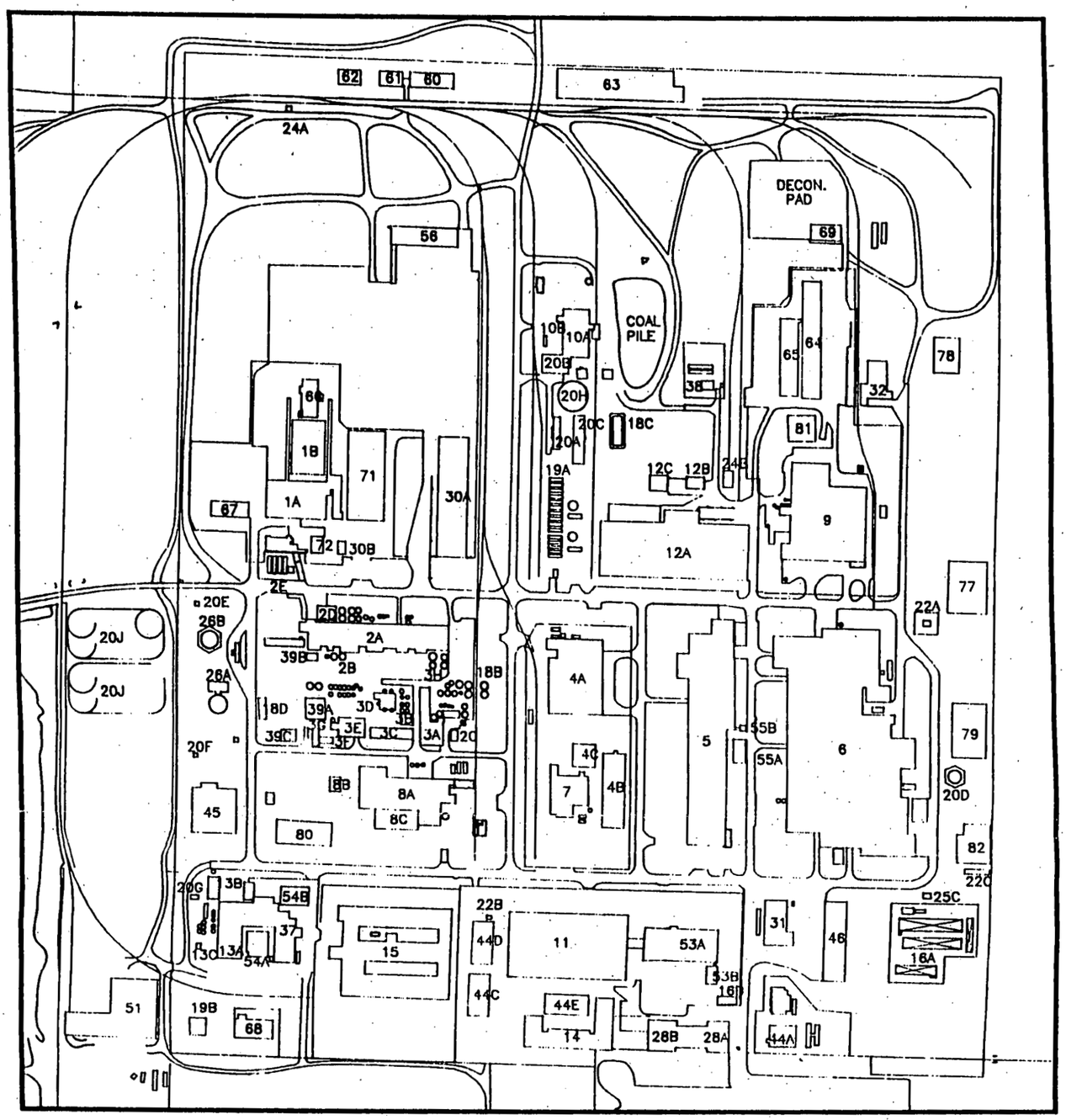


SCALE

0 250 500 FEET

1A	PREPARATION PLANT	15	LABORATORIES	39A	INCINERATOR BLDG.
1B	PLANT 1 STORAGE BLDG.	16A	MAIN ELECTRICAL STATION	39B	SHELTER STORAGE BLDG.
2A	ORE REFINERY PLANT	16B	ELECTRICAL SUBSTATION	39C	INCIN. BLDG. SPRINKLER RISER HOUSE
2B	LIME HANDLING BLDG.	18B	GENERAL SUMP	44A	TRAILER COMPLEX (6-PLEX)
2C	BULK LIME HANDLING BLDG.	18C	COAL PILE RUNOFF BASIN	44C	TRAILER COMPLEX (7 PLEX S)
2D	METAL DISSOLVER BLDG.	18D	BIODENITRIFICATION TOWERS	44D	TRAILER COMPLEX (7 PLEX N)
2E	MFS STORAGE AND PUMP HOUSE	19A	MAIN METAL TANK FARM	44E	TRAILER COMPLEX (NO PLEX)
3A	MAINTENANCE BLDG.	19B	PILOT PLANT AMMONIA TANK FARM	45	RUST ENG. BLDG.
3B	OZONE BLDG.	20A	VALVE/CONTROL BLDG	46	HEAVY EQUIPMENT BLDG.
3C	CONTROL HOUSE	20B	FILTER/CHEMICAL BLDG.	51	6 TO 4 REDUCTION FACILTY #2
3D	NAR TOWERS	20C	COOLING TOWERS	53A	O.S. & H. BLDG.
3E	HOT RAFFINATE BLDG.	20D	ELEVATED POTABLE STORAGE TANK	53B	IN-VIVO BLDG.
3F	DIGESTION FUME RECOVERY	20E	WELL HOUSE #1	54A	6 TO 4 REDUCTION FACILITY #1
3G	REFRIGERATION BLDG.	20F	WELL HOUSE #2	54B	PILOT PLANT WHSE.
3H	REFINERY SUMP	20G	WELL HOUSE #3	55A	SLAG RECYCLING BLDG.
4A	GREEN SALT PLANT	20H	PROGESS WATER STORAGE TANK	55B	SLAG RECYCLING PIT/ELEVATOR
4B	PLANT 4 WHSE.	20J	LIME SLURRY PITS	56	CP STORAGE WHSE.
4C	PLANT 4 MAINTENANCE BLDG.	22A	GAS METER BLDG.	60	QUONSET HUT #1
5	METALS PRODUCTION PLANT	22B	SEWER LIFT STATION	61	QUONSET HUT #2
6	METALS FABRICATION PLANT	22C	TRUCK SCALE	62	QUONSET HUT #3
7	PLANT 7	24A	RAILROAD SCALE HOUSE	63	KC-2 WHSE.
8A	RECOVERY PLANT	24B	RAILROAD ENGINE HOUSE	64	THORIUM WHSE.
8B	MAINTENANCE BLDG.	25C	SEWAGE LIFT STATION BLDG.	65	(OLD) PLANT 5 WHSE.
8C	ROTARY KILN/DRUM RECOND. BLDG.	25D	U.V. DISINFECTION BLDG.	66	DRUM RECONDITIONING BLDG.
9	SPECIAL PRODUCTS PLANT	25E	DIGESTER CONTROL BLDG.	67	PLANT 1 THORIUM WHSE.
10A	BOILER PLANT	26A	PUMP HOUSE-HP FIRE PROTECTION	68	PILOT PLANT WHSE.
10B	BOILER PLANT MAINTENANCE BLDG.	26B	ELEVATED WATER STORAGE TANK	69	DECONTAMINATION BLDG.
11	SERVICE BLDG.	28A	SECURITY BLDG.	71	GENERAL IN-PROCESS STORAGE WHSE.
12A	MAIN MAINTENANCE BLDG.	28B	HUMAN RESOURCES BLDG.	72	DRUM STORAGE BLDG.
12B	CYLINDER STORAGE BLDG.	30A	CHEMICAL WHSE.	77	FINISHED PRODUCT WHSE.
12C	LUMBER STORAGE BLDG.	30B	DRUM STORAGE WHSE.	78	D & D BLDG. (NOT CONSTR.)
13A	PILOT PLANT WET SIDE	31	ENGINE HOUSE/GARAGE	79	PLANT 6 WHSE.
13B	PILOT PLANT MAINTENANCE BLDG.	32	MAGNESIUM STORAGE BLDG.	80	PLANT 8 WHSE.
13C	SUMP PUMP HOUSE	37	PILOT PLANT ANNEX	81	PLANT 9 WHSE.
14	ADMINISTRATION BLDG.	38	PROPANE STORAGE	82	RECEIVING/INCOMING MTRLS. INSP. BLDG.

FIGURE 1-5
EXISTING PRODUCTION AREA LAYOUT

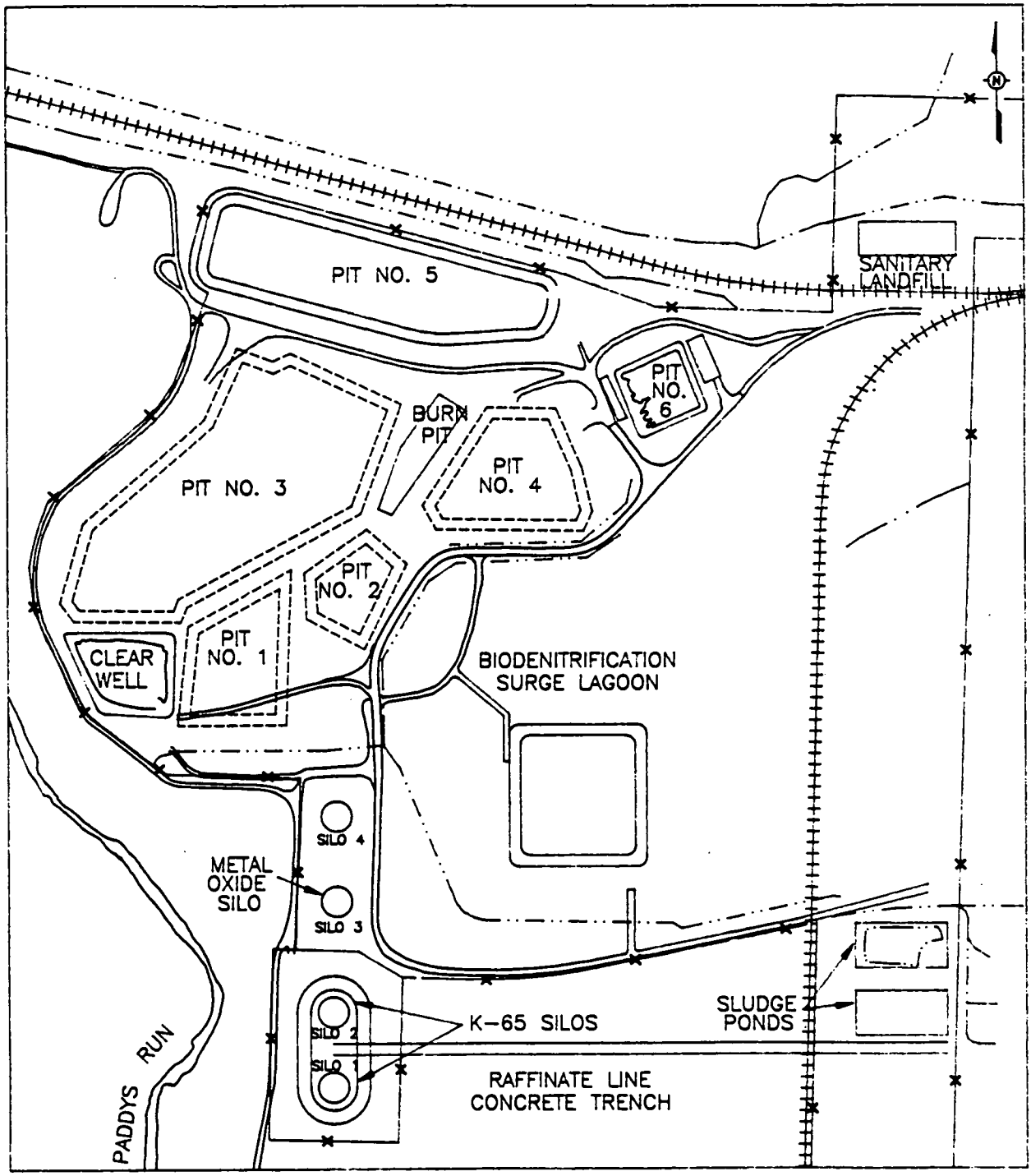
A variety of chemical and metallurgical processes were utilized at the FMPC for manufacturing uranium products. During the manufacturing process, high quality uranium compounds were introduced into the FMPC processes at several points. Impure starting materials were dissolved in nitric acid and the uranium was purified through solvent extraction to yield a solution of uranyl nitrate. The tributyl phosphate (TBP)-kerosene mixture was used in the extraction process. Evaporation and heating converted the nitrate solution to uranium trioxide (UO_3) powder.

This compound was reduced with hydrogen, derived from dissociated ammonia, 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 magnesium fluoride (MgF_2) slag-lined vessel. This primary uranium metal was then remelted with scrap uranium metal to yield a purified uranium ingot. Various uranium metalworking processes also existed.

From 1953 through 1955, the FMPC Refinery processed pitchblende ore from the Belgian Congo (Boback et al. 1986a). Pitchblende ore contains all daughter products of the uranium decay chains and is particularly high in radium content. No chemical separation or purification was performed on the ore prior to arrival at the FMPC. 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 daughters had been removed. The yellowcake contained radium-226 (Ra-226) in amounts that varied with the process.

Small amounts of thorium were produced at the FMPC 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 FMPC currently serves as the thorium repository for DOE and maintains storage facilities for a variety of thorium materials.

Large quantities of liquid and solid wastes are generated by the various operations at the FMPC. Prior to 1984, solid and slurried wastes from FMPC processes were disposed of in the on-property waste storage area. This area, which is located west of the production facilities (Figure 1-6), includes six low-level radioactive waste storage pits; two earthen-bermed concrete silos containing K-65 residues which are high-specific activity, low-level radium-bearing residues resulting from the pitchblende refining process; one concrete silo containing metal oxides; two lime sludge ponds; and a sanitary landfill. The Waste Storage Area is addressed under Operable Units 1 and 4.



NOTES:

PITS 1, 2 AND 3 ARE COVERED

PIT 4 HAS AN INTERIM CAP

LEGEND:

RAILROAD

DRAINAGEWAYS

FENCELINE

ROADWAY

SCALE

0 175 350 FEET

602A_WPAREA_BP_FND

FIGURE 1-6. WASTE STORAGE AREA

38

Solid waste materials associated with uranium metals production are presently stored on property in steel drums awaiting further processing or off-site disposal at approved facilities. These wastes include oils, sludges, contaminated combustibles, filter cake, off-spec 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 in either 55-gallon or 80-gallon carbon steel drums, depending on their size. Other waste materials are in warehouses, stored in drums on contained surfaces that have dikes and sumps. These materials include spent degreasing solvents and polychlorinated biphenyl (PCB)-contaminated material.

An inactive fly ash disposal area and an active fly ash pile, 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 fly ash from the FMPC coal-fired boiler plant. An area between and adjacent to the fly ash areas, known as the Southfield, is believed to be the disposal site for construction debris and possibly other types of solid wastes from FMPC operations. The Southfield is also being addressed as a solid waste unit under Operable Unit 2.

Surface water runoff from the Waste Storage Area, fly ash piles, and other affected areas within the western portion of the FMPC that does not go to the settling basin called the Clearwell enters Paddys Run, a tributary of the Great Miami River. Paddys Run originates just north of the FMPC and flows south-southeast along the western edge of the site. For most of the year it is a dry streambed with occasional rainfall-induced flows.

Leachate from these same areas can potentially migrate vertically through a glacial overburden layer of varying thickness to the regionally important Great Miami Aquifer, which underlies the site. The Great Miami 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 the Great Miami 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 from the FMPC process operations is sent to a general plant sump for treatment and analysis before 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 FMPC. 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 site boundary.

Storm water runoff from the Production Area is collected in storm water retention basins to allow for solids removal before being 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 FMPC have contributed substantial information to the RI/FS investigation. Fenneman (1916) performed an extensive survey of the geology in the Cincinnati area. This report is among the first that describes in detail the interbedded limestone and shale bedrock and its mantle of glaciofluvial and alluvial sediments. Later, workers 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 the glacial overburden in the study area have also been produced (Brockman 1986). Lerch et al. (1980 and 1982) performed soil surveys of Butler and Hamilton counties, Ohio. A detailed discussion of the current understanding of the geology at the FMPC is presented in Section 3.0.

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 Environmental Protection Agency (OEPA) 1982].

Flow in the drainage basin is monitored by the U.S. Geological Survey (USGS) using a gaging station on the Great Miami River at Hamilton, Ohio. Flow regulation on the Great Miami River has been studied by Spieker (1968a). Paddys Run data have been compiled by Dames and Moore (1985). Realignments and other modifications of Paddys Run and its tributaries on the FMPC have been documented by Dove (1961) and WMCO (1987). Surface water quality data for the FMPC area are available from NLO for the period 1979 through 1983 and the OEPA for the period 1977 through 1983. WMCO has maintained surface water quality data since 1983. A detailed discussion of the surface water hydrology at the FMPC is presented in Section 3.0.

1.2.2.3 Hydrogeologic Studies

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 FMPC 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. A detailed discussion of the current understanding of the hydrogeology of the FMPC is presented in Section 3.0.

1.2.2.4 Contamination Releases at the FMPC

Dove and Norris (1951) were the first to describe the possible fate of chemical and radionuclide wastes that infiltrate the groundwater in the Great Miami Aquifer. Publications released in the last five years document radionuclide releases from the FMPC into the environment. These studies are either from DOE (1985) or are internal WMCO documents (Boback et al. 1985, 1986a, 1986b; WMCO 1987, 1989a; 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 FMPC area (ODH 1988). Sedam (1984) investigated the occurrence of uranium in the groundwater in the vicinity of the FMPC for DOE. Starkey et al. (1962) and the NLO (Spencely 1983) performed internal investigations to distinguish between FMPC contamination and non-FMPC contamination.

1.2.2.5 Environmental Surveys

For more than 10 years, the environment in and around the FMPC has been closely monitored by DOE (1977, 1985, 1987), Oak Ridge Associated Universities (ORAU 1985), various FMPC-related committees (WMCO 1986, 1987; Fleming and Ross 1984), and various contracted agencies (IT 1986; Weston 1986a; Battelle 1981). The DOE and ORAU documents include environmental impact assessments, RI/FS studies, and environmental surveys. Internal reports of studies by WMCO and NLO include the annual Environmental Monitoring Reports and the Aquifer Contamination Control Reports (various authors 1965 to present). These documents are available through WMCO. The contracted studies represent more comprehensive environmental sampling and analysis programs. The material contained in these reports document the analytical results from a large number of groundwater, surface water, sediments, soils, and air samples. The analytical constituents included radionuclides, organic compounds, metals, and general water quality parameters. A sampling and analysis program to comply with RCRA provisions is also ongoing at the FMPC.

1.2.2.6 Vegetation and Wildlife Studies

Vegetation and wildlife in the FMPC area have been studied and characterized by WMCO, NLO, and OEPA. WMCO performed two studies of the fish that are indigenous to Paddys Run and the Great Miami River in the vicinity of the FMPC (WMCO 1986, 1987). The OEPA study (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 WMCO, described the general terrestrial and aquatic environments of the FMPC and surrounding areas. The data base compiled in this study is the most complete characterization of the environmental resources available. More information on vegetation and wildlife studies is presented in Section 3.0.

1.3 OPERABLE UNIT 4

This section provides detailed background information on Operable Unit 4. It includes a description and history of the unit and a discussion of previous investigations pertaining to the unit and associated silos.

1.3.1 Description and History

The waste storage silos are large concrete storage structures that were built in 1951 and 1952 at the FMPC. The waste storage silos are located south of the Waste Pit Area on the west side of the FMPC property (Figure 1-6). The silos are 80 feet in diameter, constructed with floors of 4-inch-

thick concrete over an 8-inch layer of gravel containing an underdrain system of 2-inch-diameter slotted pipe that drains to a collection tank. Below the gravel is a 2-inch-thick layer of asphaltic concrete underlain by approximately 18 inches of compacted clay. The walls are approximately 26 feet high and are constructed of 8-inch-thick concrete with a 0.75-inch-thick gunite coating on the exterior. The domed roofs taper from eight inches thick at the silo walls to four inches thick at the apex. Figure 1-7 presents a cross-sectional view of the silos' construction and a plan view of the K-65 silo leachate collection system. More details of the current state and recent studies on the silos are presented in Section 1.3.2.

The following discussion of the refining process and handling of the K-65 residues is excerpted primarily from the following documents:

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

These documents will not be specifically referenced in all instances in the text.

The silos were constructed to provide storage for the residues resulting from processing pitchblende ore and concentrates to extract their uranium content. The term "K-65" refers specifically to various radium-bearing raffinate wastes generated during the extraction step of the processing of pitchblende and other radium-bearing ores. A schematic flow diagram of the refinery process is presented in Figure 1-8. The FMPC used the TBP-kerosene extraction system.

Feed material to the Refinery consisted of either naturally occurring ore such as pitchblende or a concentrate made by a preliminary milling process. The feed material specifications and typical compositions are presented in Table 1-2 (Harrington and Ruehle 1959). The process was also designed to handle scrap metals generated on site or received from other sources (FMPC 1988).

When the plant was designed, a substantial amount of radium-bearing pitchblende was anticipated as feed material. Hence, equipment for handling both "hot" and "cold" feeds was provided. The radium-bearing feeds did not require different chemical treatment, but the radioactivity hazard required that equipment for handling these materials be shielded. Because the purchase contracts specified that the vendor retained title to the radium-bearing raffinate, special equipment was required to handle and store the hot raffinate separately (Harrington and Ruehle 1959).
As shown in Figure 1-9, cold raffinate from the primary extraction columns, after being washed

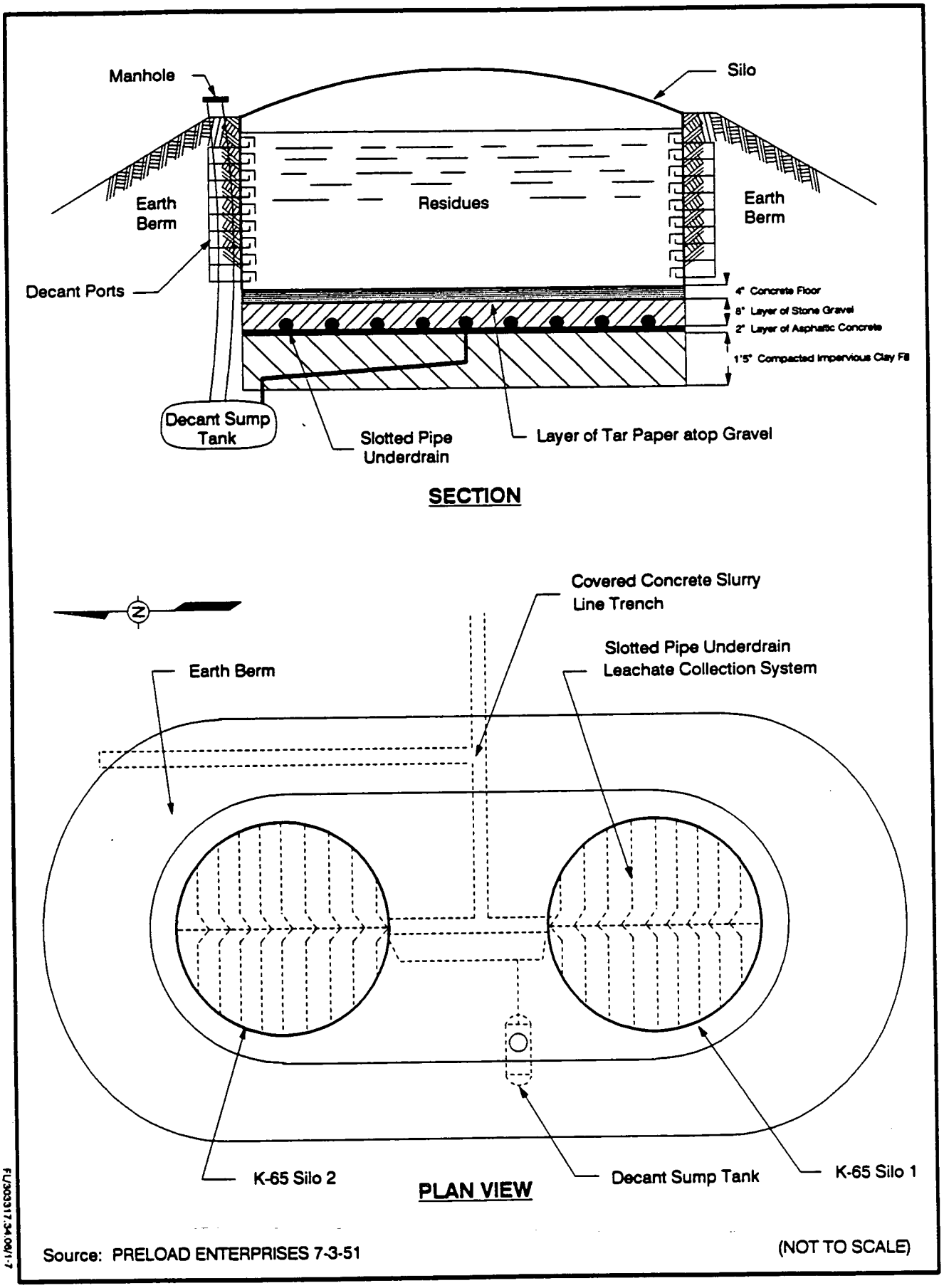


FIGURE 1-7. K-65 SILO LEACHATE COLLECTION SYSTEM

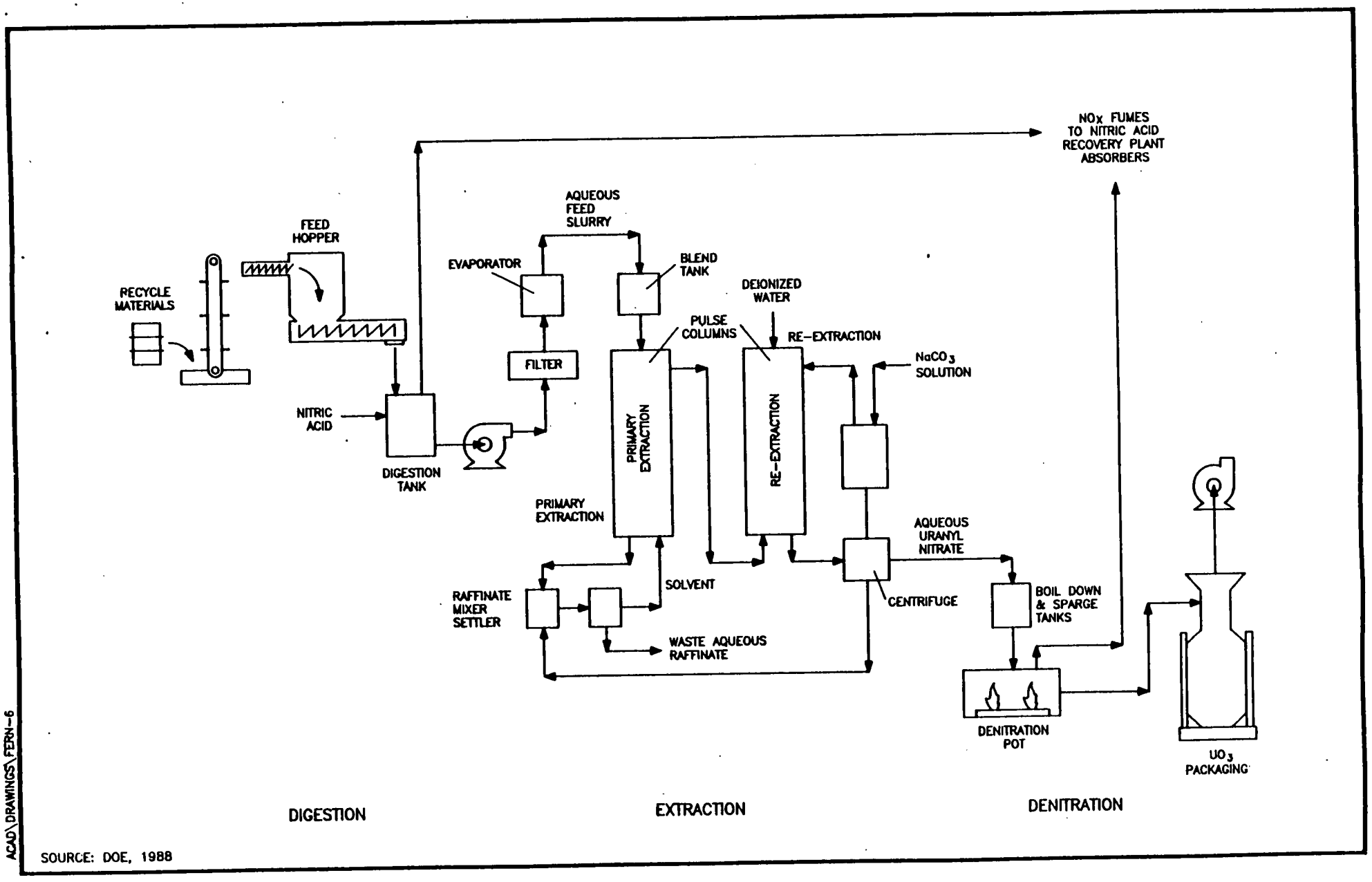


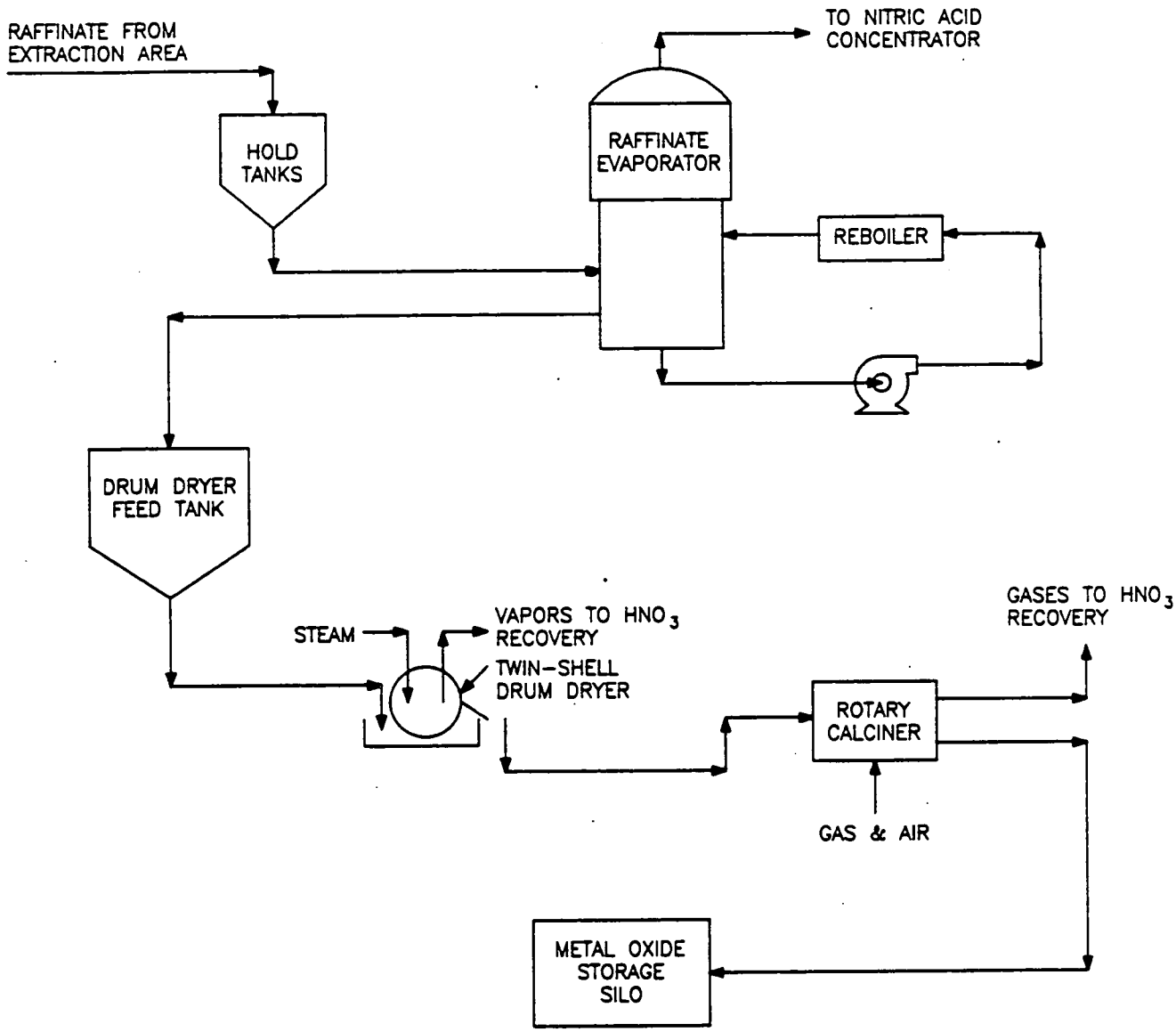
FIGURE 1-8. FMPC REFINERY PROCESS FLOW

TABLE 1-2

ANALYSES OF TYPICAL URANIUM CONCENTRATES

Constituent	African Concentrates		Australian Concentrates
	Belgian Congo	South Africa	
	Acid Leach, Ion Exchange	Acid Leach, Ion Exchange	Acid Leach, Ion Exchange
U_3O_8 (%)	48 - 73	75 - 85	55 - 70
H_2O (%)	0.1 - 0.5		0.2 - 0.5
As (%)	<0.02	<0.10	0.02 - 0.2
B (ppm)	80 - 600	20	4 - 40
Cu (%)	0.4 - 2	0.4	0.01 - 1
Halides (%)	0.02 - 0.03	0.03	0.05 - 0.15
Fe (%)	0.4 - 4	>0.4	>4
MoO_3 (%)	0.2 - 0.6	0.01	0.01 - 0.08
P_2O_5 (%)	0.25 - 0.7	0.06	0.1 - 1
Na (%)	0.07 - 2	0.04 - 0.2	~2
SO_4^{-2} (%)	1 - 37	1 - 5	0.5 - 2.5
V_2O_5 (%)	0.002 - 0.004	<0.002	<0.002

Source: Harrington and Ruehle, 1959.



SOURCE: HARRINGTON AND RUEHLE, 1959

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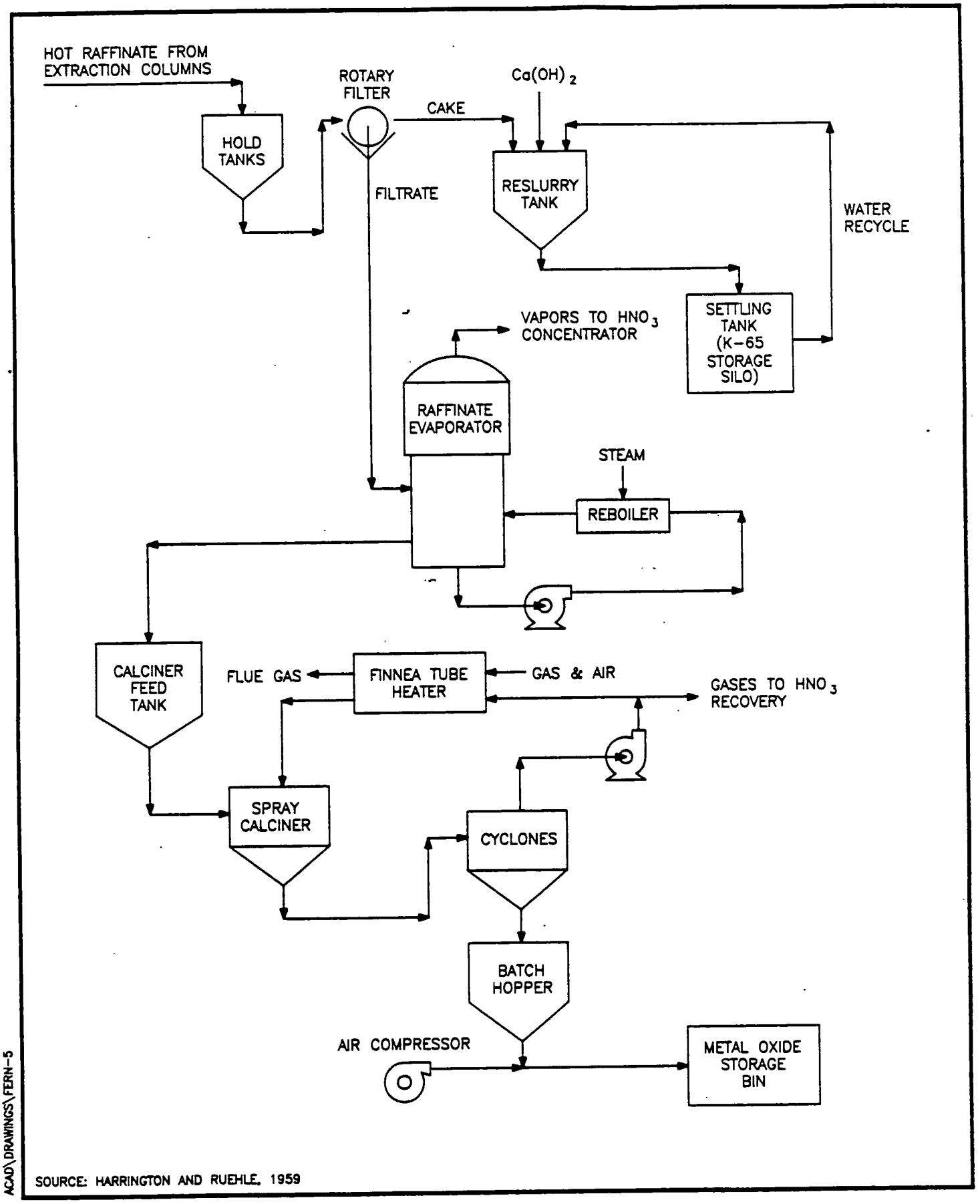
FIGURE 1-9. COLD RAFFINATE PROCESSING SYSTEM

with kerosene to remove residual solvent, was sent to a forced circulation evaporator where the volume was reduced approximately 10 to 1. The vapor stream, containing approximately 23 weight percent nitric acid, was sent to the nitric acid recovery system. The thickened slurry from the evaporator was then fed to a pair of twin-shell, steam-heated drum dryers. Most of the water and all the free nitric acid were removed, giving a product containing about 10 percent moisture. This material was fed to a gas-fired rotary kiln where the nitrates were completely decomposed, yielding a solid product containing oxides of the metal impurities originally present in the ore concentrate. The gases were sent to the nitric acid absorber for recovery and concentration. The dried metal oxides were then air-conveyed to Metal Oxide Silo 3.

Hot raffinate was handled in a slightly different manner, as shown in Figure 1-10. After being washed with kerosene to remove residual solvent, the hot raffinate stream was filtered on a precoat rotary vacuum filter to remove the suspended solids. Most of the radioactivity was caused by radium and its daughters, which form insoluble silicates and sulfates. Thus, the bulk of the radioactivity was removed in the filter cake. The cake was reslurried, neutralized with lime, and pumped to the K-65 storage silos where it settled. After settling, the supernatant water was decanted and returned to the reslurry operation. The filtrate from the rotary filter was concentrated in a forced-circulation evaporator similar to that used in the processing of cold raffinates. Volume was reduced 10 to 1. Vapors were sent to the nitric acid recovery system.

Thickened slurry from the evaporator then went to a spray calciner for complete denitration and drying. The calciner feed was atomized by steam in a two-fluid nozzle, and heat was introduced by circulating product gases through a set of gas-fired fin-tube heaters. The dried metal oxide product was removed from the gases by a set of cyclones discharging into a storage hopper. The gases were sent to the nitric acid recovery system. Solids from the storage hopper passed through a cooling screw conveyor and dropped into a surge hopper. Periodically, the collected solids were transferred by air pressure to Metal Oxide Silo 3.

The primary function of the K-65 area was to process and store radioactive solids that had been recovered from the nitric acid digestion of pitchblende. This solid material, K-65, consists primarily of siliceous matter but may also contain metallic compounds such as molybdenum, vanadium, lead, and others. The K-65 area was equipped to handle raw materials from either the Ore Refinery at FMPC or from outside sources.



SOURCE: HARRINGTON AND RUEHLE, 1959

FIGURE 1-10. HOT RAFFINATE PROCESSING SYSTEM

K-65 material was received in this area either as wet solids or as a slurry. The wet solids comprised material that had been produced at another activity and had been temporarily stored in 55-gallon drums. The slurry was produced in the FMPC Ore Refinery and was regularly transferred to the K-65 area. As a result of the work performed in the area, the K-65 was permanently stored as wet solids in two concrete storage tanks (silos). All material to be stored was pumped into the silos as a slurry. The K-65 settled out and formed a bed of wet solids while the slurrying liquor was periodically decanted from the silos. This liquor was physically processed and was retained in storage for further use as a slurrying agent.

The storage and handling processes are discussed below under three categories:

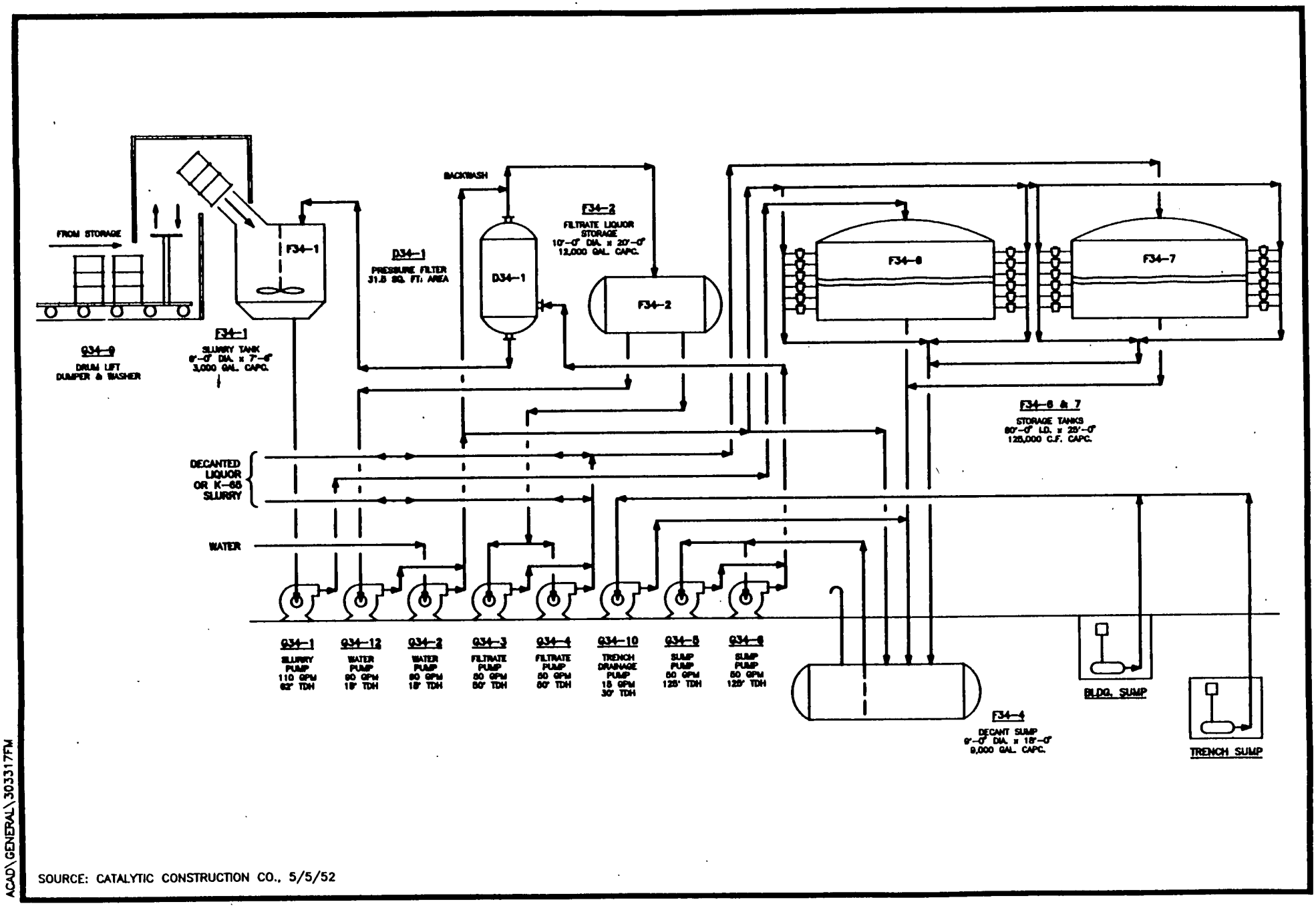
- The methods by which the incoming wet solids are removed from the drums, slurried, and transferred to the K-65 silos
- The processing involved in handling the slurry received from the Ore Refinery
- The recovery and processing of the slurrying liquor

A schematic process flow diagram of the area is presented in Figure 1-11. As shown on this diagram, the area consists essentially of two concrete storage tanks (K-65 silos), general solids and slurry handling equipment that were housed in a processing building, and a piping system for the transfer of slurry to the storage tanks from the processing building and from the Ore Refinery. (The processing building and all its associated equipment were completely dismantled and are no longer present at the site.)

Wet Solids Processing

The wet solids were delivered to the area in 55-gallon drums, each containing approximately 500 pounds of material. When produced, the material had a bulk density of approximately 90 pounds per cubic foot and contained approximately 40 weight percent moisture. Chemically, the material should have been alkaline or neutral.

One drum of the material was handled at a time. Each drum was placed on a slat conveyor by a shielded drum handling truck. The conveyor moved it inside the building where it was placed on a skip hoist and raised to a point above the slurry tank. Here it was inverted and the contents of the drum were dumped into the tank by vibration and also by a high-velocity water jet. The water jet also served to wash the drum, which was eventually returned to the conveyor and removed from the building. Approximately 75 gallons of slurrying liquor, which was fresh water during initial operations, was consumed in removing the solids from one drum. The resulting slurry, which had



SOURCE: CATALYTIC CONSTRUCTION CO., 5/5/52

FIGURE 1-11. PROCESS FLOW DIAGRAM K-65 HANDLING AND STORAGE

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a consistency of approximately four pounds of wet solids per gallon of slurry, was continuously agitated in the slurry tank.

When approximately 2000 gallons of slurry had been produced, the contents of the slurry tank were pumped to storage in Silo 1 (Tank F34-6). This slurry pumping was followed by a 1650-gallon clear liquor wash which was passed through the slurry tank, slurry pump, transfer line, and into the storage silo. Approximately 400 gallons of the liquor was allowed to remain in the slurry tank to aid in preparing the next batch of slurry.

FMPC Slurry Handling

The neutralized slurry produced in the hot raffinate area constituted feed that was pumped to the K-65 area for storage in Silo 2. The slurry had a consistency of approximately four pounds of wet solids per gallon of slurry; it was alkaline and may have contained traces of free caustic. The slurry liquor consisted of an aqueous solution of metallic nitrate.

The frequency and quantity of slurry to be transferred to the K-65 area varied with the quantity of pitchblende fed to the Ore Refinery. The average daily load was approximately 4000 gallons of slurry but may have gone as high as 10,000 gallons. The pumping rate was approximately 110 gallons per minute (gpm) in the three-inch schedule 80 transfer line. This flow rate was considered a safe minimum for maintaining turbulent flow and preventing the settling of solids in the transfer line. Slurry pumping was carried out once daily. Slurry pumping was followed by a clear liquor wash amounting to 1200 to 1500 gallons of the recovered nitrate solution.

The processing of this slurry and wash solution as received in the K-65 area was relatively simple. The material was received in the storage tank together with a certain amount of wash liquor. The wash liquor remaining in the pipe line was drained to the decant sump (F34-4).

Slurry Liquor Recovery

The slurries that were pumped into the storage silos eventually settled into two layers. The slurry liquor, either water or a metal nitrate solution, formed the top layer over a bed of wet K-65 solids. Periodically, this layer of clear liquid was decanted from the tanks and allowed to flow by gravity to the decant sump tank (F34-4).

This liquid was periodically removed from the sump tank, passed through a pressure filter, and temporarily stored in the filtrate storage tank (F34-2). From here, the material was either used for

slurry preparation in the K-65 area or was returned to the hot raffinate area of the Ore Refinery where it was used as a neutralizing liquid. The purpose of the filtration step was to remove any sediment that could have been carried from the storage silos during decantation. All solid material delivered to the K-65 area had to be retained there for accountability purposes.

The decantation operation proceeded automatically as the liquid level built up in the storage silos. These silos possess a series of drawoff ports where the decantation took place. These ports are arranged in two vertical lines that are located on diametrically opposite sides of the silos. There are 25 ports on each line making a total of 50 per silo. The bottom port on each silo is 1 foot from the silo bottom. Initial decantation began when the liquid level reached the 1-foot elevation. The remaining 49 ports are located at 6-inch intervals.

The great majority of the pitchblende ore processed at the FMPC came from one mine, the Shinkolobwe Mine, in the Belgian Congo. This mine began operation in 1921 for the purpose of obtaining radium. With the increased importance of uranium during the 1940s, the mine was reopened in 1943 for its uranium content. As the radium was still of considerable value at the time, an agreement was reached between the AEC and African Metals Corporation based on the ore being processed for removal of uranium, with the provision that the residue from this processing would be returned to its owner, African Metals Corporation.

The residues which are stored in the K-65 silos were initially generated at the Mallinckrodt Chemical Works (MCW) in St. Louis, Missouri. The process that was used for extraction of uranium at MCW was the dual-cycle ether process. This process was different from the TBP-kerosene extraction system utilized at the FMPC.

Initially, the residues from the MCW operation were sent back to African Metals Corporation. However, beginning in April 1949, the residues were no longer returned to African Metals Corporation following processing, but were stored at MCW for future shipment. Due to continued production, storage began to be a problem. As a result, shipments of the drummed K-65 residues were sent from MCW to Lake Ontario Ordnance Works (LOOW) near Niagara Falls, New York. Also, the two K-65 silos were planned as part of the uranium processing plant scheduled to be constructed at Fernald, Ohio. Some of the drums that were sent to LOOW were emptied into a concrete water tower at that site. A smaller number (approximately 6000) was shipped to Fernald by rail. In addition, the continuing production at MCW resulted in approximately 25,000 drums being sent directly from St. Louis to the FMPC. These shipments began in 1951.

At the FMPC, the drums were sent to a drum handling building that had been specifically built near the silos to transfer the contents of the drums of off-site origin into the silos. The material was slurried into the silo, where the solids would settle. The free liquid was decanted, and the clarified liquid was sent to the Refinery sump. As the depth of solids reached the level of a given valve, the valve was sealed and the next higher valve was used to decant liquids. Settling and decanting were continued in this way until the silos were filled to approximately four feet below the top of the vertical wall. This process left a sludge with an estimated density of 100 pounds per cubic foot. The decanted liquid was recycled. The volume of material from LOOW and from St. Louis filled Silo 1.

The processing of the pitchblende ore through the FMPC Refinery ran concurrently with the latter stages of processing the off-site drums through the drum handling building. It is understood, therefore, that although Silo 1 was filled completely from off-site drums, Silo 2 material is a mixture of off-site K-65 material and FMPC-generated K-65 material. The residue slurry from the Refinery was conveyed to Silo 2 through the underground transfer line that lay in a concrete trench and was allowed to settle in the same manner as the off-site residue. During 1957 and 1958, the residue from processing Australian pitchblende was added to Silo 2. The total amount of Australian pitchblende residue was estimated to be almost 400,000 pounds. The rest of the material subsequently added to Silo 2 was residue generated by the FMPC from the remaining Belgian Congo ores.

After Silo 2 was decanted, some drummed material was added. Most of this material was soil that was contaminated with K-65 material leaking from the drums. This contamination occurred because the drum storage area was adjacent to the drum handling building. Containment and cleanup measures were taken as previously stated in Section 1.2.1. Other materials reportedly added to the silo contents were drum cleanout residues, cleanup materials from Q-11 (unprocessed uranium ore) storage and process areas, residues from decontamination of lab equipment, and Q-11 and K-65 samples.

Silo 3 was constructed in mid-1952 and was designed to receive dry materials only. Slurries from Refinery operations were dewatered in an evaporator and spray calcined to produce a dry waste form for removal to Silo 3. The waste was blown under pressure into Silo 3. (Silo 4 was also constructed in mid-1952; however, as stated earlier, this silo was never used.)

Large areas of spalling occurred in the exterior surface gunite coating of the silos, particularly on Silo 2, leaving post-tensioning wires corroded and exposed to the weather. The exterior surfaces of the silos exhibited sufficient deterioration by 1963 to require repairs in 1964. All loose material was chipped away and the surface was patched with a 0.75-inch-thick coat of cement mortar. After the gunite was repaired and a waterproofing membrane was applied, an earthen embankment was built to the top of the walls of Silos 1 and 2 to provide relief from tensile stress that had developed within the walls. This embankment also provides weather protection, a reduction of radon emissions, and increased shielding from penetrating radiation. The embankments were originally constructed on a slope of 1.5:1; however, the slope was subsequently modified to 3:1 in 1983 to reduce soil erosion (Grumski 1987a; Boback et al. 1987). Vents in the silos were sealed in 1979 (Camargo 1986).

In January 1986 the FMPC had a temporary dome cover, which was 30 feet (9.1 meters) in diameter, installed to span across the deteriorated portion of the concrete domes of Silos 1 and 2. The cover is self-supporting and sits on a rolled plate-steel skirt. The cover is composed of structural steel members which support 0.75-inch (1.9 centimeters) plywood sheeting. The plywood sheeting is covered with a weatherproofing membrane. The dome cover increases the stresses in the existing concrete, but all stresses are outside the deteriorated area and within acceptable limits. The dome cover was installed so that containment of the silos' contents will be maintained in the event of a center silo dome collapse (Shanks and Vogel 1988).

In 1987, an Interim Stabilization Project (ISP) was implemented at the K-65 silos to comply with the CERCLA section of the FFCA (Grumski 1987a). Compliance required that DOE take immediate measures to control radioactive emissions from the FMPC. Work performed as part of the ISP included:

- Implementation and periodic operation of a radon gas treatment system (RGTS)
- Application of a layer of rigid polyurethane foam insulation to the exterior of the dome surfaces of Silos 1 and 2. The foam thickness was 3 inches at the outer dome surface and 1.5 inches at the dome cap

The RGTS consists of a calcium sulfate bed to remove moisture, followed by charcoal beds to absorb the radon. It is a closed system in which the treated air is recirculated back to the silos. The RGTS is designed to be operated on an interim basis, such as when the dome is opened; it is not designed for continuous operation. The foam coating was applied to the domes to further reduce weathering, temperature changes inside the silos, and radon gas emissions.

1.3.2 Previous Operable Unit 4 Investigations

As part of the comprehensive waste management and environmental program for the FMPC, several investigations have been conducted at the site. The results of these previous investigations that are relevant to Operable Unit 4 are briefly summarized below. A chronological summary of significant sampling and data gathering activities relevant to Operable Unit 4 that have been conducted since 1983 is presented in Figure 1-12. Planned sampling activities that will support the Operable Unit 4 RI evaluation are also shown in Figure 1-12.

Waste Material in Silos

Several previous studies have been conducted that provided data on the waste material contained in the K-65 and metal oxide silos. The earliest recorded study providing data on the K-65 residue was conducted by Vitro Corporation between March 1950 and November 1951 (Vitro 1952).

The objective of the Vitro study was to evaluate the ability to recover radium from the K-65 residues. The K-65 residues were analyzed for percent moisture, metal salts, and metal oxides. The data from the Vitro study are summarized in Section 4.1 of this report.

A study entitled "Treatment of Pitchblende Residues for Recovery of Metal Values" was conducted by Hazen Research, Inc. The report on this study was authored in 1974 by J. E. Litz (Dettorre et al. 1981). The Hazen Report concluded that, "the FMPC K-65 residues are composed of two fractions: (1) a `slimes´ fraction (<400 mesh) containing solubilized recrystallized fractions including radium-contaminated barium sulfate; and (2) a `sand´ fraction (>400 mesh) containing undissolved ore particles and primarily less soluble silicate secondary minerals. According to Litz (1974), only about 5.6 percent of the radium content of the residue is found in the 26.9 percent sand fraction [24 parts per billion (ppb) in 65 x 100 mesh, 105 ppb in >65 mesh]. The average residue radium concentration was reported by Litz (1974) to be approximately 300 ppb (Dettorre 1981)."

A study to evaluate short-term and long-term storage costs for K-65 residues was conducted by NLO (1980). This report references analyses of the K-65 residues that were conducted in 1970. Data from these analyses are consistent with other studies and are summarized in Section 4.1.

WMCO collected and analyzed K-65 silo residue probe samples in the summer of 1988 (Gill 1988). This study collected samples from both Silos 1 and 2. Analyses were performed on isotopes of uranium, thorium, and radium. Radioisotopes were identified and categorized as alpha or gamma

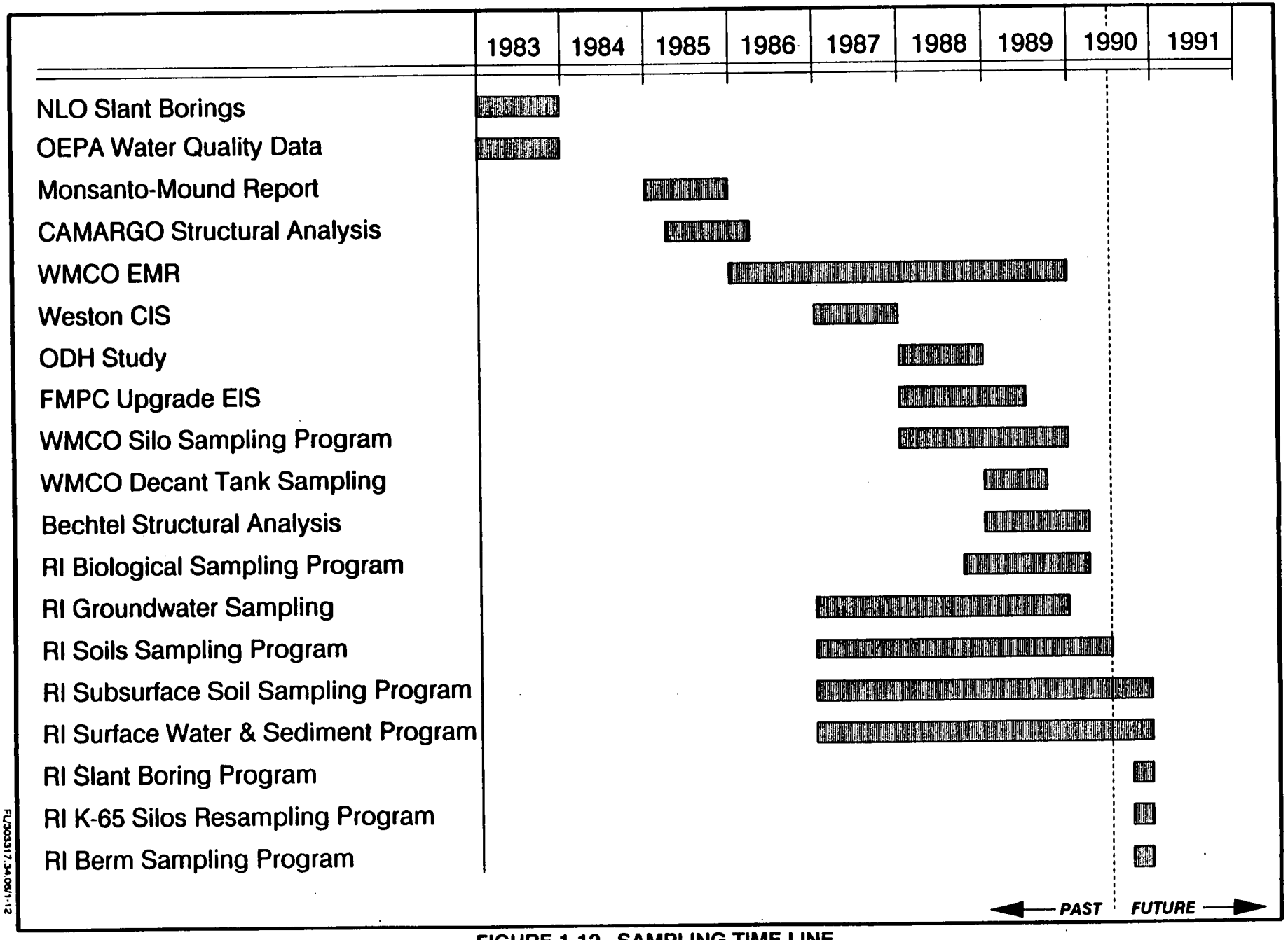

FIGURE 1-12. SAMPLING TIME LINE

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radiation emitters. Sample analysis by X-ray fluorescence spectrometry assisted in characterizing the elemental composition of the K-65 residues. The physical and radiological data from the WMCO study are consistent with other data and are summarized in Section 4.1 of this report.

Metal Oxide Silo 3 contains approximately 5100 cubic yards (yd^3) of calcined residues, which are awaiting final disposal (DOE 1989). Approximately 39,600 pounds (18,000 kilograms) of uranium and approximately 15 to 23 curies of radium were estimated to be present in the contents of Silo 3. Other metals were also known to be present in the stored materials. Isotopic thorium concentrations were unknown until analytical data became available in March 1990 for samples collected by WMCO from Silo 3 in July 1989. Metal Oxide Silo 4 remains empty with the exception of some infiltrated rain water. Analysis data on the wastes contained in Silo 4 are presented in Section 4.1.

A sampling program undertaken in 1989 by WMCO was designed to collect representative core samples of the K-65 residues. Only partial cores were recovered and these could not be related to the depth in the silos from which they were collected. Physical, radiological, and chemical analyses were performed on the partial cores to provide additional characterization data on the contents of the K-65 silos. The contents of Silo 3 were successfully sampled and characterized. Sample analysis data for the contents of Silos 1, 2 and 3 are presented in Section 4.1.

Advanced Sciences, Inc./IT Corporation (ASI/IT) initiated a sampling program in March 1990 with the objective of collecting representative core samples from the K-65 silos (Silos 1 and 2). These cores will be analyzed for physical, chemical, and radiological parameters. These data are needed to support the FS for Operable Unit 4 (ASI/IT 1990a). This program is scheduled for completion in the fall of 1990.

Physical Structure of the Silos

In 1985, a nondestructive testing program and structural analysis on the silos were performed by Camargo Associates, Ltd. (Camargo). The investigation consisted of three phases. Phase I involved computer analysis of the original silo design based on the original drawings. Phase II consisted of field work that was divided into three areas: soil exploration study; a survey using the Echo Pulse system to test the silo domes, walls, and base slabs; and the ground penetrating radar study of the earthen embankment around the silos. Phase III consisted of a computer analysis based on the field data collected in Phase II. The pertinent conclusions of the Camargo investigation are summarized as follows:

- The base slab and walls at the time of investigation were structurally stable under the existing static loads being applied to them and should continue to remain stable for approximately 5 to 10 years.
- The center 20-foot-diameter portion of the dome top is structurally unsound for a load greater than the existing static dead load, and no life expectancy was assigned to it.

More information is contained in a report prepared by Camargo (1986).

Several corrective measures were taken by DOE as a result of the Camargo analysis. In January 1986, protective covers for the center portion of the domes of Silos 1 and 2 were constructed and put in place. In April 1986, a weatherproof protective membrane was installed over the top of Silo 2. In November and December of 1987, a 3-inch foam covering was placed over both Silos 1 and 2.

During the period March 13 through May 15, 1987, WMCO started monitoring the temperature and pressure changes of the K-65 silos (Grumski 1987b). The objectives of the study were to:

- Find out if there was any pressure buildup in the silos that could lead to their failure.
- Study the breathing pattern of the silos.

The ambient temperature varied a maximum of approximately 42°F during the 12-hour monitoring period. Correspondingly, the internal gas temperature measurements for both K-65 silos showed an approximate 35°F temperature variation over the same 12-hour monitoring period.

Silo 1 showed negligible pressure variations as the internal gas temperature varied due to ambient temperature fluctuations. Silo 2 was able to maintain a positive differential pressure of approximately 7.6 pounds per square foot and a negative 4.9 pounds per square foot during the monitoring period.

The pressure data indicated that both of the K-65 silos exchange gas freely with the surrounding atmosphere, otherwise much higher pressure differentials would have been recorded. The study concluded that neither of the K-65 silos are capable of sustaining a great enough pressure differential with the ambient surroundings to result in silo or dome failure. (Installation of the foam during the ISP has reduced temperature fluctuation to about 5°F.)

As a result of findings from a July and August 1989 DOE investigative team inspection, Bechtel National, Inc. (BNI) was contracted to perform additional testing and analysis of the silos.

The objectives of the testing and analysis conducted by BNI were to:

- Determine the structural integrity of the K-65 silos and perform an independent verification of the previous structural analyses performed by Camargo.
- Verify the in situ compressive strength of the tank concrete.
- Provide a qualitative assessment of risk of structural failure of the tanks.

The BNI study generally supported the Camargo study results (BNI 1990).

The University of Cincinnati prepared a report that evaluates the probable risk to human health and the environment associated with a catastrophic failure of the silos. Revision 1 of this report was published in May 1990 (University of Cincinnati 1990). This report stated that the current chronic release of radon from the domes would give workers located 100 meters (328 feet) away from the source a dose of approximately 2.57 rem/year. The nearest residents located 500 meters (1640 feet) away from the source would receive approximately 0.21 rem/year. An individual in the nearest population center would receive approximately 1.2×10^{-3} rem/year.

The study also estimated that under tornado conditions, residues found at depths up to 1 meter (3.28 feet) in the silos would be picked up and distributed. If this occurred, workers located 100 meters (328 feet) away from the source would receive 31 rem. Residents located approximately 500 meters (1640 feet) away from the source could receive approximately 1.5 rem. An individual in the nearest population center 14,500 meters (9 miles) from the source would receive 1.3×10^{-3} rem.

BNI's subsequent Engineering Evaluation/Cost Analysis (EE/CA) explored options for the K-65 Removal Action (BNI 1990b). Conducted in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40CFR300.415), this study found that a tornado-induced structural failure of both silos could result in an initial uncontrolled release of approximately 66 Ci of radon-222 (Rn-222) and some K-65 residues. Furthermore, a spontaneous failure of either silo would result in release of 33 Ci of radon. In both cases, radon release would increase following the initial release until corrective action could be implemented by FMPC personnel. Hence, due to the substantial risk associated with the silos, remedial action should not be undertaken at the silos without providing additional structural support for the silos.

WMCO has been conducting monthly sampling of the K-65 decant sump since August 1989 (Vogel 1990). The underground decant sump tank is currently the only means of monitoring for

underground leaks in the silos. However, because the sump was a receiving tank for decant liquor from the silo residues, the sump and its related piping were contaminated as a result of K-65 processing operations. Any long-term, low-level leakage from the K-65 silos that may be occurring is practically impossible to detect because the sump remains contaminated.

Soil Berms

No previous investigations have been conducted to evaluate the potential accumulation of Pb-210 and Po-210 in the soils. A berm sampling program is planned as part of the RI but it has not yet been conducted.

Glacial Overburden Beneath the Silos

On November 6, 1953, a liquid was noticed oozing from the ground adjacent to K-65 Silo 1 (NLO 1953). Further investigation indicated that the leak originated at the silo and not the decant line. Soil tests confirmed that some contamination had occurred. It was not clear from the communications related to this incident whether the source of the leak was ever positively identified or how the problem was ultimately corrected. Reference was made, however, to one or more events resulting in an overflow of the decant liquor tank (Karl 1953). A set of slant boring samples were collected by NLO in 1983 that confirmed the presence of uranium [1.2 to 14.5 parts per million (ppm) total uranium] and radium [0.53 to 1.8 micrograms/gram (µg/g)] in soils beneath the silos (Vogel 1989a).

A slant boring program, which has been planned as part of the RI, will be conducted by ASI/IT in the fall of 1990. More information on this sampling program is contained in Section 2.2. Results from the slant boring program will characterize the nature and extent of contamination in the glacial overburden (ASI/IT 1990b).

Data from the slant boring program and from the ongoing quarterly groundwater monitoring program will be utilized in a vadose zone model. The vadose zone model has been developed by ASI/IT to simulate contaminant migration and transport in the vadose zone. Results of the vadose modeling are presented in Attachment E.III, Appendix E of this report.

Operable Unit 4 Study Area

Several previous investigations directed at the entire FMPC facility have acquired data that are relevant to the evaluation of Operable Unit 4. From September 20, 1984 to February 5, 1985, Monsanto-Mound conducted special radon monitoring around the silos. This program assessed the

extent to which radon concentrations in the surrounding area were due to the radium-bearing residues stored in the silos. Average radon concentrations ranged from 0.24 pCi/L to 5.1 pCi/L. Maximum observed concentrations are observed at monitoring locations around the tanks within 120 feet of the silos although minimum concentrations were observed along the eastern site perimeter at 4800 feet from the silos. The study concluded that radon monitoring should be continued and that a sealant should be applied to the surface of the tanks to inhibit the transport of radon (Monsanto 1985).

A radiological characterization of the surface soils in the Waste Storage Area, which includes Operable Unit 4, was conducted by Roy F. Weston, Inc. in 1986 and 1987 (Weston 1987). A systematic survey of the surface soils throughout the Waste Storage Area, associated on-site drainages, and the fly ash piles was conducted over a 10-month period. Approximately 24,400 locations were surveyed throughout the Waste Storage Area to locate areas where uranium concentrations exceeded 35 picocuries/gram (pCi/g). Soil samples at depths down to 18 inches were taken and sent to the on-property gamma spectroscopy laboratory where estimations of concentrations were made for uranium-238 (U-238), Ra-226, thorium-232 (Th-232), cesium-137 (Cs-137), and ruthenium-106 (Ru-106). Data collected during this study which are relevant to Operable Unit 4 are summarized and discussed in Section 4.4 of this report.

WMCO conducts an environmental monitoring program at the FMPC as part of its ongoing effort to protect the health and safety of nearby residents. The program entails a broad range of activities related to environmental monitoring and sampling, waste management, and overall site remediation.

The primary objectives of the environmental monitoring program are:

- To ensure that the FMPC can detect any release of materials as quickly as possible so that corrective actions can be implemented immediately
- To estimate the radiation dose that area residents may be exposed to as a result of any release of materials
- To measure progress of correcting problems from past operations and in implementing improved environmental management practices

The FMPC waste management activities are directed at disposal, elimination, and safe storage of both liquid and solid wastes in compliance with all applicable regulations. The results of the environmental monitoring program are reported annually in an Environmental Monitoring Report (EMR).

Data from reports that were relevant to the Operable Unit 4 evaluations were utilized to supplement data from the RI. Site environmental monitoring data contained in the EMR were also used, when possible, to supplement data from the 1986 Weston study and the RI.

Regional Environment

All of the previous studies considered relevant to the Operable Unit 4 study area evaluation were also considered relevant to the evaluation of the regional environment. Several additional studies that are important to the regional evaluation are discussed below. These data are presented in Section 4.0.

The ODH performed independent indoor and outdoor radon concentration measurements in the vicinity of the FMPC (ODH 1988). The ODH established 16 outdoor radon monitoring stations around the FMPC, including 12 locations along the FMPC site boundary (samples) and 4 locations distant from the FMPC (controls). Analyses of the detectors located at the site boundary closest to the K-65 silos and at background locations do not reveal consistent significant differences in measured radon concentrations (ODH 1988). The ODH study also concluded that environmental measurements of radon and radon progeny concentrations at the FMPC boundary are low and often cannot be distinguished from variations in natural background concentrations (ODH 1988).

In response to DOE direction and in accordance with the Notice of Intent published on May 15, 1990, ASI/IT is preparing a site-wide Environmental Impact Statement (EIS) that will evaluate alternative strategies for remediation of the entire site. Data from the EIS specific to Operable Unit 4 will then be considered during the development and evaluation of alternatives for Operable Unit 4 and will be integrated, as appropriate, into the Operable Unit 4 RI/FS documents.

A computerized finite-difference groundwater flow model has been developed by ASI/IT to simulate groundwater flow and solute transport in the vicinity of the FMPC. Both a regional model and a local model are being developed. Predictions generated by the model will be helpful in estimating the migration potential for any groundwater contaminants associated with Operable Unit 4. Preliminary model predictions are presented and discussed in Appendix E, the Baseline Risk Assessment.

1.4 REPORT ORGANIZATION

This RI report is formatted in accordance with the latest EPA guidance (EPA 1988). Section 1.0 has discussed the purpose of the RI report, has presented information on the site background, and has discussed previous investigations. The objectives of Section 1.0 are to focus the evaluation on Operable Unit 4 while providing the regional perspective necessary to evaluate fully any environmental impacts associated with the operable unit.

The investigation procedures employed for the RI are summarized and presented in Section 2.0. The specific data objectives for each procedure as it relates to Operable Unit 4 are also presented in Section 2.0.

Section 3.0 describes the physical characteristics of the study area. Most of the data relevant to the physical characteristics of the study area are presented from a site-wide perspective because specific data pertaining to the Operable Unit 4 study area are not available.

Section 4.0 presents the results of the RI and discusses the nature and extent of contamination associated with Operable Unit 4. Relevant data from previous studies are also included in Section 4.0.

An evaluation of possible fate and transport scenarios for contaminants originating from Operable Unit 4 is presented in Section 5.0. Physical and chemical characteristics of the contaminants are considered during this evaluation.

The baseline risk assessment for Operable Unit 4 has been prepared as a separate stand-alone document to accompany the RI report as an appendix. Section 6.0 presents a summary of the significant findings drawn from the risk assessment.

Section 7.0 presents a summary of the results and conclusions drawn from evaluation of the RI data relevant to Operable Unit 4. This section also discusses the remedial objectives that are being addressed under the Operable Unit 4 FS.

The appendices to this report contain summary tables of the RI data relevant to Operable Unit 4. These appendices are comprehensive with respect to the data obtained within the Operable Unit 4 study area during the RI. Excerpted data from the Characterization Investigation Study (CIS) are also summarized in the appendices.

2.0 OPERABLE UNIT 4 INVESTIGATIONS

The various investigations performed for Operable Unit 4 are part of the RI being conducted for the FMPC site. This section describes the investigative activities that were conducted at Operable Unit 4 and the data collected during the investigation. Details of the RI procedures are contained in the RI/FS Work Plan and Sampling Plan, as well as specific sampling plans for the characterization of the silo material (IT 1988b).

2.1 WASTE CHARACTERIZATION (SILOS 1, 2, AND 3)

Previous studies have been conducted on the K-65 residues in Silos 1 and 2. In addition, samples of the materials have been collected during residue transfer into the silos. These studies indicate that the silo residues are not totally homogeneous materials. Because of the inconsistency in the analytical results from the various studies, the data from previous sampling and analysis efforts did not adequately characterize the K-65 residues. These data could not be used to evaluate release potential and the technical feasibility of remedial actions. Similarly, previous analyses conducted on the metal oxides in Silo 3 were not sufficiently documented to characterize adequately those materials; therefore, an additional sampling effort was required as part of the RI. The sampling effort described below was conducted by WMCO in the summer of 1989 to acquire the additional data needed to support the FS.

The sampling of Silos 1 and 2 conducted by WMCO was only partially successful because of poor core recovery. Even though an average of 20 feet of penetration of the material was achieved, there was no sample recovered in three locations. The samples obtained from Silos 1 and 2 were essentially a collection of grab samples instead of continuous sample cores. To recover continuous core samples for the characterization of the silo contents, a resampling effort is being conducted by ASI/IT.

The sampling of Silo 3 by WMCO was successful. Core samples of up to 11 feet were recovered from 31 feet of material penetration. These cores and the data obtained from analysis of core samples are considered adequate to characterize the contents of Silo 3 and to support the FS. No additional sampling of Silo 3 contents is anticipated.

The resampling of Silos 1 and 2 will be done in three steps:

- Field testing of sampling equipment
- Mock sampling of the silo sampling operation on the empty Silo 4
- Actual sampling of Silos 1 and 2

2.1.1 Objectives

The main objectives for the silo sampling program are:

- Confirm the maximum depth and estimate the volume of material contained in the silos.
- Determine the physical characteristics of the silo contents, including engineering and geotechnical properties.
- Characterize the radiological and chemical composition of the silo contents.

Analytical results from the sampling were completed in March 1990. These results have been incorporated into Section 4.1 of this RI report.

2.1.2 Methodology

Sampling operations will be conducted as three distinct activities:

- Equipment testing
- Mock sampling of Silo 4 (one sampling point)
- Sampling of Silos 1 and 2 (four sampling points in each silo)

This step-by-step sampling approach was chosen because of the public health and worker safety concerns associated with the silo sampling program. Mock sampling will be conducted on Silo 4 to demonstrate and refine the specialized sampling techniques and to test equipment operation. This sequence will aid in training the sampling personnel so that they will become more experienced, precise, and efficient as they proceed to the higher risk sampling of Silos 1 and 2.

Details of the equipment to be used and the sampling and decontamination procedures are provided in the "Implementation Plan for the K-65 and Metal Oxide Residue Sampling Project" (IT 1988b). The layout of the K-65 and metal oxide silos sampling area, which shows the planned sampling locations, is presented in Figure 2-1. This figure shows the sampling sequence to be employed by ASI/IT during their resampling effort. Silo 3 is not shown as part of the sequence because it has been sampled by WMCO.

2.1.3 Analytical Parameters

The K-65 samples will be analyzed for physical, chemical, and radiological parameters. The purpose of the sampling campaign is to characterize the materials for the evaluation of release potential, risk, and remedial technologies (including disposal options). The required radiological analyses are:

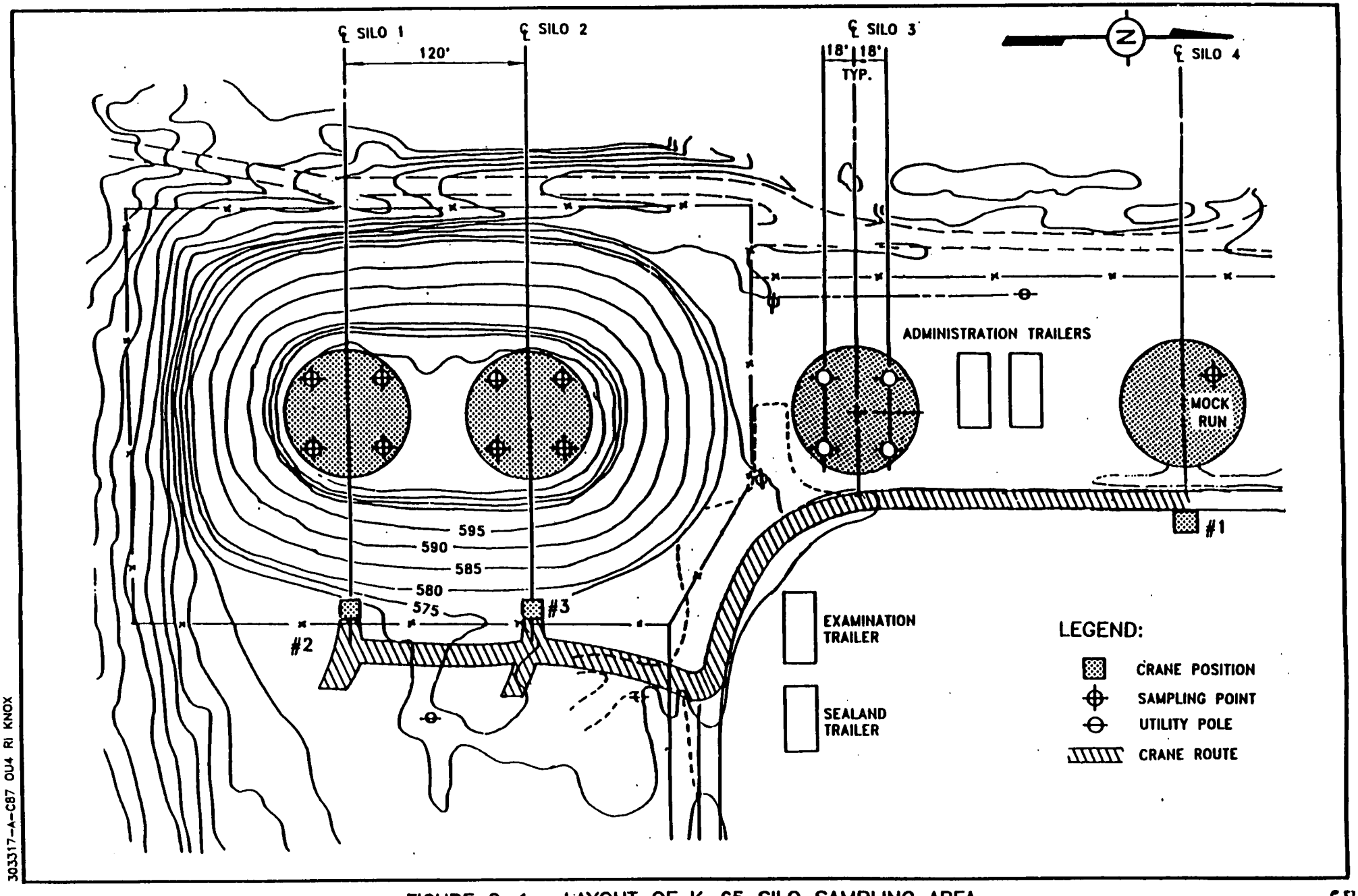


FIGURE 2-1. LAYOUT OF K-65 SILO SAMPLING AREA

- Isotopic uranium
- Isotopic thorium
- Isotopic radium
- Pb-210 (sample concentrations of Po-210 can also be determined from this analysis because there has been sufficient time to allow the radionuclides to reach secular equilibrium)
- Gamma spectroscopy

Selected samples will be analyzed for the following chemical parameters:

- Hazardous Substance List (HSL) inorganics
- HSL volatiles
- HSL semivolatiles
- HSL pesticides and PCBs
- Toxicity Characteristic Leaching Procedure (TCLP) metals

The following physical properties will be determined for the silo residues using the specified American Society for Testing and Materials (ASTM) method:

- Particle size distribution (ASTM D422-63)
- Atterberg limits (ASTM D4318-84)
- Moisture content (ASTM D2216-80)
- Specific gravity (ASTM D854-83)

Physical properties of the K-65 residues will be determined to predict the expected behavior of the wastes during treatment and disposal operations.

2.2 K-65 SILO EMBANKMENT AND SUBSOIL SAMPLING

Two slant borings were drilled under the K-65 silos by NLO in 1983. Locations for these borings were selected based on areas where leaks were suspected to have occurred during silo filling in the 1950s. As discussed in Section 1.0, the K-65 silo leakage history is documented in a memorandum from R.C. Heatherton, NLO, to Central Files, NLO, dated November 25, 1953 ("K-65 Storage Tank No. 1"). Analyses for the samples from the slant borings were limited to general radioactivity scans and uranium analysis. The results of this sampling program are documented in Section 4.0. These data were not adequate to define the nature and extent of potential contaminants under the silos.

Based on this historical information, a sampling plan for testing the K-65 silo embankment and denoted subsoils (below-silo soils) has been prepared. Two other reasons for this sampling effort are discussed below.

- A baseline risk assessment performed by IT indicated the potential presence of Pb-210, Po-210, and stable lead in the soils surrounding the K-65 silos. These are daughter products of radon generated from the radon that escaped through the silo walls and decayed within the porous matrix of the embankment soils.

- The existence of a buried underground decant tank, historically known as the upper sump, and the associated piping system adjacent to and underneath the silos is a potential source for leakage to the surrounding soils. This system was used to transport K-65 waste slurry and decanted silo liquids between the silos and the refinery.

The K-65 silos embankment and subsoils will be sampled utilizing a two-phase approach described in Section 2.2.2. The samples will be analyzed for radiological, chemical, and geotechnical parameters. The program will be conducted in accordance with "RI/FS Work Plan Addendum: K-65 Silo Embankment and Subsoils Sampling and Analysis Plan with Site Specific Health and Safety Plan" prepared by ASI/IT in June 1990.

2.2.1 Objectives

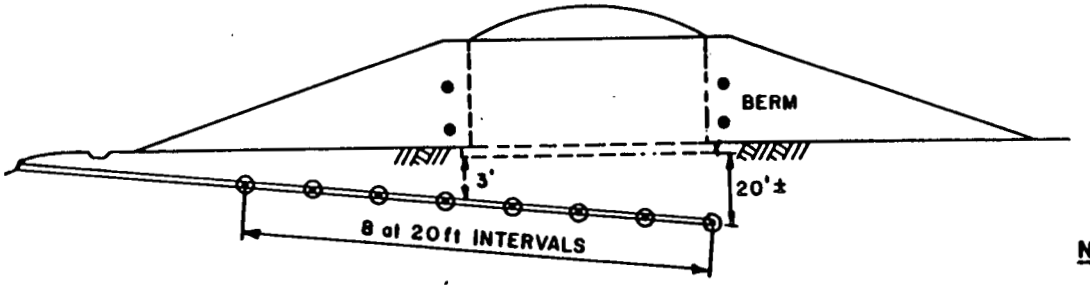
The objective of the K-65 silo embankment and subsoil sampling program is to provide the data necessary to determine and verify the source and extent of contamination in the soils directly below and surrounding the K-65 silos. These data will be used to support a mathematical model to estimate the potential for contaminant migration in the subsoils and to support the evaluation of alternatives in the FS. These data will also be used to establish a source term for the model of the Great Miami Aquifer if it is determined that any contamination below the silos will ultimately impact the groundwater.

2.2.2 Methodology

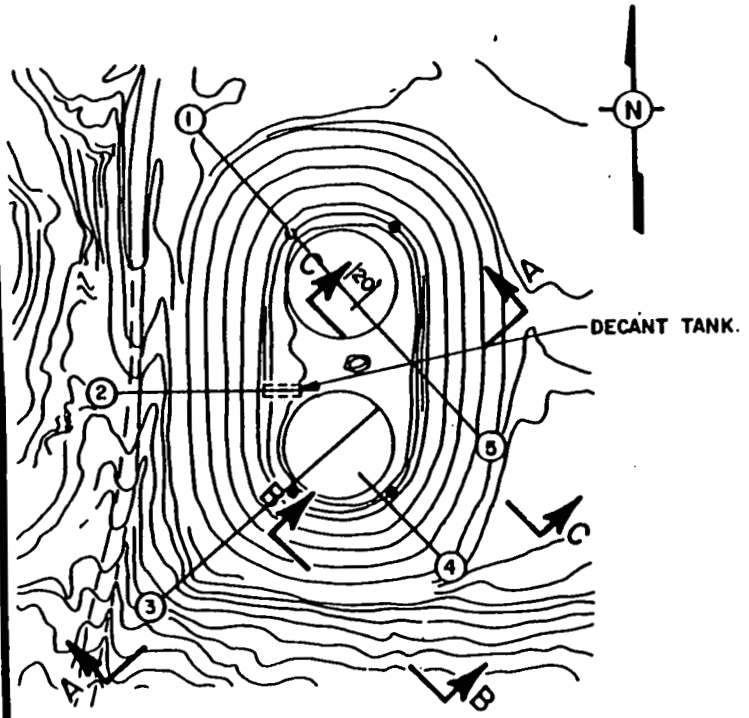
Sampling of the embankment and subsoils will be conducted in two phases. Phase I is briefly described below. Phase II will consist of additional data gathering, as necessary, and will be developed after the Phase I data have been evaluated.

Per the Sampling and Analysis Plan, the Phase I sampling pattern (Figure 2-2) will consist of the following elements:

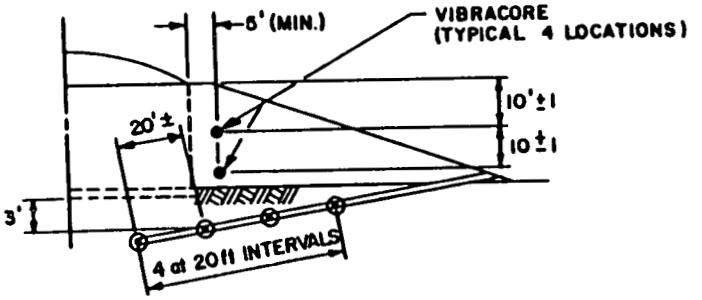
- Five low-angle borings using 30-inch-long tenite sleeves. The specified analyses will be performed on samples collected at 20-foot intervals. A minimum total of 28 samples will be collected in this fashion.



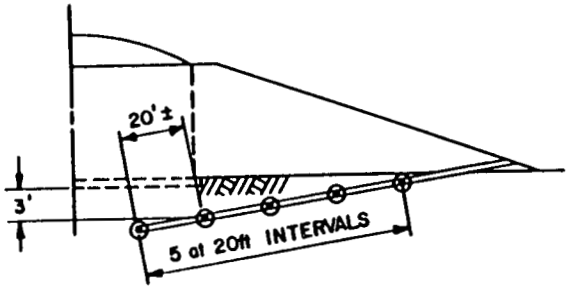
SECTION A-A



BORING LAYOUT



SECTION B-B



SECTION C-C

NOTES:

1. FOR DECANT TANK DETAILS SEE DRAWINGS. 34X1450P00074 34X3500A00067
2. FILL ALL BORINGS WITH BENTONITE GROUT PRIOR TO ABANDONING.
3. GENERAL LAYOUT K-65 STORAGE AREA: DWG. 3034-H-53-A, REV. 3
4. FLOW DIAGRAM OF K-65 TRENCH PIPING: DWG. 34-4008, REV. 0
5. K-65 TANK EMBANKMENT STABILIZATION GENERAL LAYOUT: DWG. 34X5500G00084, REV. 1

LEGEND

- ● NON-DIAGONAL BORING SAMPLE LOCATION
- ⊙ DIAGONAL BORING SAMPLE LOCATION
- ① THROUGH ⑤ DIAGONAL BORING ALIGNMENT

NOT TO SCALE

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- Four vertical borings will be placed approximately five feet from the exterior silo walls. The vibracore technique will be utilized to collect samples at depths of approximately 10 and 20 feet. A total of eight samples will be collected.

- One liquid and one sediment sample will be recovered from the underground decant tank.

Sample analysis parameters are specified below. Depending on the results of the Phase I effort, additional geotechnical, radiological, and chemical sampling data requirements may be identified to complete the risk assessment and FS. Any associated investigations would be conducted under Phase II.

2.2.3 Analytical Parameters

The required radiological analyses for all embankment and subsoil samples are listed below.

- Isotopic uranium
- Isotopic thorium
- Isotopic radium
- Pb-210 (sample concentrations of Po-210 can also be determined from this analysis because there has been sufficient time to allow the radionuclides to reach secular equilibrium)
- Gamma spectroscopy

Samples will also be analyzed for the following chemical parameters.

- HSL inorganics
- HSL volatiles
- HSL semivolatiles
- HSL pesticides and PCBs
- TCLP metals

Sample preparation and analyses will be performed in accordance with the approved RI/FS Work Plan, and Quality Assurance Project Plan (QAPP), dated March 1988.

The following physical properties of the embankment and subsoils will be measured to determine the expected soils behavior under the various remedial alternatives and to provide general geotechnical descriptions:

- Moisture content (ASTM D2216-80)
- Atterberg limits (ASTM D4318-84)
- Specific gravity (ASTM D854-83)
- Particle size distribution (ASTM D422-63)
- Soils classification (ASTM D2487-85)

All sample collection, preparation, and analytical testing will be conducted as specified under the appropriate ASTM standards and laboratory procedures using qualified geotechnical technician(s) and properly calibrated equipment, which meet the intent of ASTM D3740-80.

2.3 RADIATION MEASUREMENTS

2.3.1 Objectives

Previous direct radiation measurement programs have been conducted at the FMPC using either the Aerial Measuring System (AMS) to assess on- and off-site exposure rates or thermoluminescent detectors to assess exposure rates at the site boundary. As part of the CIS (Weston 1987), a walkover radiation survey of the Waste Storage Area was performed which included the K-65 silo area. These data are included in Section 4.0.

The radiation measurement plan for the RI focused on the surface radiation fields within the FMPC and had the following objectives:

- Collect sufficient data to quantify surface radiation fields.
- Develop exposure rate contours for selected areas of the FMPC site.
- Develop uranium concentration contour estimates for selected areas of the FMPC site through the correlation of field survey data with measured uranium concentration in soils.
- Locate anomalies in both exposure rate contours and uranium concentration contours for further investigation.
- Indicate the locations for biased (as opposed to random) surface soil sampling.

Only limited surface radiation sampling was conducted within the bounds of the Operable Unit 4 study area. All sampling was conducted outside the security fence surrounding the K-65 silos.

2.3.2 Methodology

To ensure proper characterization of the radioactive contaminants in the soils of the FMPC, walkover radiation surveys were performed to determine appropriate sampling locations. The principal radionuclides of concern across the FMPC were U-238 and uranium-234 (U-234); Ra-226 and radium-228 (Ra-228) were also important radionuclides of concern within the Operable Unit 4 study area. Measurement of natural background was included as part of the walkover survey.

Because U-238 and U-234 decay through alpha emission and, therefore, could not be readily measured with adequate sensitivity over such a large area, the gamma emission from the decay of U-238 progeny [thorium-234 (Th-234) and protactinium-234m (Pa-234m)] was measured. These progeny are in equilibrium with U-238. The higher energy gamma radiations from Ra-226 and Ra-228 decay chains were also measured.

To provide a comprehensive and systematic method of survey that ensures appropriate coverage, the area surrounding the K-65 silos was marked to establish a refined 100-foot grid for use in the conduct of a walkover radiation survey. In those locations where radiation measurements were above reference levels (see Section 2.3.3) the refined grid was extended another 300 feet. Each 100-foot grid was subdivided into sixteen 25-foot grids to enable adequate coverage. During the survey, each grid (or subgrid) was walked in a serpentine manner, beginning along one side and covering the subgrid in a rectilinear fashion until the entire subgrid was surveyed.

To assess the levels of radioactive contamination, radiation detection/measurement instruments were chosen that could detect the type and energy of the radiations of concern. Three kinds of radiation survey instruments were selected to span the energy range of interest and to optimize the detection sensitivity in each energy range. The instruments selected were the Pressurized Ionization Chamber (PIC); a portable, large-volume scintillation detector (Eberline Model SPA-3); and the Field Instrument for Detection of Low Energy Radiation (FIDLER).

As mentioned above, the radiation energy ranges targeted for measurement included:

- Natural radiation
- Low-energy radiation (U-234 and U-238)
  - Th-234
  - Pa-234m
- High-energy radiation (Ra-226, Ra-228)

The FIDLER used was the BICRON Model G5S probe coupled with a Ludlum Model 2220 rate meter. The FIDLER is well suited to detect low-energy photons, such as the 63 kiloelectron volt (keV) gamma emitted from Th-234.

The Eberline Model SPA-3 is a portable, large volume scintillation detector. It was used principally to detect the 1001 keV photons from Pa-234m; however, it will also detect radiation emitted from other radionuclides.

The PIC was a Reuter Stokes Model RSS-111. Unlike the other two survey instruments, the RSS-111 is relatively large and is stationary during use. It directly measures the gamma radiation exposure rate. The PIC measurements were made at selected locations to determine the magnitude of the gamma ray field (exposure rate) and to calibrate the hand-held, large-volume scintillation survey instruments. Locations for the PIC measurements were dispersed throughout the radiation survey areas and were selected to span the full range of radiation levels encountered at the FMPC site. The PIC measured and recorded the low-level exposure rates such as those from natural background radiation.

The Eberline Model SPA-3 was used to scan both the 100-foot grid and the 25-foot subgrids using the walkover techniques described above. These walkover surveys detected and measured the gamma ray field.

The FIDLER was used to survey the 25-foot subgrids. During surveys of these subgrids, the FIDLER was held approximately 2 inches from the ground surface. Regions within the individual subgrids that exhibited elevated radioactivity were identified. Any suspected hot spot was marked with a red flag and systematically surveyed with the FIDLER beginning at the flag and working outward to determine the areal extent of the elevated reading.

These gamma measurements (Appendix A) were used to locate areas for biased surface soil sampling and through statistical correlation with measured soil concentrations, provide a site-wide view of the trends in uranium concentrations in surface soils. Radiation measurements and random (unbiased) soil sampling were also performed throughout the site, including areas where soil concentrations of U-238 were determined to be less than 10 pCi/g.

2.3.3 Analytical Parameters

An objective of the walkover surveys using the FIDLER was to determine a reference level for biased soil sampling. The FIDLER was selected for this purpose because it best detects the 63 keV gamma ray from Th-234. Therefore, it is the most sensitive portable radiation survey instrument for detecting U-238 daughters. The estimated lower limit of detection (LLD) for U-238 in soil using the FIDLER is approximately 35 pCi/g. This LLD value was used as the reference level for selecting biased soil sampling locations. However, as indicated above, (Section 2.3.2, last paragraph) this choice did not preclude collection of soil samples with concentrations less than 35 pCi/g.

2.4 SURFACE SOILS

Surface soils at some locations at the FMPC facility have previously been investigated (Weston 1987). These past investigations were limited to the Waste Storage Area and other related waste units (e.g., the fly ash piles) and were mainly concerned with the analysis of uranium. Investigations conducted under the RI were more extensive in area, methodology, and analyses. These more extensive investigations were intended to determine the areal and vertical extent of on-site soil contamination by radionuclides and hazardous substances and to confirm the contamination in critical areas as reported in previous investigations. The RI/FS surface soil sampling program was completed in 1988 with the collection of more than 1000 samples site-wide.

2.4.1 Objectives

Specific objectives of the surface soil sampling program within the Operable Unit 4 study area were to:

- Collect sufficient data to determine the extent of contamination by radioactive substances on site.
- Confirm areas of surface radiological contamination identified in the radiation measurements survey and quantify the types and concentrations of radionuclides found.
- Provide data to characterize the source term for all radionuclides that have the potential to contribute to off-site environmental doses.
- Identify the types and determine the concentrations and areal extent of hazardous substances contamination in surface soils on site.
- Provide data that will be used to determine where future surface soil sampling may be necessary.

These data will be evaluated along with the surface soil sampling data from previously conducted programs in the Operable Unit 4 study area to support the Operable Unit 4 FS.

2.4.2 Methodology

The surface soils were sampled using two different tools - a coring tool and a hand auger. Use of the hand auger was limited to sampling locations inside the Production Area of the FMPC. The soil sampling conducted outside the Production Area was accomplished using the coring tool to obtain 2-inch core soil samples to a depth of 6 inches. The area around Operable Unit 4 was covered by a 1000-foot grid. Very few samples were collected in this area because it was previously investigated by Weston during the radiological characterization of surface soils at the

FMPC (Weston 1987). The locations where surface soil samples were collected within the Operable Unit 4 study area during the RI are shown in Figure 2-3.

The criteria for selecting biased areas of surface soil sampling were those areas that indicated radioactive contamination exceeding 35 pCi/g (the nominal lower limit of detection for U-238) during the walkover survey. Within the defined area, two methods were employed to determine the specific locations for taking the soil sample. The area corresponding to the highest reading within a grid was sampled if singular elevated readings occurred; this is termed biased sampling. If there were relatively uniform readings across an entire grid, then a random sample was taken.

The sampling technique consisted of:

- Trimming existing vegetation from the sample location
- Attaching a clean coring bit to the sampler handle
- Driving the bit into the soil to a specified depth
- Removing the soil from the bit and place the soil sample into a plastic bag
- Placing the plastic bag containing the soil sample into a cardboard container
- Placing custody tape over the lid of the container

Between each sample, the bit was removed from the handle, the handle was wiped with disposable alcohol wipes, and then a clean bit was attached. All contaminated bits and other sampling equipment were decontaminated according to procedures specified in the RI/FS Sampling Plan (IT 1988).

2.4.3 Analytical Parameters

Soil samples collected within the site boundaries were analyzed for parameters that are representative of the materials found at the FMPC. At present, the radiological analyses listed below have been performed:

- Gamma spectral analysis
- Isotopic uranium
- Isotopic thorium
- Isotopic plutonium
- Total uranium
- Strontium-90
- Technetium-99
- Cesium-137
- Ruthenium-106
- Neptunium-237
- Radium-226
- Radium-228

No analyses have been performed for nonradioactive organic or inorganic constituents.

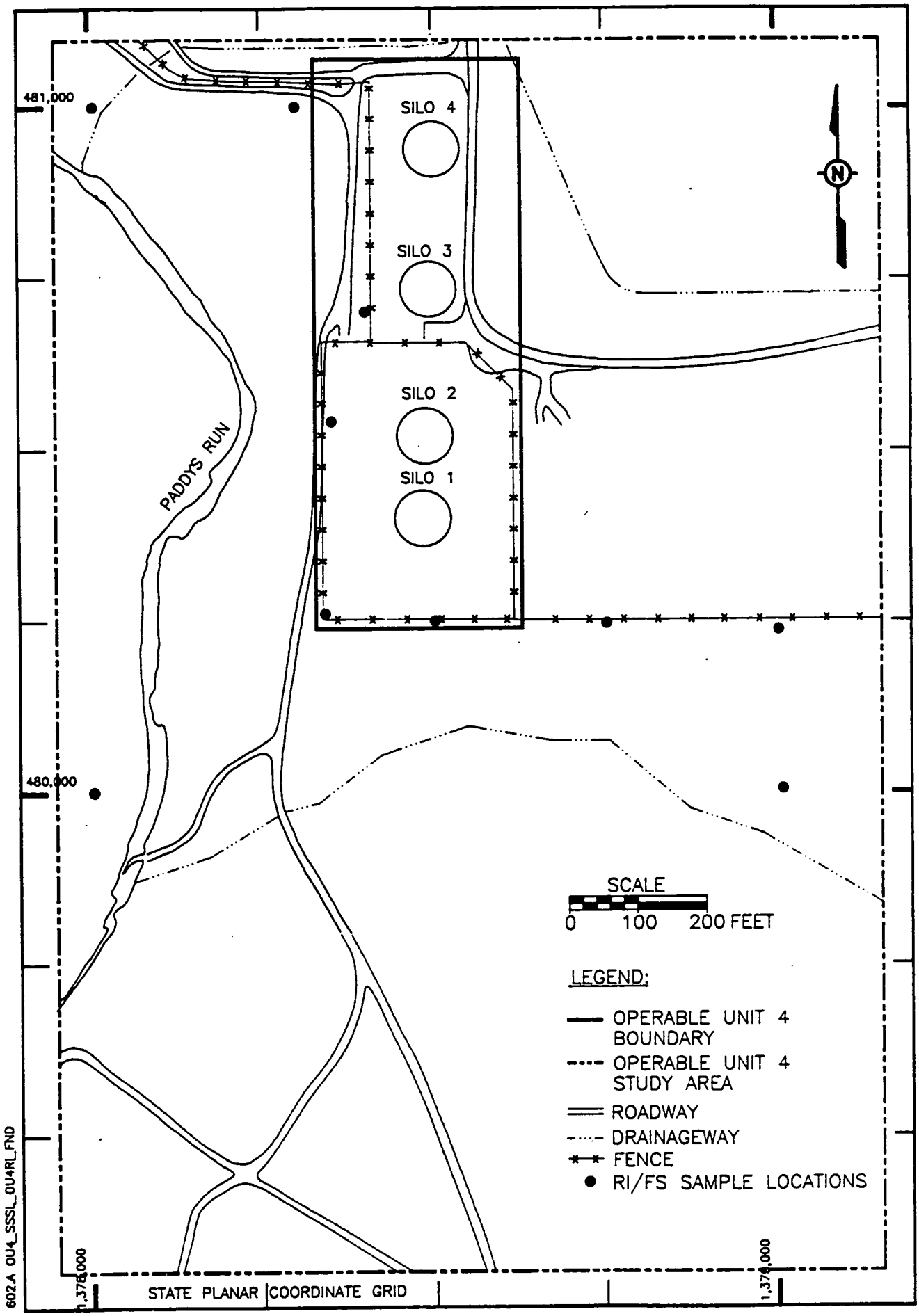


FIGURE 2-3. SURFACE SOIL SAMPLING LOCATIONS

2.5 SUBSURFACE SOILS

2.5.1 Objectives

The main objective for the subsurface soils investigations was to provide additional data on subsurface conditions within the FMPC facility that may define or influence contaminant migration pathways. To accomplish this, an evaluation of the physical-chemical properties of the subsurface soils was performed.

2.5.2 Methodology

The subsurface soil sampling program was an integral part of the groundwater monitoring well installation program. It was addressed separately from the surface soils program because of the difference in objectives and the specificity of methods and equipment. Boreholes for subsurface soil sampling coincided with locations for monitoring wells. Subsurface soils were investigated during the drilling of groundwater monitoring wells.

During the monitoring well drilling program, standard penetration tests were conducted and subsurface soil samples were collected using an 18-inch-drive split-spoon sampler in accordance with ASTM Method D1586-84. The soils were sampled continuously in the glacial overburden; thereafter, samples were taken at five-foot intervals to the total depth of the borehole. The Unified Soils Classification (USC) system was used in logging the soils. Soil boring logs are included in Appendix B for those borings within the Operable Unit 4 study area. Subsurface soil sampling locations within the Operable Unit 4 study area are presented in Figure 2-4. Immediately upon opening each split spoon, the samples were screened for volatile organics using an organic vapor analyzer (OVA) or an HNu photoionization detector. If volatiles were detected, a sample of the soil core was to be submitted for full HSL analysis. This same approach was applied for soils exhibiting unusual odors or evidence of visual contamination. The field screening procedure for radionuclides utilized a large volume scintillation detector (SPA-3). For each boring location, the sample with the highest reading within each geologic horizon was selected for full radiological analysis. The subsurface soil sampling logs are included in Appendix B.

2.5.3 Analytical Parameters

Subsurface soil samples were analyzed for radiological and geochemical parameters. Samples selected for radiological analysis were screened in the field as mentioned in Section 2.5.2. All

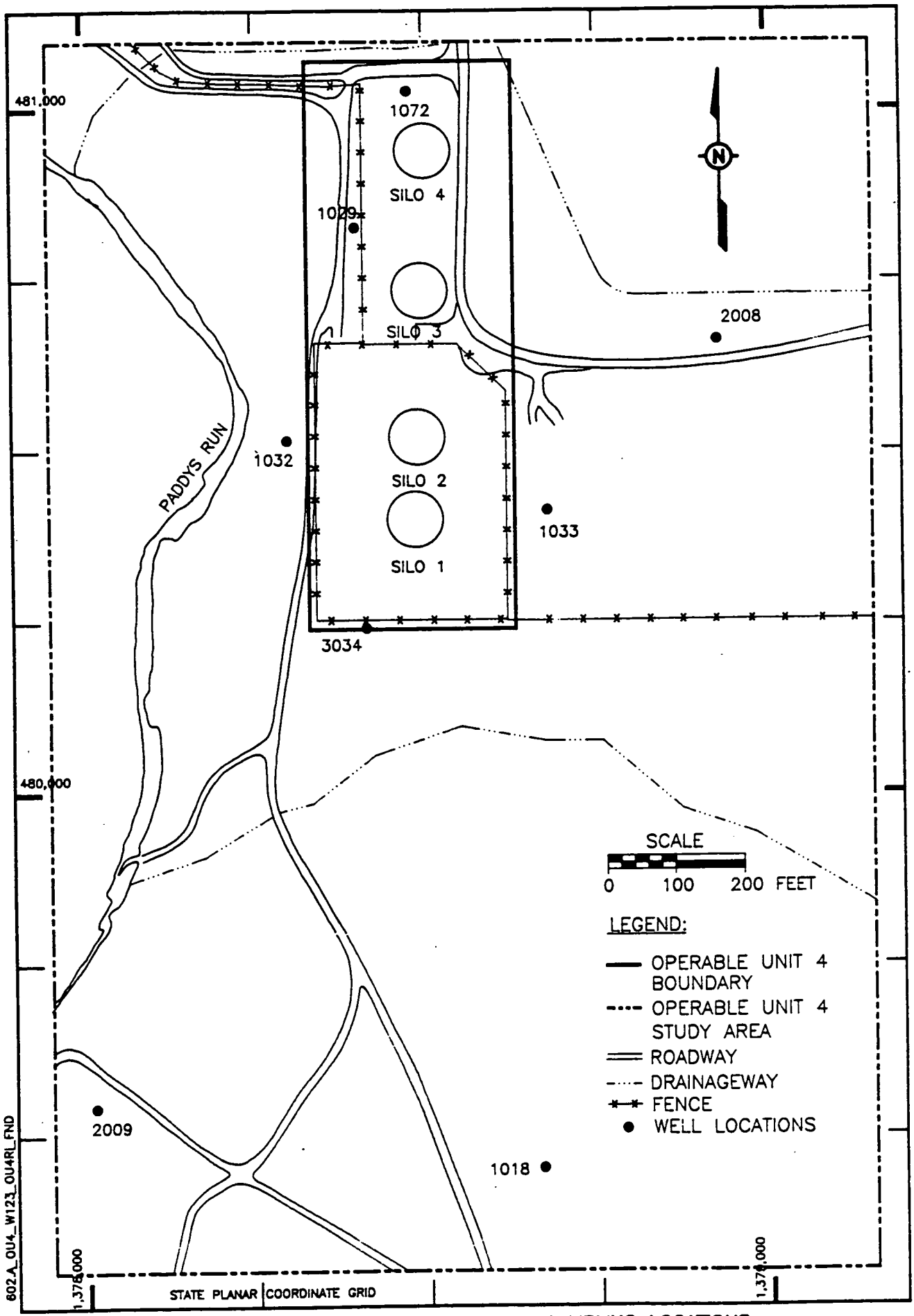


FIGURE 2-4. SUBSURFACE SOIL SAMPLING LOCATIONS

samples sent to the laboratory were tested for a set of radionuclides historically used, stored, or produced at the FMPC. These parameters were:

- Gamma spectral analysis
- Total uranium
- Uranium-234
- Uranium-235
- Uranium-236
- Uranium-238
- Radium-226
- Radium-228
- Technetium-99
- Thorium-228
- Thorium-230
- Thorium-232
- Cesium-137
- Strontium-90
- Ruthenium-106
- Neptunium-237
- Plutonium-238
- Plutonium-239
- Plutonium-240

Geochemical analyses were performed on selected samples based on differences in visual properties (i.e., color, texture) with spatial distribution being a second criterion. The soil properties selected as indicators of contaminant migration and attenuation were:

- Total cation exchange capacity
- Total organic carbon (TOC)
- Grain size

In addition to the common indicator parameters listed above, leachable iron and manganese will also be used to assist in determining contaminant migration and attenuation. Iron and manganese occur as oxide coatings on soils and sediments in areas where conditions are reducing. They have very high adsorption capacities and very high affinities for heavy metals. They are sensitive to changes in oxidation potential (pE) and pH within certain ranges, thus they are leachable. Their presence as determined by leach tests can be quantified and used to assist in the determination of contaminant attenuation.

Most of the samples for geochemical analysis were taken from the glacial overburden, with the remainder being collected from the Great Miami Aquifer. For the Operable Unit 4 study area, no analyses were performed for full HSL analyses because no volatile organics were detected during the field screening of samples.

2.6 SURFACE WATER AND SEDIMENTS

The surface water and sediments of the Great Miami River have been sampled for the past 30 years (WMCO 1989b). More recently, Paddys Run was also included in the monitoring program. The RI/FS surface water and sediment sampling program was very extensive because it covered Paddys Run, seeps from the eastern side cliff face of Paddys Run, the Great Miami River, and the areas

where water collects on the ground at the FMPC. In addition to the radiological constituents, hazardous chemical constituents of the surface water and sediments were also investigated.

2.6.1 Objectives

The objectives for investigating the surface water and sediments during the RI were to:

- Identify the distribution and extent of radiological constituents in sediments from site drainage systems, Paddys Run, and the Great Miami River.
- Determine the presence of radiological constituents and their concentrations at a given point in time in the Great Miami River and Paddys Run at several locations (Figure 2-5).
- Determine if the FMPC is a source of organics and selected inorganics that could potentially be discharged to the Great Miami River and Paddys Run.

2.6.2 Methodology

Storm sewer flows, waste effluent, storm water runoff, and natural surface water drainage were sampled (Figure 2-5) in accordance with standard sampling methods outlined in Section 6.3 of the QAPP (IT, 1988). The smaller drainages and seeps having little flow were sampled by hand using a pond or dip sampler. The greater drainages, such as the Great Miami River and Paddys Run, were sampled at mid-depth in the mid-section or deepest flow channel. Samples were collected directly into the sample container if the water was deep enough; otherwise, a dip sampler was used.

Sediment samples from flowing water courses or areas of ponded water were collected (Figure 2-5) below the water surface using a stainless scoop or Ponar dredge. Samples from dry stream channels or drainages were collected by using a stainless steel scoop to scrape away and collect the upper inch of sediments. Five scoops of sediments were collected at each location.

All sampling equipment was decontaminated at an off-site location. Great care was taken to ensure that there was no cross contamination of the samples.

2.6.3 Analytical Parameters

The field analyses performed on the water samples included the following parameters: pH, temperature, conductivity, and dissolved oxygen. Sediment samples were screened for radionuclides in the field using a large volume scintillation detector (SPA-3). The sample with the highest reading at each location was selected for further laboratory analysis; the other samples were archived. The same procedure previously mentioned for screening subsurface soils for radioactive contamination was also used to screen the sediment samples.

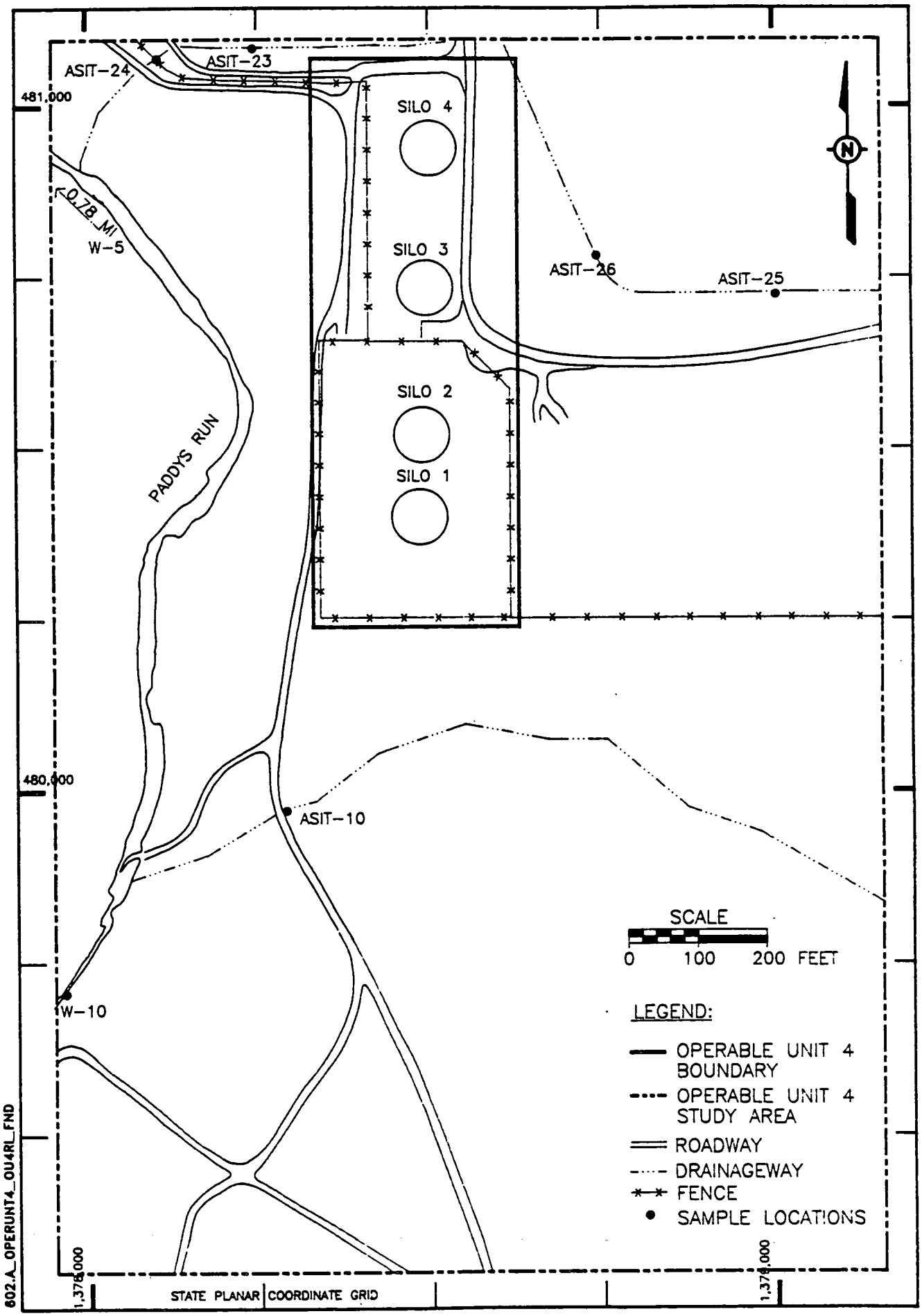


FIGURE 2-5. SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS

The surface water samples were analyzed for radionuclides, TOC, total organic halogens (TOX), and general water quality parameters. Samples from selected locations were also analyzed for extended HSL parameters in accordance with the surface water and sediment plan. Sediment samples were analyzed for radionuclides, extended HSL parameters, and grain size (Appendix C).

The parameters selected for analysis are listed below:

- Total uranium
- Uranium-234
- Uranium-235
- Uranium-236
- Uranium-238
- Radium-226
- Radium-228
- Technetium-99
- Thorium-228
- pH
- Specific conductance
- Chloride
- Iron
- Manganese
- Phenols (total)
- Sodium
- Sulfate
- Gross alpha
- Gross beta
- Copper
- Molybdenum
- Ammonia
- Alkalinity
- Magnesium
- Potassium
- Thorium-230
- Thorium-232
- Cesium-137
- Strontium-90
- Ruthenium-106
- Neptunium-237
- Plutonium-238
- Plutonium-239
- Plutonium-240
- Arsenic
- Barium
- Cadmium
- Chromium (hexavalent, total)
- Fluoride
- Lead
- Mercury
- Nitrate
- Selenium
- Silver
- Nickel
- Total organic nitrogen
- Carbonate/bicarbonates
- Calcium
- Sodium
- Phosphate

Extended HSL parameters are defined to include HSL organics and inorganics, HSL pesticides/PCBs, primary drinking water organics, and organophosphorous pesticides.

2.7 GROUNDWATER

As part of the environmental monitoring program at the FMPC, 13 wells drilled over a 20-year period have been routinely sampled and analyzed for various water quality indicators. This monitoring started in 1952 with the installation of the FMPC's first production well (Dames and Moore 1985a). From December 1981 until July 1985, the monitoring program was expanded to include both the on-property wells and more than 22 off-site wells located upgradient and downgradient of the site.

The ongoing RCRA monitoring program began in August 1985 as a requirement under RCRA for managing a hazardous waste unit (Waste Pit No. 4). The RCRA monitoring program was included in the RI/FS sampling network. During the RI/FS, the FMPC installed and sampled more than 110 wells, both on and off site, as part of the groundwater monitoring program.

2.7.1 Objectives

The principal objective in conducting groundwater investigations during the RI was to fill identified data gaps to:

- Determine whether the groundwater at the FMPC has been contaminated, both on and off site, and to evaluate the extent of contamination.
- Determine the concentrations and sources of contaminants on site and indicate migration of hazardous substances to off-site areas.
- Determine the rate and direction of groundwater flow within each separate hydrologic unit.
- Determine the effects that pumping groundwater and resulting recharge/discharge relationships have on groundwater flow and contaminant transport.
- Define areas of subsurface contaminant migration and groundwater discharge.

2.7.2 Methodology

A total of 12 wells were installed within the Operable Unit 4 study area during the RI: eight 1000-series wells (MW-1008, MW-1009, MW-1018, MW-1029, MW-1032, MW-1033, MW-1034, and MW-1072) to depths ranging between 11 and 36 feet; three 2000-series wells (MW-2008, MW-2009, and MW-2034) to a depth of 65 feet; and one 3000-series well (MW-3034) to a depth of 140 feet. These wells were installed in the corresponding boreholes from which the subsurface soil samples were collected. The locations for the wells installed during the RI within the Operable Unit 4 study area are shown on Figure 2-4. These three series of wells monitor three water-bearing zones at the site: the perched water table aquifer in the glacial overburden, the top of the Great Miami Aquifer, and a deeper zone of the Great Miami Aquifer, respectively.

The wells were installed by the Pennsylvania Drilling Company using cable tool drilling methods. The rigs that were used for the drilling operations were a Cyclone 42 and a Bucyrus-Erie 24-W. Cuttings were removed from the borehole using either a sand pump or bailer and stored on site in 55-gallon drums. All wells were constructed of four-inch, 316 stainless steel pipe, threaded flush-jointed; and four-inch-diameter, 316 stainless steel continuous slot screen (0.01 inch slot size). Screen lengths for the wells were 10 feet, with the exception of the following well numbers: MW-

1009 - 5 feet; MW-1032 - 2 feet; and MW-2009 and MW-2034 - 15 feet. Figures 2-6 and 2-7 show generalized well construction diagrams for the 1000- and 2000- series wells, and the 3000-series wells, respectively. The specific construction details for each well are contained in Appendix D.

The 3000-series wells are screened at greater depths for the purpose of monitoring the deeper zone of the Great Miami Aquifer. Because of the high water level in these wells, it was not possible to install a bentonite seal; the bentonite pellets would not fall through the long water column without swelling and bridging. Therefore, no bentonite pellets were used in the construction of the 3000-series wells. These wells incorporate Volclay™ grout which was set from the top of the sandpack to the surface.

Upon completion, the monitoring wells were developed by pumping and surging to remove fines. After fully recovering from well development, static water levels were measured.

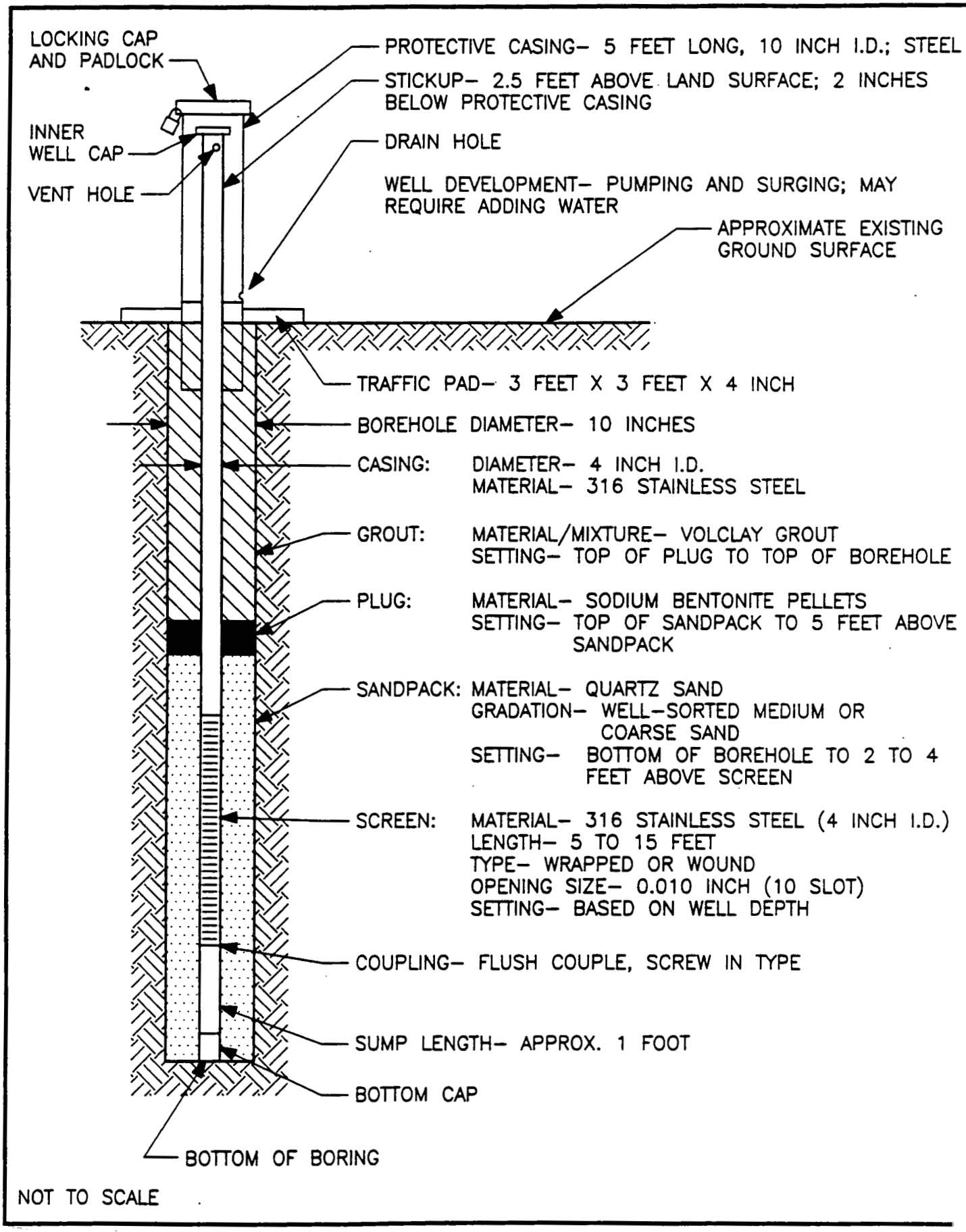
2.7.3 Groundwater Sampling

Figure 2-8 shows all the wells that were sampled during the RI within the Operable Unit 4 study area. The quarterly sampling program also included wells that were installed before the RI/FS program (MW-2018, MW-3005, MW-3009, and MW-3018).

Groundwater samples for each well have been taken quarterly for one year beginning in May 1988 for those wells installed as of that date. All samples were collected using the FMPC RI/FS sampling procedures to ensure that no contamination was introduced into the samples. All groundwater samples were analyzed for a full suite of radiological parameters and drinking water quality parameters. The radionuclides being analyzed include:

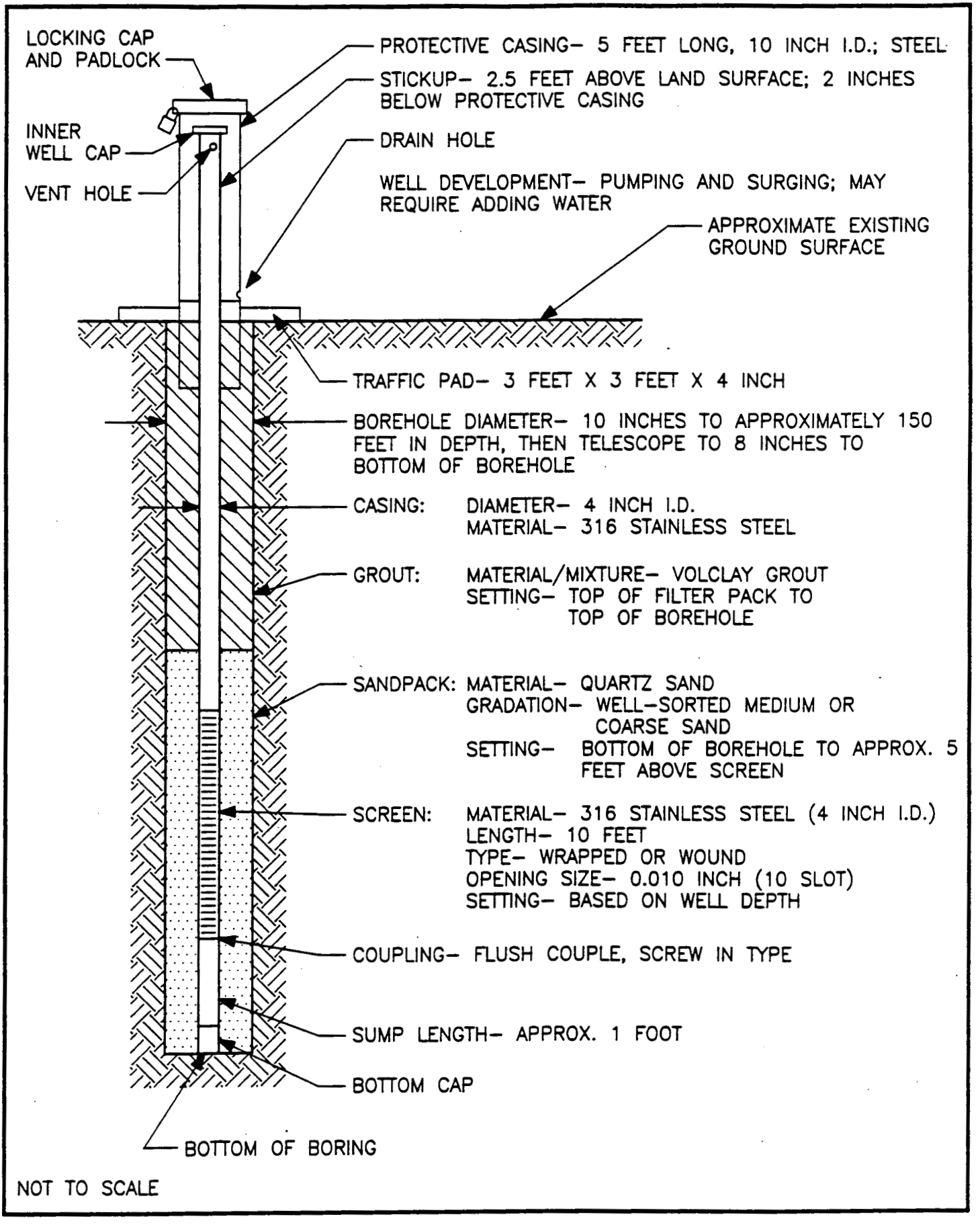
- Total uranium
- Isotopic uranium
- Isotopic plutonium
- Radium 226 and radium-228
- Neptunium-237
- Total thorium
- Isotopic thorium
- Technetium-99
- Cesium-137
- Ruthenium-106
- Strontium-90

General groundwater quality was established by analyzing groundwater samples for the following parameters:



303317-A-C23 OU4 RI KNOX 8/90
ACAD\DRAWINGS\FERN-13

FIGURE 2–6. SUMMARY OF SPECIFICATIONS FOR WELL COMPLETION 1000 AND 2000 SERIES WELLS



303317-A-C24 OU4 RI KNOX 8/90
ACAD\DRAWINGS\FERN-14

FIGURE 2-7. SUMMARY OF SPECIFICATIONS FOR WELL COMPLETION 3000 AND 4000 SERIES WELLS

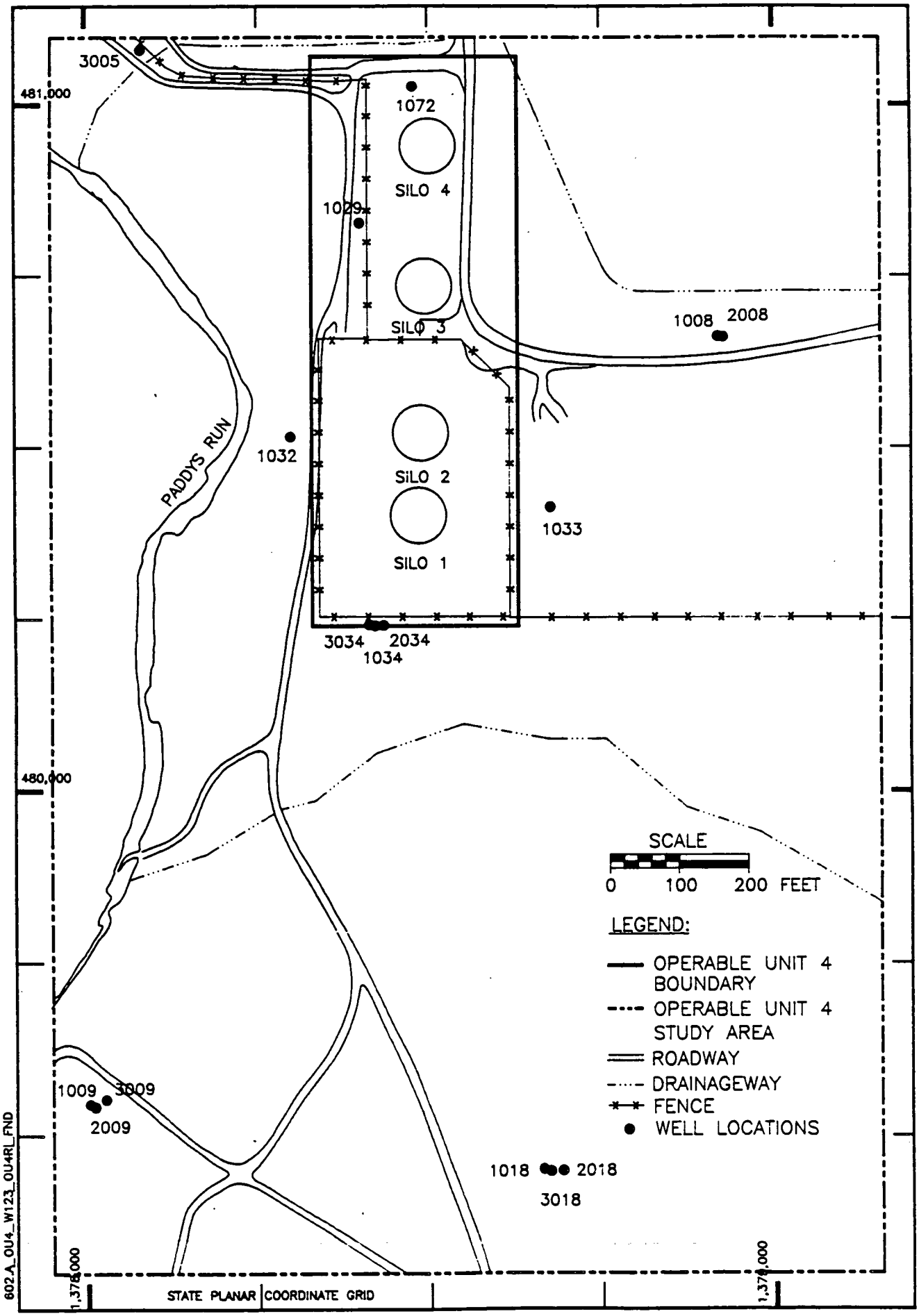


FIGURE 2-8. GROUNDWATER SAMPLING LOCATIONS

- pH
- Specific conductance
- Chloride
- Iron
- Manganese
- Phenols (total)
- Sodium
- Sulfate
- Gross alpha
- Gross beta
- Alkalinity as $CaCO_3$
- Carbonate/bicarbonate
- Copper
- Nickel
- Phosphate
- Potassium
- Arsenic
- Barium
- Cadmium
- Chromium (hexavalent, total)
- Fluoride
- Lead
- Mercury
- Nitrate
- Selenium
- Silver
- Ammonia
- Total organic nitrogen
- Molybdenum
- Calcium
- Magnesium
- Sodium

Selected wells [1029, 1072 (became dry), 2008, and 2034] were analyzed for HSL volatile and semivolatile organics, HSL inorganics (including cyanide), HSL pesticides/PCBs, primary drinking water organics, and organophosphorous pesticides. These extended HSL parameters were analyzed one time only to augment and confirm the findings of the ongoing RCRA program.

2.8 BIOLOGICAL RESOURCES

The earliest study on the biological resources at the FMPC was conducted by Battelle Columbus Laboratories in 1977. A more extensive biological and ecological characterization of the FMPC was conducted by researchers from Miami University (Facemire et al. 1990), and studies of the fish in the Great Miami River have been conducted by the University of Cincinnati as part of a continuing monitoring program. RI/FS studies of biological resources at the FMPC include: a study of radionuclide uptake by plants and animals on the site; surveys for threatened or endangered species; toxicity testing of FMPC effluent and soils; macroinvertebrate surveys of Paddys Run and the Great Miami River; wetlands delineation; and a bioaccumulation study. Only the studies addressing uptake of radionuclides by plants and animals and the survey for threatened or endangered species have been completed. Threatened or endangered species were not found at the FMPC (ASI/IT 1990c).

2.8.1 Objectives

The main objectives for the biological resources investigation were to determine if:

- Any radiological or hazardous substance release to the FMPC environs results in significant uptake, assimilation, and transfer through ecological habitats including surface water, sediments, and adjacent wetlands.

- Any radiological or hazardous substance release to the FMPC environs results in uptake and assimilation in agricultural products and crops.
- Such releases and uptake represent significant pathways to human receptors.
- Federal or state threatened or endangered species exist within the FMPC environs and potential risk is posed to their existence or welfare through contaminant release from the FMPC.

2.8.2 Methodology

The radionuclide uptake study was designed in 1987, prior to the introduction of operable units, to examine FMPC site-wide contamination of both terrestrial and aquatic organisms. As a consequence, there were no sampling sites located within the boundaries of Operable Unit 4. One aquatic sampling site on Paddys Run, PR-3, was adjacent to Operable Unit 4 (Figure 2-9). Details of the sampling methodology are provided in the biological resources sampling and analysis report (ASI/IT 1990c). Fish and benthic macroinvertebrates were sampled at several locations on Paddys Run and the Great Miami River, including Site PR-3 (Figure 2-9). Fish were collected by either electroshocking or capturing with nets. They were then segregated by species, wrapped in aluminum foil and Ziplock® bags, labeled, and frozen before shipment to the analytical laboratory. Benthic macroinvertebrates were collected with a Surber sampler, and packaged and shipped in the same manner as fish samples.

2.8.3 Analytical Parameters

Biological samples were analyzed for the isotopes of uranium (U-234, U-235, and U-238), strontium-90 (Sr-90), and Cs-137. A subset of biological samples was analyzed for technetium-99 (Tc-99) and HSL organic and inorganic constituents (ASI/IT 1990c).

2.9 QUALITY ASSURANCE PROGRAM

The quality assurance (QA) program, which is composed of the FMPC RI/FS QAPP and its implementing programs, is an essential component of the project management system that governs all aspects of the FMPC RI/FS. Specifically, all aspects of the QA programs are contained in Volume V of the FMPC RI/FS Work Plan. In general, a QA program represents all those planned and systematic actions necessary to provide adequate confidence that the product or service provided to the customer will comply with all regulatory requirements and also satisfies the needs and expectations of the customer(s) and public. Specific to the needs of an RI/FS project, the QA program should provide the assurance that adequate provisions have been specified and implemented before and during the performance of all project work to control all data collection, handling,

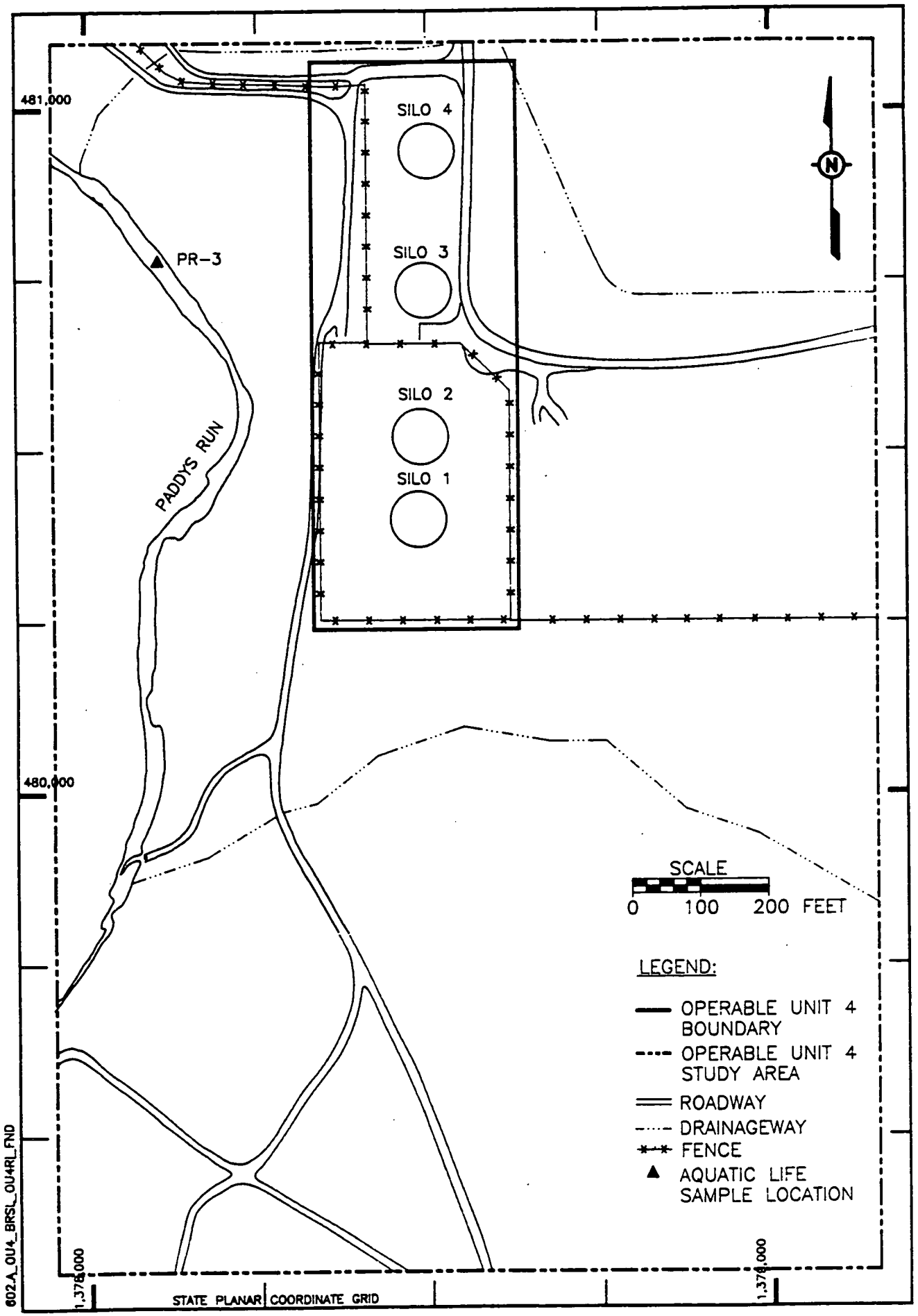


FIGURE 2-9. AQUATIC LIFE SAMPLING LOCATIONS

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analysis, interpretation, and reporting activities. The end result of designing and implementing such a QA program is technically sound, legally defensible data that can be used by the DOE and EPA to evaluate and select remedial action alternatives that protect the public health and environment from the characterized substances, pollutants, or contaminants.

Fernald FMPC RI/FS QA Program

The project's QA program described in the QAPP is based on EPA's QA program requirements promulgated in Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans (QAMS-005/80), dated 1983. Some selected aspects of Quality Assurance Program Requirements for Nuclear Facilities (ANSI ASME/NQA-1) are also implemented for the broader project control aspects such as document control, audits, and records management. By combining the elements of QAMS-005/80 and NQA-1, the RI/FS QA program addresses all aspects of a sound project management system designed to ensure the quality of RI/FS data used in technical evaluation and decision making. The QA program elements are as follows:

- Project Organization and Responsibilities
- Field Procedures
- Sample Collection Procedures
- Chain-of-Custody Procedures
- Equipment Calibration/Maintenance
- Laboratory Analytical Procedures
- Data Reduction, Validation, and Reporting
- Internal QC Checks
- QA Audits
- Preventive Maintenance
- Specific Routine Procedures to Assess Data Precision, Accuracy, and Completeness
- Document Control
- Nonconformance/Corrective Action and Variances
- QA Reports to Management
- Records Administration

All the above listed QA elements have been designed and implemented to ensure the following RI/FS project goals:

- Scientific data will be of sufficient or greater quality to meet scientific and legal scrutiny.

- Data will be gathered or developed in accordance with procedures appropriate for the intended use of the data.

Data will be of known and acceptable precision, accuracy, completeness, representativeness, and comparability (referred to frequently as the PARCC parameters of QAMS-005/80).

The FMPC RI/FS project management personnel are responsible for establishing and executing a QA program that is compliant with all applicable regulatory requirements and satisfies all project objectives. Project management will provide adequate funding and resources to effectively support project QA objectives; will stay apprised of QA issues and project QA problems and will effect resolution; and will retain responsibility for the quality of work delegated to other project participants such as contractors and consultants.

The RI/FS QA Officer is delegated the responsibility and authority to direct and control QA functions to ensure that the QA program objectives are consistently met. The QA Officer is responsible for the coordination, integration, and overview of project QA activities, and for ensuring that the appropriate quality management, policy, training, and verification controls are present. Specifically, the QA Officer will coordinate the development of the QA program documents (QAPP and Procedures), manage the document control and records management systems, provide QA training , schedule and conduct project audits, and report and track nonconforming conditions and their corrective action.

In summary, it is through the commitment to the QA program by the project management personnel, its implementation by the technical personnel, and its routine monitoring and assessment by the QA organization that the quality and defensibility of the data presented in this RI report can be ensured.

3.0 SITE SETTING

The results of the RI/FS field investigation and previous studies were synthesized to provide an understanding of the site and regional setting. The physical, environmental, and demographic settings of the study area are described in this section. Information is provided on surface features, climate, surface water hydrology, geology and groundwater hydrology, soils, land use and population, and vegetation and wildlife.

Two documents (IT 1988; DOE 1987) were relied on substantially for the information provided in the following sections and are not specifically referenced in the text. Other documents used to support individual statements are appropriately cited within the text. More detailed information on certain features of the site setting is available in the EIS that is being prepared in support of the RI/FS decision process.

3.1 SURFACE FEATURES

The FMPC lies on the boundary between the southernmost extent of Pleistocene glaciation and the ancient unglaciated upland. The advance and retreat of continental glaciers not only shaped the topography but determined the hydrogeologic setting for the site.

3.1.1 Physiographic Province

The FMPC 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 in the region 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 vary 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, which 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.

3.1.2 Topography

The maximum relief on the site is a little more than 700 feet above mean sea level (msl) at the highest point along the northern boundary of the site. The FMPC Production Area and Waste

Storage Area rest on a relatively level plain approximately 580 feet msl. The plain slopes from 600 feet msl along the eastern boundary of the FMPC to 570 feet msl at the K-65 silos. The plain then drops off into Paddys Run at an elevation of 550 feet msl. All drainage on the FMPC is from east to west into Paddys Run, with the exception of the northeast corner, which drains eastward to the Great Miami River.

3.2 CLIMATE

Information on the local climate was gathered from two main sources - an on-property meteorological system installed at the FMPC in 1986 and the Greater Cincinnati Airport. Windflow data from the Dayton Airport were used as a secondary data source.

3.2.1 Prevailing Winds

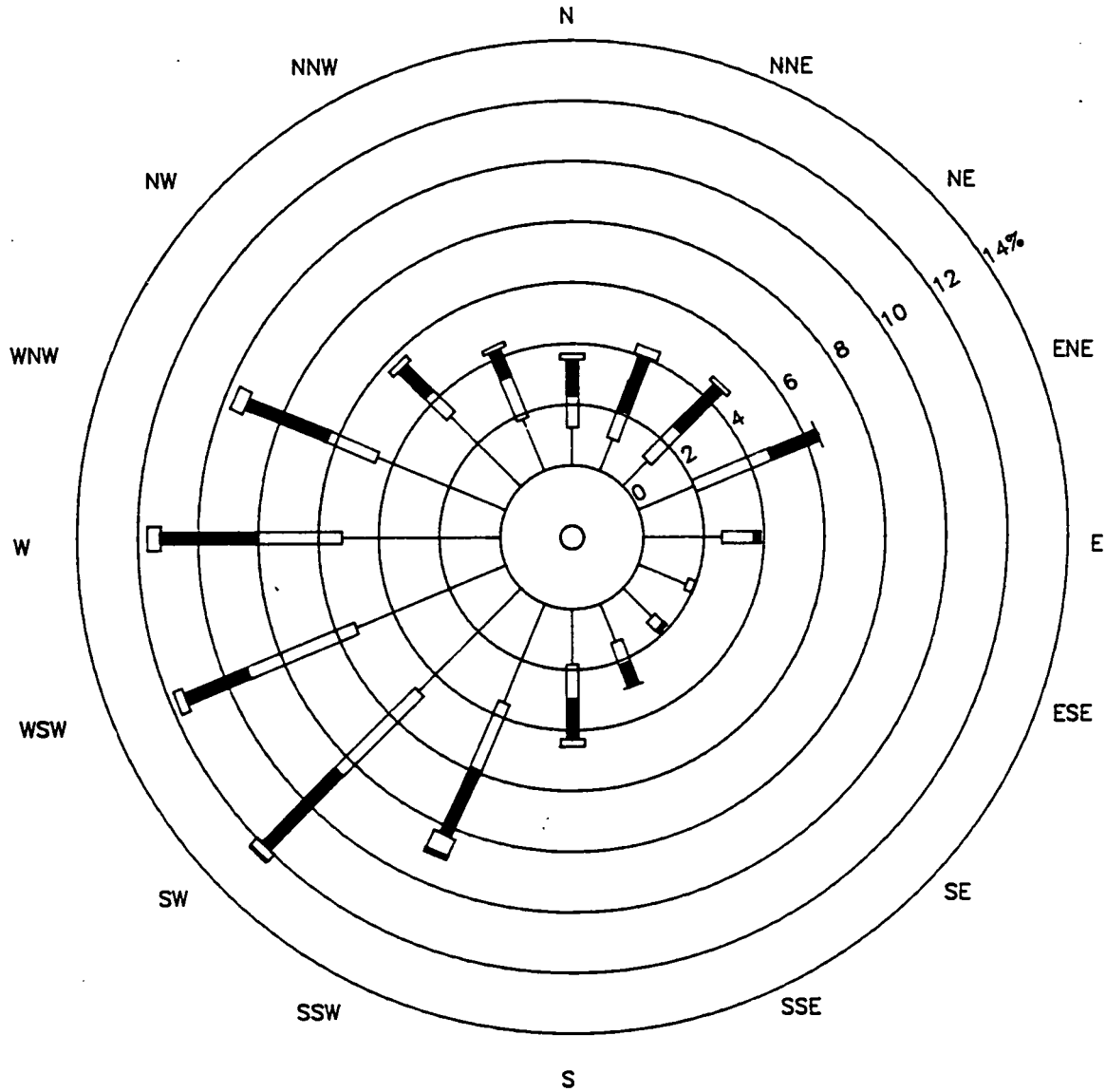
The on-property meteorological system was installed to collect site-specific data for wind speed and direction, ambient air temperature, lapse rate, dew point, temperature, relative humidity, barometric pressure, and precipitation. The system was used by the National Oceanic and Atmospheric Administration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

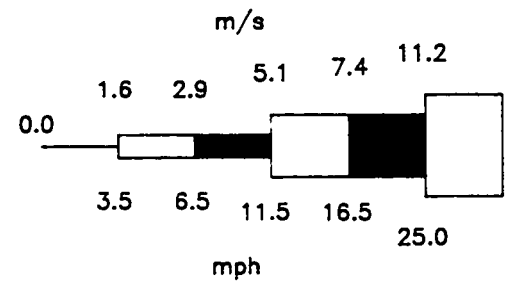
Figure 3-1 shows the typical wind pattern at the site for a 10-meter elevation. Prevailing winds are from the southwest and south-southwest.

3.2.2 Precipitation

The average annual precipitation for the Cincinnati area for the period 1955 through 1984 was 37.75 inches and ranged from 29.22 to 40.64 inches. The highest precipitation occurs during the spring and early summer; precipitation is lowest in late summer and fall. The average annual snowfall for the same period (1955 to 1984) was 24.0 inches, with the heaviest snowfall in January.

The total rainfall for this area in 1988 was 40 inches. Of this, more than 50 percent fell in April through September, which encompasses the growing season for most crops. The wettest month was July, with 6.9 inches of rainfall, most of which fell during two thunderstorm events. By contrast, the least precipitation was recorded in June when 1.2 inches of rain fell.





SOURCE:

WESTINGHOUSE MATERIALS COMPANY
OF OHIO METEOROLOGICAL DATA,
DECEMBER 16, 1987 TO DECEMBER 16, 1988

NOTE:

APPROXIMATELY 87% OF THE POSSIBLE
OBSERVATIONS ARE REPRESENTED.

602A_WINDROSE_BP_FND

FIGURE 3-1. WIND ROSE FOR 10-M LEVEL

3.2.3 Temperature

The regional climate is defined as continental, with temperatures ranging from a monthly average of 29.0°F in January to 75.5°F in July. The highest temperature recorded from 1950 through 1984 was 102°F in August 1962, and the lowest was minus 25°F in January 1977. The average number of days per year with a minimum temperature of 32°F or less is 110 days, and the average number of days with a maximum temperature of 90°F or above is 20 days per year. Frost depth ranges from 30 to 36 inches.

3.3 SURFACE WATER HYDROLOGY

The FMPC is located within the Great Miami River Basin drainage but above the river's present day floodplain. The Great Miami River is the receiving stream for the FMPC effluent discharge and represents the main surface water feature in the vicinity of the FMPC (Figure 3-2). The river flows generally to the southwest and has a drainage area of approximately 3360 square miles at the Hamilton gage, which is located about 10 miles upstream from the FMPC discharge outfall.

The river exhibits meandering patterns that result in sharp directional changes over distances of less than 3000 feet. Directly east of the FMPC and within the RI/FS study area, the river passes through a 180-degree curve known as the "Big Bend" (Figure 3-2). A 90-degree bend in the river also occurs near New Baltimore, approximately two miles downstream from the FMPC point of The average discharge of the Great Miami River at Hamilton, based on 55 years of records, is 3305 cubic feet/second (ft^3/s). Using drainage area scaling, the corresponding average flow at the FMPC point of discharge has been estimated to be 3460 ft^3/s. The maximum discharge recorded for the Great Miami River at Hamilton occurred on March 26, 1913 and was estimated to be 352,000 ft^3/s.

The maximum discharge since the construction of five retarding basins in 1922 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 seven-day, 10-year low flow value ($Q_{7\text{-}10}$) of 267 ft^3/s, as computed by the USGS for the Hamilton gage. This translates to 280 ft^3/s at the site reach.

Natural surface drainage from the FMPC is primarily to Paddys Run. Paddys Run originates north of the site, drains southward along the west side of the FMPC, and eventually enters the Great Miami River approximately 1.5 miles south of the FMPC (Figure 3-2). This stream loses flow to the underlying aquifer along much of its course because of its highly permeable channel bottom

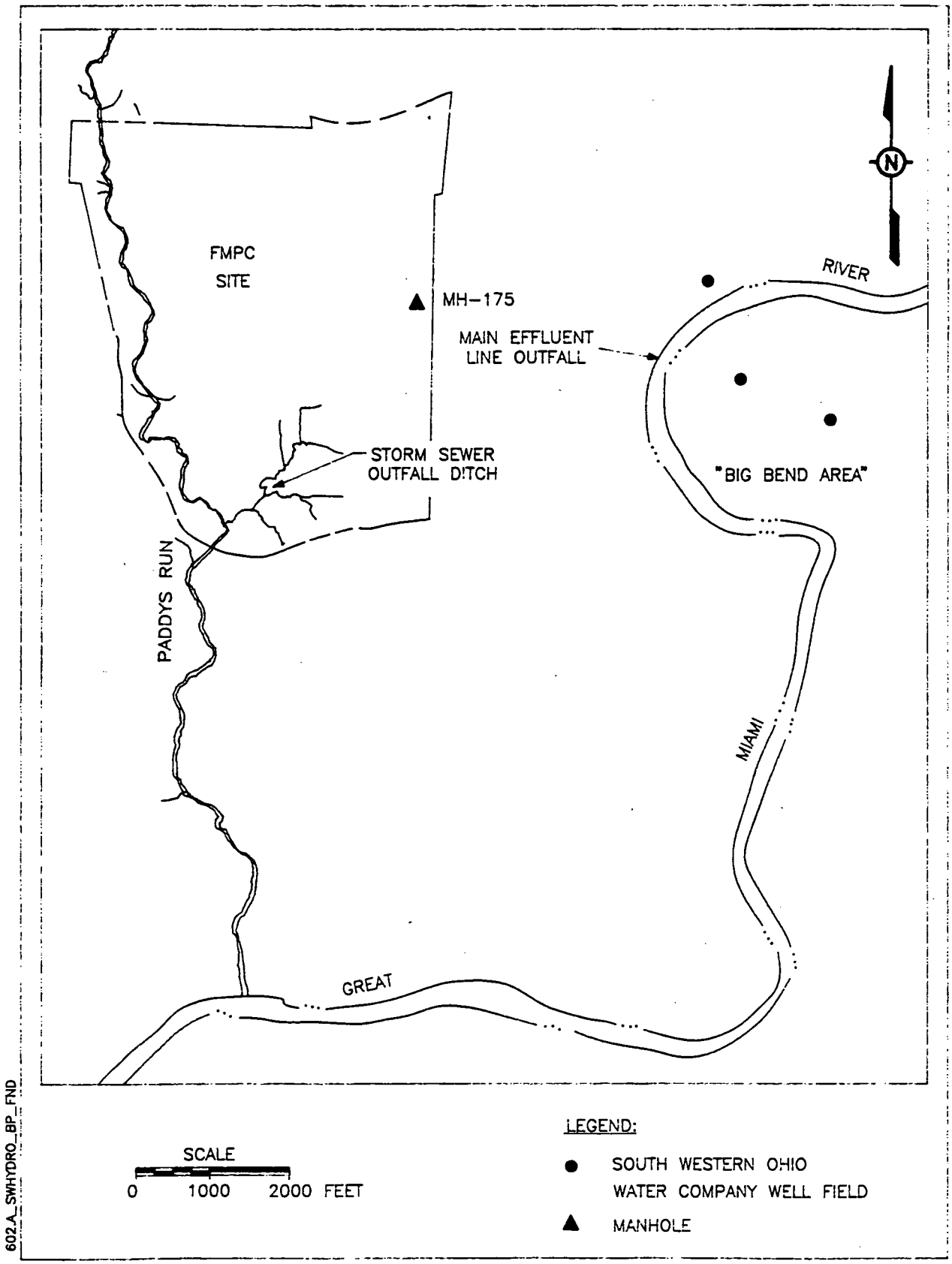


FIGURE 3-2. SURFACE WATER HYDROLOGY

which is carved into the Great Miami aquifer. Paddys Run is an ungaged, intermittent stream that flows primarily between January and May and has an estimated discharge for this period ranging between 0.2 and 4.0 ft^3/s. Peak flows have not been measured.

A principal drainage feature of the FMPC is a tributary to Paddys Run known as the storm sewer outfall ditch. This drainage course originates east of the production area, flows southwest across the southern portion of the site, and enters Paddys Run near the southwest corner of the property (Figure 3-2). Much of the stream bottom of this drainage course, which also collects runoff from an area east of the production area, is composed of sand and gravel. Vertical seepage rates through the stream bottom are similar to Paddys Run. This drainage course is generally dry throughout most of the year with flows occurring during and immediately after precipitation.

The storm sewer outfall ditch historically conveyed surface water runoff from the production area directly to Paddys Run. This occurred when the capacity of the storm sewer lift station, which diverts low flow storm water to Manhole 175, was exceeded. Manhole 175 is the main effluent line to the Miami River. Two storm water retention basins were recently constructed at the head of the storm sewer outfall ditch. Storm water runoff from the production area is now conveyed to these retention basins. After at least a 24-hour retention period to allow for settling of suspended solids, the water is pumped out of the basins to the Great Miami River via the FMPC's main effluent line. The basins are designed to retain the runoff from a 10-year, 24-hour rainfall event. However, the basins overflowed in January 1989 and February 1990 when several heavy storms occurred. In the event of an overflow, storm water from the Production Area would enter the outfall ditch.

3.4 GEOLOGY AND GROUNDWATER HYDROLOGY

The following section provides a summary of the geologic history and hydrogeologic setting of the area surrounding the FMPC.

3.4.1 Geologic History

The FMPC is located within 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 till. The geological history of the FMPC area, as presented by Fenneman (1916), is summarized in the following paragraphs.

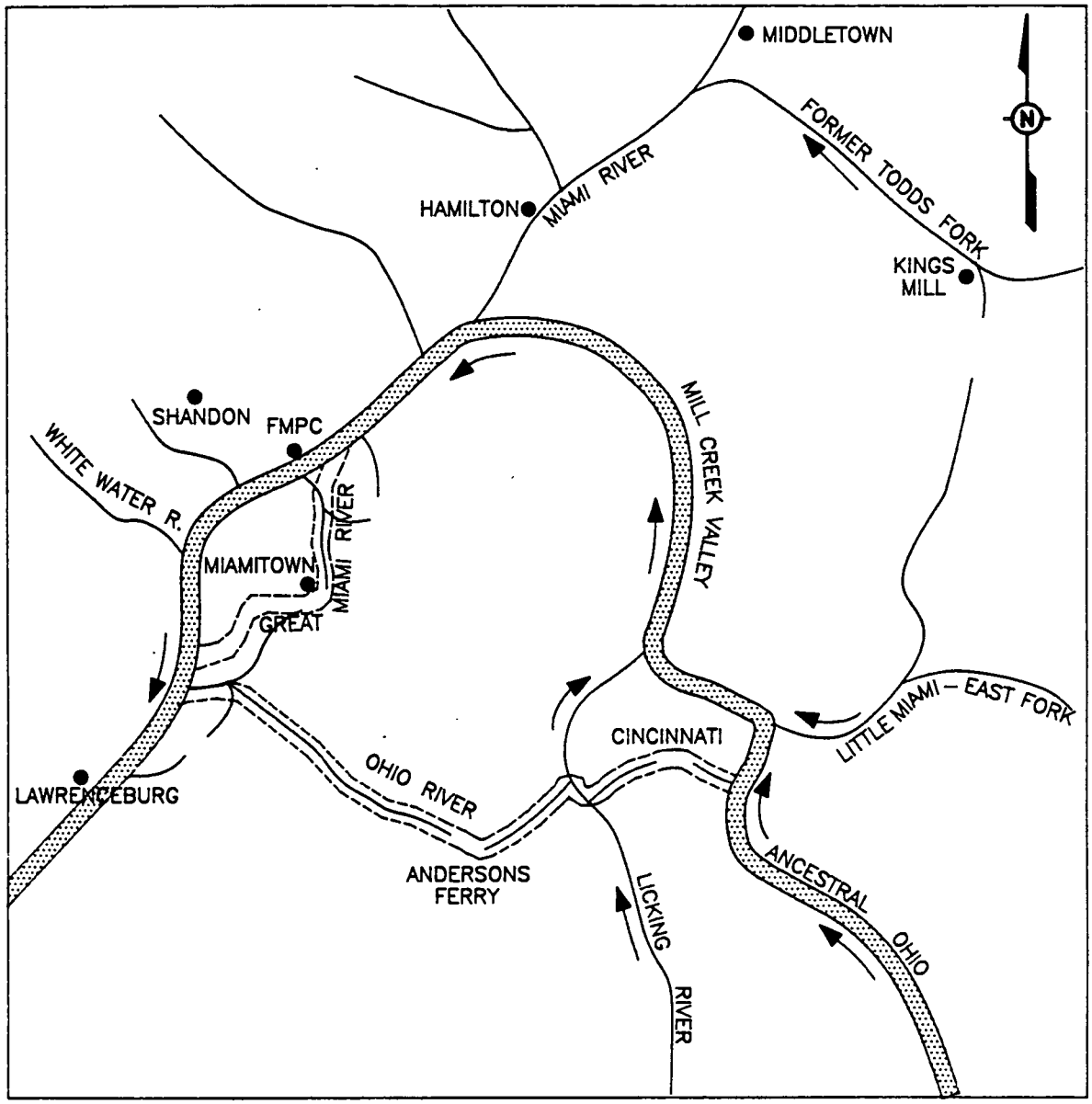
In Late Ordovician time, approximately 450 million years ago, sediments that would become a predominantly flat-lying shale with thin interbedded limestone were deposited in a shallow sea. This shale is the relatively impermeable bedrock that now underlies the FMPC site area and forms the adjacent highlands.

Before Pleistocene glaciation, the area was relatively flat and sloped in a northward direction. This level plain contained a northward flowing drainage system. This system is referred to as the Teays River System and consisted of two major streams with many tributaries. At some time during the early Pleistocene period, this north-flowing river system was disrupted by the advance of Nebraskan and Kansan glaciation to the north of the Cincinnati area. The drainage system that developed south of the advancing ice sheets is known as the Deep Stage Drainage System (Figure 3-3).

The Deep Stage 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, Ohio. 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. There it was joined by the East Fork and flowed west through the Norwood Trough to the Mill Creek Valley where it joined the Licking River. The stream then flowed north through the Mill Creek Valley and turned west to join the Miami River south of Hamilton, Ohio. It continued to the southwest through the New Haven Trough to near Harrison, Ohio, where it turned and flowed south through what is now the Whitewater River Valley (Figure 3-3).

Several tributary streams of later importance entered the main stream in the vicinity of the FMPC. 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 east to Shandon and then flowed south through what is now the Paddys Run Valley (Figure 3-3).



NOT TO SCALE

LEGEND:

DIRECTION OF FLOW

ANCESTRAL OHIO

PRESENT RIVER COURSES

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

602A_DEEPSTAG_BP_FND

FIGURE 3-3. SCHEMATIC DIAGRAM OF THE DEEP STAGE DRAINAGE

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 Miami River and its confluence with the ancestral Ohio River. This caused water to pond in the Mill Creek Valley. For a time, water still flowed to the west along the front of the advancing ice sheet and carved the present-day Great Miami River Valley along the tributary system near Miamitown (Figure 3-3).

When the confluence of the Miami River and the ancestral Ohio River was completely blocked, the ponded water in the Mill Creek Valley rose until it overflowed low divides and carved outlets at Anderson's Ferry and at what is now downtown Cincinnati. This created the present-day channel of the Ohio River. As the ice retreated, the valleys of the Deep Stage Drainage were filled with well-sorted sand and gravel outwash deposits, and the Great Miami River and the Ohio River were established in their present-day channels.

The last stage of glaciation, the Wisconsin, was much less disruptive to the drainage in the area. The ice sheet advanced only as far as the south side of the FMPC. The main effect of this glacial advance in the area was the displacement of the Dry Fork of the Whitewater River from its historic channel into its present-day channel. As it retreated, the ice deposited a moraine in the historic channel which formed a dam. The dam was breached two times, with 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 till and lacustrine mantle left by the ice sheets. The Great Miami River has eroded through the till and is now in direct contact with the glaciofluvial outwash deposits that comprise the buried valley aquifer. Paddys Run is also in contact with these deposits in its lower reaches. The FMPC site is located on a dissected till plain and lacustrine deposits left by Wisconsin Glaciation.

3.4.2 Hydrogeologic Setting

The bedrock in the vicinity of the FMPC consists of predominantly flat-lying olive-gray Ordovician shales with thin, interbedded layers of limestone. This shale forms the floor and valley walls of the New Haven Trough. The buried channel is generally carved into this shale between 60 and more than 200 feet below the pre-erosional land surface in the vicinity of the FMPC.

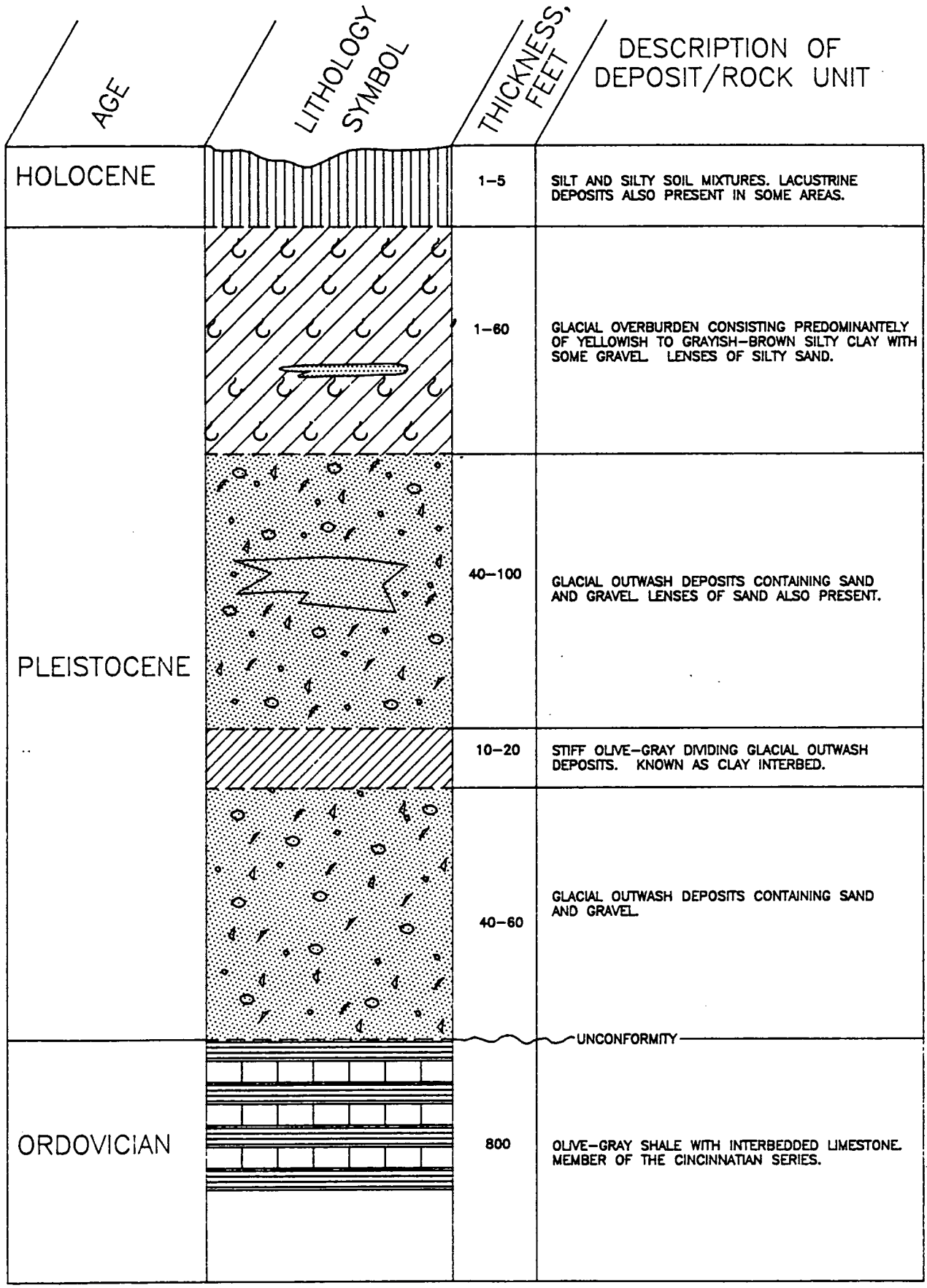
Unconformably overlying the shales in the bedrock channel is approximately 150 feet of regionally extensive Pleistocene glacial valley fill deposits. Figure 3-4 is a generalized stratigraphic column of the valley till deposits. As indicated by the hydrogeologic cross sections, the buried valley is about 0.5 to more than 2 miles wide and is U-shaped, having a broad, relatively flat bottom and steep valley walls. Interbedded glacial till deposits occur within the outwash deposits, but in most cases are of limited lateral extent. The till deposits are composed primarily of poorly sorted pebbles, cobbles, and boulders in a predominantly clay matrix.

Within some areas, till deposits overlie the bedrock uplands and portions of the outwash materials where they form the thick unconsolidated sediment layers beneath the soil zone. This glacial till is composed of dense, silty clay that varies in composition vertically and laterally. The silty clay till contains lenses of poorly sorted fine- to medium-grained sand and gravel, silty sand, and silt with layers of silty clay.

Regional hydrogeologic environments of the buried channel aquifer have been investigated and reported by the USGS. A hydrogeologic environment describes a portion of an aquifer possessing hydrologic and geologic properties that differ from the properties of the aquifer in adjacent areas. Five major hydrogeologic environments have been identified and mapped in the Great Miami River Valley. Type I, III, and V environments generally describe the hydrogeologic conditions in the vicinity of the FMPC and are summarized in the following paragraphs.

The Type I hydrogeological environment is found along the floodplain of the Great Miami River to the south and east of the FMPC facility. The lithology of the aquifer consists principally of sand and gravel. Scattered lenses of clay and other fine-grained material may exist anywhere in this environment. However, these lenses are not of sufficient thickness or areal extent to act as semiconfining layers or to otherwise affect groundwater movement. The potential for induced stream infiltration exists in these areas. Transmissivity values generally range from 40,000 to 67,000 square feet per day (ft^2/day). The Type I aquifer may be classified with a storage coefficient of about 0.2. Individual wells can yield as much as 3000 gpm.

The Type III hydrogeologic environment is characterized by 50 or more feet of clayey till overlying the main buried channel aquifer. In the FMPC region, the buried channel aquifer is further divided into an upper and lower part by a semipervious clay layer approximately 10 to 20 feet thick, occurring approximately 120 feet below land surface. Hence, the lower aquifer is classed as



602.A_GENSTRAT_BP_FND

FIGURE 3–4. GENERALIZED STRATIGRAPHIC COLUMN OF THE FMPC REGION

a semiconfined or leaky confined aquifer. A coefficient of storage of 0.001 was estimated for the lower sand and gravel aquifer. Estimated transmissivities range from 4700 to 40,000 ft^2/day.

The Type V hydrogeologic environment includes all of the area outside of the buried channel. These areas are uplands and consist of shale with interbedded limestone overlain by 50 or less feet of clay-rich till. Large quantities of groundwater are not generally transported through this material. Well yields vary widely, typically ranging from near 0 to 10 gpm; however, because sand and gravel lenses are erratically distributed throughout the overlying till, wells completed in these units may yield up to 50 gpm.

Large groundwater supplies occur in the outwash deposits of the buried channel aquifer and are recharged by three principal sources: recharge from bedrock, precipitation recharge, and recharge by stream infiltration. Although the shales and limestones have a low permeability, small amounts of water occur in erratically distributed joints and cracks and produce seepage into the glacial deposits. The average permeability of the bedrock has been estimated to be five gallons per day (gpd) per square foot of contact with the glacial deposits. Recharge by precipitation amounts to approximately 570,000 gpd per square mile of catchment area and represents the dominant source of recharge on a regional basis. Under natural conditions, the gradient of groundwater flow is from the aquifer to the Great Miami River, except during dry periods when the gradient is reversed. Intermittent recharge to the aquifer also occurs along Paddys Run.

The groundwater in the regional aquifer enters the FMPC study area from the buried valleys on the west, north, and east. Natural gradients cause the groundwater to exit the FMPC study area by either flowing to the east to the Great Miami River upstream from New Baltimore, Ohio, or by flowing south through the branch of the bedrock channel west of New Baltimore. In either case, the Great Miami River is the ultimate receptor of all groundwater in the study area (Figure 3-5).

The large pumping wells of the Southwest Ohio Water Company (SOWC) in the "Big Bend" meander of the Great Miami River east of the FMPC produce a pronounced and persistent cone of depression in the potentiometric surface centered on the pumping wells. Groundwater elevation maps indicate that the resultant cone of depression from the SOWC wells influences groundwater flow patterns beneath the FMPC. In particular, a groundwater flow divide is created such that groundwater underlying the northern portion of the FMPC, including those areas underlying the waste storage area and the production area, flows to the east toward the SOWC wells and the Great Miami River. Groundwater from the southern and southwestern portion of the FMPC continues to

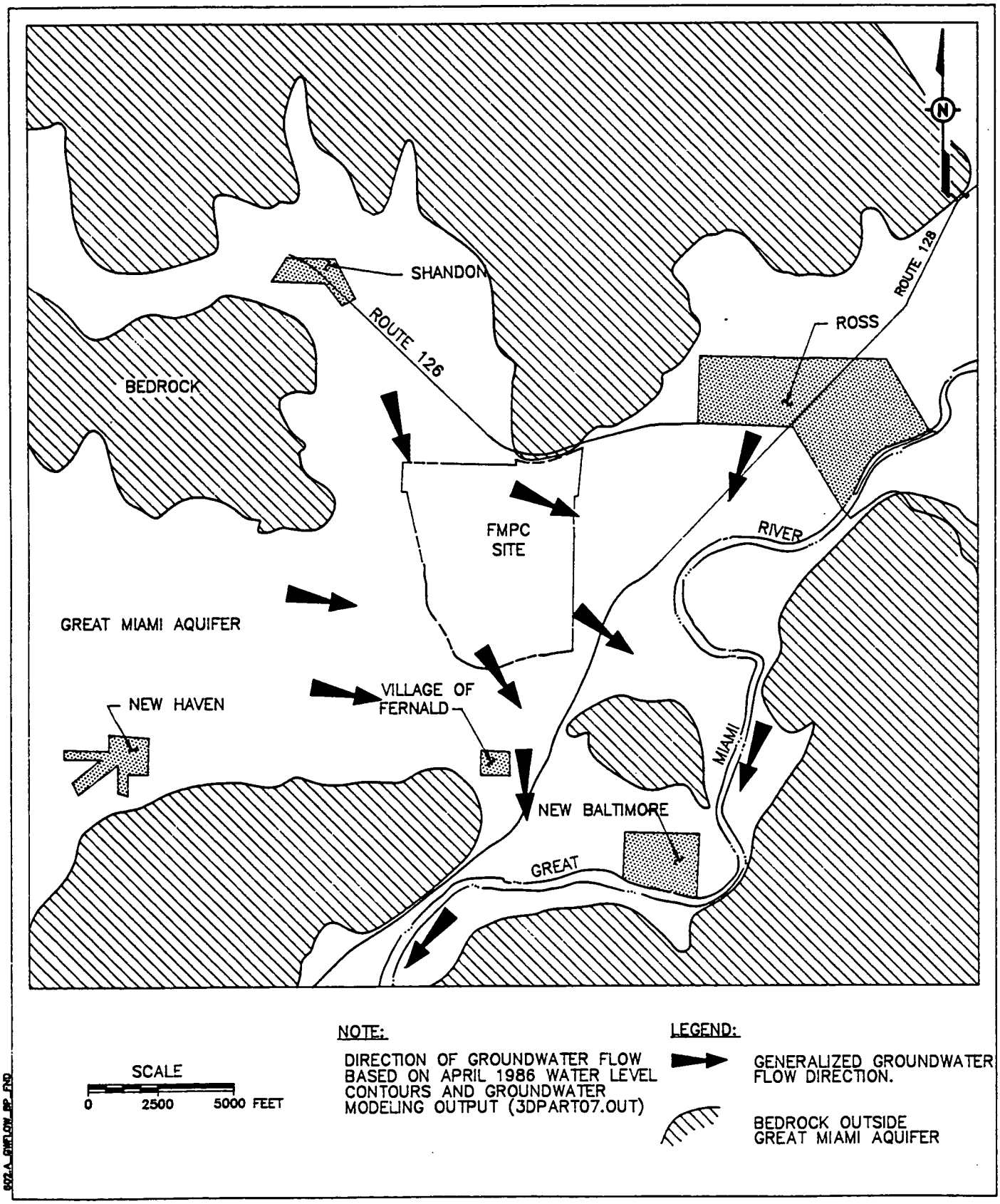


FIGURE 3-5. GENERALIZED GROUNDWATER FLOW IN BURIED CHANNEL AQUIFER

flow along the natural gradient to the south-southwest through the buried valley. Near the southwest corner of the FMPC, a groundwater component from the west is also present due to the western leg of the buried channel (Figure 3-5). This causes the recharge from certain reaches of Paddys Run to flow east-southeast until the regional southern component of flow is encountered.

3.4.3 Hydrogeology of Operable Unit 4

The site-specific depositional characteristics of the overburden are shown in Figure 3-6 (found in end pocket), the Operable Unit 4 Glacial Overburden Fence Diagram. Although the descriptions in the diagram are based on color and lithology, a depositional correlation can be made using the descriptions found in other publications (Brockman 1988; Hendry 1988; Cravens 1987; Barari 1986; Leggett 1976) and from outcrop studies at the site. Generally it is assumed that the gray and brown clays and silts represent the Wisconsin age glacial tills. The coloration of the till is a weathering phenomenon and is not due to depositional differences. Based on the location of the glacial lake spillway (Brockman 1988) and descriptions found in the U.S. Army Corps of Engineers boring program conducted during plant construction, it is felt that near-surface brown silts found in Operable Unit 4 represent lacustrine deposits. Sand and gravel stringers and beds found within the glacial overburden are classified as glaciofluvial without regard to specific origin (i.e. outwash stream or beach).

As shown on the fence diagram, the geologic setting beneath Operable Unit 4 consists of a sequence of lacustrine beds, till with silty sand interbeds, and the glaciofluvial deposits of the Great Miami Aquifer. The silty lacustrine beds are seen at the surface predominantly in the central portion of Operable Unit 4 (Wells 1029, 1032, and 1072). The glacial overburden, composed primarily of till, unconformably overlies the sands and gravels of the Great Miami Aquifer and ranges from 21 to 34 feet thick. In general the glaciofluvial interbeds of sand and gravel are discontinuous across the operable unit, although they may be correlatable between two or more nearby wells.

The brown upper weathered zones within the glacial overburden (lacustrine, till, glaciofluvial interbed) extend to a depth of approximately 15 feet below the ground surface. The grey, or unweathered till in the western portion of Operable Unit 4 (boring 1032) is approximately five feet thick. This unweathered till thickens to the north to a thickness of approximately 25 feet (boring 1029).

Each of the layers underlying Operable Unit 4 have separate hydrogeologic characteristics that affect the movement of water and contaminants. The hydrologic characteristics of the different units is outlined below.

Glaciofluvial Deposits

Most of the large productive aquifers, such as the Great Miami Aquifer, found in the areas once covered by continental glaciers, are typically glaciofluvial outwash deposits left by the meltwater of receding glaciers. In the FMPC area, the Great Miami Aquifer deposits consist of highly sorted sands and gravels deposited as fill within buried channels. Within the FMPC, this unit has an interbedded clay layer of limited extent.

Within the glacial overburden there are numerous small perched water bearing zones with limited interconnection. These perched zones are primarily of glaciofluvial origin and consist of thin beds of well-sorted sands and gravels. These beds are probably the result of small meltwater streams that occurred along the ice margin and within the glacier itself. The beds tend to be discontinuous, both laterally and vertically, due to the rapidly changing environment near an active glacier. Some locally continuous beds may occur in two or more nearby wells. The only significant interbedded unit in Operable Unit 4 is seen in Borings 1032, 1033, 2034, and 2008. This unit is believed to be depositionally correlatable; however, there is only limited hydrologic communication between the borings as evidenced by uranium levels and seasonal hydrograph responses.

Glaciolacustrine Deposits

In the meltwater lakes that existed during Pleistocene time, thick deposits of glaciolacustrine silt and clay were laid down offshore. These deposits form some of the most extensive shallow aquitards in North America. However, at the FMPC site the lacustrine units were deposited near the top of the stratigraphic column and have subsequently been eroded. They are not extensive across Operable Unit 4, being found only in three wells in the central portion of the area. These deposits are jointed and weathered and would be expected to have a substantial secondary permeability.

Till Deposits

Dense, fine-grained glacial tills are the most common aquitards in most of the northern part of the United States. These deposits have intergranular hydraulic conductivities that are very low, with values in the 10^{-7} to 10^{-5} feet/day range (Heath 1983). Extensive deposits of clayey till can cause isolation in zones of near surface groundwater flow. At the FMPC, a series of slug tests of water

bearing zones in the till found hydraulic conductivities ranging from 1.6 feet/day (5.6 X 10^{-4} centimeter/second) in Well 1048 to 7.1 X 10^{-3} feet/day (2.5 X 10^{-6} centimeter/second) in Well 1079.

In the Great Plains region and in parts of the Midwest, deposits of clayey or silty till and glaciolacustrine clay have networks of predominantly vertical joints or fractures due to weathering. This jointing pattern in the Wisconsin tills has also been noted in the area surrounding the FMPC (Brockman 1988). In the FMPC area the joints are commonly near vertical and have a polygonal expression with a typical maximum axial dimension of 18 to 25 inches. The joints are generally oxidized to a radius of approximately two inches. Within the FMPC, fractures were noted in the till during the RI/FS drilling program and field reconnaissance. These fractures can impart an enhanced bulk hydraulic conductivity of up to 1000 times above that of an unweathered till (Hendry 1988). As a result of increased lateral stresses caused by overburden loading, as well as decreasing weathering, the hydraulic conductivity of fractured till and clay decreases with depth.

From a hydrogeologic standpoint the till deposits can be differentiated into a brown weathered zone and a gray unweathered zone (Barari and Hedges 1985; Hendry 1988; Cravens 1987). The cited studies indicate that infiltration is primarily limited to the weathered till. Although precipitation enters this upper zone, it does not act as a significant source of recharge to deeper aquifer zones because the majority of the water lost from till deposits is from evapotranspiration. In addition, some water discharges laterally to small seeps or drainages. In the Operable Unit 4 area, surveys have been conducted to look for seeps along Paddys Run adjacent to the silos and along small drainageways in the vicinity. No seeps have been noted. However, it is likely that the fill zone located between the silos and Paddys Run would intercept any seasonal seeps, preventing them from having a surface expression.

3.5 SOILS

Soils in the region were formed in parent materials that were deposited by the action of Wisconsin and Illinoisan glaciers. These materials consist mainly of glacial till but include sand, gravel, glacial lake clays, and silt clays.

There are three major soil associations in the vicinity of the FMPC: Russell-Xenia-Wynn, Fincastle-Xenia-Wynn, and Fox-Genesee. The soils are usually light-colored, acidic, and well-drained. Many of the soils have developed on wind-blown material (loess), except along present and old 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.

Tables 3-1, 3-2, 3-3, and 3-4 give the engineering, physical, and chemical properties for the soil types found in the region of the FMPC, while Figure 3-7 is a soils map of the area.

Soils at the FMPC site are primarily categorized as Fincastle-Xenia silt loams. 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. Soils have formed 18 to 40 inches of loess over limey loam till of Wisconsin age. Fincastel soils have poor drainage. In areas where these soils are predominant, artificial drainage is required for moderate crop productivity. If artificial drainage is not used, the water table remains high for extended periods in winter and spring. Fincastle-Xenia soils cover large areas west of the FMPC.

Before development of the FMPC, soils of the production area consisted primarily of Fincastle silt loams. Fincastle soils are characterized by low permeability, moderate productivity, seasonal wetness, and low soil strength. Because of production area development, on-property native soils have been covered by introduced gravels, paving materials, and facilities. Areas that are currently planted with grasses and maintained as lawns or buffer zones tend to represent native Fincastle soils.

Soils along Paddys Run are categorized as Fox-Genesee loams. These soils are light-colored, highly productive, moderately fertile, and contain moderate amounts of organic matter. Fox soils are slightly to medium acidic, have a moderate moisture-supplying capacity, and are well-drained. They generally contain 24 to 40 inches of silty materials over sand and gravel. Fox-Genesee soils are well drained, high in moisture-supply capacity, and are subject to flooding.

Soils in a small area on the north side of the site are classified as Russell-Xenia-Wynn, which develop on sloping topography. These upland soils are light-colored and medium acidic and have formed from wind-blown silty material on limey loam glacial till, 18 to 40 inches thick.

3.6 SEISMOLOGY

A seismic risk zone of two has been assigned to the region of the FMPC. The occurrence of an earthquake in the region of the FMPC could damage facilities and cause the release of contaminants into the environment. Local geologic structures and historical seismicity are used to analyze the potential for seismic events in the site areas.

TABLE 3-1

PHYSICAL AND CHEMICAL PROPERTIES OF BUTLER COUNTY SOILS ON THE FMPC

Soil Name and Map Symbol	Depth in	Permeability in/hr	Available Water Capacity in/in	Soil Reaction pH	Shrink-Swell Potential
DaA, DaB	0-13	0.6-2.0	0.22-0.24	5.6-7.3	Low
Dana	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	0-5	0.06-0.6	0.12-0.18	5.1-8.4	Moderate
Eden	5-27	0.06-0.2	0.10-0.15	5.1-8.4	Moderate
	27-40	---	---	---	---
FdA, FdB	0-8	0.6-2.0	0.22-0.24	5.1-6.5	Low
Fincastle	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	---	---	---	---
Gn	0-8	0.6-2.0	0.20-0.24	6.1-7.8	Low
Genesee	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	0-9	0.6-2.0	0.18-0.23	5.6-6.5	Low
Henshaw	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:	0-6	0.6-2.0	0.17-0.20	5.6-7.3	Low
Miamian	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	0-10	0.6-2.0	0.21-0.24	5.6-7.3	Low
Russell	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	0-12	0.6-2.0	0.21-0.23	6.1-7.3	Moderate
Ragsdale	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
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
	49-68	0.2-2.0	0.18-0.22	6.6-8.4	Low

TABLE 3-1 (continued)

PHYSICAL AND CHEMICAL PROPERTIES OF BUTLER COUNTY SOILS ON THE FMPC

Soil Name and Map Symbol	Depth in	Permeability in/Hr	Available Water Capacity in/in	Soil Reaction pH	Shrink-Swell Potential
XeA, XeB, XeB2— Xenia	0-10	0.6-2.0	0.22-0.24	6.6-7.3	Low———·
	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———·
XIA, XIB, XIB2——— Xenia	0-8	0.6-2.0	0.22-0.24	6.6-7.3	Low———·
	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	—	—	—	—

TABLE 3-2

ENGINEERING PROPERTIES AND CLASSIFICATIONS OF BUTLER COUNTY SOILS ON THE FMPC

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		MH, CH	75-100	70-100	65-100	60-100		
		Flaggy silty clay, flaggy clay, silty clay	MH, CH CL	---	---	---	---	45-75	20-45
	27-40	Weathered bedrock	----					---	---
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 loam	CH, CL	95-100 85-95	90-98 75-90	85-95 70-85	75-85 55-75	45-58 30-50	30-38 15-35
	42-56	Flaggy clay loam	CL	---	---	---	---	---	---
	56	Weathered bedrock	----						
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
RwB2—— Russell	0-10	Silt loam——	CL, CL-ML	100	95-100	80-100	50-90	20-35	5-15
	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

The symbol < means less than; > means more than. Absence of an entry indicates that data were not estimated

TABLE 3-2 (continued)

ENGINEERING PROPERTIES AND CLASSIFICATIONS OF HAMILTON COUNTY SOILS ON THE FMPC

Soil Name and Map Symbol	Depth In	USDA Texture	Classification Unified	Percentage Passing Sieve Number 4	10	40	200	Liquid Limit Pct	Plasticity Index
								35-50	15-30
Ra——— Ragsdale	0-12	Silty clay loam———	CL	100	100	90-100	80-100	35-50	15-30
	12-50	Silty clay loam———	CL	100	100	90-100	80-95	25-35	5-15
	50-72	Silt loam———	CL, CL-ML	100	100	90-100	70-90		
RdA, RdB——— Raub	0-15	Silt loam———	CL,CL-ML	100	100	90-100	75-95	25-35	5-15
	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——— Uniontown	0-10	Silt loam———	ML, CL-ML	100	95-100	90-100	80-100	25-35	2-10
	10-49	Silt loam, silty clay loam	CL, ML	100	95-100	90-100	65-100	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——— Xenia	0-10	Silt loam———	CL,CL-ML	100	100	90-100	70-100	25-35	5-15
	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
XIA, XIB, XIB2——— Xenia	0-8	Silt loam———	CL,CL-ML	100	100	90-100	70-100	25-35	5-15
	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	—	—	—	—	—	—	—

The symbol < means less than; > means more than. Absence of an entry indicates that data were not estimated

TABLE 3-3

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

Soil Name and Map Symbol	Depth (in)	Moist Bulk Density	Permeability (in/Hr)	Available Water Capacity (in/in)	Shrink-Swell Potential
EpA, EpB2, EpC2 Eldean	0-7	1.30-1.50	0.6-2.0	0.18-0.22	Low
	7-36	1.40-1.60	0.2-2.0	0.08-0.14	Moderate
	36-60		>6.0	0.01-0.04	Low
FdA Fincastle	0-8	1.40-1.55	0.6-2.0	0.22-0.24	Low
	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 Fincastle	0-8	1.40-1.55	0.6-2.0	0.22-0.24	Low
	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 Genesee	0-9	1.30-1.50	0.6-2.0	0.20-0.24	Low
	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 Hennepin	0-2	1.20-1.40	0.6-2.0	0.18-0.24	Low
	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 Henshaw	0-8	1.20-1.40	0.6-2.0	0.18-0.23	Low
	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, MaD2, MaE2 Markland	0-10	1.35-1.50	0.2-0.6	0.18-0.23	Moderate
	10-33	1.55-1.70	0.06-0.2	0.11-0.13	High
	33-60	1.55-1.70	0.06-0.2	0.09-0.11	High
McA, McB Martinsville	0-9	1.30-1.45	0.6-2.0	0.20-0.24	Low
	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
MoD2, MoE2 Miamian	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
XIA, XIB2 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

TABLE 3-4

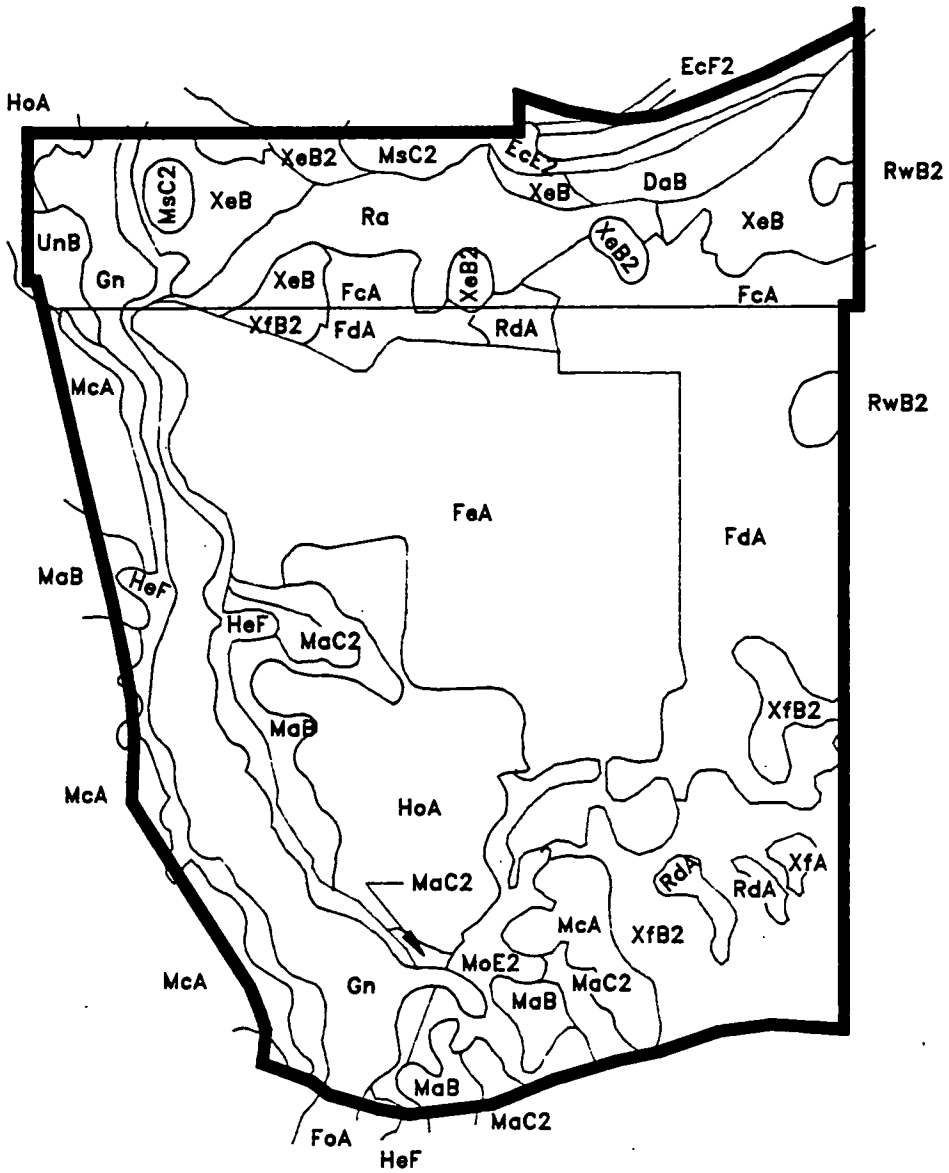
ENGINEERING INDEX PROPERTIES OF HAMILTON COUNTY SOILS ON THE FMPC

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— Eldean	0-7	Loam————	ML,CL-ML,CL	85-100	80-100	70-100	55-90	20-40	4-14
	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	—	NP
FdA———— Fincastle	0-8	Silt Loam————	CL, ML	100	95-100	90-100	75-93	27-36	4-12
	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	88-98	82-90	70-86	50-66	20-35	3-12
FsA*: Fincastle	0-8	Silt loam————	CL, ML	100	95-100	90-100	75-93	27-36	4-12
	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	88-98	82-90	70-86	50-66	20-35	3-12
Gn———— Genesee	0-9	Loam————	ML, CL	100	100	90-100	75-90	26-40	3-15
	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	50-80	20-35	3-15
HsF———— Hennepin	0-2	Silt loam————	CL,CL-ML	90-100	85-100	70-100	60-95	25-40	5-20
	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———— Henshaw	0-8	Silt loam————	ML,CL,CL-ML,	95-100	95-100	90-100	60-100	20-35	3-10
	8-44	Silty clay loam, silt loam	CL,ML	95-100	95-100	95-100	85-100	30-40	8-18
	44-68	Silt loam, silty clay loam	ML, CL, CL-ML	95-100	90-100	85-100	75-100	25-40	5-15
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, MIA-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

TABLE 3-4 (continued)

ENGINEERING INDEX PROPERTIES OF HAMILTON COUNTY SOILS ON THE FMPC

Soil Name and Map Symbol	Depth (In)	USDA Texture	Classification Unified	Percentage Passing Sieve Number 4	10	40	200	Liquid Limit (Pct)	Plasticity Index
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
XIA, XIB2 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



LEGEND:

SOIL SYMBOL BY COUNTY

SOIL NAME	BUTLER COUNTY	HAMILTON COUNTY
DANA	DaB	N/A
EDEN	EcE2, EcF2	N/A
FINCASTLE	FcA	FdA, FeA
FOX	N/A	FoA
GENESEE	Gn	Gn
HENNEPIN	N/A	HeF
HESHAW	HoA	HoA
MARKLAND	N/A	MaB, MaC2
MARTINSVILLE	N/A	McA
MIAMIAN-HENNEPIN	N/A	MoE2
MIANIAN-RUSSEL	MsC2	N/A
RAGSDALE	Ra	N/A
RAUB	N/A	RdA
RUSSELL	RwB2	RwB2
UNIONTOWN	UnB	N/A
XENIA	XeB, XeB2	XfA, XfB2

SOURCE:

OHIO DEPARTMENT OF NATURAL RESOURCES

SCALE

0 900 1800 FEET

602.A_FND56_BP_FND

FIGURE 3-7. FMPC SOILS MAP

The presence of minor faults cannot be completely dismissed because 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-Wisconsinan faults show that significant damage from local earthquakes at the FMPC is highly unlikely. Throughout the 19th and 20th centuries no damaging earthquakes have been recorded within 71 miles of the FMPC. Nine earthquakes caused minor damage within 71 to 199 miles of the FMPC, and one earthquake caused localized moderate damage at Anna, Ohio, about 81 miles north of the FMPC.

3.7 LAND USE AND POPULATION

The land use surrounding the FMPC is mainly agricultural consisting of dairy, beef, corn, and soy bean production. Several industries, including Delta Steel, Albright & Wilson Chemical Company, Ruetgers-Nease Chemical Company, two commercial gravel operations, and a cement plant are located south of the site. The Miami Whitewater Forest, a Hamilton County park, is located five miles to the southwest of the FMPC.

Scattered residences and several villages, including Fernald, New Baltimore, Ross, New Haven, and Shandon, are located near the FMPC. The City of Cincinnati and its suburbs are 10 to 15 miles southeast of the FMPC and the City of Hamilton is 8 miles to the northeast. There is an estimated population of more than 24,000 within a five-mile radius of the site.

The area surrounding the FMPC contains several sites of historical interest. The National Register of Historic Places lists four prehistoric Indian sites within a three-mile radius. These include the Adena Circle, the Demoret Mound, the Colerain Work, and the Dunlap Work. The closest site, the Colerain Work, is situated approximately one mile east of the FMPC. The State Historical Preservation Officer reports that there are no known sites of archaeological significance on the FMPC site.

3.8 VEGETATION AND WILDLIFE

The following ecological data have been summarized from the report "Biological & Ecological Site Characterization of the Feed Materials Production Center" (Facemire et al. 1990). Additional source documents are appropriately cited in the text.

The FMPC lies in the Oak-Hickory Forest Section of the Eastern Deciduous Forest, as described by Bailey (1978). Ecological communities consist of grazed and ungrazed pastures, two pine plantations, deciduous woodlands, riparian woodlands, and a reclaimed fly ash pile area. These

habitats are estimated to contain 47 species of trees and shrubs, 190 species of herbaceous plants, 13 mammal species, 98 bird species, 10 species of amphibians and reptiles, 21 species of fish, 47 families of benthic macroinvertebrates, and 132 families of terrestrial invertebrates.

Typical grasses found on the FMPC 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 is white pine, with Norway spruce occurring occasionally. Common trees in the deciduous woodlands are white ash, American elm, shellbark hickory, and slippery elm. Dominant tree species in the riparian woodlands are eastern cottonwood, hackberry, American elm, and box elder. The reclaimed fly ash pile is dominated by American elm, eastern cottonwood, and black locust.

Mammal species observed on the FMPC include white-tailed deer, coyote, red fox, opossum, raccoon, groundhog, eastern cottontail, and fox squirrel. 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 property 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 FMPC include the American toad, spring peeper, eastern box turtle, and snapping turtle. Several species of snakes also occur on property, 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 FMPC habitats. Leaf hoppers are abundant in all habitats, and less abundant groups include short-horned grasshoppers, leaf beetles, springtails, fruit flies, dark-winged fungus gnats, ants, bees, and wasps.

Potential jurisdictional wetlands occupy areas along the railroad on the north side of the FMPC, along Paddys Run, and in several drainageways. These habitats harbor small fish, amphibians, and a variety of benthic macroinvertebrates. The most common fish are the bluntnose minnow, creek chub, and stoneroller minnow. The most common benthic macroinvertebrates are non-biting midges, riffle beetles, mayflies, and stoneflies.

No federally listed threatened or endangered species have been observed on the FMPC or in its immediate vicinity. Suitable habitat for one species of mammal listed as federally endangered, the Indiana bat, occurs along Paddys Run; however, the Indiana bat was not found on property.

4.0 NATURE AND EXTENT OF CONTAMINATION

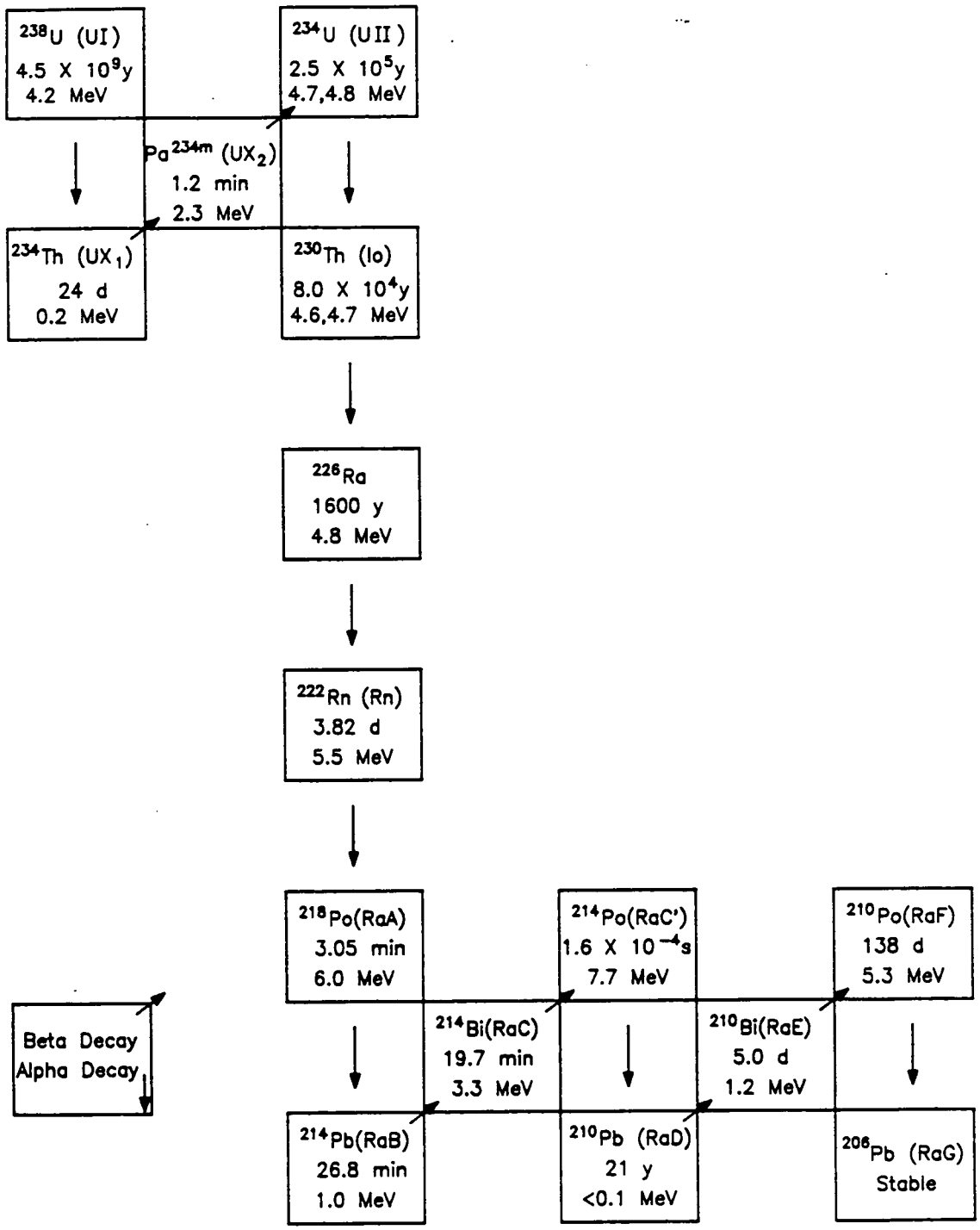
This section presents the data collected within the Operable Unit 4 study area during the RI. These data, along with available data from previous studies, were evaluated to determine the nature and extent of chemical and radiological contamination within the Operable Unit 4 study area.

Most analyses of environmental samples collected from the Operable Unit 4 study area have been limited to radioactive constituents. The following primary sources were reviewed for relevant environmental sampling data to support the evaluation of the nature and extent of contamination associated with Operable Unit 4:

- Analytical results of samples collected as part of the RI/FS sampling effort (ASI/IT 1990c)
- Analytical results of samples collected as part of the WMCO environmental monitoring program (WMCO 1988 and 1989b; Frazier 1989)
- Analytical results of samples collected as part of the CIS (Weston 1987)

The radioactive materials present at FMPC originated from natural sources - pitchblende ore or concentrates. All elements found in natural sources with an atomic number greater than 83 (bismuth) are radioactive (Friedlander et al. 1981). They belong to chains of successive decays, and all the species in one such chain constitute a radioactive family or series. Three of these families include all the natural activities in this region of the periodic chart. One family has U-238 as the parent substance, and after 14 transformations (8 of them by α-particle emission and 6 by β-particle emission) reaches a stable end product, Pb-206. This is known as the uranium series, which includes radium and its decay products. Figure 4-1 shows the members and transformations of the uranium series. The actinium series has U-235 (formerly known as actino-uranium) as the parent and Pb-207 as the stable end product. This series is shown in Figure 4-2. Thorium (Th-232) is the parent substance of the thorium series with Pb-208 as the stable end product. This series is shown in Figure 4-3.

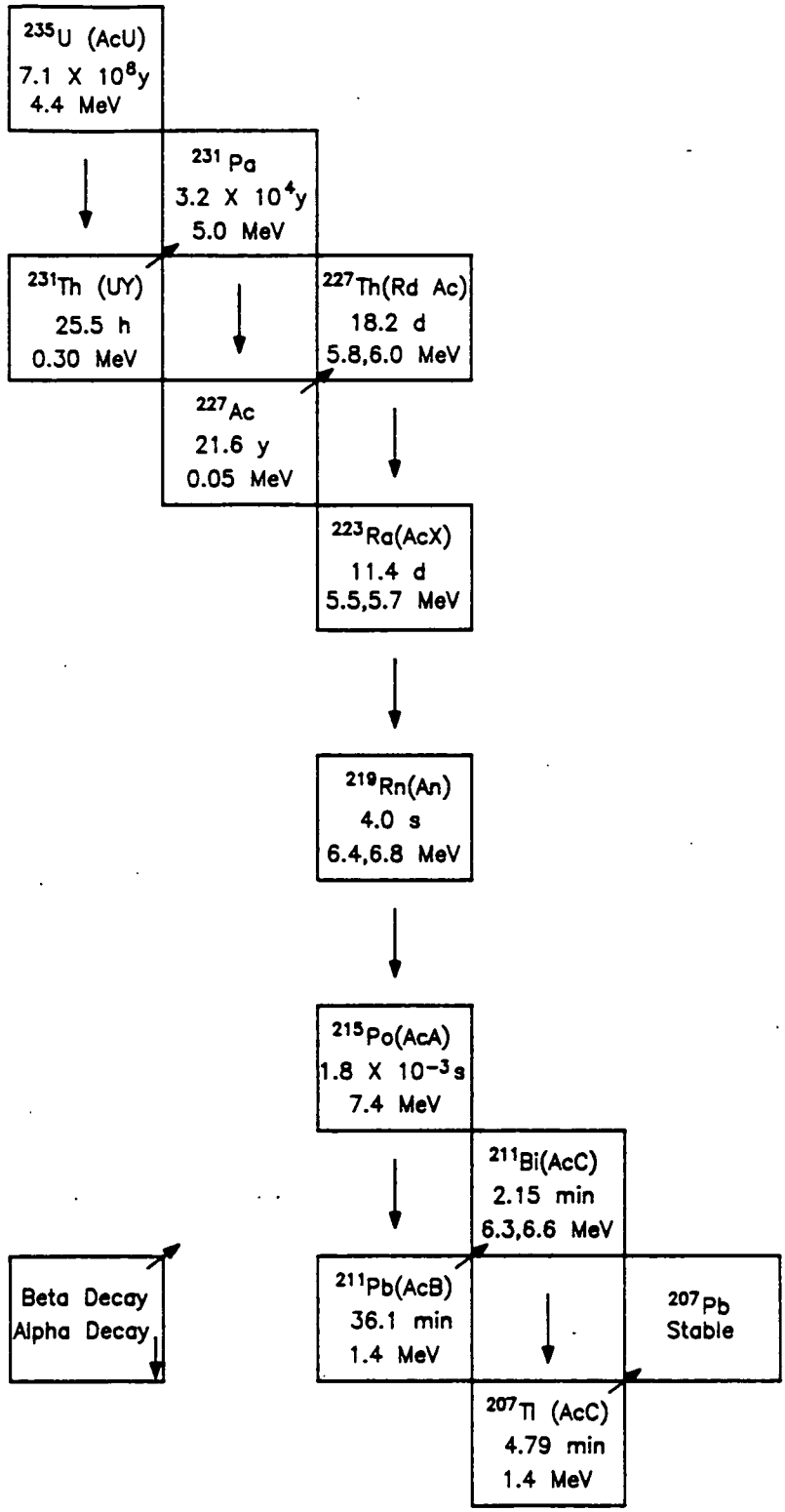
If they are not subject to chemical or physical separation, the members of a series attain a state of radioactive equilibrium, wherein the rate of decay of each nuclide is essentially equal to that of the nuclide that heads the series. This is always the case on a global basis for each series, but local concentrations can vary widely when natural chemical forces separate the series members.



SOURCE: N.C.R.P., 1987

ACAD\DRAWINGS\FERN-1

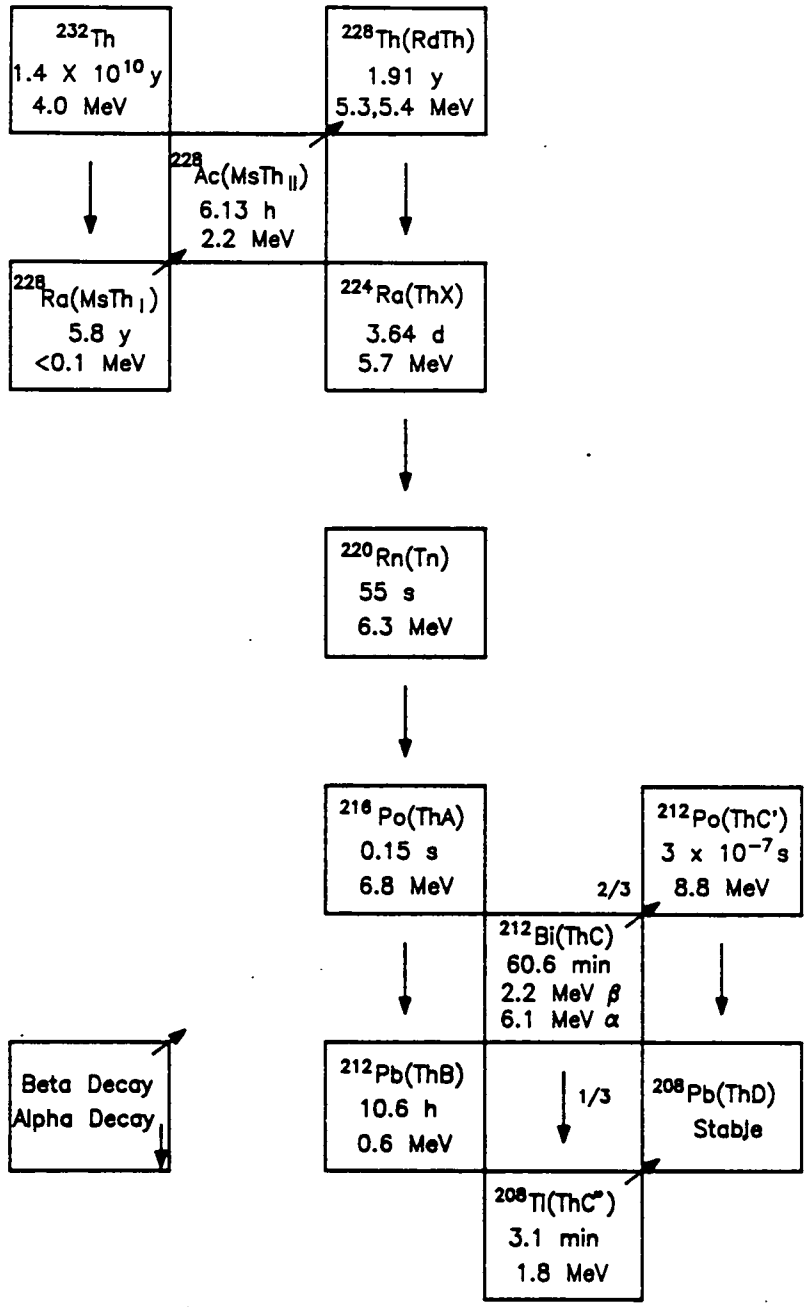
FIGURE 4-1. PRINCIPAL DECAY SCHEME OF THE URANIUM SERIES



SOURCE: N.C.R.P., 1987

ACAD\DRAWINGS\FERN-2

FIGURE 4-2. PRINCIPAL DECAY SCHEME OF THE ACTINIUM SERIES



SOURCE: N.C.R.P., 1987

ACAD\DRAWINGS\FERN-3

FIGURE 4–3. PRINCIPAL DECAY SCHEME OF THE THORIUM SERIES

Previous studies on the K-65 and metal oxide waste provide only radiological and metallic composition; no organic constituents were analyzed. A review of metallic constituents is presented under Section 4.1.2.

Throughout the course of the radionuclide data review for Operable Unit 4, one important assumption is made: Ra-226 and Pb-210 are considered to be the indicators for radioactive contamination present in soil and groundwater which has originated from the K-65 silos. Ra-226 is a decay product of U-238. The half-life of U-238 is 4.468 x 10^9 years; therefore, the production rate of Ra-226 from the refined uranium product is relatively low. However, the uranium refining process at the FMPC removed most impurities from the uranium ore, including Ra-226. These impurities were contained in the hot raffinate solutions sent to the K-65 waste storage silos. Ra-226, which has a half-life of approximately 1600 years, is expected to be limited to the K-65 silos. The highest concentrations of Ra-226 would be expected to appear in the silo contents or in material originating from the silos.

4.1 K-65 SILOS AND SILO 3

The RI sampling of the contents of the K-65 silos being conducted by ASI/IT has not yet been completed. The contents are scheduled to be resampled in mid to late October 1990. Previous attempts to sample the silo contents were unsuccessful because a continuous, representative sample core could not be recovered for inspection and analysis. The variability and inconsistency of results from previous sampling efforts precludes the use of the data for fully characterizing the silo contents. The current sampling effort is being conducted in accordance with a detailed sampling and analysis plan. Rigorous data verification and validation procedures are being applied.

As part of the RI the contents of the silos were sampled by WMCO during the months of May, June, and July 1989. Sampling of Silos 1 and 2 was only partially successful because continuous cores were not able to be recovered. Even though an average of 20 feet of penetration of the material was achieved, there was no sample recovered in three locations. One sample contained 12.5 feet of core (66 percent core recovery); eight were less than 1.5 feet (4 to 9 percent recovery); and four cores ranged from 3.25 to 4.25 feet (18 to 30 percent recovery). The samples obtained from Silos 1 and 2 were essentially a collection of grab samples instead of continuous sample cores. Figure 4-4 provides a summary of the core recovery results of the WMCO sampling effort. The silo contents vary in color from white to brown to black. This variability in color may be due to variability in chemical composition of the material. To recover continuous core samples for the characterization of the silo contents, the silos will be resampled by ASI/IT as stated above.

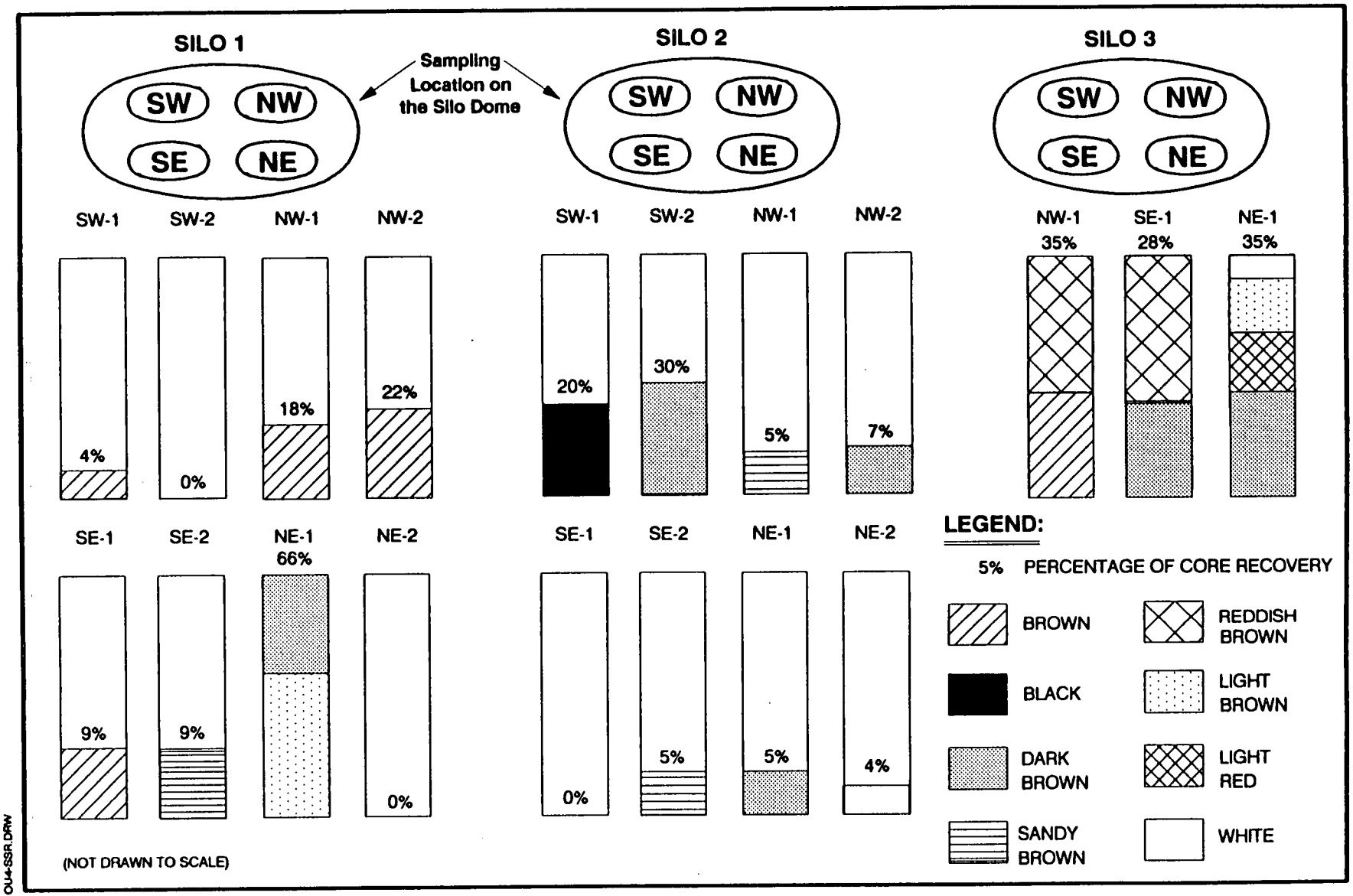


FIGURE 4-4 K-65 AND METAL OXIDES SILOS SAMPLING RESULTS

The sampling of Silo 3 was relatively successful. Continuous 9- to 11-foot (28 to 35 percent) core samples were recovered from 31 feet of material penetration. These cores and the data obtained from analysis of core samples are considered adequate to characterize the contents of Silo 3 and to support the FS. This is because all the material in Silo 3 was produced on property, all came from the same waste stream, was calcined to produce a powder-like material, and air conveyed to the silo. Thus the material is expected to be fairly homogeneous because of its source and how it was processed and handled. Therefore, a 30 percent sample recovery should be nearly representative and adequate to characterize the waste material in Silo 3. No additional sampling of Silo 3 contents is anticipated. The core recoveries for the Silo 3 sampling are presented in Figure 4-4.

4.1.1 Radionuclide Analysis

Historic analyses of the K-65 silo residues indicated that approximately 11,200 kilograms of uranium (0.71 percent U-235) is present in the residues (Grumski 1987b; ASI/IT 1988). Analytical results of residue samples taken in July 1988 (Gill 1988) indicated that the uranium concentration was 1400 ppm in Silo 1 and 1800 ppm in Silo 2. In addition, approximately 1.6 to 3.7 kilograms of radium were estimated to be in the K-65 silo residues (Grumski 1987b; Litz 1974). Data from these previous studies are summarized in Table 4-1.

Data from the WMCO sampling effort conducted in 1989 for Silos 1 and 2 are presented in Table 4-2. The concentration of Ra-226 in Silo 1 ranges from 89,280 pCi/g to 192,600 pCi/g; in Silo 2 it ranges from 657 to 145,300 pCi/g. Th-230 concentrations in Silo 1 range from 10,569 to 40,818 pCi/g; 8365 to 40,124 pCi/g in Silo 2. The concentrations of Pb-210 in Silo 1 range from 48,980 to 181,000 pCi/g; and they range from 77,940 to 399,200 pCi/g in Silo 2. Total uranium concentrations in Silo 1 range from 1189 to 2753 ppm and they range from 137 to 3717 ppm in Silo 2.

The radium content of Silo 3 was previously estimated at between 15 curies (DOE 1988b) and 23 curies (DOE 1989). Therefore, radon emissions from Silo 3 are low compared to the K-65 silos. The material stored in Silo 3 was estimated to contain 20 tons of uranium; the quantity of thorium was unknown (DOE 1988b).

The results of Silo 3 core sample analysis from the 1989 WMCO sampling effort are presented in Table 4-2. Ra-226 concentrations range from 467 to 6435 pCi/g, comparatively lower than the results from Silos 1 and 2. Th-230 concentrations in Silo 3 range from 21,010 to 71,650 pCi/g, which are almost twice as high as the Th-230 concentrations observed in the K-65 silos. Total uranium was present in Silo 3 in concentrations ranging from 738 to 4554 ppm.

TABLE 4-1

CHARACTERISTICS OF THE K-65 RESIDUES STORED AT THE FMPC

	Silos 1 and 2				Silo 3
Characteristics	Vitro (1952)	Litz[a] (1974)	NLO[a] (1980)	Gill (1988)	DOE (1987)
Physical					
Dry weight (kg)	1.59×10^6	--	8.79×10^6	--	--
Volume (m^3)	3,155	--	5,522	--	3,902
Density (kg/m^3)	1,179	--	--	--	--
Water content (%)	30	--	--	--	--
Radiological	(ppm)	(ppm)	(ppm)	(ppm)	(kg)
Radium	0.3	0.28-0.36	0.2	0.13-0.21	0.015[b]
Uranium	2,110	1,800-3,200	600	1,400-1,800	18,000
Total thorium	--	--	--	301-322	--
Chemical					
Carbonates + Sulfates (%)	20				
Quartz (%)	25				
Muscovite clay (%)	60				

[a]As reported by Dettore et al., 1981.
[b]Assumes all radium in K-65 residues is Ra-226 with specific activity of 0.988 Ci/g.
Note: Data validation is currently in progress.

TABLE 4-2

RADIONUCLIDE CONCENTRATION IN THE SILOS
(1989 Sampling Program)

SILO 1

Nuclide (pCi/g)	S1NE1A	S1NE1B	S1NE1C	S1SE1	S1SE2	S1SW1	S1NW1
Th-228	ND	ND	ND	ND	ND	ND	ND
Th-230	21,412	39,693	30,751	10,569	20,848	40,818	43,771
Th-232	ND	ND	ND	ND	ND	ND	766
Ra-226	108,100	192,600	166,400	116,800	89,280	181,200	163,300
Ra-228	ND	ND	ND	ND	ND	ND	ND
Pb-210	181,100	83,110	77,460	71,920	48,980	69,480	54,350
U-234	815	326	622	663	814	594	897
U-235/236	ND	ND	ND	ND	56	ND	50
U-238	920	398	610	545	758	532	687
U-Total (ppm)	2753	1189	1831	1633	2280	1602	2066

SILO 2

Nuclide (pCi/g)	S2SW1	S2NW1	S2NE2	S2SW2	S2NE1	S2NW2
Th-228	ND	ND	ND	411	ND	638
Th-230	31,825	32,784	8365	29,716	40,124	25,391
Th-232	ND	ND	ND	851	ND	ND
Ra-226	145,300	61,780	657	104,900	65,520	68,310
Ra-228	ND	ND	ND	ND	ND	ND
Pb-210	141,900	145,200	87,930	77,940	150,700	399,200
U-234	859	1107	974	121	848	1404
U-235/236	ND	74	47	ND	36	70
U-238	661	1069	874	46	814	1240
U-Total (ppm)	1972	3210	2620	137	2437	3717

ND = Not Detected
Note: Data validation is currently in progress.

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TABLE 4-2 (Continued)

SILO 3

Nuclide (pCi/g)	# 21	# 22	# 23	# 24	# 25	# 26
Ac-227	523	416	234	1363	534	706
Pa-231	521	401	266	NA	556	889
Th-228	907	ND	554	ND	459	859
Th-230	41,911	33,881	21,010	71,650	40,968	41,555
Th-232	1451	ND	815	911	411	ND
Ra-224	453	451	64	213	295	335
Ra-226	2589	2192	467	6435	3073	1862
Ra-228	525	559	82	ND	392	441
Pb-210	2437	2221	454	6427	2493	1910
U-234	1935	1618	348	1524	1467	1910
U-235/236	152	117	ND	127	54	76
U-238	2043	1649	320	1600	1392	1860
U-Total (ppm)	4040	4305	738	2595	3064	4554

SILO 3

Nuclide (pCi/g)	# 27	# 28	# 29	# 30	# 33
Ac-227	421	412	443	773	566
Pa-231	458	NA	564	931	431
Th-228	ND	996	537	ND	949
Th-230	53,227	63,649	61,190	68,759	65,488
Th-232	ND	755	672	581	672
Ra-224	370	106	137	449	313
Ra-226	1518	3702	4169	2240	4451
Ra-228	325	ND	117	360	415
Pb-210	1084	2589	3553	1942	3674
U-234	1317	1052	1843	1643	1600
U-235/236	80	42	158	75	118
U-238	1243	994	1951	1574	1878
U-Total	2740	1463	1114	4050	3854

NA = Not Analyzed
ND = Not Detected

Note: Data validation is currently in progress.

Silos 1 and 2 have distinctly higher radium and lead concentrations than Silo 3. The presence of these radionuclides in large amounts in the silos supports the assumption made previously that their presence in the soil berm, the soil underneath the silos, or the groundwater would indicate that the K-65 silos are leaking. Although thorium and uranium are present in higher concentrations in the Silo 3 contents than in the contents of Silos 1 and 2, these radionuclides are not indicative of a specific source. The area around Operable Unit 4 and the FMPC boundary fenceline has been monitored for direct exposure to penetrating radiation (gamma radiation). During 1988, the boundary monitoring station exhibiting the highest average radiation exposure rate was the station directly west of Operable Unit 4 at a distance of 340 meters (1116 feet), along the western FMPC site boundary (WMCO 1989b). The dose equivalent rate measurement for this location was an annual average of 15.3 µrem/hr; the maximum was 23.53 µrem/hr; and the minimum was 11.56 µrem/hr. Natural background radiation for the area surrounding the FMPC has been estimated to range from 10 to 12 µrem/hr. Section E.2.0 of Appendix E contains background concentrations for the different media sampled in Operable Unit 4.

Radon flux density measurements from the surfaces of the K-65 silo domes were collected before the installation of the foam covering. No flux measurements have been collected on dome surfaces since foaming. Airborne radon concentrations at various locations on and off the FMPC site have also been measured (Boback 1987; WMCO 1988 and 1989b). The sampling of the silo contents will provide additional information on the quantity of radium in the waste. This information could be used to estimate the radon flux densities after the installation of the foam covering.

The results of routine airborne radon concentration measurements that are performed as part of the FMPC environment monitoring program are provided to DOE in the environmental monitoring annual reports (WMCO 1989b). Airborne radon measurement data on samples collected in 1988 after the installation of the foam covering indicate that annual average background radon concentrations range from 0.5 to 1.25 pCi/L. Off-site monitoring stations positioned at private residences near the FMPC recorded annual average concentrations ranging from 1.13 to 1.65 pCi/L. FMPC boundary fenceline monitoring stations recorded annual average concentrations ranging from 0.6 to 1.65 pCi/L, with the measurement of 1.65 pCi/L being recorded along the FMPC boundary just west of the silos (Gels 1990).

ODH performed independent indoor and outdoor radon concentration measurements in the vicinity of the FMPC (ODH 1988). The ODH established 16 outdoor radon monitoring stations around the FMPC - 12 locations along the FMPC site boundary and 4 control locations distant from the

FMPC. Analyses of the detectors located at the site boundary closest to the K-65 silos and those located distant from the FMPC do not reveal consistent significant differences in measured radon concentrations (ODH 1988). The ODH report concluded that environmental measurements of radon and radon progeny concentrations at the FMPC boundary closest to the K-65 silos are sufficiently low that they often cannot be distinguished from variations in natural background concentrations, and that measured concentrations do not appear to correlate with distance or prevailing wind direction from the K-65 silos.

The conclusions made by the ODH are not very different from the airborne radon assessment made in Appendix E of the Operable Unit 4 RI report and those produced on the previous page. Thus the above-background contribution from the FMPC may be as high as the contributions from natural background, or there may be no additional contribution at all from the site. Considering the variation that occurs in background airborne radon concentrations, the potential for an above-ground contribution to airborne radon from the site that is less than or equal to background is not very different form the conclusions made by the ODH. The airborne radon assessment in Appendix E of the Operable Unit 4 RI report employs the above-background airborne radon contribution associated with the highest annual average airborne radon concentration along the western FMPC boundary in order to incorporate a degree of conservatism.

4.1.2 Chemical Analysis

Chemically, the K-65 residues are mixtures of hydroxides, carbonates, and sulfates. Approximately 40 to 60 percent of the waste is silicates (SiO_2); carbonates and sulfates comprise approximately 20 percent. The primary form of uranium contained in the residues is sodium uranyl carbonate (Dettorre et al. 1981). Other elements contributing at least 1 percent to the total are calcium, iron, magnesium, and lead. Table 4-3 presents a summary of the elemental, nonradioactive constituents of the silos. Constituents in Silo 3 are residues from raffinate slurries that were dewatered in an evaporator and spray calcined (DOE 1988a). The waste is in a dry, powder-like form. Principal constituents of Silo 3 include aluminum, calcium, iron, magnesium, sodium, phosphate, silicates, and sulfate (Table 4-3).

A total of 24 samples were collected from Silos 1, 2, and 3 by WMCO. These samples were analyzed for HSL inorganics and organics. A summary of the analytical data for inorganic and organic constituents is provided in Tables 4-4 and 4-5. Complete analytical results are included in Appendix B.

NONRADIOLOGICAL CONSTITUENTS OF WASTE STORAGE SILO CONTENTS

	Silos 1 and 2							Silo 3
Constituents	Vitro (1952) (ppm)	Litz (1974) (ppm)	NLO (1980) (ppm)	Grumski (1987) (% wt)	Gill (1988) (% wt)		Vogel (1989) (ppm)	DOE (1989) (metric tons)
Aluminum				0.875	3.7	2.6		98.67
Antimony				ND	<0.1	ND		<0.53
Arsenic				0.03				
Barium	45,300	50,000		0.07	2.0	2.1		0.70
Boron				0.015		2.1	0.76	0.70
Cadmium				ND				
Calcium				3.89	4.0	13.2	820	144.48
Chlorine							0.1	
Chromium				0.012	ND	0.4	<0.2	1.76
Cobalt		1,600-2,000	1,500-2,000	0.175	0.6	1.1	6.0	8.81
Copper		500-800	400-600	0.50	0.2	0.4	1.0	8.81
Fluorine								
Gold		65-70	<40-60	<0.005				<0.14
Iron		13-18,000		1.2	8.3	9.8		225.52
Lanthanum				0.089	0.2	0.1		
Lead	94,900	60-70,000	48-52,000	5.1	7.5	10.3	630.0	8.81
Magnesium				1.25			25.0	229.52
Manganese				0.02			1.4	17.27
Mercury							<.03	
Molybdenum				0.02	0.4	<0.1		2.11
Nickel		3,500-3,700	2,000-3,000	0.225	1.0	1.8	8.0	22.9
Palladium		13-18						
Platinum		0.9-1.4						
Potassium							12.0	
Selenium							<0.1	
Silver		18	20	0.002			<0.1	<0.07
Sodium				0.7			307.0	133.0
Strontium							7.3	
Tin				0.008				1.4
Titanium				0.07				2.11
Vanadium				0.021				3.52
Zinc				ND	<0.1	<0.1		
Zirconium				0.02	0.1	0.2		
PO_4				ND				683.62
SiO_2				40.76	68.9	55.1	55.0	461.62
SO_4								692.08

ND = Not Detected.
Note: Data validation is currently in progress.

TABLE 4-4

INORGANICS CONCENTRATION IN THE SILOS
1989 Sampling Program)

Contaminant (ppm)	Silo 1	Silo 2	Silo 3
Aluminum	60.4 - 1430	464 - 2570	10800 - 23700
Antimony	ND	ND - 7.2	ND
Arsenic	14.7 - 68.4	57.5 - 1960	532 - 6380
Barium	1970 - 7860	89.2 - 8370	118 - 332
Beryllium	0.88 - 2.8	0.66 - 6.0	10.0 - 39.9
Cadmium	2.1 - 8.0	3.4 - 19.1	21.5 - 204
Calcium	2150 - 5700	2430 - 301000	21300 - 39900
Chromium	21.0 - 165	12.9 - 68.8	139 - 560
Cobalt	349 - 1260	6.2 - 2430	ND - 3520
Copper	122 - 473	ND - 1790	1610 - 7060
Iron	4340 - 75100	4010 - 37800	13900 - 67600
Lead	35800 - 85100	153 - 29800	646 - 4430
Magnesium	1500 - 6020	1520 - 8740	38200 - 80900
Manganese	33.5 - 257	74.2 - 403	2420 - 6500
Mercury	0.23 - 2.8	ND - 2.3	ND - 0.69
Nickel	629 - 2580	14.6 - 2200	1200 - 6170
Potassium	158 - 492	37.8 - 289	1300 - 22800
Selenium	106 - 180	ND - 118	101 - 349
Silver	5.0 - 23.3	ND - 22.8	9.2 - 23.8
Sodium	360 - 13100	226 - 4070	22900 - 51700
Thallium	ND - 0.52	ND - 1.4	3.1 - 73.9
Vanadium	72.2 - 240	21.9 - 214	418 - 4550
Zinc	14.4 - 212	11.2 - 154	301 - 672
Cyanide	0.52 - 4.4	ND - 4.5	ND

ND = Not Detected
Note: Data validation is currently in progress

TABLE 4-5

ORGANICS CONCENTRATIONS IN THE SILOS

CONTAMINANT	Silo 1	Silo 2	Silo 3
VOLATILE ORGANICS ANALYSIS DATA (ppb)			
Methylene Chloride	840 - 4100	1100 - 6300	1000 - 2800
Acetone	140 - 5300	ND - 1600	3400 - 12000
Chloroform	480 - 1500	660 - 1300	560 - 810
2-Butanone	7100 - 21000	7800 - 15000	9700 - 16000
4-Methyl-2-Pentanone	ND - 1400	ND - 2700	ND
Toluene	ND - 430	ND - 250	180 - 6800
Trichloroethane	ND	ND - 120	ND
Chloromethane	ND	ND	ND - 140
Styrene	ND - 350	ND - 200	ND
Total Xylenes	ND	ND - 200	ND
SEMIVOLATILE ORGANICS ANALYSIS DATA (ppb)			
Bis(2-Ethylhexyl)Phthalate	93 - 6000	ND - 560	ND - 40
Di-n-Octyl Phthalate	ND - 820	ND	ND
PESTICIDE ORGANICS ANALYSIS DATA (ppb)			
Aroclor-1248	ND - 8000	ND	ND
Aroclor-1254	1100 - 14,000	420 - 6000	ND

ND = Not Detected
Note: Data validation is currently in progress.

The results of the HSL analyses show that the principal inorganic constituents in Silos 1 and 2 are barium, calcium, iron, lead, and magnesium. The principal inorganic constituents in Silo 3 are aluminum, calcium, iron, magnesium, potassium, and sodium. The results of the inorganic analyses are summarized in Table 4-4.

As Table 4-4 also shows, there are distinct differences in the concentrations of metals contained in Silos 1 and 2 residues as compared to the results from Silo 3. Silos 1 and 2 contain a higher lead content, and Silo 3 contains distinctly higher concentrations of aluminum, arsenic, chromium, magnesium, manganese, potassium, and sodium. These characteristic differences have been utilized to distinguish between any contamination that might have originated from Silos 1 and 2 and any contamination that might have originated from Silo 3.

Extraction Procedure (EP) Toxicity was measured by using the EPA extraction procedure designed to simulate the leaching a waste could undergo if it is disposed on in a landfill. After extraction, the extract from each sample was analyzed for the EP Toxic metals. The results are summarized in Table 4-6. Lead was found to have leached from the Silos 1 and 2 residue samples in concentrations as high as 904 ppm and 714 ppm, respectively. The maximum concentration of selenium in the leachate from Silo 2 was 1.56 ppm. These values are in excess of the maximum allowable concentration (MAC) specified under federal standards. The leachate obtained from Silo 3 samples contained arsenic, cadmium, chromium, and selenium above the MAC. The highest observed concentrations of these metals in the Silo 3 sample leachates were 41.5, 6.3, 11.9, and 11.7 ppm, respectively.

Several volatile organics were detected in the silo samples as summarized in Table 4-5. This table indicates that methylene chloride, acetone, chloroform, 2-butanol, and toluene were detected in all three silos (Silos 1, 2, and 3). 4-methyl-2-pentanone and styrene were detected in Silos 1 and 2. Total xylenes and trichloroethane were detected in Silo 2, and chloromethane was detected in Silo 3. Phthalates were detected in all three silos. PCBs were detected in samples from Silos 1 and 2 with maximum concentrations of 14,000 and 6000 ppb, respectively. No PCBs were detected in Silo 3.

Many of the detected organics were also detected in laboratory method and system blanks. No field or trip blanks were available for analysis. Two chemicals, trichloroethane and chloromethane, were detected only once in all samples taken.

TABLE 4-6

EP TOXIC METALS RANGE OF VALUES FOR K-65 AND METAL OXIDE SILOS
(1989 Sampling Program)

Analyte	Silo 1	Silo 2	Silo 3	Maximum Allowable Concentration
Arsenic (ppm)	ND - 0.484	0.163 - 0.592	ND - 41.5	5.0
Barium (ppm)	0.079 - 14.5	0.095 - 2.62	0.020 - 0.156	100
Cadmium (ppm)	ND - 0.100	0.017 - 0.278	0.108 - 6.32	1.0
Chromium (ppm)	0.020 - 0.964	ND - 1.02	0.336 - 11.9	5.0
Lead (ppm)	0.159 - 904	0.155 - 714	ND - 1.01	5.0
Selenium (ppm)	0.217 - 0.997	0.240 - 1.56	0.92 - 11.7	1.0
Silver (ppm)	ND - 0.121	ND - 0.213	ND - 0.032	5.0
Mercury (ppm)	ND	ND	ND - 0.003	0.2

ND = Not Detected
Note: Data validation is currently in progress.

However, at present, the presence or absence of hazardous substance list (HSL) volatile organic compounds cannot be accurately determined because the holding times for these compounds were exceeded by more than three months. However, it is expected that during the resampling of the K-65 silos these compounds will be analyzed within the required holding times.

Silo 4 Water

Currently there is standing water in Silo 4. Radiological and chemical analyses of water samples collected from Silo 4 in June 1989 indicate that although the silo was never used, there are quantities of uranium isotopes and inorganic chemicals present (Table 4-7). The low concentration of these materials in Silo 4 are consistent with the likely scenario that their presence is due to resuspension of materials from the nearby waste storage pits, subsequent atmospheric transport, and deposition onto the silo dome and percolation of rain water into the silo. Removal of the water contained in Silo 4 will be conducted either as part of the routine plant maintenance process or as part of a planned facilities upgrade program. No further action is recommended for Silo 4.

4.1.3. Geotechnical Analysis

Silos 1 and 2 contain waste raffinate slurries that were decanted by means of baffles and weirs placed along the height of the silo wall. Over the years the waste slurries have settled to form a wet muddy-looking material that is a mixture of clay and silty sand particles. During WMCO's 1989 sampling effort, this material was easily penetrated by the LEXAN sampling tube, which reached to the bottom of the silos. This indicated that the material might be in a sludge-like condition. Free liquid was occasionally observed during the course of the sampling.

Silo 1 contains material that is brown; Silo 2 contents vary in color from white to brown to black. Water content for the materials in both silos is consistently high ranging from 21.8 to 73.5 percent. The specific gravity is between 2.59 and 3.37. Only two out of eight samples taken from the silos were plastic. Table 4-8 provides a summary of results from the geotechnical analyses.

Metal Oxide Silo 3 contains waste raffinate slurries that had been dewatered in an evaporator and spray calcined to produce a dry powder-like waste. The material in this silo is brown with a tone that varies from dark to reddish. As a result of the evaporation and calcination of this waste, the water content is very low ranging between 3.7 and 10.2 percent. The specific gravity varies between 2.08 and 2.75. Approximately 90 percent of the Silo 3 residues pass through a 200-mesh-sieve (0.074 mm). This size designation is the break between sand and silt. All the samples

TABLE 4-7

SILO 4 WATER ANALYTICAL RESULTS
(1989 Sampling Program)

Analyte	Concentration Units	Sample ID S4-NW-1R	Sample ID S4-SE-1R
Ra^{226}	(pCi/l)	<4.8	<4.8
Ra^{228}	(pCi/l)	<4.8	<4.8
Th^{228}	(pCi/l)	<0.16	<0.19
Th^{230}	(pCi/l)	<0.26	<0.31
Th^{232}	(pCi/l)	<0.20	<0.24
U^{234}	(pCi/l)	22	16
U^{235}	(pCi/l)	1.2	1.3
U^{236}	(pCi/l)	0.52	0.32
U^{238}	(pCi/l)	39	42

Analyte	Concentration Units	Sample ID S4-NW-2R	Sample ID S4-SE-2R
Silver	(ppb)	4	4
Aluminum	(ppb)	<200	<200
Arsenic	(ppb)	21	20
Barium	(ppb)	<5	<5
Beryllium	(ppb)	<1	<1
Calcium	(ppm)	3.2	3.2
Cadmium	(ppb)	<4	<4
Cobalt	(ppb)	<20	<20
Chromium	(ppb)	21	21
Copper	(ppb)	11	11
Iron	(ppb)	74	145
Mercury	(ppb)	<0.2	<0.2
Potassium	(ppm)	181	201
Magnesium	(ppm)	1.0	1.0
Manganese	(ppb)	3	3
Sodium	(ppm)	294	294
Nickel	(ppb)	<10	<10
Lead	(ppb)	1	<1
Antimony	(ppb)	NA	NA
Selenium	(ppb)	41	35
Thallium	(ppb)	<10	<10
Vanadium	(ppb)	32	32
Zinc	(ppb)	78	21

NA = Not Analyzed
Note: Data validation is currently in progress

TABLE 4-8

GEOTECHNICAL ANALYTICAL RESULTS
(1989 Sampling Plan)

Sample ID	Color	Water Content (%)	Specific Gravity	Liquid Limit	Plastic Limit	Plasticity Index	200 Sieve (Percent Finer)
S1-NE-1A	Dark Brown	50.7	3.19	55.2	50.0	5.2	72.7
S1-NE-1C	Light Brown	71.5	2.74	70.3	66.6	3.7	71.5
S1-SE-2T	Sandy Brown	31.9	3.37	NP	NP	NP	43.9
S1-Compos.	NA	22.8	2.58	NP	NP	NP	54.5
S2-NW-1A	Brown	25.9	2.87	NP	NP	NP	39.8
S2-NE-2BT	White	21.8	2.59	NP	NP	NP	51.9
S2-SW-1A	Black	73.5	3.11	NP	NP	NP	63.3
S2-Compo	NA	34.2	2.78	NP	NP	NP	38.1
S3-NW-1A	Reddish Brown	7.4	2.35	NP	NP	NP	93.2
S3-NW-1C	Brown	3.7	2.08	NP	NP	NP	93.9
S3-SE-1A	Reddish Brown	10.2	2.58	NP	NP	NP	90.0
S3-SE-1C	Dark Brown	6.3	2.29	NP	NP	NP	92.9
S3-Compo	NA	3.8	2.75	NP	NP	NP	87.8

NA = Not Applicable
NP = Non Plastic
Note: Data validation is in progress

collected from Silo 3 were nonplastic (Table 4-8). The physical characteristics of the Silo 3 contents suggest the material is immobile.

4.2 K-65 SILO EMBANKMENT AND SUBSOIL SAMPLING

No sampling of the K-65 silo embankment, and only limited sampling of the soils beneath the silos, has been conducted. As discussed in Section 2.2 of this report, a sampling program has been planned under the RI/FS to address these environs.

The primary concern regarding the embankment soils is that as high levels of Ra-226 in Silos 1 and 2 decay to Rn-222, the radon will diffuse through the silo walls into the embankment soil surrounding the silos. As radon diffuses through the silo walls and soil, it decays and its progeny are deposited. Two of these daughters, Pb-210 and Po-210, have sufficiently long half-lives to accumulate in the embankment soil. No chemical or radiological characterization of the K-65 silo embankment soils has been performed to date; therefore, the significance of this potential accumulation cannot be fully assessed at this time.

The subsoils beneath the waste storage silos are of concern because of previous reports that Silo 1 has leaked. The full nature and extent of contamination beneath the silos cannot be evaluated based on the existing data collected by NLO in 1983. One borehole was located south of Silo 1, and the other borehole was located southwest of Silo 2 near the decant tank. These data consist of soil samples collected from two diagonal borings drilled beneath the silos. Analysis of these soil samples identified the presence of uranium and radium in the soil in concentrations ranging from 0.77 to 9.66 pCi/g and 0.68 to 1.2 pCi/g of soil, respectively. The concentrations of Ra-226 are below background levels for soil (1.5 pCi/g). Samples were collected at four approximately equal incremental depths starting at 5 feet and going to 20 feet below land surface. The highest concentrations were observed in the first eight feet below land surface (Vogel 1989a).

Although the uranium and radium may have originated from the silos, there is no conclusive evidence to support this assertion or to ascertain if the contamination was caused by noncontinuing activities at the time of silo filling. Additional sampling and analysis is required to determine the nature and extent of contamination beneath the waste storage silos. These data are critical because they establish whether or not the waste storage silos are current contributors to soil and groundwater contamination.

4.3 SURFACE RADIATION MEASUREMENTS

Gamma exposure rate measurements were made at a height of three feet above the ground surface during the mobilization phase of the CIS to estimate personnel exposure while working in the waste storage area (Weston 1987). The CIS included several exposure rate measurements along the perimeter fence of the waste storage silos. A Reuter Stokes Model RS-111 PIC and a portable scintillation detector (Eberline SPA-3) were used to conduct the exposure rate measurements in areas in which the exposure rates were less than 100 microroentgen (µR/hr). Where exposure rates exceeded 100 µR/hr, an Eberline Model HP-270 energy compensated Geiger-Mueller (GM) probe coupled to an Eberline PRS-1 ratemeter/scaler was used. Elevated exposure rates were found in the vicinity of the waste storage silos. The highest exposure rate measured was 230 µR/hr along the northern perimeter fence surrounding the K-65 silos. FIDLER readings were taken along the northern edge of the Operable Unit 4 study area and beta-gamma dose rates were determined in the area surrounding the metal oxide silos with an Eberline Model HP-210T pancake-type thin-window GM detector. In general, the FIDLER and GM beta-gamma measurements were used in the CIS to determine soil sampling locations; however, the exposure rate data from soils in the Operable Unit 4 study area were ambiguous with respect to quantifying soil radioactivity.

During the RI, a number of additional walkover measurements using the FIDLER and SPA-3 were taken within the Operable Unit 4 study area. The exposure rate was measured with the SPA-3 at 10 nodes and with the PIC at 2 nodes within the Operable Unit 4 study area. These data are provided in Appendix A.

The FIDLER survey was directed primarily toward detecting the 63 keV gamma emitted from Th-234, a uranium progeny. Although the FIDLER has the potential to discriminate against higher energy gamma emissions, the exposure rate contribution from the K-65 silos produced excessive interference. The use of shielding to reduce radiation interference from the K-65 silos was ineffective. As a result, FIDLER measurements did not enable reliable quantification of contributions from surface soils within the Operable Unit 4 study area; therefore, the surveys conducted within the Operable Unit 4 study area using the FIDLER provide supplemental exposure rate data rather than identifying radioactively contaminated soils. The FIDLER survey data related to Operable Unit 4 are presented in Appendix A.

The PIC measurements were used to calibrate the SPA-3 readings, thus enabling the hand-held SPA-3 reading to be expressed as exposure rate in units of µR/hr. The PIC readings within the Operable Unit 4 study area are shown in Figure 4-5. The SPA-3 walkover measurements were

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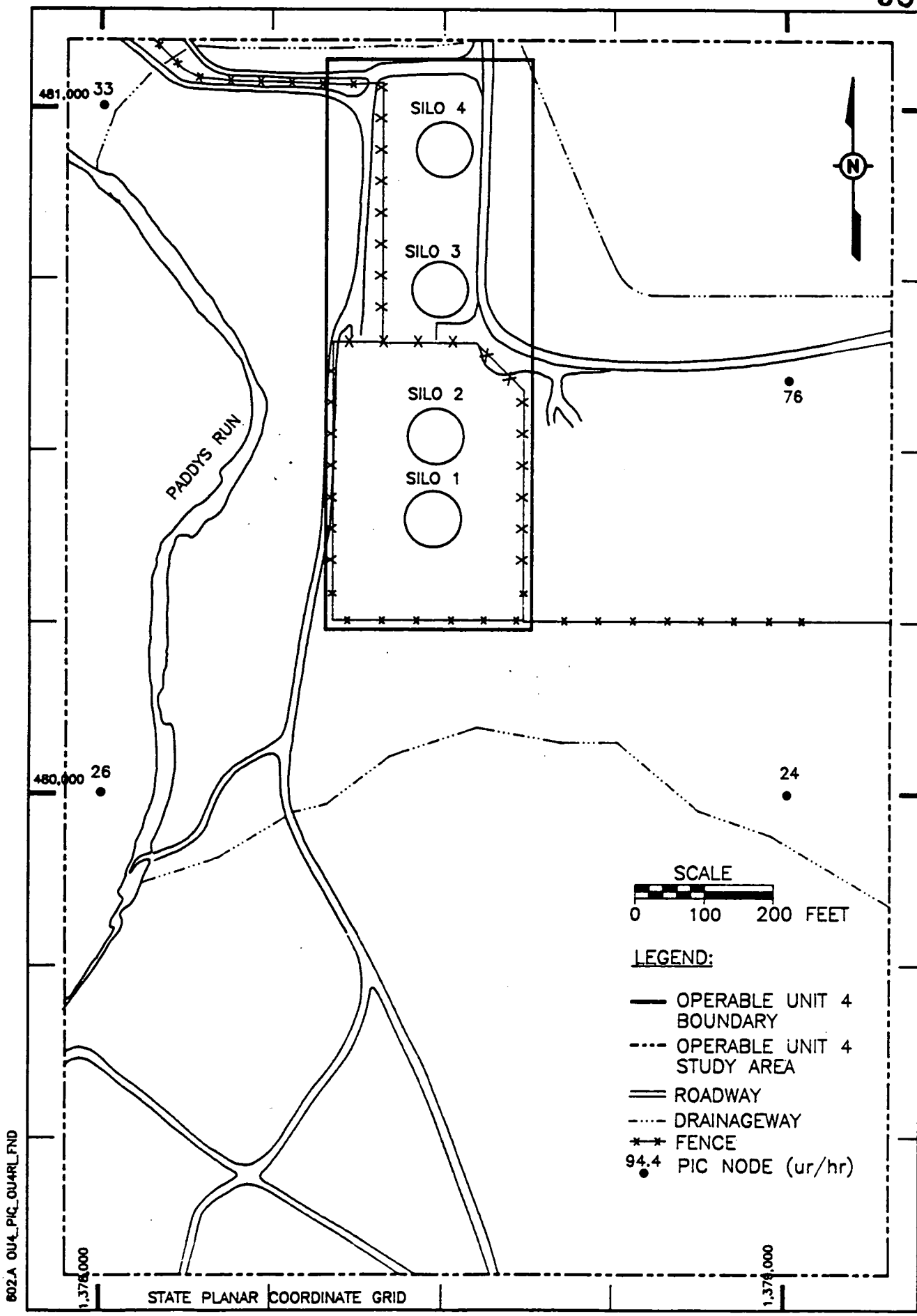

FIGURE 4–5. DISTRIBUTION OF PRESSURIZED IONIZATION CHAMBER (PIC) READINGS

taken at essentially all the same locations as the FIDLER measurements. Exposure rate measurements are highest near the silos. Because the SPA-3 reading included significant contributions from the silos, they were also of limited value in determining the presence of radioactively contaminated soils within the Operable Unit 4 study area.

The silo gamma radiation levels were sufficiently high to preclude detection of radioactively contaminated soils nearby; the concentration and extent of surface soil contamination could not be determined from measurements using field survey instruments. The exposure rate data are the only viable field survey measurements collected from within the Operable Unit 4 study area. Evaluation of surface soil contamination must rely on surface soil sample analysis rather than field survey measurements.

4.4 SURFACE SOILS

Surface soils within the Operable Unit 4 study area were sampled and analyzed for radiological parameters during the CIS and the RI. The complete results of the CIS and the RI relevant to Operable Unit 4 are presented in this report. Analyses for nonradiological parameters in surface soils were not performed during either study.

Background surface soil radiation measurements reported in the CIS were collected at 15 background stations in the vicinity of the FMPC (Weston 1987). However, these stations were located far enough from the FMPC to be free of impacts from site activities. The background activity concentrations reported for selected radionuclides were: U-238, 0.7 to 1.2 pCi/g; U-234, 0.7 to 1.0 pCi/g; Th-230, 0.7 to 1.3 pCi/g; Th-232, 0.5 to 1.2 pCi/g; and Ra-226, 0.5 to 1.0 pCi/g. These values will be used as references when comparing surface soil concentration values obtained during field investigative activities with local background levels.

4.4.1 Summary of Analytical Results

Radiological characterization of surface soils inside the Operable Unit 4 study area during the CIS identified above background activities for selected radionuclides. Sampling locations addressed during the CIS that fell within the Operable Unit 4 study area included the following: samples taken on the east side of the silos; around Metal Oxide Silo 3; and from two drainageways located north and south of the silos. Measured concentrations as high as 37.4 pCi/g for U-238; 35.8 pCi/g for Ra-226; and 295 pCi/g for Th-230 were observed (Weston 1987).

Concentrations observed during the RI were as high as 21.0 pCi/g for U-234, 21.1 pCi/g for U-238, 8.4 pCi/g for Th-230, 5.2 pCi/g for Th-232, and 4.2 pCi/g for Ra-226. Results from the RI are summarized in Table 4-9, and the CIS data are presented in Appendix B. Maps of the Operable Unit 4 study area presenting the distribution of data from the RI for U-238 and Ra-226 are presented in Figures 4-6 and 4-7, respectively. Figure 4-8 shows the distribution of U-238 from the CIS data A detailed presentation of the CIS data appears in the Weston report (Weston 1987).

The data presented in Table 4-9 indicate the contamination is in the Operable Unit 4 study area. The contaminant concentrations presented in Table 4-9 are only slightly above-background concentrations for surface soil with the exception of U-234 and U-238. There is no demonstrated direct mechanism relating contamination in adjacent surface soils to the silos other than historical silo filling operations. Migration from other operable units could account for the contaminant concentrations identified in Table 4-9. The need to characterize further the extent of soil contamination in the Operable Unit 4 study area has led to the proposal for sampling the berm soil and the soil beneath the silos. Analytical results from these additional sampling programs will be incorporated when they are available.

Attempts to classify the uranium contamination present in the Operable Unit 4 study area as either depleted or natural uranium and, in turn, identify a possible source, have proven unsuccessful. Table 4-9 presents data that indicate both depleted and natural uranium (e.g., 2.4 pCi/g U-238/2.4 pCi/g U-234 and 3.3 pCi/g U-238/2.8 pCi/g U-234) exist. Because there are other potential sources of contamination besides Operable Unit 4, the data are inconclusive in identifying a specific source.

It is unlikely that depleted uranium would have been placed in the silos because depleted uranium is of no value for producing reactor fuel or weapons grade material. Instead, the depleted uranium would have been dumped in the waste pits. The silos are likely to contain only natural uranium because natural uranium would still have the potential to be recovered and run through the enrichment process at an enrichment facility.

4.4.2 Magnitude and Extent

The results of the surface soil sample analyses indicate that uranium is the most prevalent radionuclide in surface soils within the Operable Unit 4 study area. Uranium concentrations ranged from below background levels to 37.4 pCi/g around the K-65 silos. According to the CIS study, the areal extent of above background Ra-226 activity is small compared to U-238. Only two samples

TABLE 4-9

SURFACE SOIL SAMPLE ANALYSIS RESULTS WITHIN OPERABLE UNIT 4 STUDY AREA

Coordinates*			Analytical Results (pCi/g)					
East	North	Depth (in.)	Ra-226	U-238	U-234	U-235	Th-232	Th-23
Background			1.5	1.4	1.4	0.06	1.0	1.4
1378400	480700	0 - 2	NA	7.3	4.7	<0.6	NA	NA
		2 - 4	1.1	NA	NA	NA	1.3	3.3
		4 - 6	1.2	NA	NA	NA	1.0	3.3
1378350	480540	0 - 2	NA	20.8	6.9	<0.6	NA	NA
		2 - 4	2.3	NA	NA	NA	1.2	3.9
		4 - 6	4.2	NA	NA	NA	0.9	4.3
1378340	480260	0 - 2	NA	4.8	2.5	<0.6	NA	NA
		2 - 4	1.0	NA	NA	NA	1.7	2.5
		4 - 6	1.0	NA	NA	NA	1.2	1.9
1378500	480250	0 - 6	1.1	2.4	2.4	<0.6	0.9	2.2
1378750	480245	0 - 6	0.9	3.3	2.8	<0.6	1.0	1.4
1378000	480000	0 - 2	<0.4	1.7	1.3	<0.6	<0.6	1.2
1378000	481000	0 - 2	<0.3	2.6	1.7	<0.6	0.8	1.0
1378000	481000	0 - 2	0.6	3.2	1.5	<0.6	<0.6	1.1
1378300	481000	0 - 2	0.6	4.5	3.2	<0.6	<0.6	3.4
1379000	480000	0 - 2	1.0	21.1	21.0	1.4	5.2	8.4
1379000	480239	0 - 6	1.3	5.1	4.5	<0.6	1.0	3.5

*The Ohio State plane coordinate system is used. These locations are shown in Figures 4-6 and 4-7.
NA = Not analyzed.
Note: Data validation is currently in progress.

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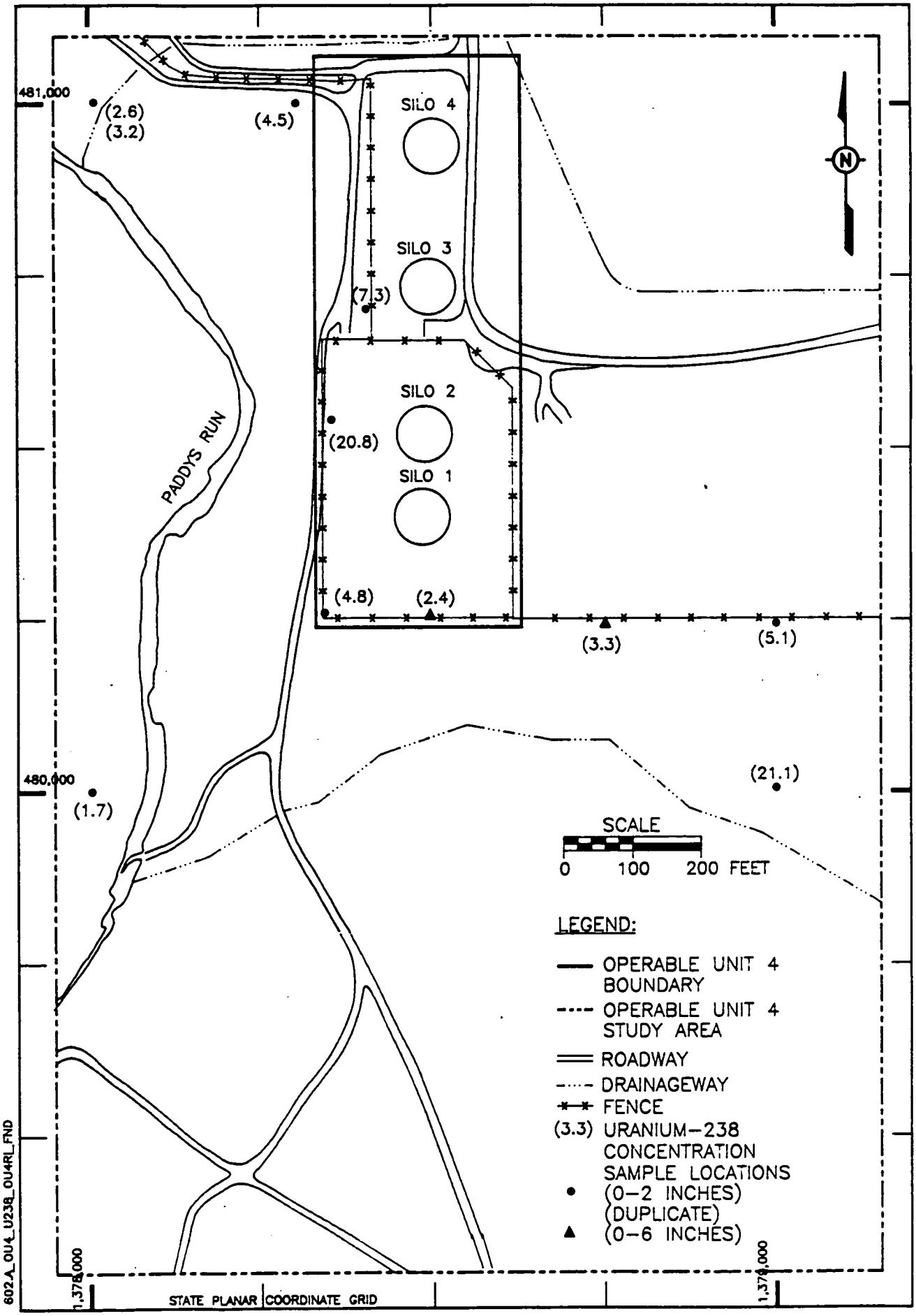

FIGURE 4-6. URANIUM-238 IN pCi/g IN SURFACE SOILS

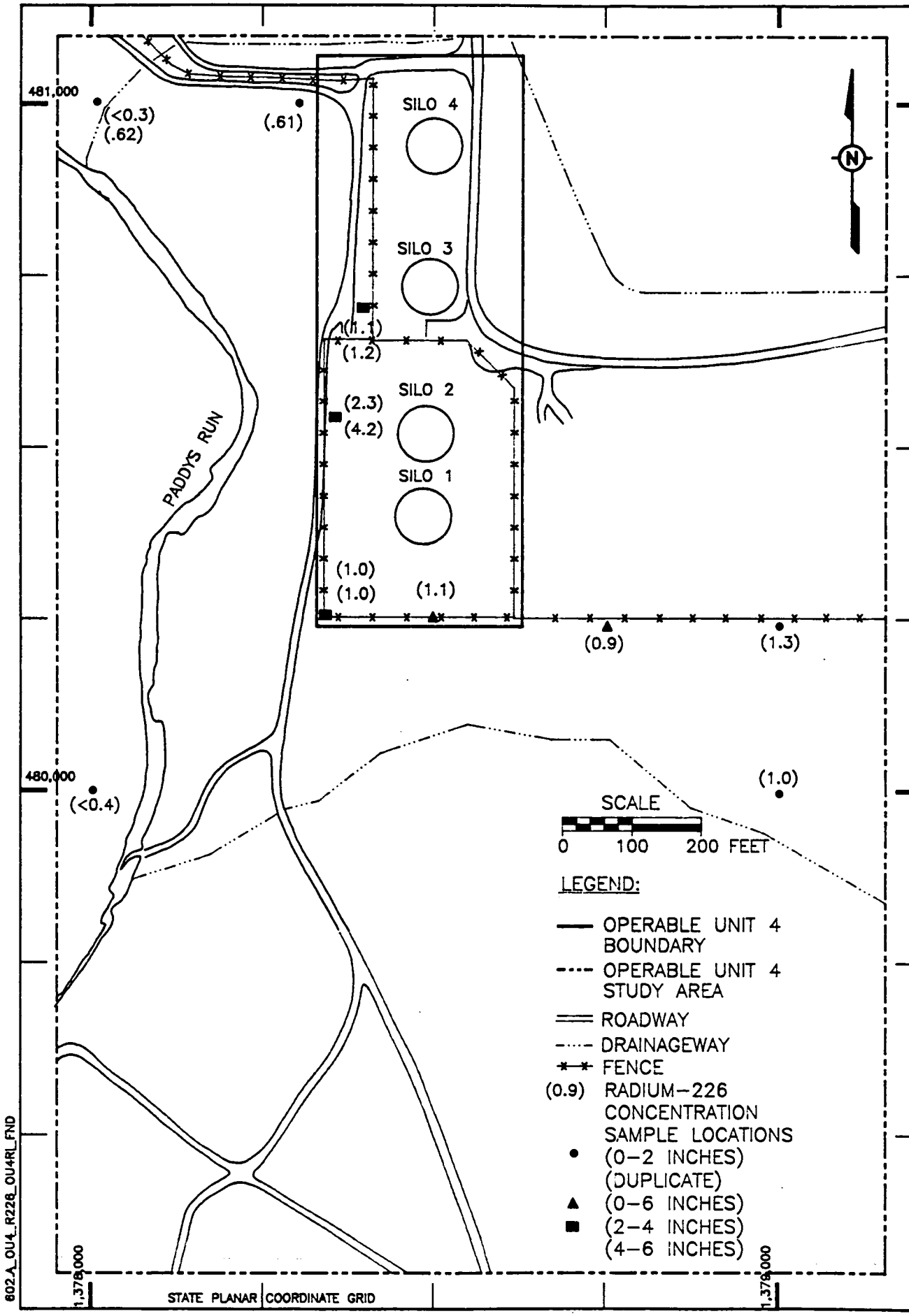

FIGURE 4-7. RADIUM-226 IN pCi/g IN SURFACE SOILS

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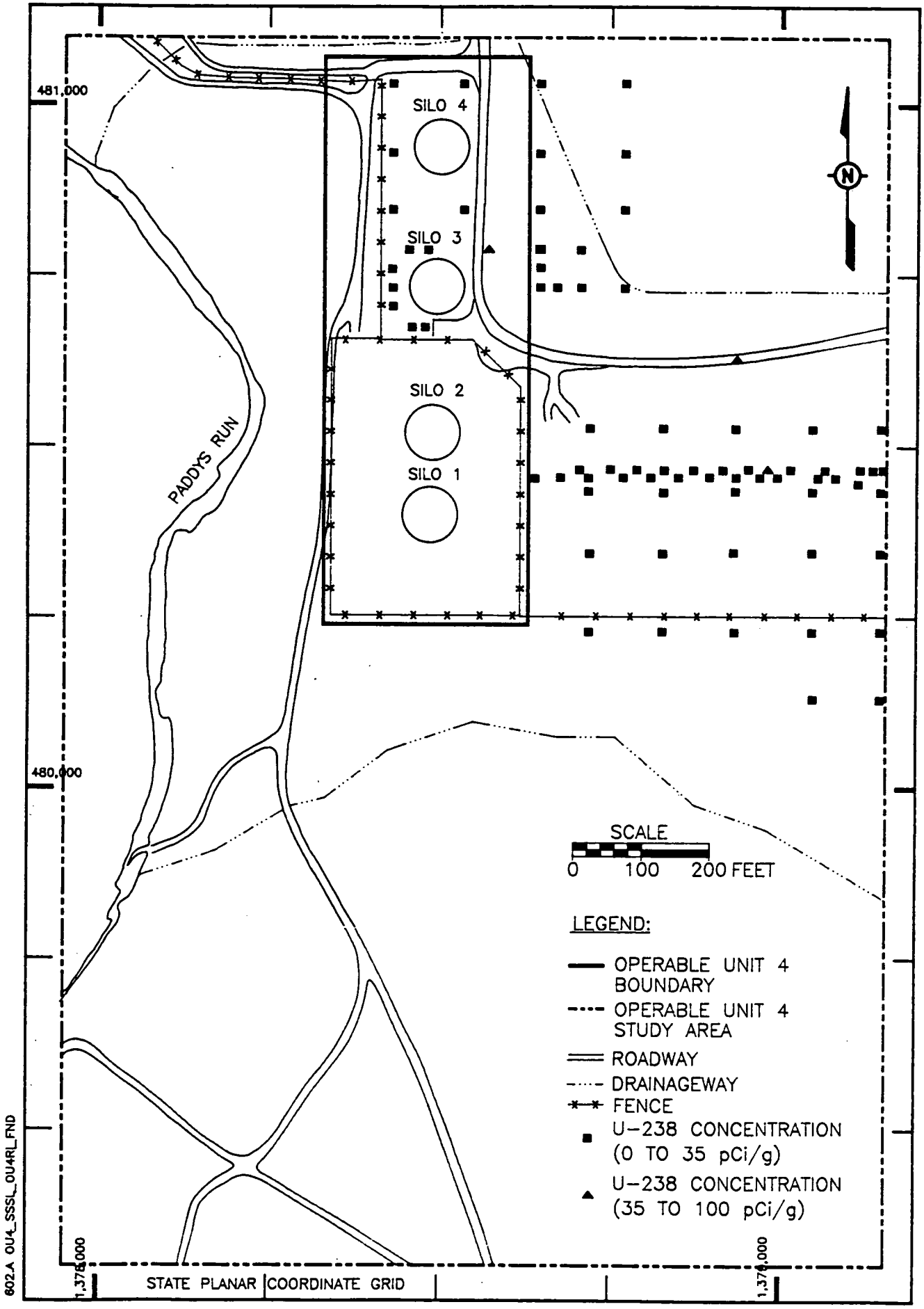

FIGURE 4-8. URANIUM 238 CONCENTRATIONS IN SURFACE SOILS

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contained Ra-226 in excess of 15 pCi/g (arbitrarily selected); one location east of the Metal Oxide Silo 3; and one location between Silo 2 and the Metal Oxide Silo 3 (Weston 1987). Several sample locations around Silo 3 contain Ra-226 concentrations between 5 and 15 pCi/g. Most of these locations correlate well with locations containing elevated concentrations of U-238 (Weston 1987).

Two locations, one east of Silo 3 and one on the east side of the K-65 silos, contain Th-232 concentrations ranging from 5 to 15 pCi/g. Th-230 was also detected in a sample taken near Silo 3. Concentrations in this sample were as high as 295 pCi/g.

There are two drainageways present in the Operable Unit 4 study area. One runs along the north side of the gravel road (south of the Biodenitrification Surge Lagoon) and curves north toward the Clearwell, which accepts runoff from the Waste Storage Area. Samples collected at locations along this drainageway north of the metal oxide silos contained uranium at activities below background; thorium and radium activities were slightly above background. A second drainageway flows south of the K-65 silos. Samples collected from the southern drainageway contained uranium concentrations as high as 16 pCi/g; radium and thorium activities were at or below background (Weston 1987).

The data collected during the RI show only one sample location within the Operable Unit 4 study area containing U-238 in excess of 10 pCi/g (arbitrarily selected). The remaining locations contain U-238 and Ra-226 in concentrations less than 10 pCi/g (Figures 4-6 and 4-7). These data do not conclusively identify a source of the observed contamination.

4.5 SUBSURFACE SOILS

4.5.1 Summary of Analytical Results

A full radiological analysis was performed on 12 subsurface soil samples taken from borings described in Section 2.5.2 (Figure 2-4). Full radiological analysis consists of analysis of all radionuclides specified in the sampling plan, including gamma spectral analysis. (Refer to Section 2.0 for sampling plan details including lists of analytical parameters for various media.) The results of these analyses are summarized in Table 4-10, and the complete analytical results are provided in Appendix B. In addition, average concentrations from the silo waste samples are reported in Appendix E. The radionuclides that were present in measurable concentrations were uranium, thorium, technetium, and radium.

TABLE 4-10
SUBSURFACE SOIL RADIOLOGICAL RESULTS WITHIN OPERABLE UNIT 4 AREA

			Analytical Results (pCi/g)							
Well No.	Sample ID	Depth (ft.)	Ra-226	Ra-228	Tc-99	Th-230	Th-232	U-234	U-235/236	U-238
Background			1.5	1.0	-	1.4	1.0	1.4	0.06	1.4
1018	07311	3.0- 4.5	1.1	<0.8	<0.9	1.8	0.8	1.0	<0.6	1.1
1029	07407	13.5-15.0	0.6	0.5	<0.9	1.0	<0.6	<0.6	<0.6	0.6
1032	07504	15.0-16.5	1.0	0.6	<0.9	1.6	0.7	2.1	<0.6	1.3
1033	08854	1.5- 3.0	1.3	1.1	<1.3	1.6	1.3	1.2	<0.6	1.4
1072	08188	0.0- 1.5	1.5	1.0	3.6	4.8	0.9	3.4	<0.6	15.0
2008	08810	13.5-15.0	0.9	0.8	3.6	1.7	0.9	1.0	<0.6	0.9
2008	08827	55.0-56.5	0.6	<0.5	<0.9	1.5	<0.6	0.8	<0.6	0.8
2009	07073	4.5- 6.0	0.7	0.5	<0.9	1.5	<0.6	<0.6	<0.6	<0.6
2009	07087	53.0-54.5	0.5	0.3	<0.9	1.0	<0.6	1.0	<0.6	0.8
3034	08272	10.5-12.0	<0.3	<0.5	<0.9	0.9	0.6	0.6	<0.6	0.6
3034	08279	21.0-22.5	0.7	0.6	2.1	3.8	0.7	0.8	<0.6	0.9
3034	08295	95.0-96.5	0.6	<0.5	<0.9	0.7	<0.6	<0.6	<0.6	<0.6

Note: Data validation is currently in progress.

The presence of high concentrations of numerous radionuclides in the Silo 1 and 2 waste samples interfered with the quantification of actinium (Ac-227) and protactinium (Pa-231) concentrations in the Silo 1 and 2 waste samples. Therefore, the values of Ac-227 and Pa-231 in Silos 1 and 2 had to be estimated for use in the risk assessment. This interference was not a problem in Silo 3 waste samples because the concentrations of interfering radionuclides are lower in Silo 3 waste.

U-238 concentrations in the subsurface soils ranged from less than 0.6 to 15.0 pCi/g. Th-230 concentrations ranged from 0.7 to 4.9 pCi/g; Tc-99 from less than 0.9 to 3.9 pCi/g; and Ra-226 concentrations ranged from less than 0.3 to 1.5 pCi/g.

Only two samples were analyzed for the geochemical parameters of cation exchange capacity, total organic carbon, iron, manganese, and leachable iron-manganese. The results for the geochemical analyses are summarized in Table 4-11. An interpretation of the geochemical data is difficult because only these two data points are available for Operable Unit 4. However, considering the site-wide range of values for the geochemical parameters obtained during the RI, the two sets of data presented in Table 4-11 for the Operable Unit 4 study area appear to be consistent with values obtained at other locations around the FMPC.

4.5.2 Magnitude and Extent

The subsurface soil sample collected from Well 1072 at a depth interval of 0 to 18 inches contained 15.0 pCi/g of U-238, the highest concentration observed. This sample is actually more representative of surface soil. Typically, the subsurface soils contained radionuclide concentrations of less than 2.0 pCi/g.

These data indicate that contamination within the Operable Unit 4 study area is limited primarily to the surface. There does not appear to be any substantial migration of contamination from the surface through the vadose zone.

Based on these data, leakage does not appear to have occurred from the waste storage silos, or the leaked materials have not migrated far enough to have been encountered during the RI. This situation cannot be fully evaluated until the slant borings beneath the silos are completed.

The geochemical data indicate that there will be some retardation or attenuation of chemical movement through the vadose zone. The movement of any organic chemicals that might be present at the site would be retarded by the presence of organic carbon in the subsurface soils. Migration

TABLE 4-11

SUBSURFACE SOIL GEOCHEMICAL ANALYTICAL RESULTS (OPERABLE UNIT 4)

Well ID Number	Sample Depth (ft)	TOC[a] (ppm)	CEC[b] (meq/100g)	Fe (ppm)	Mn (ppm)
2009	38.5 - 40.0	3,900	2.8	6.2	1.8
3034	50.0 - 51.5	5,000[c]	2.9	9.4	2.8
Site wide	NA[d]	1400 - 16,000	1.5 - 26	4.6 - 92	1.1 - 8.3

[a]TOC = Total organic carbon; values represent three or more separate analyses.
[b]CEC = Cation exchange capacity.
[c]Value represented by the average of two analyses.
[d]Not applicable.
Note: Data validation is currently in progress.

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of radionuclides and other inorganics would be attenuated as a result of the ion-exchange capacity of the soils.

4.6 SURFACE WATER AND SEDIMENTS

4.6.1 Summary of Analytical Results

Surface water samples were collected during the RI at six selected locations along drainageways at points downstream from potential releases within the Operable Unit 4 study area (Figure 2-5). Samples from ASIT-10, -25, and -26 were analyzed for total uranium, Ra-226, Ra-228, and gross alpha and beta. Samples from ASIT-23 and -24 were analyzed for a full suite of radiological parameters.

Radium was below the detection limit in all the surface water samples (Table 4-12). A surface water sample from ASIT-10, which is the closest downstream location from the K-65 silos, contained 2219 µg/L of total uranium, the highest observed concentration for samples in the Operable Unit 4 study area; no radium was detected in this sample. The sample from ASIT-26, which is southwest of the Biodenitrification Surge Lagoon, contained 201 µg/L of total uranium. Sampling location W-5 on Paddys Run is considered to be a background location and contained 2 µg/L of total uranium. W-10, downstream from the K-65 silos on Paddys Run, contained total uranium concentrations ranging from 5 to 12 µg/L. Tc-99 was present in a sample collected at ASIT-24 at 36.9 pCi/L. Tc-99 is a fission product and is not likely to have originated from the silo contents because materials associated with spent nuclear fuel were not added to the silo contents. Appendix C contains the complete analytical results for surface water and sediment samples.

DOE Order 5400.5 sets guidelines, which are now in effect for the FMPC, for the discharge of radionuclides. Concentrations established from these guidelines are called Derived Concentration Guides (DCGs). The DCG is the concentration of a radionuclide in air or water (in this case water) that, under conditions of exposure for one year by one exposure mode (i.e., ingestion of water), would result in an effective dose equivalent of 100 mrem. The relevant DCGs for radionuclides observed in surface water within the Operable Unit 4 study area are presented in Table 4-12. All of the reported results are well below their respective DCGs.

Two rounds of sediment samples from Paddys Run have been analyzed; the results of the analyses summarized in Table 4-13 reveal a maximum total uranium concentration of 3 ppm. Appendix C

TABLE 4-12

SURFACE WATER SAMPLE ANALYSIS RESULTS WITHIN OPERABLE UNIT 4 AREA

Sample Location	Sample ID	Analytical Results (pCi/l) Ra-226	Th-230	Th-232	U-234	U-235/236	U-238	U-TOTAL (µg/L)
DCGs		30	300	50	500	600	600	-
Background		<0.5	1.2	-	1.2	0.02	1.0	3.0
ASIT-10	01047	<1.0	NA	NA	NA	NA	NA	2199.0
ASIT-10	01117	<1.0	NA	NA	NA	NA	NA	282.0
ASIT-10	01118[a]	<1.0	NA	NA	NA	NA	NA	231.0
ASIT-23	01150	<1.0	<1.0	<1.0	80.3	4.9	165	465.0
ASIT-23	01151[a]	<1.0	<1.0	<1.0	76.9	6.0	165.0	433.0
ASIT-24	01152	<1.0	<1.0	<1.0	86.4	6.7	205.0	517.0
ASIT-24	01153[a]	<1.0	<1.0	<1.0	85.8	6.7	195.0	576.0
ASIT-25	01114	<1.0	NA	NA	NA	NA	NA	247.0
ASIT-26	01115	<1.0	NA	NA	NA	NA	NA	216.0
ASIT-26	01116[a]	<1.0	NA	NA	NA	NA	NA	201.0
W-10	01108	<1.0	<1.0	<1.0	2.7	<1.0	4.8	12.0
W-10	01216	<1.0	<1.0	<1.0	1.2	<1.0	4.5	25.0
W-10	01217[a]	<1.0	<1.0	<1.0	1.3	<1.0	2.0	5.0
W-11	01107	<1.0	<1.0	<1.0	3.2	<1.0	6.8	19.0
W-11	01209	<1.0	<1.0	<1.0	2.5	<1.0	2.6	9.0

DCGs = Derived Concentration Guides are DOE standards for discharge of radionuclides
NA = Not Analyzed
[a]Duplicate sample
Note: Data validation is currently in progress.

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TABLE 4-13

SEDIMENT SAMPLE ANALYSIS RESULTS WITHIN OPERABLE UNIT 4 AREA

		Analytical Results (pCi/g)			Analytical Results (ppm)			
	Sample ID	Ra-226	Ra-228	U-Total[a]	Al	Ca	Fe	Mg
Background		0.7	0.7	-	57.000	6300	25,000	4600
ASIT-10	09050	0.7	0.9	30.3	5460	25,200	10,000	8580
W-5	09036	0.4	<0.5	3.0	NA	NA	NA	NA
W-5	09146	NA	NA	NA	1970	25,900	6700	18,700
W-5	09149	0.4	<0.5	1.0	NA	NA	NA	NA
W-10	09038	0.9	<0.5	3.0	NA	NA	NA	NA
W-10	09147	NA	NA	NA	3920	78,700	8830	18,300
W-10	09153	1.0	<0.5	1.0	NA	NA	NA	NA
W-11	09037	0.5	<0.5	2.0	NA	NA	NA	NA
W-11	09145	NA	NA	NA	2080	110,000	5940	26,600
W-11	09155	0.6	<0.5	<1.0	NA	NA	NA	NA

NA = Not analyzed.
[a]Parts per million (ppm).
Note: Data validation is currently in progress.

provides the full range of analytical results. ASIT-10 is the only location where a sediment sample was collected along a drainageway within Operable Unit 4. This sample was analyzed for radionuclides and HSL constituents. The sample contained a total uranium concentration of 30.3 ppm and 2.37 ppm of radium. Because the bedrock in this area is calcareous shale and limestone, the metals calcium, magnesium, aluminum, and iron were present in concentrations of 110,000 ppm, 26,600 ppm, 5460 ppm, and 10,000 ppm, respectively. These are all typical values corresponding to regional background concentrations. No volatile organics or PCBs were detected in the sediments within the Operable Unit 4 study area.

Sediment sampling conducted as part of the WMCO environmental monitoring program is summarized in environmental monitoring reports (WMCO 1988; WMCO 1989b). Sediment samples were collected every 100 meters (328 feet) in Paddys Run upstream of the confluence with the Storm Sewer Outfall Ditch (SSOD), every 200 meters (656 feet) in Paddys Run between the SSOD and the Great Miami River, and every 100 meters in the SSOD. Three samples were collected from each location; at each bank and at the center of the stream bed. Samples were analyzed for isotopes of uranium, thorium, radium, plutonium, and Tc-99. Analytical results are summarized in the WMCO Environmental Monitoring Reports (WMCO 1988; WMCO 1989b). In 1987 and 1988, above-background concentrations of uranium, thorium, and radium were detected in sediment samples from the SSOD. Uranium, thorium, and radium concentrations detected in sediment samples from Paddys Run were determined to be representative of background (WMCO 1988; WMCO 1989b).

4.6.2 Magnitude and Extent

The water and sediment samples at ASIT-10 showed the maximum total uranium concentration of 2199 µg/L and 30.3 ppm, respectively. Two rounds of sediment sampling from Paddys Run show an average concentration of 2.0 ppm at locations W-5 and W-10. Very low to nondetectable concentrations of radium were found in both the sediment and water samples.

A review of the analytical data on surface water runoff within the waste pit area, which lies approximately 800 to 1000 feet north of the K-65 silos and Silo 3, reveals a high degree of variability in concentration patterns. Three samples collected at locations in the waste pit area are consistently contaminated with uranium concentrations as high as 2840 pCi/g for U-238 (ASI/IT 1990d).

Runoff from the waste pits is a large enough problem that a storm water runoff removal action has been initiated. This removal action will result in the collection and treatment of runoff from the Waste Storage Area, which includes the pits and the waste storage silos. The persistence of the current problem of runoff leaving the waste pit area provides support to the conclusion that contamination observed in surface water and sediments within the Operable Unit 4 study area may have originated from the waste pit area. Historical information for the FMPC also shows that potentially contaminated storm water runoff originating in the Pilot Plant area flowed through drainageways lying within the Operable Unit 4 study area before discharging to Paddys Run. Regardless of the source of contamination, the planned removal action will control any future spread of contamination by storm water runoff.

4.7 GROUNDWATER

4.7.1 Groundwater Flow

Groundwater at the FMPC is present as perched water in potentially interconnected permeable zones within the glacial overburden and within the Great Miami Aquifer. The glacial overburden is composed of dense, silty clay that varies in composition vertically and laterally. The silty clay contains lenses of poorly sorted fine- to medium-grained sand and gravel, silty sand, and silt with layers of silty clay.

Water level measurements from Operable Unit 4 monitoring wells have been provided in Appendix D. Data sets for winter, spring, summer, and fall were chosen to represent groundwater flow conditions across the site. Water levels were plotted to generate groundwater contour maps for the entire site. Only the portion of these maps that covers the Operable Unit 4 study area is presented for local view of groundwater flow within the glacial overburden (1000-series wells, Figure 4-9) at the water table within the Great Miami Aquifer (2000-series wells, Figure 4-10), and at approximately the central part of the Great Miami Aquifer just above the clay interbed (3000-series wells). The water table map (Figure 4-9) for the glacial overburden indicates that the hydraulic gradient generally slopes from northeast to southwest, based on the assumption that the perched groundwater beneath the Operable Unit 4 study area is continuous. Surface drainage is also to the west, and many drainage channels act as local discharge points from the glacial overburden. Paddys Run flows along the western side of the FMPC and has eroded through the glacial overburden to the upper point of the Great Miami Aquifer, intercepting all westward groundwater

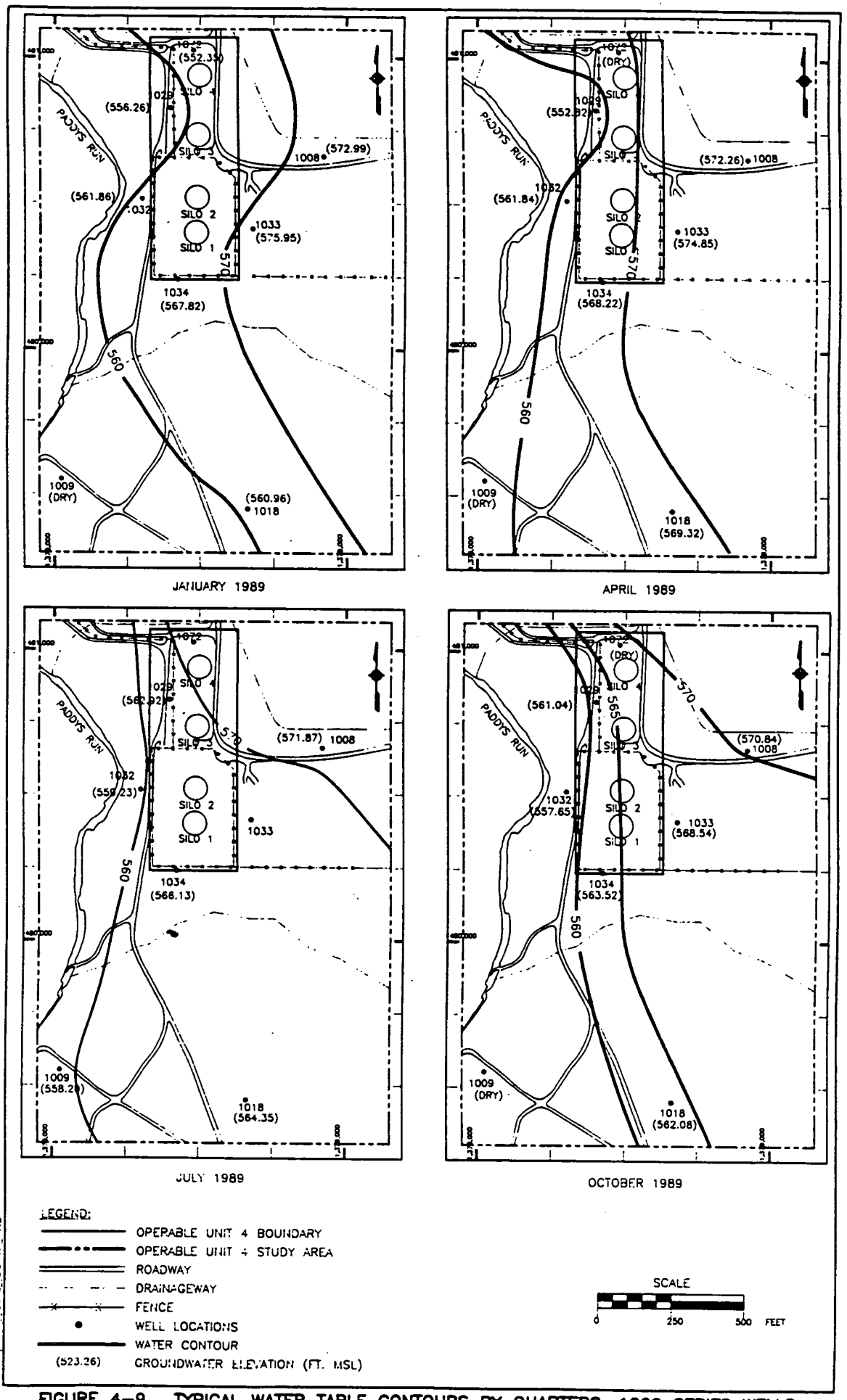

FIGURE 4-9. TYPICAL WATER TABLE CONTOURS BY QUARTERS, 1000 SERIES WELLS

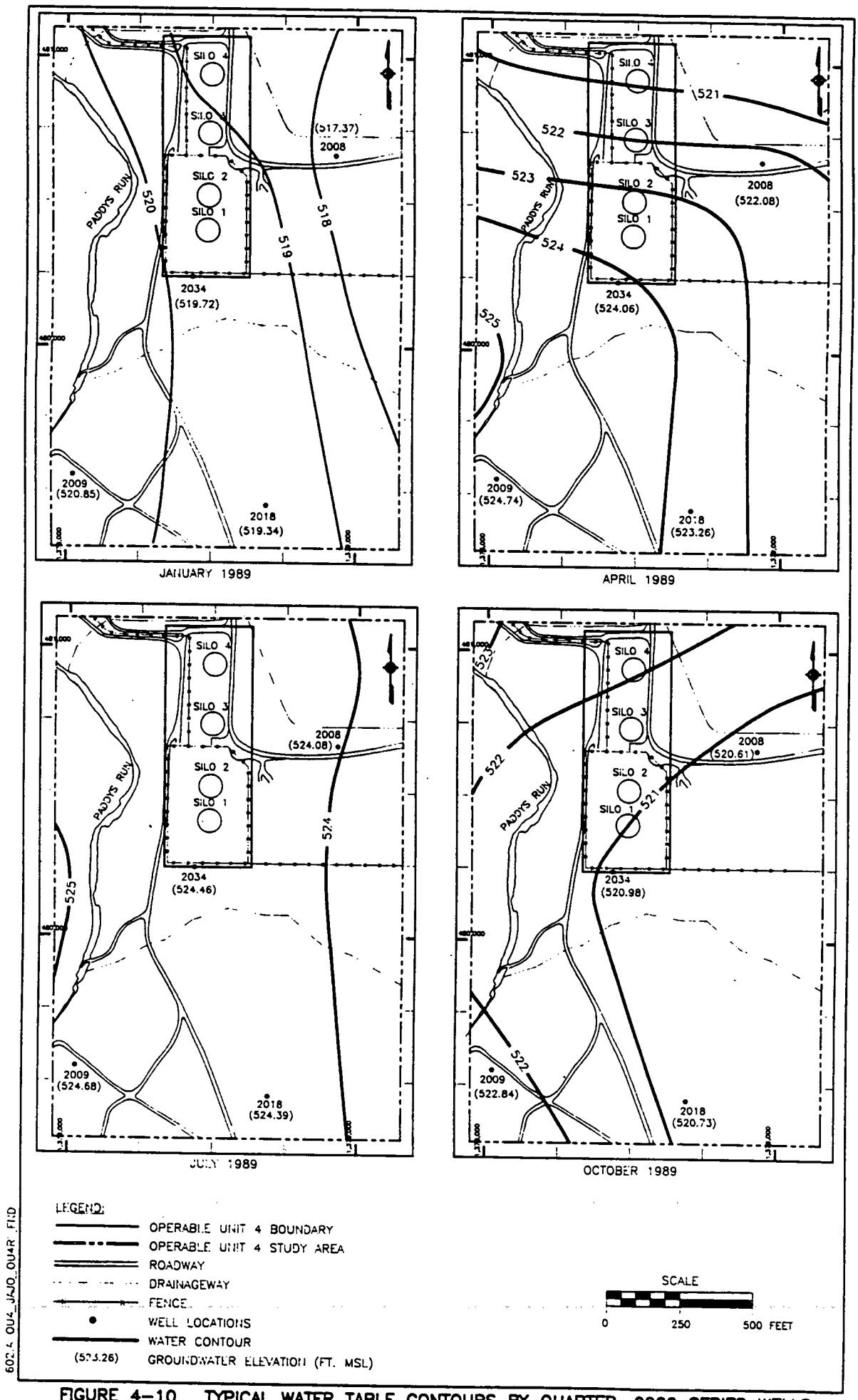

FIGURE 4-10. TYPICAL WATER TABLE CONTOURS BY QUARTER, 2000 SERIES WELLS

flow within the glacial overburden. In the area of the K-65 silos, the hydraulic gradient slopes westward to Paddys Run. Thus, any leakage of material from the silos might be detected in Well 1032.

Groundwater flow in the Great Miami Aquifer under the K-65 silos is generally from west to east (Figure 4-9) with a gradient of approximately 1 foot per 1000 feet. Paddys Run, located immediately west of the silos, is a dry stream bed for most of the year; however, from January through May, there can be sufficient rainfall to generate flow in Paddys Run. When there is flow, there is also a significant amount of infiltration from the creek into the Great Miami Aquifer. The area where infiltration is known to occur begins at a point north of Silo 4 and extends to the south along the length of Paddys Run. The impact of this recharge on the water table under the K-65 silos is not completely documented; however, it is clear that the gradient for the eastward flow can increase to 3 feet per 1000 feet in the immediate vicinity of Paddys Run. The mounding from the recharge can also alter the direction of the local flow from east to northeast for short periods of time. Therefore, any leakage from the silos into the glacial overburden could migrate to the west into Paddys Run, then down into the Great Miami Aquifer, and back to the east with the regional flow.

The 3000- and 4000-series wells are screened in the same Great Miami Aquifer unit as the 2000-series; therefore, the hydraulic gradient for these wells will be the same as for the 2000-series wells. For this reason groundwater elevation maps were not prepared for the 3000- and 4000-series wells. The discussion of hydrogeology in the Great Miami Aquifer is relevant to the 3000-series wells.

4.7.2 Summary of Analytical Results

The complete set of analytical data for the wells within the Operable Unit 4 study area are presented in Appendix D. Table 4-14 lists the categories of parameters analyzed for samples from each of the 1000-, 2000-, and 3000-series monitoring wells in the Operable Unit 4 study area. As noted in Table 4-14, not all parameters were analyzed for each round of sampling. The parameters composing the HSL were analyzed only for select wells to provide an indication of potential chemical contamination and to confirm the findings of the ongoing RCRA groundwater monitoring program at the FMPC.

The detected chemical/radiological parameters from all four sampling rounds and their concentration ranges are presented in Table 4-15. Each of these parameters was detected in one or more rounds of sampling and analysis. Of the detected parameters listed in Table 4-15, the radiological

TABLE 4-14

CATEGORIES OF ANALYTICAL PARAMETERS SPECIFIED FOR MONITORING WELLS AT OPERABLE UNIT 4

	Installed By	Radiological Parameters	Hazardous Substance List	Metals
1000 Series				
1029	ASI/IT[a]	X[b]	X	X
1008	ASI/IT	X		X
1018	ASI/IT	X		X
1032	ASI/IT	X		X
1033	ASI/IT	X		X
1034	ASI/IT	X		X
1009[c]	ASI/IT			
1072[c]	ASI/IT			
2000 Series				
2008	ASI/IT	X	X	X
2009	ASI/IT	X		X
2018	D&M[d]	X		X
2034	ASI/IT	X	X	X
3000 Series				
3005	NLO[e]	X		X
3009	NLO	X		X
3018	D&M	X		X
3034	ASI/IT	X		X

[a]ASI/IT - Advanced Science Inc./IT Corporation (RI/FS Program)
[b]X - Analyses required
[c]Dry wells
[d]D&M - Dames and Moore
[e]NLO - National Lead Company of Ohio

TABLE 4-15
DETECTED PARAMETERS AND THEIR RANGE VALUES FOR EACH SERIES OF MONITORING WELLS AT OPERABLE UNIT 4

	Rounds 1 to 4		
Analyte	1000-Series Wells	2000-Series Wells	3000-Series Wells
Barium (ppm)	ND - 0.373	ND - 0.049	ND - 0.07
Calcium (ppm)	74.1 - 233	75.0 - 108	34.4 - 110
Chloride (ppm)	0.5 - 616	3.0 - 51.0	9.9 - 333
Fluoride (ppm)	ND - 1.5	ND - 1.3	ND - 0.98
Iron (ppm)	ND - 0.94	ND - 1.12	ND - 19.2
Magnesium (ppm)	25.9 - 68.2	18.4 - 234	0.5 - 32.0
Manganese (ppm)	0.009 - 0.278	ND - 0.105	ND - 0.572
Molybdenum (ppm)	ND - 0.043	ND	ND
Nitrates (ppm)	ND - 1.4	ND - 11.8	ND - 9.98
Phenols (ppm)	ND - 0.04	ND - 0.22	ND - 0.096
Phosphorus (ppm)	0.024 - 0.6	ND - 523	ND - 555
Potassium (ppm)	ND - 7.63	ND - 2.84	ND - 6.0
Sodium (ppm)	3.82 - 282	5.34 - 18.0	5.4 - 29.6
Sulfate (ppm)	11.0 - 375	4.0 - 131	ND - 126
Total Organic Nitrogen (ppm)	ND - 15.0	ND - 15.0	ND - 1.2
U-234 (pCi/L)	ND - 84.9	ND - 9.1	ND - 3.7
U-238 (pCi/L)	ND - 96.8	ND - 9.3	ND - 2.3
Total U (μg/L)	ND - 276	ND - 27.0	ND - 10.0

ND = Not Detected
Note: Data validation is currently in progress

parameters are of particular significance because these are representative of FMPC operations. The only consistently detected radiological parameters in the wells surrounding Operable Unit 4 were U-238 and U-234 as well as total uranium. The remaining detected parameters are elements found to be naturally occurring in these types of aquifer media. The magnitude of these parameters is within the expected range of background concentrations. These data were evaluated as part of the risk assessment, supporting the conclusion that uranium is the primary chemical of potential concern.

Because total uranium is a composite of all uranium isotopes, the focus of the remaining discussion will be directed toward the distribution of the total uranium at Operable Unit 4 to provide an indication of the source of radiological contamination.

4.7.3 Magnitude and Extent

Maps that present the distribution of total uranium were prepared for one round of sampling conducted during the second quarter of 1988 for each series of monitoring wells. These maps (Figures 4-11 through 4-13) were prepared to aid in the examination of the distribution of total uranium in the 1000-, 2000-, and 3000-series wells. Data collected for each series of wells subsequent to the second quarter of 1988 are summarized in Table 4-16. Only one representative figure for each series of wells is presented. The values presented on these maps and Table 4-16 may be compared to site background values that range from <1 to 2 ± 1 μg/L for total uranium.

Glacial Overburden - 1000-Series Monitoring Wells

Figure 4-10 presents the distribution of total uranium in the 1000-series wells in the glacial overburden within the Operable Unit 4 study area for the second quarter of 1988. This distribution pattern indicates that the highest concentration of uranium is on the west side of the K-65 silos.

Monitoring Well 1032, which is downgradient of Operable Unit 4, contains the highest concentration of total uranium in the 1000-series wells. Total uranium levels in Well 1032 may be attributable to leakage from the silos. However, Well 1032 is also located near a former construction rubble pile where construction debris, including fill material similar in appearance to the native soils, was dumped. The boring log for Well 1032 does not show a distinct difference between the fill and the native material because both are from the glacial overburden. The site for Well 1032 was leveled by a bulldozer thus smoothing the obvious dump truck loads of material on the surface. The obvious debris was mostly removed before drilling; however, the material resembling native soils is believed to have remained. The fill material was penetrated during the drilling process, and the well appears to be partially screened in the disturbed zone. Additional

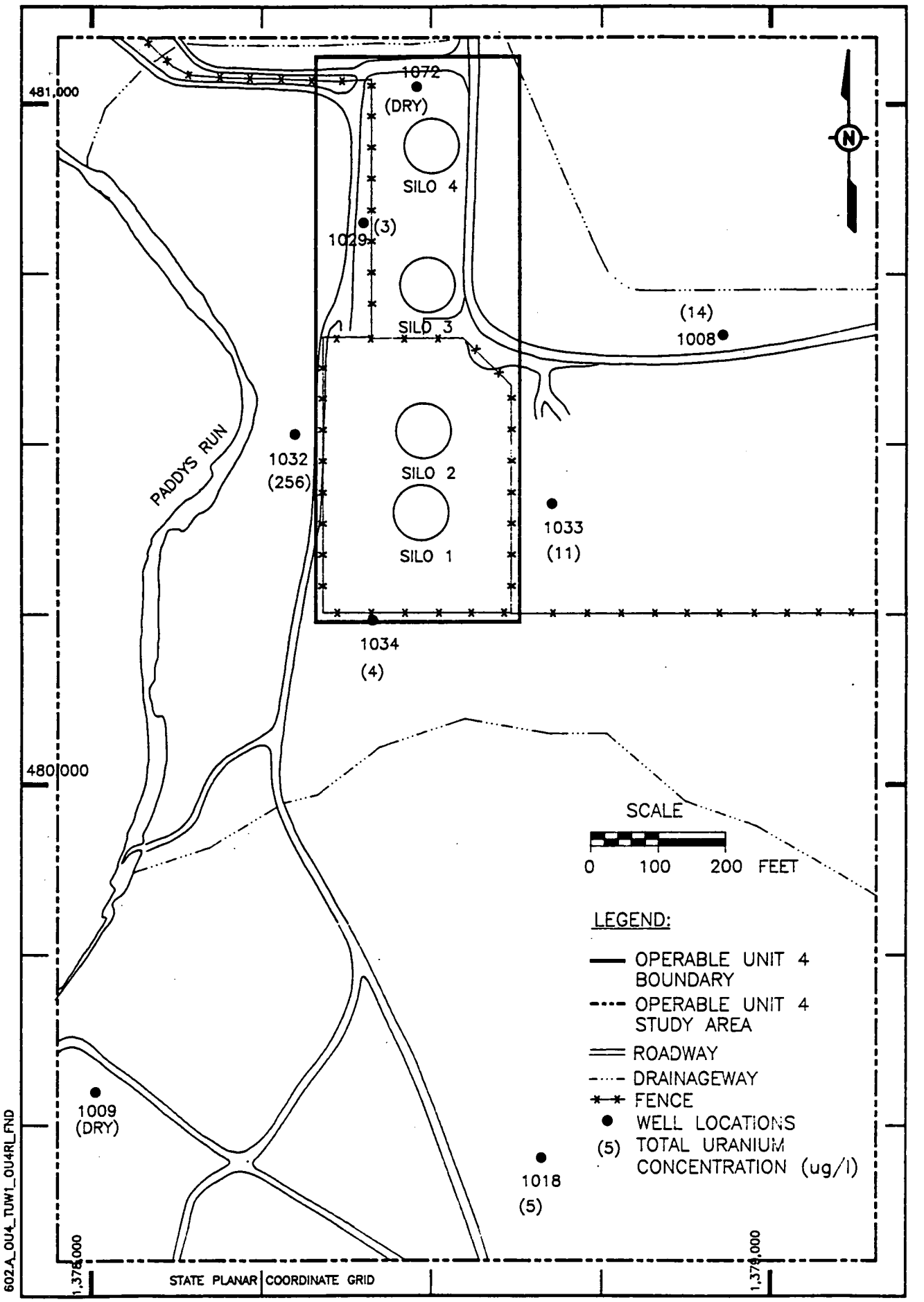

FIGURE 4–11. TOTAL URANIUM CONCENTRATION IN 1000 SERIES WELLS, SECOND QUARTER 1988

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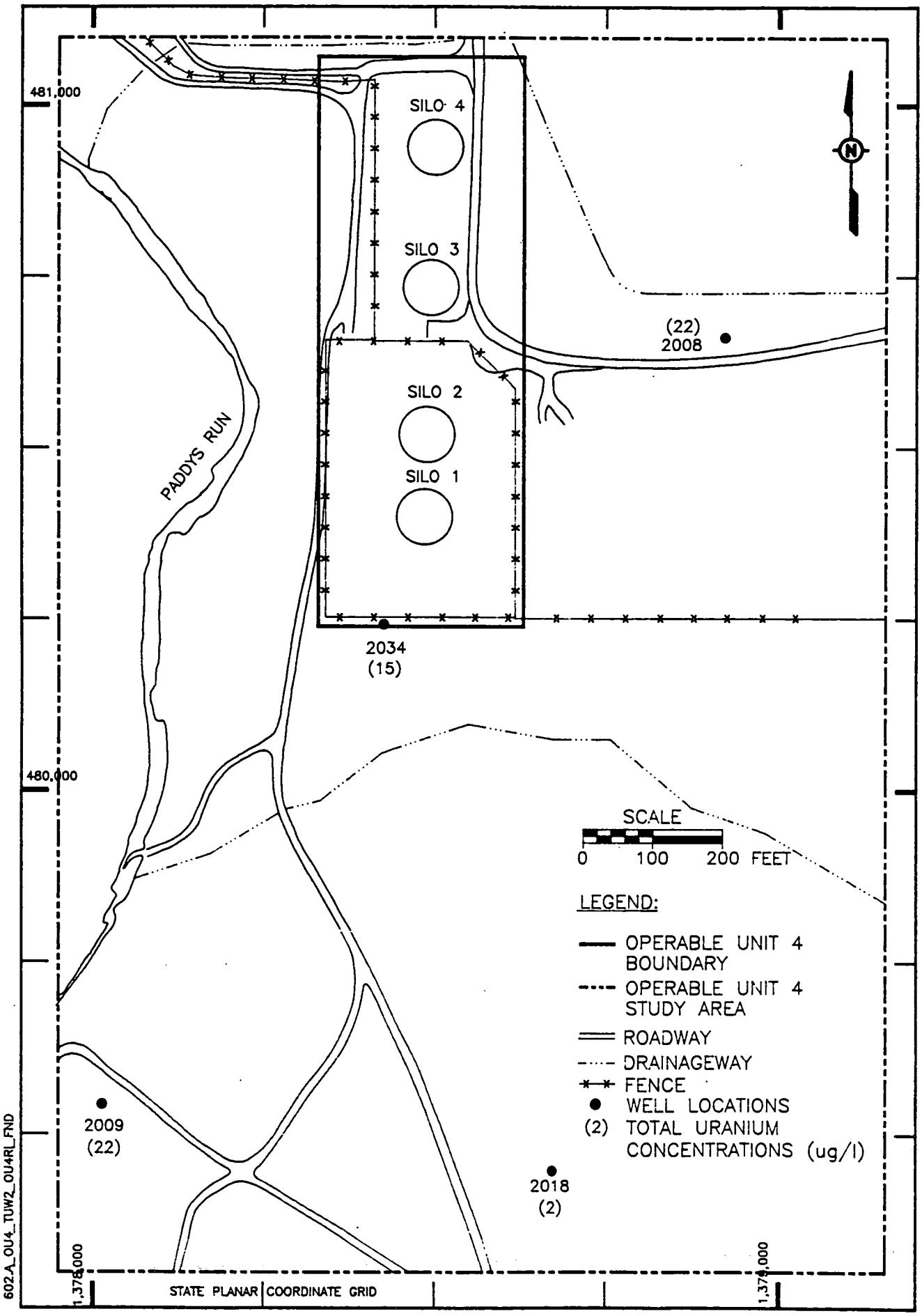

FIGURE 4–12. TOTAL URANIUM CONCENTRATION IN 2000 SERIES WELLS, SECOND QUARTER 1988

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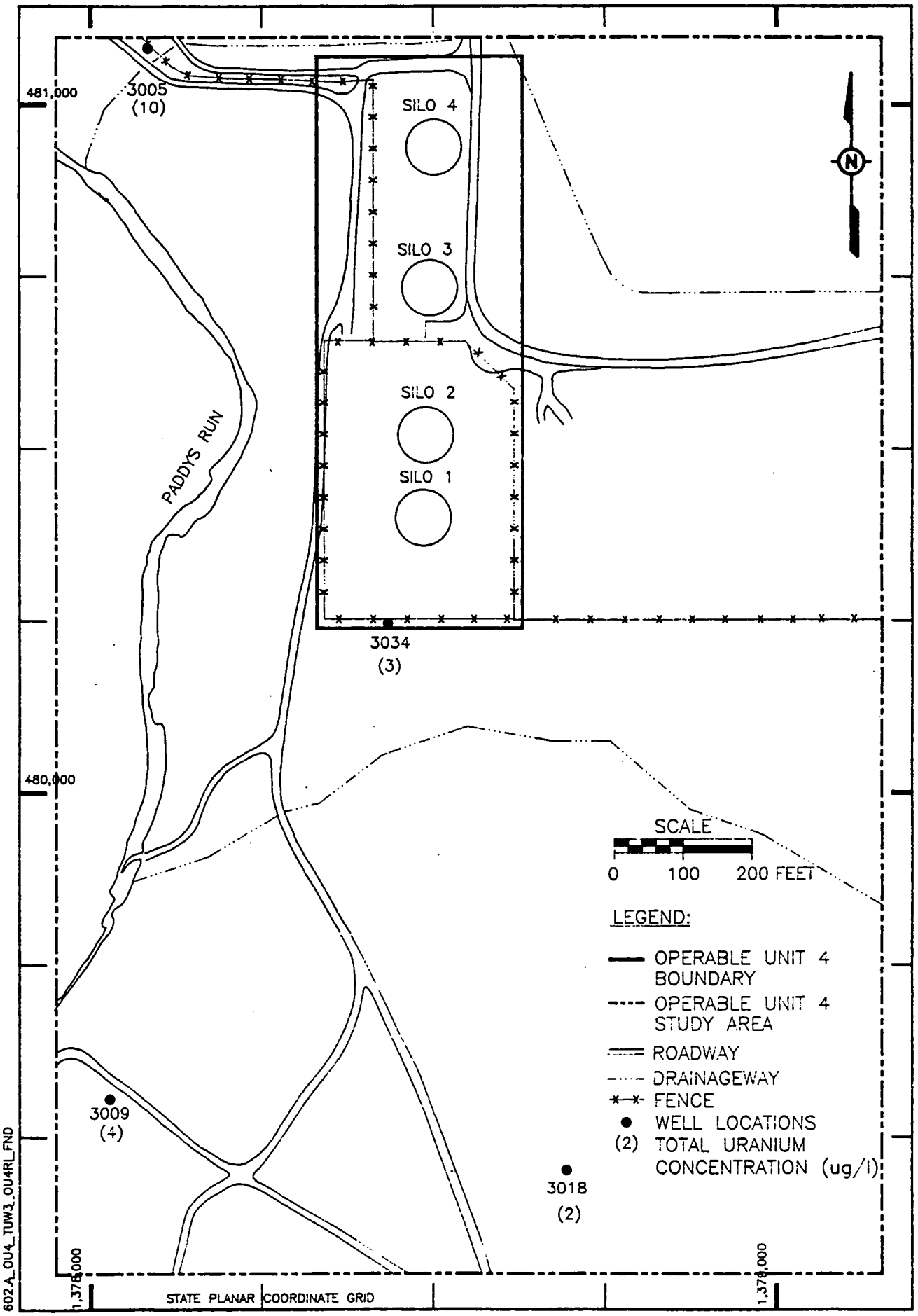

FIGURE 4–13. TOTAL URANIUM CONCENTRATION IN 3000 SERIES WELLS, SECOND QUARTER 1988

TABLE 4-16

TOTAL URANIUM CONCENTRATION IN GROUNDWATER (ug/L)

Well No.	2nd Quarter 1988	3rd Quarter 1988	4th Quarter 1988	1st Quarter 1989
1008	14	13	6	6
1009[a]	--	--	--	--
1018	5	4	3	4
1029	3	3	2	3
1032	256	196	230	276
1033	11	9	15	23
1034	4	10	7	3
1072[a]	--	--	--	--
2008	22	16	25	5
2009	22	19	24	27
2018	2	<1	3	4
2034	15	24	24	19
3005	10	3	4	3
3009	4	2	2	3
3018	2	2	1	2
3034	3	1	<1	<1

[a]Dry well or insufficient water for sample collection

Note: Data validation is currently in progress

research revealed that this construction debris and rubble originated from demolition of plant operation buildings and was deposited adjacent to Operable Unit 4 to prevent further erosion of the banks of Paddys Run which threatened to undermine the silos. It is not known if the construction debris contained uranium residues. Furthermore, trenching under the RI for Operable Unit 3 fifty south of Well 1032 indicated that fill exists to a depth of four feet. Soil samples from this trench indicate total uranium values of 2200 to 11,100 ppb. This information will be documented in the Operable Unit 3 RI.

The interpretation of data from Well 1032 is further complicated by the fact that Ra-226, which can be the tracer element for the materials in the silos, is not detected in all the sampling rounds. Radium is a major constituent of the waste stored in the silos, but is not seen in samples of the nearby environmental media. This may be attributable to the very low solubility of the form of Ra-226 in the silos (radium sulfate). Radium sulfate is not as soluble as the uranium compounds and would require a longer time to leach from the silo residues, assuming there is a mechanism and pathway for this to occur. The absence of Ra-226 in groundwater samples and data from surface and subsurface soil samples suggests that radium is presently not a contaminant of concern outside the silos. It cannot be confirmed that radium is absent from the study area until slant borings below the silos are completed. On the other hand, U-238 is present in virtually every soil sample. The presence of U-238 is not strong evidence that indicates the silos as the source because uranium could be from another source such as the waste pits. The construction rubble pile near Well 1032 will be addressed as a suspect area under Operable Unit 3.

Nonradiologic compounds such as chloride, sulfate, calcium, and sodium are found in elevated concentrations in Well 1032 than background levels. These materials or compounds are not unique to the silos; therefore any conclusion that points to the silos as the source may not be accurate. Well 1032 is in an area covered with fill from the production area and is adjacent to a road used year-round where deicing materials such as salt may be used. Until the slant borings are drilled under the silos, there will not be any definite answers as to whether the silos leak or not.

Great Miami Aquifer - 2000-Series Monitoring Wells

Uncertainty also exists as to whether Operable Unit 4 is a source of radiological contamination in the Great Miami Aquifer. A possible mechanism for contamination originating from Operable Unit 4 to reach the Great Miami Aquifer via Paddys Run is described in Section 4.7.1. This mechanism of contaminant transport will be fully evaluated as part of Operable Unit 5. Also direct vertical percolation of contaminated groundwater can impact the water quality in the Great Miami Aquifer.

Figure 4-12 presents the total uranium distributions at the water table of the Great Miami Aquifer for the second quarter of 1988. Groundwater flow within the Great Miami Aquifer is primarily toward the east, varying seasonally.

Compared to typical background levels of total uranium of <1 to 2 ± 1 µg/L, elevated levels of total uranium appear in Wells 2008 and 2009. Well 2008 is directly downgradient of Operable Unit 4 Well 2009 is upgradient. The total uranium levels in both wells may be related to other sources, such as Paddys Run for Well 2009 and the waste pits and ponds area for Well 2008. Well 2034, which is directly adjacent to but not downgradient of Operable Unit 4, also contains levels of total uranium that are comparable to those observed in Wells 2008 and 2009. Well 2034 contains uranium above background concentrations, and its proximity to Operable Unit 4 would indicate that the silos are a possible source of the uranium contamination within the Operable Unit 4 study area. However, the observation that uranium concentrations are similar in Wells 2008 and 2009, which represent both downgradient and upgradient conditions, is not conclusive with respect to identifying Operable Unit 4 as a source.

To resolve the uncertainty concerning the source of the uranium that is present in samples from the Great Miami Aquifer, two new 2000-series wells, Wells 2032 and 2033, were installed. Well 2032 was installed on the west side of the silos in February 1990. Well 2033 was installed on the east side of the silos in June 1990 and will be developed and sampled before the end of the month. The soil samples collected during the drilling activities are being analyzed for radiological and chemical contents. These wells were placed adjacent to the corresponding 1000-series wells to allow monitoring of any downward movement of uranium into the Great Miami Aquifer. Analysis of samples from these wells should help determine if the silos are contributing to the groundwater contamination in the Operable Unit 4 study area.

Great Miami Aquifer - 3000-Series Monitoring Wells

Figure 4-13 shows the distribution of total uranium in the 3000-series wells for the second quarter of 1988. The concentration of uranium in these wells is significantly lower than in the 1000- and 2000-series wells (Table 4-16). Total uranium is below 4 µg/L in all the wells except Well 3005, which contained 10 µg/L during the second quarter of 1988. The uranium concentration in the 3000-series wells in the Operable Unit 4 study area are within background ranges. However, Well 3005 shows uranium from three sampling rounds to be ranging between 3 and 4 µg/L which is slightly above but close to typical background ranges (<1 to 2 ± 1 µg/L). This well indicates the

presence of some contamination in the Great Miami Aquifer which will be fully evaluated in the Operable Unit 5 RI.

4.8 BIOLOGICAL RESOURCES

Data on radionuclide uptake by biota within the actual boundaries of Operable Unit 4 are not available. Collected environmental media data, such as the 1986 milk sampling data, cannot be related directly to Operable Unit 4. However, facility-wide data can be evaluated to draw limited conclusions. Site PR-3, adjacent to Operable Unit 4 (Figure 2-8) and lying within the Operable Unit 4 study area, was sampled for radionuclide uptake by macroinvertebrates and fish. A crayfish sample contained 5.1 pCi/g of total uranium; concentrations of Cs-137 and Sr-90 were below detection limits. Radionuclides were not detected in fish collected from this site (ASI/IT 1990c). Uranium concentrations in macroinvertebrates from three other sites outside the Operable Unit 4 study area on Paddys Run ranged from below detection limits of (1.8 pCi/g) at Site PR-1 at the northern boundary of the FMPC, to 6.4 pCi/g at Site PR-2 at the junction of Paddys Run and the C&O railroad line. Uranium concentrations in fish from Paddys Run ranged from below detection limits of 1.8 pCi/g to 3.7 pCi/g in a bluegill sample from Site PR-4, just above the confluence of Paddys Run and the Great Miami River. Specific details of the site-wide study of biological resources conducted for the RI/FS are available in the biological resources sampling and analysis report (ASI/IT 1990c). A thorough discussion of the biological resources will be conducted in the Operable Unit 5 RI Report as well.

5.0 CONTAMINANT TRANSPORT

Section 4.0 focuses on the nature and extent of chemical and radiological contamination within the Operable Unit 4 study area. This section identifies the potential transport mechanisms for the constituents of concern. The principal contaminants associated with Operable Unit 4 are long half-life radionuclides, their short-lived progeny, and stable decay products. Currently, uranium is the primary site-related chemical of concern. Other radionuclides and chemicals contained in the silo residues could become potential hazards if it is found that the silos are leaking. Uranium represents both a radiological and a chemical hazard. Lead, another major constituent of the silo residues, possesses the characteristic of "heavy-metal" toxicity. The chemical toxicity of both uranium and lead are addressed in the Operable Unit 4 Baseline Risk Assessment (Appendix E).

The radiological characteristics associated with most radionuclides generally present a greater hazard than the toxic characteristics. At occupational exposure levels, the chemical toxicity of uranium exceeds its radiotoxicity. However, at the levels encountered in the Operable Unit 4 Risk Assessment, the radiological characteristics control the hazard because the environmental concentrations are below the uranium toxicity threshold. Unlike many organic compounds, the constituents of concern for Operable Unit 4 do not degrade into less toxic compounds. However, they do undergo transformation by radioactive decay that will ultimately reduce their activity concentration. The rate of decay is expressed as the "half-life" of the radionuclide. Radioactive decay of a radionuclide is an exponential process, but the rate constant for this process is readily obtained from the "half-life," which is a measure of the time required for the decay of exactly one-half of the atoms initially present to undergo radioactive decay.

The radionuclides of concern for Operable Unit 4 have varying half-lives and may undergo a series of decays to ultimately become stable elements, such as lead. The most prevalent radionuclides within the Operable Unit 4 study area are the isotopes of uranium, radium, thorium, and their progeny. The progeny of concern, Rn-222 and its short-lived decay products, are in equilibrium with Ra-226. The inventory of these progeny are controlled by the decay rate of Ra-226. The half-life of Ra-226 is 1600 years. The half-lives of the uranium and thorium isotopes of concern in Operable Unit 4 are even longer. For all practical purposes, the radioactivity associated with radionuclides present in Operable Unit 4 can be considered constant. Under baseline conditions, they will persist at current levels for hundreds of years.

When released from the residues within the waste storage silos, the radionuclides from the Operable Unit 4 study area can contaminate the environment of the FMPC, or pose a direct hazard to

potential receptors. As a result, the radiological hazard can be direct, such as exposure to the gamma radiation from radionuclides contained in the silo domes, or the hazard may be attributable to contaminant transport through environmental media such as air, soils, surface water, or groundwater. The mechanisms for this transport from the silos to potential receptors are detailed and applied in the Operable Unit 4 Baseline Risk Assessment (Appendix E).

A wide range of environmental media and potential exposure pathways were considered in the Operable Unit 4 Baseline Risk Assessment. These pathways include three major exposure categories:

- Direct exposure
- Inhalation
- Ingestion

Four fundamental conditions must be met for any exposure pathway to exist. Each pathway must have:

- A source of contamination
- A mechanism for transporting the contaminant through an environmental medium to a point of exposure
- A potential receptor at the location of the exposure
- A route of exposure

The exposure pathways that potentially satisfied all of these conditions are listed in Table E.3-1 of Appendix E. As noted in Table E.3-1, some of these pathways were discarded after screening calculations and evaluations indicated that contributions were very low and would not contribute to an RME scenerio. The four remaining pathways that are quanitified in the exposure assessment are discussed below.

As discussed in the Operable Unit 4 Baseline Risk Assessment, contaminant transport from Operable Unit 4 is via the following exposure pathways:

- Direct exposure to gamma radiation from radioactive constituents within the silo domes

- Inhalation of radon that escapes from the K-65 silos and is dispersed by the air

- Ingestion of contaminated soils that have eroded into Paddys Run from the vicinity of the silos

- Ingestion of groundwater containing contaminants that may leach from silos via soils to underlying groundwater

The first two are existing pathways that will not change under baseline conditions for Operable Unit 4. The third is a minor potential pathway that may decrease further in importance as a result of the pending removal action to control and collect surface water runoff in the Waste Storage Area of the FMPC. The fourth is not known to be a current contributor to environmental exposure but could be a major source of transport and exposure in the future.

In addition, after termination of security control measures, the exposure pathways from residential and agricultural use of the area immediately adjacent to Operable Unit 4 will be evaluated.

Each of these potential contaminant transport pathways is discussed below. The reader should refer to the baseline risk assessment for additional information about each of these pathways, the associated transport mechanisms, and the impact on environmental media or receptors.

5.1 DIRECT RADIATION

A major contaminant transport mechanism for Operable Unit 4 is gamma radiation from the K-65 residues. This radiation is transported as electromagnetic waves, thus requiring no transport media. As the distance from the K-65 silos increases, the magnitude of the radiation's intensity decreases. The soil embankment around the silos provides shielding from the direct gamma radiation. Therefore, as long as the integrity of this embankment and the silos is maintained, there should be no change or increase in direct radiation exposure due to this pathway.

Note that although the risk assessment provides some discussion of penetrating radiation fields pertinent to Operable Unit 4, it does not discuss walkover ground survey data or present radiation contour zones. Contour plots centered on the silos would reveal that, in general, the radiation field strength decreases with increasing distance from the silos. In the vicinity of the silos, the penetrating radiation field strength from the surface soil contamination would be expected to be dominated by the radiation field strength from the silos themselves. However, considering the source strength of the silos, there is little benefit in developing detailed dose rate contour plots close to the silos from a risk assessment perspective. Text providing details concerning the quantification of potential exposure from direct radiation can be found in the baseline risk assessment (Appendix E).

5.2 AIR EMISSIONS

Rn-222 generated by the radioactive decay of Ra-226 in the K-65 residues accumulates in the void space inside the silos. At the time of their design, the K-65 silos did not need to be airtight; therefore, air exchanges with the outside environment occurs. The air exchange is a result of

changes in ambient temperatures that cause expansion and contraction of the air mass inside the silos (Grumski 1987). The foam installed on top of the K-65 silos in 1987 is thought to have reduced the silo breathing losses by limiting daily temperature variations inside the silo dome. In addition to direct release to the atmosphere, radon gas can also diffuse through the K-65 silo walls into the surrounding embankment. Radon has a short half-life (3.82 days) and is expected to decay into its daughter products, Pb-210 and Po-210, in the silo walls and in the soil embankments. These are nonvolatile products that have half-lives long enough to allow them to accumulate in the soil embankments. As discussed in Section 2.0, the K-65 silo embankment and sampling program will address sampling for lead and polonium in the soil embankments.

Accumulation of radon progeny in the berm soil cannot be meaningfully evaluated in a quantitative manner without analytical results of samples from the berm soil. These results would provide evidence to confirm or refute existence of the contamination in the berm soil and provide the basis for developing transport and exposure pathways.

The modeled results concerning accumulation of radon progeny in the berm soil reveal that the greatest concentrations would be deposited in the layers of berm soil closest to the silo walls. The potential consequences of these accumulations could be an important consideration in the evaluation of remedial alternatives. If the radon progeny in berm soil can be transported to soils that are used for growing agricultural products by either leaching to groundwater used for irrigation or from direct use of the berm soil, environmental impact is possible.

Air resuspension of particulates is another potential contaminant transport mechanism; however, it is greatly influenced by the fraction of surface covered by vegetation and the height of the vegetation. Aerial photographs of the Waste Storage Area reveal that the Operable Unit 4 study area is covered with vegetation. Thus it is not likely that air resuspension of soil from Operable Unit 4 contributes significant exposure, especially in comparison to the contribution from the airborne radon and penetrating radiation pathways.

Airborne particulate contamination collected at air monitoring stations as part of the WMCO monitoring program show that the average concentrations of uranium measured in 1988 at the 12 fenceline and off-site air monitoring stations were all less than 4 percent of the DOE standard. Generally, the air monitoring stations recorded lower average airborne uranium concentrations in 1988 than in 1987. The highest reported concentration of other trace radionuclides in 1988 was still only 1 percent of the DOE guideline. Total suspended particulates concentrations from air monitoring stations ranged from 31.6 $\mu g/m^3$ to 39.4 $\mu g/m^3$ in 1988. These results were higher than

those reported in 1987 but were still well within National Ambient Air Quality Standards (WMCO 1989b).

The most acute potential environmental impact associated with Operable Unit 4 is that of a catastrophic failure of the silos and the ensuing release of radon and radioactive silo contents. This scenario is not addressed by the Baseline Risk Assessment. One of the ground rules for the risk assessment was that current security control measures employed by DOE would prevent such an occurrence up to and beyond the date when the site is closed. The University of Cincinnati, however, has recently released a report that addresses the risk associated with a catastrophic failure of the silos (University of Cincinnati 1990). The results of this report were discussed in Section 1.0.

5.3 SURFACE WATER RUNOFF

As indicated above, Pb-210 and Po-210 are potential contaminants of concern in the Operable Unit 4 soils. Other known contaminants are uranium and Ra-226; above background levels of these materials have been detected in surface soil samples in the vicinity of Operable Unit 4. The source of the uranium and Ra-226 contamination is not known. It is possible that they have been transported from other areas of the FMPC site such as the waste pits, or they were contained in process area runoff that previously flowed in these drainage ditches. In any case, these contaminants could be transported away from Operable Unit 4 through soil erosion caused by surface water runoff, especially in the event of a heavy rainfall. This migration pathway would be applicable only to those contaminants that are present in a shallow zone near the soil surface.

The surface water drainage characteristics within Operable Unit 4 were previously described in Section 3.0. The surface water pathway and the specific interactions between surface water and groundwater are being evaluated in an upcoming Groundwater Report and as part of Operable Unit 5. The conceptual model for the transport of contaminants in the surface water system is as follows: Contaminants contained in near surface soils subject to erosion can be delivered to Paddys Run in several areas along the stream. These contaminants will be in dissolved solids in the runoff and will be attached to entrained sediments. A portion of these contaminants will partition onto stream sediments and will not be available for immediate transport to the aquifer. Contaminants in the dissolved phase will be transported to the Great Miami Aquifer by recharge from Paddys Run throughout the reach from the waste pit area to the mouth of Paddys Run. This occurs because the stream bed consists of glaciofluvial materials that are in direct contact with the matrix of the Great Miami Aquifer. This recharge is highly transient but seems to be centered on Paddys Run in the area of the K-65 silos. Contaminants partitioned into sediments will be transported into the flow as

both bedload and suspended load during high flow events. The majority of the contaminated sediment is probably flushed from the system yearly. However, a portion of these sediments may be trapped within Paddys Run and its tributaries during receding flow and may be available as a very low dispersed source.

This conceptual surface water flow model is evaluated on a site-wide basis within the SWIFT III analysis of the Great Miami Aquifer because there are low-level source calls along Paddys Run within the model. Results of this modeling effort will be published in the upcoming Groundwater Report.

An EE/CA was performed to evaluate remedial action alternatives for storm water runoff control in the waste pit area (ASI/IT 1990d). The preferred alternative was collection and treatment of runoff. Implementation of the collection and treatment removal action will control runoff from the Waste Storage Area to Paddys Run, including any runoff associated with Operable Unit 4. Any contamination not remediated by the removal action will be addressed under Operable Unit 5.

5.4 GROUNDWATER

Contamination may be transported through the vadose zone into groundwater in the vicinity of Operable Unit 4. However, the existing data are inadequate to confirm that contaminant transport from the K-65 silos or Silo 3 is taking place. Analysis of the slant borings samples from beneath the silos are required before any conclusions can be drawn regarding this potential pathway. The slant borings will allow sampling of the soil directly beneath the silos. The analytical results of these samples will provide information on whether leakage from the silos has occurred and whether it poses a potential threat of migration to the glacial overburden and the underlying Great Miami Aquifer.

Limited groundwater sampling in the vicinity of Operable Unit 4 has revealed levels of uranium above background. No above-background levels of Ra-226 have been detected in groundwater samples. The K-65 residues contain higher concentrations of radium than other uranium purification process waste streams. The K-65 silos are a unique source of large quantities of Ra-226 at the FMPC. Therefore, Ra-226 could be used as an indicator of releases from the K-65 silos if consistently detected in significant concentrations in media such as groundwater, perched water, or soils beneath the silos. However, there may be significant differences in solubility of radium and uranium from the silos and the absence of Ra-226 alone is inconclusive evidence that the silos are, or are not, the source of contamination in these media. Although the absence of Ra-226 in

groundwater suggests that the K-65 silos are not releasing contaminants to groundwater, no definitive conclusion can be drawn. Uranium contamination in groundwater could be originating from any of the waste storage facilities or operations at the site.

Groundwater sample analytical results for Pb-210 are not available. The identification of Pb-210 as a potential indicator contaminant for Operable Unit 4 was made during the risk assessment process. The initiation of sampling and analysis for groundwater began before this identification. Under the present sampling and analysis plan for Operable Unit 4, soils beneath the silos will be analyzed for Pb-210. The results of the soil analysis will provide the basis for determining if groundwater should be analyzed for Pb-210.

During a recent core sampling of K-65 silo residues, moisture was detected in one Silo 2 sample. As this was a one-time occurrence, no conclusions could be drawn. As mentioned previously, neither the K-65 silos nor any other area within the Operable Unit 4 study area has been confirmed as a source of uranium contamination to groundwater.

A conceptual model of potential contaminant transport from the bottom of the silos to the groundwater has been developed based on the current understanding of the Operable Unit 4 study area and data from past investigations. This model is depicted in Figure 5-1 and discussed below:

- The sand and gravel lenses within the glacial overburden are overlain and underlain by semi-impermeable layers having a high clay content. Although these layers do not extend over a large lateral area, they are still important for transport across and off the site as they form a larger interconnected zone over the site area.

- Any contaminated water leaking through the K-65 silos' bottoms moves both laterally and vertically down through the glacial overburden. As this water seeps down to a semiconfining bed in the glacial overburden, it proceeds to move laterally through the sand and gravel lenses until it can move downward into a more permeable zone. This process continues until the water reaches the underlying Great Miami Aquifer or it reaches a seep along Paddys Run.

- Paddys Run bank soils can be contaminated from the seeping waters from the K-65 silo that are moving laterally within the glacial overburden above the water table in the sand and gravel zones.

This conceptual model of contaminant transport is based on existing data within the Operable Unit 4 study area. Collection and analysis of slant boring samples as well as utilization of the vadose zone and SWIFT III computer models will clarify the mechanisms for contaminant transport applicable to Operable Unit 4. Modeling results based on the data available within Operable Unit 4 are

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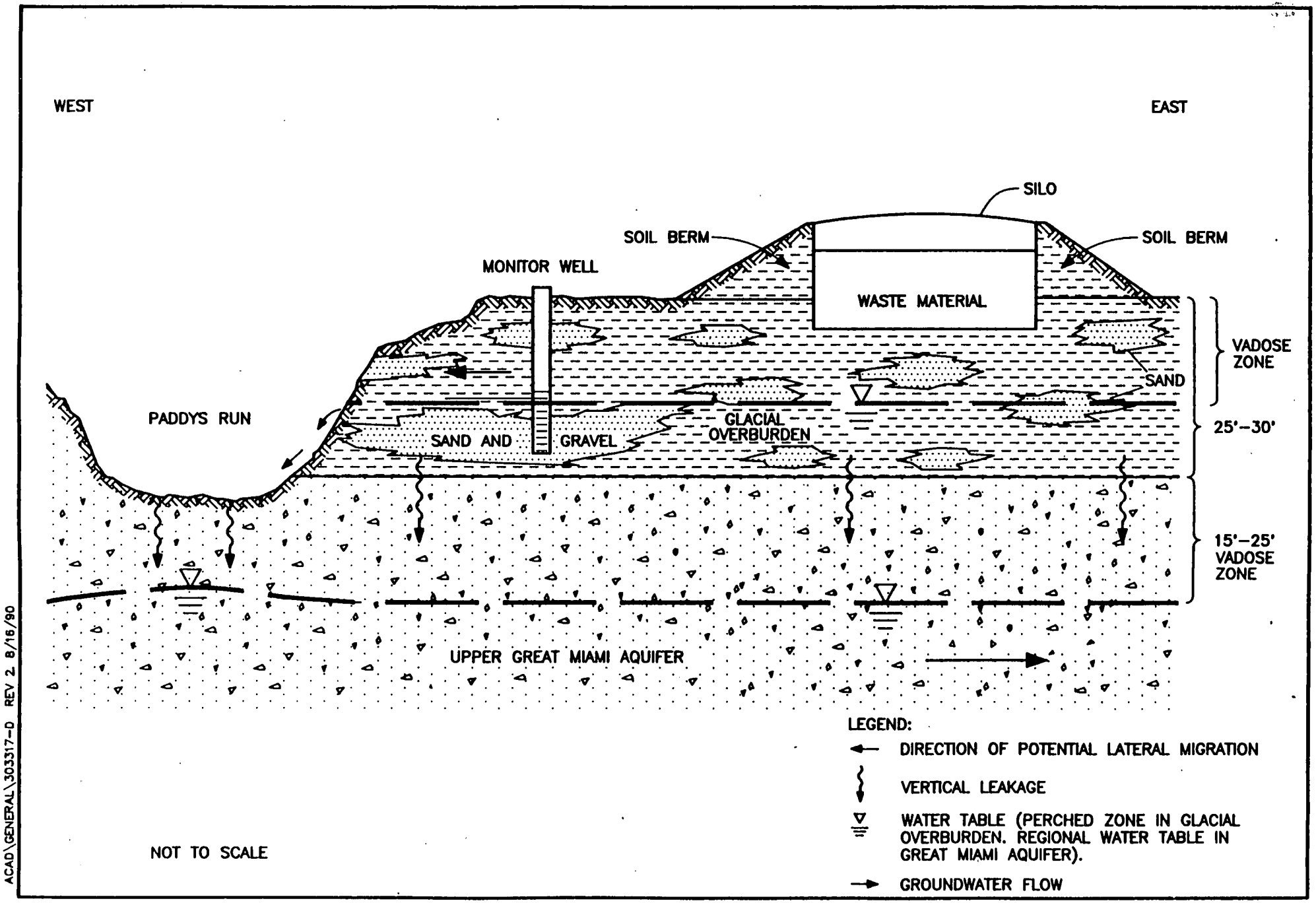

FIGURE 5–1. CONCEPTUAL MODEL OF CONTAMINANT TRANSPORT

presented and discussed in the baseline risk assessment (Appendix E). Additional data and results will be presented in the upcoming Groundwater Report and in future revisions to this report.

6.0 BASELINE RISK ASSESSMENT

A risk assessment is mandated under the Consent Agreement signed in 1990 by DOE and EPA, which implements the FFCA signed in 1986. This section presents a summary of the Operable Unit 4 Baseline Risk Assessment. It complies with provisions of both SARA and CERCLA, which require the completion of an assessment of risks to human health and the environment during the RI/FS. For a more detailed discussion, the reader is referred to Appendix E of this report, which includes supporting information, descriptions of risk assessment methods, and other pertinent information.

6.1 CHEMICALS OF POTENTIAL CONCERN

Operable Unit 4 was used historically to store by-products of the uranium separation process. Consistent with process information, it was found that the silos contain high levels of uranium, uranium decay products, radon gas, and other inorganic materials found in the initial ores.

Review of environmental sampling data suggests that silo constituents may be released to the environment. Constituents of concern based on sampling data include:

- High levels of uranium decay products, which emit gamma rays, or penetrating radiation
- Ra-226, which produces radon gas that escapes from the silos
- Uranium and Ra-226, detected in surface soils within the silo study area

Th-230 and Pb-210 are also radionuclides of potential concern, although no environmental sample analytical data confirm that Th-230 or Pb-210 has been released from the silos. Th-230 in the silo residues poses a threat to groundwater quality if the silos begin to leach constituents in the future. Pb-210 is a potential concern if it is determined that significant quantities of radon gas are migrating through the silo walls into the berm soil. Radon decay would result in the deposition of Pb-210. Berm soil sampling is planned to determine if Pb-210 is accumulating in the K-65 berms.

The deposition of progeny of radon that escapes from the K-65 silos was evaluated to estimate the accumulation of the longer half-life progeny, such as Pb-210, in surface soils and the use of these soils for agriculture. This evaluation indicates that the accumulation of the progeny will not be discernible from the natural variation in background concentrations. The resultant doses from all potential ingestion pathways are insignificant compared to natural background. Therefore, Pb-210 and its progeny associated with radon releases from the silos are not considered in the risk assessment for pathways involving potential contamination of surface soils.

Due to the complex nature of the waste problem at the FMPC and the availability of analytical sample data, it is not possible to determine what fractions of the contaminants in surface soil, groundwater, and sediment, if any, are attributable to releases from Operable Unit 4. It is believed that uranium and Ra-226 may be in the surface soils as a result of historical spills and leaks around the silos. Uranium detected in groundwater at above-background levels cannot be conclusively attributed to releases from Operable Unit 4 because there is no confirmation of significant silo leakage into the underlying soils. Additional slant boring sampling is required to resolve this issue. The necessary data are to be obtained under the proposed sampling and analysis plan. However, assuming leaking may occur sometime in the future, all constituents of the silos are considered to be of potential concern for future exposures.

6.2 EXPOSURE ASSESSMENT

Three potential current exposure pathways from Operable Unit 4 have been identified: direct exposure to penetrating radiation, exposure to airborne radon and radon progeny, and ingestion of constituents eroded from the surface soils into stream sediment. Penetrating radiation presents direct radiation exposure. Airborne radon is transported by the prevailing winds. Constituents found in the soils in Operable Unit 4 may erode into Paddys Run during periods of rain. Soil transport to exposure areas has been modeled using the Universal Soil Loss Equation (USLE).

Human exposure pathways have been identified for each constituent migrating from Operable Unit 4. The reasonable maximally exposed (RME) individual for direct exposure to penetrating radiation is a person living in the vicinity of the western FMPC boundary who receives an incremental dose of approximately 36 mrem/year, or 2500 mrem over a 70-year lifetime. The RME individual for exposure to airborne radon is also a person in the vicinity of the western FMPC boundary who receives an incremental exposure of 13 working level months (WLM) over a 70-year lifetime. The RME individual for exposure to eroded soils is a child that ingests sediments while playing in Paddys Run. This individual may be exposed to modeled concentrations of 9.6 pCi/g of uranium and 10.7 pCi/g of Ra-226. This sediment exposure scenario results in a dose equivalent of approximately 8 mrem over a 6-year exposure period.

Three potential future exposure pathways from Operable Unit 4 have been identified: direct exposure to penetrating radiation, exposure to airborne radon and radon progeny, and exposure to groundwater potentially contaminated by releases from Operable Unit 4. The RME individual for direct exposure to penetrating radiation is allowed access to land in the vicinity of the K-65 fenceline inside the FMPC boundary, assuming that security control measures are not in place in

the future after 100 years. This individual potentially receives an estimated incremental dose equivalent of approximately 50 times (1800 mrem/yr) the estimated dose equivalent under potential current conditions. The RME individual for radon exposure is also allowed access to land in the vicinity of the K-65 fenceline. This individual potentially receives an estimated incremental WLM exposure approximately 7 times (1.44 WLM/yr) the estimated exposure under potential current conditions.

The results of groundwater modeling suggest that several silo constituents could reach the FMPC property boundary within 100 years, the time period for assuming current security control measures. Some of these constituents, including uranium, radium, arsenic, and lead, may be at concentrations requiring that contributions from other operable units at the FMPC be considered in establishing remedial action objectives for this operable unit. Assuming current security control measures are lost after 100 years, an "intruder" receptor may be exposed to higher concentrations of silo constituents in groundwater at the waste unit.

Results of the assessment of potential exposures to environmental receptors indicate that radionuclide contamination has been measured in aquatic organisms collected in the vicinity of Operable Unit 4. Samples of vegetation were also analyzed for radionuclide contamination, but none was detected. These results are presented in Section E.6.0 of Appendix E. Estimated radiation doses from these levels of contamination are at least one hundred times less than radiation doses estimated to cause detectable effects in the organisms considered.

6.3 TOXICITY ASSESSMENT

The two major toxicological hazards associated with Operable Unit 4 are the radiocarcinogenicity of the radionuclides and the chemical toxicity of uranium. The radiocarcinogenic hazard is quantified using established risk coefficients expressed as a function of radiation dose or exposure to radionuclides. A risk coefficient of 125×10^{-6} rem^{-1} (NCRP 1987) is used to quantify the lifetime fatal cancer risk from exposure to ambient penetrating radiation fields. This risk coefficient is also used to quantify the lifetime fatal cancer risk from exposure to radiation emitted by internally deposited radionuclides (uranium and Ra-226). The EPA recently adopted a risk coefficient of 4×10^{-4} rem^{-1} for low linear energy transfer (LET) radiation in place of the 1.25×10^{-4} rem^{-1} used in this risk assessment. The EPA risk factor is approximately three times higher; therefore, the risks would be proportionately higher if the EPA risk coefficient is used. A risk coefficient of 360×10^{-6} WLM^{-1} (EPA 1989) is used to quantify the lifetime fatal lung cancer risk from exposure to airborne radon and radon progeny.

Uranium is a potent chemical toxicant that acts as a nephrotoxicant. Kidney damage has been seen in rabbits at levels as low as 2.8 milligram/kilogram/day (mg/kg/day). The reference dose (RfD) for humans based on the rabbit data is 3 microgram/kilogram/day (µg/kg/day), incorporating an uncertainty factor of 1000. Individual RfDs for silo constituents other than uranium are identified in Section E.4.0 of Appendix E.

6.4 RISK CHARACTERIZATION

The incremental lifetime risk of fatal cancer from lifetime exposure at the RME level to penetrating radiation from Operable Unit 4 under current conditions is 3×10^{-4}. The incremental lifetime risk of fatal lung cancer from lifetime exposure at the RME level to airborne radon released from Operable Unit 4 under current conditions is 5×10^{-3}. Each of these risk estimates is based on annual averages of measurements collected at the FMPC boundary, which incorporates the assumption that it is reasonable to use annual average data from the western FMPC boundary as a conservative representation of the potential receptor exposure in the vicinity. Assuming that a single individual could reasonably be exposed to both penetrating radiation and airborne radon, the combined incremental lifetime risk from lifetime exposure to these two exposure pathways is 5×10^{-3}.

The incremental lifetime risks of fatal cancer from lifetime exposures to RME levels of penetrating radiation and airborne radon from Operable Unit 4 under potential future conditions are 2×10^{-2} and 3×10^{-2}, respectively. Each of these risk estimates is based on annual averages of measurements collected at the K-65 fenceline, which incorporates the assumption that it is reasonable to use annual average data from the K-65 fenceline as a conservative representation of the potential future receptor exposure in the vicinity. The combined incremental lifetime risk from lifetime exposure to these two exposure pathways under potential future exposure conditions in 5×10^{-2}.

A perspective can be placed on the incremental lifetime risks associated with RME exposures from the penetrating radiation and airborne radon pathways under current conditions by considering the lifetime risks associated with background exposures from these pathways. Using the same calculation approach, the lifetime risks from lifetime exposures to background penetrating radiation and airborne radon levels under current conditions are 6×10^{-4} and 6×10^{-3}, respectively. This indicates that the background risks from these two pathways under current conditions are in the same order of magnitude as their respective incremental risks, which is consistent with the fact that the incremental RME exposures from these pathways are within a factor of approximately two of the background exposure levels.

The estimated risks associated with exposure to background levels of penetrating radiation and airborne radon are documented in the risk assessment (Appendix E) Section E.3.0. The risks from background exposures were estimated using the same calculational approach that was used to estimate risks from above-background exposures. This means that the methodology and input values were the same except for the substitution of the background exposure level in place of the above-background exposure level (refer to Table E3-3 for input values).

Exposure of children to uranium and Ra-226 via ingestion of contaminated sediments eroded from soils in Operable Unit 4 is considered separately because this exposure pathway is considered unique to children, the most sensitive population under the baseline risk assessment. The sediment ingestion pathway is presented in the risk assessment (Appendix E). Conservative assumptions were chosen to maximize any potential exposure to an infant child and provide an upper limit on the risk to the most sensitive population. The upper limit of risk of fatal cancer from this exposure pathway is 1×10^{-6}.

The calculated risk from the child sediment ingestion exposure pathway is nominal and within the acceptable range specified in 40CFR300. Although it is possible that the child may simultaneously be a receptor for airborne radon and penetrating radiation exposure pathways, the addition of the sediment risk (1×10^{-6}) to the airborne radon risk (5×10^{-3}) does not change the total risk, nor does it change the decision regarding the need for remediation from a risk assessment perspective. However, combining the three pathways in this case is questionable. The receptor for the sediment ingestion pathway is assumed for a scenario that has a very low probability of occurrence; whereas, the receptor description for the airborne radon and penetrating radiation pathways more closely approximates present potential exposures to the nearest resident. Therefore, the receptor descriptions are different. The sediment ingestion receptor is exposed at a location in Paddys Run adjacent to the silos for an exposure duration of six years, but the receptor is not continuously present at the exposure location as assumed in the case for the adult in the airborne radon and penetrating radiation pathways. The airborne radon and penetrating radiation receptor is exposed off-site at a hypothetical residence in the vicinity of the western FMPC boundary fenceline for an exposure duration of 70 years.

The potential upperbound radiocarcinogenic fatal cancer risk associated with future groundwater exposure under both current and future land-use conditions is greater than the acceptable cancer risk range of 1×10^{-4} to 1×10^{-6}.

The chemical toxicity hazard associated with exposure to the elemental form of uranium does not appear to be of concern. The value of the hazard index (HI) associated with a child ingesting 0.13 µg/kg/day of uranium in creek sediments is 0.043 using the RfD of 3 µg/kg/day in the denominator, and 0.17 using the site-specific action level of 0.75 µg/kg/day in the denominator. This suggests that children would receive an intake of uranium that is less than 20 percent of the allowable limit even under the conservative exposure scenario assumed.

The potential chemical toxicity hazard associated with future groundwater exposure under both current and future land-use conditions indicates that a receptor may be exposed to unacceptable levels of several chemical toxicants, including arsenic, lead, selenium, thallium, and uranium.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

The evaluation of data obtained from the RI as well as data from previous investigations indicate that the only confirmed releases to the environment from Operable Unit 4 are ionizing radiation and radon gas. The nature and extent of any soil or groundwater contamination attributable to Operable Unit 4 cannot be fully evaluated until the slant boring and soil berm sampling programs are completed. Based on existing data, the FS for the K-65 silos and Silos 3 and 4 will address the silo contents, the physical structures, the soil berm surrounding Silos 1 and 2 as well as any contaminated soil or perched water immediately below the silos. There is no conclusive indication that the silos have contributed to off-site environmental contamination at FMPC other than the emission of radon and ionizing radiation. The specific conclusions drawn from the RI for each of the six elements associated with Operable Unit 4 are presented below.

Waste Material in Silos

The silo sampling program conducted during the RI by WMCO in the summer of 1989 was designed to collect representative core samples of the residues in Silos 1, 2, and 3. Only partial cores could be recovered from Silos 1 and 2. Consequently, the stratification of the silo contents and the depth at which the grab contents samples were collected could not be determined. However, the fact that the material in the silos was able to be readily penetrated by the sampling equipment is an indication that the contents are soft and fluid. This information will aid in evaluating methods for extracting these materials from the silos.

The sampling of Silo 3 was successful. Representative continuous cores of the silo contents were obtained and data on physical, chemical, and radiological characteristics were acquired.

Analysis of these samples from the 1989 WMCO sampling effort show that Silos 1 and 2 contain distinctly higher amounts of radium and lead than Silo 3. High concentrations of thorium and uranium are present in the K-65 silo residues. PCBs were the only organics detected in Silos 1 and 2. The principal metals in Silos 1 and 2 are barium, calcium, iron, lead, and magnesium. Although representative continuous core samples are still needed for Silos 1 and 2, the results from these samples provide useful data for characterizing the K-65 silo contents.

Silo 3 contains significantly more thorium and uranium than Silos 1 and 2. Other radionuclides in significant amounts are isotopes of radium and lead. Toluene was the only organic compound detected in samples collected from Silo 3. The silos will be resampled, and volatile organic

compounds will be analyzed within the required holding times. The major inorganic constituents of Silo 3 are aluminum, calcium, iron, magnesium, and sodium. Other inorganic constituents that are significant include: arsenic, cobalt, nickel, potassium, and vanadium.

Physical Structure of the Silos

No new data concerning the integrity of the silo structures were obtained during the RI. Data from the two studies performed by Camargo (1986) and BNI (1990) will be used during the FS. Both studies concluded that no life expectancy could be assigned to the K-65 silo domes. The evaluation and selection of remedial alternatives must consider the deteriorating condition of the silo structures. Remedial actions that depend on the silo structures being stable and self-supporting must be dropped from future consideration unless structural improvements are incorporated into the action. The ability of the silos to contain any leakage of materials that might occur from the bottom of the silos is also questionable. This uncertainty will also be addressed when selecting the final remedial actions. Data concerning the integrity of the silo bottoms will be obtained during the slant boring program; for those portions of the K-65 silos beneath the berms, data will be obtained during the berm sampling program.

Soil Berms (Silos 1 and 2)

No previous investigations at the FMPC have addressed the soil berms surrounding the K-65 silos. A soil berm sampling program is planned as part of the RI, but it has not been conducted. No conclusions can be reached as to whether the soil berms are contaminated with radon decay products (Pb-210 and Po-210) or other materials contained in the silos until the berm sampling and analysis program is completed.

Glacial Overburden Beneath the Silos

Reports of leaks from the silos (NLO 1953) and overflow conditions at the decant liquor tank (Karl 1953) indicate that some level of contamination in the glacial overburden immediately beneath the K-65 silos is probable. No documented reports of leakage from Silo 3 were identified during the RI data evaluation. Data from the only previous sampling effort beneath the K-65 silos conducted in 1983 identified uranium and radium concentrations in the soil to be ranging from 0.77 to 9.66 pCi/g and 0.68 to 1.2 pCi/g, respectively (Vogel 1989a). These samples were collected from two borings drilled below the K-65 silos. The radium (Ra-226) in these samples was within background ranges. The 1983 sampling program was not extensive in scope and did not provide adequate data to determine the nature and extent of contamination in the glacial overburden.

A slant boring program designed to provide broad areal coverage beneath the K-65 silos and Silo 3 is presently being conducted as part of the RI (ASI/IT 1990b). Soil samples collected from this program will be subject to complete physical, chemical, and radiological analyses. Data from this program will define the full nature and extent of contamination in the glacial overburden. These data will be necessary to evaluate fully the remedial alternatives for Operable Unit 4. Until these data are available, it will not be possible to determine whether the silos are contributing to groundwater contamination observed in the Operable Unit 4 study area or whether contamination in the glacial overburden poses a potential threat of groundwater contamination.

Operable Unit 4 Study Area

Surface radiation measurements collected during the RI were affected by high background radiation emitted by the silos. The only viable measurements collected during the RI at Operable Unit 4 were for exposure rates to radiation, which were evaluated in the Operable Unit 4 risk assessment. No surface radiation measurements were collected that could be accurately correlated to surface soil contamination.

Some contamination of surface soils with uranium and radium was observed in surface soil samples collected within the Operable Unit 4 study area. The concentrations were variable and not indicative of contamination originating from a specific source term such as the K-65 and metal oxide silos. Surface soil contamination data were generally comparable to values observed at other locations within the FMPC. It was concluded that surface soil contamination observed in the Operable Unit 4 study area was not attributable to Operable Unit 4 but rather to general FMPC operations.

There was little evidence of contamination in subsurface soils collected in the Operable Unit 4 study area. Based on these data, leakage has not occurred from the silos, or the leaked materials have not migrated far enough from the silos to be encountered during the RI. This will be confirmed by collecting and analyzing soil samples from the slant boring and berm sampling programs.

Detectable concentrations of uranium are present in the groundwater beneath the Operable Unit 4 study area. However, the concentrations and contaminant distribution do not indicate that the contamination is originating from Operable Unit 4. Well 1032 contained 276 µg/L of total uranium, the highest concentration observed in the Operable Unit 4 study area. This well was completed in a former construction rubble site. This rubble site may be the source of higher uranium concentrations in the vicinity of Operable Unit 4. Ra-226 was not detected in groundwater

samples collected within the Operable Unit 4 study area. However, there were isolated detections of Ra-228 in 4 out of 56 groundwater samples. The silos cannot be completely eliminated from consideration as a source of groundwater contamination until the data from the slant boring and berm sampling programs become available. The former construction rubble site near Well 1032 will be addressed under Operable Unit 3.

Two additional 2000-series wells have been installed near Well 1032 and Well 1033 to assess the magnitude and extent of groundwater contamination within the Operable Unit 4 study area. Installation of Well 2032 adjacent to Well 1032 will allow monitoring of any downward movement of uranium into the Great Miami Aquifer. Soil samples collected during the drilling activities and water samples collected after the completion of well installation are being analyzed for radiological and chemical content. These data will aid in assessing the recharge/discharge relationships between the glacial overburden, Paddys Run, and the Great Miami Aquifer. The second well, 2033, has been placed to serve as a downgradient well for Operable Unit 4.

Surface water collected from selected drainageways around the Operable Unit 4 study area contained elevated uranium concentrations. The highest observed uranium concentration was in a sample collected from a drainageway downstream from the K-65 silos. Lower uranium concentrations were observed in the water samples collected from Paddys Run. No radium was detected in any of the surface water samples. Historically, storm water runoff in this drainage ditch came from the Pilot Plant area draining to Paddys Run; thus the Pilot Plant is the most likely source of the observed contamination. Contaminated surface water runoff from the Waste Pit Area is also a potential source of the observed contamination. Surface water runoff from the Operable Unit 4 study area will be addressed by the Waste Pit Area Storm Water Runoff Control Removal Action (ASI/IT 1990d).

Sediment samples collected during the RI also contained elevated concentrations of total uranium. The highest observed concentration was 30.3 ppm in a sample collected downstream of the K-65 silos from location ASIT-10. Two sediment samples from Paddys Run location W-10, downstream from the K-65 silos, contained uranium in the range of 1.0 to 3.0 ppm.

The sampling of biological resources conducted during the RI addressed the FMPC facility in its entirety. Although some uptake of radionuclides was observed in biological system, it is unlikely that Operable Unit 4 is the source (ASI/IT 1990c).

Regional Environment

The principal impacts on the regional environment related to Operable Unit 4 appear to be ionizing radiation and radon gas. The slant boring program must be completed before Operable Unit 4 can be completely eliminated as a potential source of regional groundwater contamination.

The Baseline Risk Assessment determined that risks associated with current exposures to radiation from Operable Unit 4 are:

- 3×10^{-4} from penetrating radiation
- 5×10^{-3} from inhalation of airborne radon

Thus the combined radiation cancer risk under current land-use conditions is 5.3×10^{-3}. The acceptable cancer risk range, as specified in 40CFR300 Subpart E, is 1×10^{-4} to 1×10^{-6}. Therefore, the risks associated with current exposures to Operable Unit 4 are unacceptable, and the no-action alternative is unacceptable.

In addition, estimated risks to future potential exposures, including direct radiation, inhalation of radon, and ingestion of contaminated groundwater and food contaminated by groundwater, are higher than current estimated risks. This suggests that remediation alternatives must be sensitive to preventing potential future releases of Operable Unit 4 materials into the groundwater.

7.2 RECOMMENDATIONS

The following RI activities must be completed at Operable Unit 4 before final conclusions can be drawn:

- Complete the silo contents sampling program
- Complete the slant boring program
- Conduct the berm sampling

Completion of these planned programs will provide the additional data needed to complete the evaluation of the environmental impacts associated with Operable Unit 4.

Additional radiological sampling of Paddys Run bank and stream sediments and stream water is recommended near Operable Unit 4. Review of existing sediment sampling data indicate the presence of higher levels of radiological contamination in Paddys Run sediments nearest the K-65 silos. The significance of the existing data could be established by collecting and analyzing additional samples.

A visual examination of the eastern bank of Paddys Run directly west of Operable Unit 4 and sampling of the occasional events of groundwater seeping from the bank is recommended. The sample analyses should include radiological and chemical parameters. These data could provide support to the evaluation of contaminant migration pathways.

7.3 REMEDIAL ACTION OBJECTIVES

Operable Unit 4 represents a potential source of contamination to groundwater and other environmental media. Remedial action objectives (RAOs) for source units such as the waste storage silos must be formulated to achieve the overall goal of protecting human health and the environment by isolating, removing, or treating the source of contamination.

The primary RAOs are to ensure site-wide compliance with:

- Chemical-specific applicable or relevant and appropriate requirements (ARARs) and to be considered (TBCs)
- EPA guidance for risk to public health from hazardous chemicals
- Regulatory standards for control of radiation and radioactivity in the environment

To accomplish these objectives, each operable unit at the FMPC is subject to an action level of 25 percent of each site-wide limit, unless it can be demonstrated that the collective impact of operable units throughout the FMPC will not exceed the site-wide limit. This serves as the basis for the operable unit-specific RAOs set forth in this section. Should it be impractical to achieve an operable unit-specific RAO, this action level may be revised to the extent that it results in failure to comply with the site-wide RAO.

The specificity of these objectives may vary depending on the availability and quality of site information, site conditions, and site complexity.

The RI/FS Work Plan presented 26 RAOs for the FMPC. Of those, four are applicable to Operable Unit 4. They focus on source control rather than pathway elimination or receptor modification:

- Prevent current and future above-background radiation doses to the public from all pathways and all radionuclides (other than radon) from exceeding 25 percent of the 100 mrem annual dose limit

- Prevent current and future Rn-222 flux from a source from exceeding 20 pCi/m^2-s public health or environmental standards

- Prevent current and future above-background radiation doses to the public from airborne radionuclides (other than radon) from exceeding 25 percent of the 10 mrem/year annual dose limit

- Prevent contamination of the groundwater from reaching: 25 percent of a 4 mrem above-background annual dose limit for radionuclides; and MCLs, proposed MCLs, or risk-based cleanup levels for nonradioactive hazardous materials.

There are a number of response actions or remedial action alternatives that are being considered to achieve these RAOs. These remedial action alternatives, in addition to the no-action alternative, include both waste removal and nonremoval actions. The nonremoval alternatives range from simple containment of the wastes to in situ stabilization coupled with containment technologies. The removal alternatives involve various combinations of waste removal technologies, postremoval actions, and waste disposal actions. The postremoval actions include an ex situ waste stabilization, contaminant separation, and on-property disposal in an engineered disposal facility, or off-site disposal. These remedial action alternatives will satisfy the established RAOs and are being evaluated under the Operable Unit 4 FS.

The Waste Pit Area Storm Water Runoff Control Removal Action is a program separate from the Operable Unit 4 RI/FS, which, if completed, has the potential to remove environmental media contaminants that would exceed public health or environmental standards in the Operable Unit 4 study area. This program's objective is to mitigate the potential for contamination of drinking water supplies or sensitive ecosystems, which is posed by the presence of contaminants in surface soils that may migrate into the groundwater. This program overlaps the Operable Unit 4 RI/FS by including management of the storm water runoff from the Waste Storage Area, which includes six waste pits in Operable Unit 1, the four silos in Operable Unit 4, and a perimeter area. The planned removal action is designed to collect contaminated storm water runoff and process it through existing FMPC water treatment systems.

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APPENDIX A

RADIATION MEASUREMENTS

RADIATION MEASUREMENT DATA
PIC AND SPA-3 NODE READINGS
RI/FS DATA

PIC readings are reported in microrem per hour (ur/hr) and SPA-3 Node readings are reported in counts per minute (CPM). The column titled Serial Number represents the serial number of the instrument used to take the measurement. Duplicate numbers at a location indicate that duplicate readings were taken.

North Coordinate	East Coordinate	PIC Reading	Serial Number	SPA-3 Node Reading	Serial Number	Reading Date
480000	1378000	26	9691	136000	01	10/28/87
480000	1379000	24	9691	104000	30	09/14/87
480000	1379000			161000	01	05/04/88
480000	1379000			182000	20	05/04/88
480100	1378900			357000	20	05/04/88
480100	1378900			322000	01	05/04/88
480100	1379000			243000	20	05/04/88
480100	1379000			244000	20	05/04/88
480100	1379000			224000	01	05/04/88
480100	1379000			225000	01	05/04/88
480200	1378300			889000	01	10/03/87
480200	1378400			1280000	30	10/03/87
480200	1378400			1270000	01	10/03/87
480200	1378500			1460000	30	10/03/87
480200	1378500			1180000	23	10/03/87
480200	1378600			1070000	23	10/03/87
480200	1378600			1380000	30	10/02/87
480200	1378700			889000	23	10/02/87
480200	1378700			895000	30	10/02/87
480200	1378800			583000	23	10/02/87
480200	1378800			594000	23	10/02/87
480200	1378900			390000	01	05/04/88
480200	1378900			362000	01	10/02/87
480200	1378900			394000	23	10/02/87
480200	1379000			300000	20	05/04/88
480200	1379000			237000	30	10/02/87
480200	1379000			274000	01	05/04/88
480200	1379000			329000	01	10/02/87
480300	1378700			1490000	30	10/02/87
480300	1378700			1450000	23	10/02/87
480300	1378800			822000	23	10/02/87
480300	1378800			822000	23	10/02/87
480300	1378900			309000	01	10/02/87
480300	1378900			506000	23	10/02/87
480300	1379000			319000	30	10/02/87
480300	1379000			206000	01	10/02/87
480600	1379000	76	9691	328000	23	12/07/87
481000	1378000	33	9691			10/08/87
481000	1378000			13200	30	08/28/87
481000	1378000			90700	01	10/08/87
481100	1377900			71000	33	05/26/88
481100	1377900			75300	33	05/26/88
481100	1377900			72000	33	05/26/88
481100	1378000			93000	01	05/26/88
481100	1378000			97500	33	05/26/88

RADIATION MEASUREMENT DATA
FIDLER AND SPA-3 WALKOVER SURVEY
RI/FS DATA

All readings are presented in counts per minute (CPM).
The column titled Serial Number represents the serial number of the instrument used to take the measurement. Duplicate numbers at a location indicate that duplicate readings were taken at that location.

North Coordinate	East Coordinate	FIDLER Reading	Serial Number	Reading Date	SPA-3 Reading	Serial Number	Reading Date
480000	1378950	45770	52838	05/04/88	373000	2058	05/04/88
480000	1378975	42543	52838	05/04/88	18400	2058	05/04/88
480000	1379000	65292	34780	05/04/88	283000	1795	05/04/88
480000	1379025	61627	34780	05/04/88	270000	1795	05/04/88
480000	1379050	59189	34780	05/04/88	250000	1795	05/04/88
480025	1378925	50379	52838	05/04/88	115000	2058	05/04/88
480025	1378950	45770	52838	05/04/88	373000	2058	05/04/88
480025	1378975	44999	52838	05/04/88	350000	2058	05/04/88
480025	1379000	72075	34780	05/04/88	303000	1795	05/04/88
480025	1379025	67841	34780	05/04/88	276000	1795	05/04/88
480025	1379050	64037	34780	05/04/88	264000	1795	05/04/88
480050	1378925	50379	52838	05/04/88	115000	2058	05/04/88
480050	1378950	55403	52838	05/04/88	409000	2058	05/04/88
480050	1378975	49949	52838	05/04/88	375000	2058	05/04/88
480050	1379000	78904	34780	05/04/88	324000	1795	05/04/88
480050	1379025	73613	34780	05/04/88	300000	1795	05/04/88
480050	1379050	72003	34780	05/04/88	285000	1795	05/04/88
480075	1378925	58919	52838	05/04/88	462000	2058	05/04/88
480075	1378950	59354	52838	05/04/88	439000	2058	05/04/88
480075	1378975	53598	52838	05/04/88	407000	2058	05/04/88
480075	1379000	85159	34780	05/04/88	348000	1795	05/04/88
480075	1379025	77761	34780	05/04/88	319000	1795	05/04/88
480075	1379050	72394	34780	05/04/88	299000	1795	05/04/88
480100	1378925	114076	34780	05/04/88	457000	1795	05/04/88
480100	1378950	102568	34780	05/04/88	423000	1795	05/04/88
480100	1378975	93211	34780	05/04/88	385000	1795	05/04/88
480100	1379000	47617	52838	05/04/88	368000	2058	05/04/88
480100	1379025	44092	52838	05/04/88	350000	2058	05/04/88
480100	1379050	41021	52838	05/04/88	327000	2058	05/04/88
480125	1378925	113735	34780	05/04/88	474000	1795	05/04/88
480125	1378950	99460	34780	05/04/88	429000	1795	05/04/88
480125	1378975	93066	34780	05/04/88	386000	1795	05/04/88
480125	1379000	48215	52838	05/04/88	387000	2058	05/04/88
480125	1379025	45302	52838	05/04/88	362000	2058	05/04/88
480125	1379050	42593	52838	05/04/88	336000	2058	05/04/88
480150	1378300	532479	34786	10/03/87	1210000	1795	10/03/87
480150	1378325	573805	34786	10/03/87	1330000	1795	10/03/87
480150	1378350	599662	34786	10/03/87	1400000	1795	10/03/87
480150	1378375	623146	34786	10/03/87	1460000	1795	10/03/87
480150	1378400	701232	35626	10/03/87	1610000	1793	10/03/87
480150	1378425	696687	35626	10/03/87	1660000	1793	10/03/87
480150	1378450	722260	35626	10/03/87	1700000	1793	10/03/87
480150	1378475	706896	35626	10/03/87	1690000	1793	10/03/87
480150	1378500	734033	34786	10/03/87	1430000	1794	10/03/87
480150	1378525	674341	34786	10/03/87	1410000	1794	10/03/87
480150	1378550	658926	34786	10/03/87	1300000	1794	10/03/87
480150	1378575	673139	34786	10/03/87	1040000	1794	10/03/87
480150	1378900				555000	1795	05/04/88
480150	1378925	120260	34780	05/04/88	507000	1795	05/04/88
480150	1378950	115075	34780	05/04/88	461000	1795	05/04/88
480150	1378975	100797	34780	05/04/88	406000	1795	05/04/88
480150	1379000	51170	52838	05/04/88	412000	2058	05/04/88
480150	1379025	47688	52838	05/04/88	380000	2058	05/04/88

RADIATION MEASUREMENT DATA
FIDLER AND SPA-3 WALKOVER SURVEY
RI/FS DATA

All readings are presented in counts per minute (CPM).
The column titled Serial Number represents the serial number of the instrument used to take the measurement. Duplicate numbers at a location indicate that duplicate readings were taken at that location.

North Coordinate	East Coordinate	FIDLER Reading	Serial Number	Reading Date	SPA-3 Reading	Serial Number	Reading Date
480150	1379050	44293	52838	05/04/88	348000	2058	05/04/88
480175	1378300	595495	34786	10/03/87	1360000	1795	10/03/87
480175	1378325	664595	34786	10/03/87	1500000	1795	10/03/87
480175	1378350	703110	34786	10/03/87	1590000	1795	10/03/87
480175	1378375	703167	34786	10/03/87	1640000	1795	10/03/87
480175	1378400	708606	35626	10/03/87	1820000	1793	10/03/87
480175	1378425	734994	35626	10/03/87	1890000	1793	10/03/87
480175	1378450	742899	35626	10/03/87	1950000	1793	10/03/87
480175	1378475	808121	35626	10/03/87	1930000	1793	10/03/87
480175	1378500	778513	34786	10/03/87	1650000	1794	10/03/87
480175	1378525	770893	34786	10/03/87	1660000	1794	10/03/87
480175	1378550	749437	34786	10/03/87	1800000	1794	10/03/87
480175	1378575	731152	34786	10/03/87	1190000	1794	10/03/87
480175	1378900	126498	34780	05/04/88	578000	1795	05/04/88
480175	1378925	118193	34780	05/04/88	526000	1795	05/04/88
480175	1378950	109552	34780	05/04/88	491000	1795	05/04/88
480175	1378975	101079	34780	05/04/88	449000	1795	05/04/88
480175	1379000	57576	52838	05/04/88	446000	2058	05/04/88
480175	1379025	53299	52838	05/04/88	405000	2058	05/04/88
480175	1379050	47583	52838	05/04/88	373000	2058	05/04/88
480200	1378300	659925	34786	10/03/87	1490000	1795	10/03/87
480200	1378325	696749	34786	10/03/87	1640000	1795	10/03/87
480200	1378350	774853	34786	10/03/87	1780000	1795	10/03/87
480200	1378375	778074	34786	10/03/87	1810000	1795	10/03/87
480200	1378400	781261	35626	10/03/87	2050000	1793	10/03/87
480200	1378425	814104	35626	10/03/87	2140000	1793	10/03/87
480200	1378450	912030	35626	10/03/87	2160000	1793	10/03/87
480200	1378475	901560	35626	10/03/87	2140000	1793	10/03/87
480200	1378500	864545	34786	10/03/87	1880000	1794	10/03/87
480200	1378525	884964	34786	10/03/87	1850000	1794	10/03/87
480200	1378550	842352	34786	10/03/87	1780000	1794	10/03/87
480200	1378575	808967	34786	10/03/87	1830000	1794	10/03/87
480200	1378600	1123533	34780	10/03/87	1850000	1793	10/02/87
480200	1378625	1037098	34780	10/03/87	1760000	1793	10/02/87
480200	1378650	932673	34780	10/03/87	1620000	1793	10/02/87
480200	1378675	373554	34780	10/03/87	1540000	1793	10/02/87
480200	1378700	610781	35626	10/02/87	1380000	1794	10/02/87
480200	1378725	566000	35626	10/02/87	1300000	1794	10/02/87
480200	1378750	445967	35626	10/02/87	1190000	1794	10/02/87
480200	1378775	445208	35626	10/02/87	1090000	1794	10/02/87
480200	1378800	369353	35626	10/02/87	958000	1794	10/02/87
480200	1378825	340696	35626	10/02/87	875000	1794	10/02/87
480200	1378850	330160	35626	10/02/87	814000	1794	10/02/87
480200	1378875	276290	35626	10/02/87	724000	1794	10/02/87
480200	1378900	149268	34780	10/02/87	628000	1795	10/02/87
480200	1378925	135937	34780	10/02/87	582000	1795	10/02/87
480200	1378950	136253	34780	10/02/87	530000	1795	10/02/87
480200	1378975	122069	34780	10/02/87	479000	1795	10/02/87
480200	1379000	188812	34786	10/02/87	467000	1793	10/02/87
480200	1379025	155734	34786	10/02/87	424000	1793	10/02/87
480200	1379050	157315	34786	10/02/87	388000	1793	10/02/87
480225	1378300	689570	34786	10/03/87	1660000	1795	10/03/87
480225	1378325	765985	34786	10/03/87	1800000	1795	10/03/87

RADIATION MEASUREMENT DATA
FIDLER AND SPA-3 WALKOVER SURVEY
RI/FS DATA

All readings are presented in counts per minute (CPM).
The column titled Serial Number represents the serial number of the instrument used to take the measurement. Duplicate numbers at a location indicate that duplicate readings were taken at that location.

North Coordinate	East Coordinate	FIDLER Reading	Serial Number	Reading Date	SPA-3 Reading	Serial Number	Reading Date
480225	1378350	821907	34786	10/03/87	1910000	1795	10/03/87
480225	1378375	866228	34786	10/03/87	2080000	1795	10/03/87
480225	1378400	855106	35626	10/03/87	2290000	1793	10/03/87
480225	1378425	695228	35626	10/03/87	2360000	1793	10/03/87
480225	1378450	723773	35626	10/03/87			
480225	1378475	542266	35626	10/03/87			
480225	1378500	963184	34786	10/03/87	2090000	1794	10/03/87
480225	1378525	970134	34786	10/03/87	2020000	1794	10/03/87
480225	1378550	907561	34786	10/03/87	1950000	1794	10/03/87
480225	1378575	875963	34786	10/03/87	2100000	1794	10/03/87
480225	1378600	1233112	34780	10/03/87	1970000	1793	10/02/87
480225	1378625	1128863	34780	10/03/87	1890000	1793	10/02/87
480225	1378650	431979	34780	10/03/87	1780000	1793	10/02/87
480225	1378675	410199	34780	10/03/87	1610000	1793	10/02/87
480225	1378700	664034	35626	10/02/87	1520000	1794	10/02/87
480225	1378725	614116	35626	10/02/87	1410000	1794	10/02/87
480225	1378750	480716	35626	10/02/87	1280000	1794	10/02/87
480225	1378775	466610	35626	10/02/87	1610000	1794	10/02/87
480225	1378800	421331	35626	10/02/87	1030000	1794	10/02/87
480225	1378825	373511	35626	10/02/87	936000	1794	10/02/87
480225	1378850	336058	35626	10/02/87	844000	1794	10/02/87
480225	1378875	293660	35626	10/02/87	775000	1794	10/02/87
480225	1378900	163995	34780	10/02/87	658000	1795	10/02/87
480225	1378925	151164	34780	10/02/87	611000	1795	10/02/87
480225	1378950	140927	34780	10/02/87	550000	1795	10/02/87
480225	1378975	129788	34780	10/02/87	504000	1795	10/02/87
480225	1379000	198191	34786	10/02/87	483000	1793	10/02/87
480225	1379025	168444	34786	10/02/87	456000	1793	10/02/87
480225	1379050	173951	34786	10/02/87	407000	1793	10/02/87
480250	1378625	1275561	34780	10/03/87	2110000	1793	10/02/87
480250	1378650	460379	34780	10/03/87	1990000	1793	10/02/87
480250	1378675	460997	34780	10/03/87	1770000	1793	10/02/87
480250	1378700	709122	35626	10/02/87	1680000	1794	10/02/87
480250	1378725	584589	35626	10/02/87	1530000	1794	10/02/87
480250	1378750	553454	35626	10/02/87	1380000	1794	10/02/87
480250	1378775	496330	35626	10/02/87	1240000	1794	10/02/87
480250	1378800	435092	35626	10/02/87	1100000	1794	10/02/87
480250	1378825	410763	35626	10/02/87	1000000	1794	10/02/87
480250	1378850	373847	35626	10/02/87	898000	1794	10/02/87
480250	1378875	310783	35626	10/02/87	816000	1794	10/02/87
480250	1378900	169541	34780	10/02/87	691000	1795	10/02/87
480250	1378925	152429	34780	10/02/87	623000	1795	10/02/87
480250	1378950	140857	34780	10/02/87	574000	1795	10/02/87
480250	1378975	133286	34780	10/02/87	522000	1795	10/02/87
480250	1379000	204239	34786	10/02/87	494000	1793	10/02/87
480250	1379025	185824	34786	10/02/87	456000	1793	10/02/87
480250	1379050	175179	34786	10/02/87	420000	1793	10/02/87
480275	1378625	1411131	34780	10/03/87	2430000	1793	10/02/87
480275	1378650	525802	34780	10/03/87	2240000	1793	10/02/87
480275	1378675	532326	34780	10/03/87	1910000	1793	10/02/87
480275	1378700	733877	35626	10/02/87	1870000	1794	10/02/87
480275	1378725	621195	35626	10/02/87	1680000	1794	10/02/87
480275	1378750	587475	35626	10/02/87	1480000	1794	10/02/87

RADIATION MEASUREMENT DATA
FIDLER AND SPA-3 WALKOVER SURVEY
RI/FS DATA

All readings are presented in counts per minute (CPM).
The column titled Serial Number represents the serial number of the instrument used to take the measurement. Duplicate numbers at a location indicate that duplicate readings were taken at that location.

North Coordinate	East Coordinate	FIDLER Reading	Serial Number	Reading Date	SPA-3 Reading	Serial Number	Reading Date
480275	1378775	521480	35626	10/02/87	1280000	1794	10/02/87
480275	1378800	467993	35626	10/02/87	1190000	1794	10/02/87
480275	1378825	449394	35626	10/02/87	1080000	1794	10/02/87
480275	1378850	383485	35626	10/02/87	949000	1794	10/02/87
480275	1378875	330914	35626	10/02/87	857000	1794	10/02/87
480275	1378900	179521	34780	10/02/87	740000	1795	10/02/87
480275	1378925	166417	34780	10/02/87	638000	1795	10/02/87
480275	1378950	147002	34780	10/02/87	586000	1795	10/02/87
480275	1378975	135417	34780	10/02/87	517000	1795	10/02/87
480275	1379000	210595	34786	10/02/87	501000	1793	10/02/87
480275	1379025	194065	34786	10/02/87	465000	1793	10/02/87
480275	1379050				427000	1793	10/02/87
481050	1377950	21970	52838	05/26/88	154000	2057	05/26/88
481050	1377975	23624	52838	05/26/88	162000	2057	05/26/88
481075	1377900	19209	52838	05/26/88	137000	2057	05/26/88
481075	1377925	19209	52838	05/26/88	137000	2057	05/26/88
481075	1377950	20802	52838	05/26/88	152000	2057	05/26/88
481075	1377975	22025	52838	05/26/88	161000	2057	05/26/88
481100	1377900	31140	34780	05/26/88	123000	1795	05/26/88
481100	1377925	33322	34780	05/26/88	134000	1795	05/26/88
481100	1377950	33320	34780	05/26/88	138000	1795	05/26/88
481100	1377975	36162	34780	05/26/88	145000	1795	05/26/88

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APPENDIX B

SOILS AND SILO CONTENTS DATA

DATA QUALIFIERS

EXPLANATION FOR DATA QUALIFIERS SHOWN ON THE FOLLOWING GENERAL CHEMICAL RESULTS

On the data tables that follow, an individual analytical result may include one or more data qualifiers. The list below presents all possible qualifiers and can be used as a reference when looking at the data. The qualifiers are standard Contract Laboratory Program (CLP) data qualifiers.

One note of caution; two types of chemical results tables are presented in this appendix: general chemical results and hazardous substance list results. There are two separate lists of data qualifiers for these separate tables and, although some of the symbols are the same for each, they may have different definitions.

Concentration Qualifiers

B = Reported value was obtained from a reading that was less than the Contract Laboratory Program (CLP) Contract Required Detection Limit (CRQL), but greater than or equal to the Instrument Detection Limit (IDL).

Quality Qualifiers

E = The reported value is estimated because of the presence of interference.

M = Duplicate injection precision not met.

N = Spiked sample recovery not within controls limits.

S = The reported value was determined by the Method of Standard Additions.

W = Post-digestion spike for Furnace AA analysis is out of control limits (85-115%), while sample absorbance is less than 50% of spike absorbance.

G = Native analyte > 4 times spike added; therefore acceptance criteria do not apply.

X = Detection limit is higher than normal due to sample matrix interferences.

* = Duplicate analysis not within control limits.

+ = Correlation coefficient for the MSA is less than 0.955.

EXPLANATION FOR DATA QUALIFIERS SHOWN ON THE FOLLOWING HAZARDOUS SUBSTANCE LIST RESULTS

On the data tables that follow, an individual analytical result may include one or more data qualifiers. The list below presents all possible qualifiers and can be used as a reference when looking at the data. The qualifiers are standard Contract Laboratory Program (CLP) data qualifiers.

One note of caution; two types of chemical results tables are presented in this appendix: general chemical results and hazardous substance list results. There are two separate lists of data qualifiers for these separate tables and, although some of the symbols are the same for each, they may have different definitions.

J = Indicates an estimated value. This flag is used when the mass spectral data indicate the presence of a compound that meets the identification criteria, but the result is less than the sample quantitation limit but greater than zero.

C = This flag applies to pesticide results where the identification has been confirmed by GC/MS.

B = This flag is used when the analyte is found in the associated blank as well as in the sample. It indicates possible/probable blank contamination and warns the data user to take appropriate action.

E = This flag identifies compounds whose concentrations exceed the calibration range of the GC/MS instrument for that specific analysis. This flag will <u>not</u> apply to pesticides/PCBs analyzed by GC/EC methods.

D = This flag identifies all compounds identified in an analysis at a secondary dilution factor.

F = Estimated value due to a confirmed compound which is off-scale in both columns.

X = A flag that FORMASTER III CLP software automatically inserts to indicate that the data was entered manually.

Z = No estimated value reported, or an elevated CRQL reported because matrix effects interfere with or obscure the compound on one or both columns. In either situation, the compound does not confirm as a positive identification.

* = Values outside of contract laboratory-required QC limits.

SILO ANALYTICAL DATA

CHEMICAL CONCENTRATION REPORT FOR SILOS 1, 2, AND 3
OPERABLE UNIT 4

Inorganics Analysis Data (mg/kg)
SILO 1

Sample Location	S1NE1A	S1NE1B	S1NE1C	S1NW1	S1SE1	S1SE2	S1SW1
Parameter							
Aluminum	1260	60.4	1380	450	364	1430	733
Antimony	ND	ND	ND	ND	ND	ND	ND
Arsenic	57.0	47.9	45.8	54.5	14.7	68.4	61.0
Barium	4340	1970	4140	5000	2720	2190	7860
Beryllium	2.8	1.3	1.4	1.1	0.88(B)	2.4	1.3
Cadmium	4.4	2.3	2.9	2.1	3.0	8.0	2.7
Calcium	5580	2320	2150	4130	3500	5700	5410
Chromium	43.3	25.8	22.8	21.0	165	111	42.6
Cobalt	1260	404	1210	681	349	814	657
Copper	473	122	410	217	126	307	209
Iron	24,100	9090	7170	4340	22,600	75,100	8370
Lead	35,800	61,400	85,100	81,300	38,900	38,800	76,900
Magnesium	2770	3270	3620	1900	1500	6020	2830
Manganese	178	36.5	83.1	33.5	94.2	257	54.0
Mercury	2.8	0.47	0.72	0.43	0.23	0.60	0.56
Nickel	1970	815	2580	1180	629	1350	1140
Potassium	158(B)	347(B)	424(B)	350(B)	173(B)	293(B)	492(B)
Selenium	172	139	170	162	106	180	168
Silver	9.8	5.0	23.3	9.5	6.3	13.1	9.8
Sodium	360(B)	5730	13,100	7080	1640	2610	7010
Thallium	0.09(B)	0.38(B)	ND	0.49(B)	0.24(B)	ND	0.52(B)
Vanadium	240	111	110	105	72.2	140	106
Zinc	212	14.4	26.3	24.7	23.9	57.3	17.8
Cyanide	0.52	1.4	1.4	2.9	0.99	1.6	4.4

Inorganic Qualifiers
ND - Compound analyzed for but not detected above instrument detection level (IDL)
B - Compound found between IDL and CRQL

Note 1: S1 indicates Silo 1, S2 indicates Silo 2, 21-33 indicate Silo 3
Note 2: Data validation is currently in progress
Source: Winter 1989 WMCO sampling

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CHEMICAL CONCENTRATION REPORT FOR SILOS 1, 2, AND 3
OPERABLE UNIT 4

Inorganics Analysis Data (mg/kg) (Continued)
SILO 2

Sample Location	S2NE1	S2NE2	S2NW1	S2NW2	S2SW1	S2SW2
Parameter						
Aluminum	2570	1360	1250	1180	464	551
Antimony	ND	ND	ND	ND	7.2(B)	6.4(B)
Arsenic	1960	330	71.3	57.5	81.4	64.5
Barium	2460	89.2	1190	3090	8370	8000
Beryllium	2.0	0.66(B)	6.0	2.7	1.6	2.1
Cadmium	19.1	4.1	5.6	5.0	3.6	3.4
Calcium	41,900	301,000	10,300	2430	3610	8570
Chromium	42.2	12.9	68.8	47.2	24.3	34.1
Cobalt	2430	6.2(B)	648	543	692	602
Copper	1790	ND	220	221	263	249
Iron	13,500	4010	37,800	26,900	8330	11,400
Lead	21,600	153	15,100	17,600	28,500	29,800
Magnesium	7390	8740	4200	4220	1520	2060
Manganese	403	335	170	160	74.2	83.2
Mercury	1.0	2.3	1.7	0.37	ND	0.34
Nickel	2200	14.6	878	787	1070	897
Potassium	207(B)	37.8(B)	271(B)	192(B)	118(B)	289(B)
Selenium	91.1	ND	117	95.9	118	105
Silver	22.8	ND	9.1	12.0	7.4	10.1
Sodium	4070	588(B)	912	226(B)	3100	857
Thallium	0.61(B)	ND	0.33(B)	0.39(B)	1.4(B)	0.82(B)
Vanadium	142	21.9	214	211	151	193
Zinc	154	11.2	31.6	70.8	25.8	25.7
Cyanide	1.1	ND	4.5	0.90	2.5	1.6

Inorganic Qualifiers
ND - Compound analyzed for but not detected above instrument detection level (IDL)
B - Compound found between IDL and CRQL

Note 1: S1 indicates Silo 1, S2 indicates Silo 2, 21-33 indicate Silo 3
Note 2: Data validation is currently in progress
Source: Winter 1989 WMCO sampling

Inorganics Analysis Data (mg/kg) (Continued)
SILO 3

Sample Location	21	22	23	24	25	26	27
Aluminum	21,300	18,000	18,000	23,700	15,800	10,800	20,800
Antimony	ND	ND	ND	ND	ND	ND	ND
Arsenic	1380	2450	1610	6380	2200	532	1460
Barium	297	253	332	194	210	118	319
Beryllium	20.8	20.6	39.9	35.1	26.5	10.0	25.2
Cadmium	41.7	60.3	40.1	204	62.4	21.5	45.5
Calcium	39,500	33,100	32,600	23,300	25,800	21,300	39,900
Chromium	260	171	421	139	213	170	335
Cobalt	2580	1100	1340	1870	1340	ND	2190
Copper	2020	2430	1610	7060	2440	1620	2140
Iron	41,700	26,200	60,400	13,900	31,200	28,200	67,600
Lead	1700	1440	646	4430	1310	1510	1130
Magnesium	74,400	62,400	44,900	38,200	44,100	44,800	72,400
Manganese	5200	3610	6500	2420	3980	2700	5790
Mercury	ND	ND	ND	0.30	ND	0.69	ND
Nickel	3280	1200	1810	2280	1760	6170	3150
Potassium	5310	3880	22800	4520	7360	3300	13600
Selenium	159	108	129	122	105	349	192
Silver	23.8	21.5	9.2	14.8	14.3	14.9	20.2
Sodium	30,100	43,100	44,100	38,100	31,200	22,900	39,500
Thallium	10.0	37.6	6.5	73.9	35.8	7.2	11.9
Vanadium	1180	2030	1420	4550	2030	499	1270
Zinc	497	361	637	387	380	301	563
Cyanide	ND	ND	ND	ND	ND	ND	ND

Inorganic Qualifiers
ND - Compound analyzed for but not detected above instrument detection level (IDL)
B - Compound found between IDL and CRQL

Note 1: S1 indicates Silo 1, S2 indicates Silo 2, 21-33 indicate Silo 3
Note 2: Data validation is currently in progress
Source: Winter 1989 WMCO sampling

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CHEMICAL CONCENTRATION REPORT FOR SILOS 1, 2, AND 3
OPERABLE UNIT 4

Inorganics Analysis Data (mg/kg) (Continued)
SILO 3

Sample Location	28	29	30	33
Aluminum	14,800	13,500	15,300	17,500
Antimony	ND	ND	ND	ND
Arsenic	1420	1010	1060	1980
Barium	142	118	215	185
Beryllium	31.2	13.9	16.6	26.4
Cadmium	69.8	24.2	35.1	52.7
Calcium	26,200	25,600	29,900	25,900
Chromium	560	443	236	221
Cobalt	2800	3520	2950	1350
Copper	2760	1640	2010	2280
Iron	45,000	40,000	37,800	23,800
Lead	1800	1960	1330	1750
Magnesium	71,400	80,900	58,100	52,800
Manganese	5940	5290	3970	2780
Mercury	ND	ND	0.30	ND
Nickel	3040	3830	4230	1970
Potassium	3740	1300	6690	7340
Selenium	204	186	254	101
Silver	13.3	9.5	17.4	16.1
Sodium	51,700	27,000	30,400	39,000
Thallium	5.5	4.0	13.7	3.1
Vanadium	2540	418	1040	3040
Zinc	672	449	397	306
Cyanide	ND	ND	ND	ND

Inorganic Qualifiers
ND - Compound analyzed for but not detected above instrument detection level (IDL)
B - Compound found between IDL and CRQL

Note 1: S1 indicates Silo 1, S2 indicates Silo 2, 21-33 indicate Silo 3
Note 2: Data validation is currently in progress
Source: Winter 1989 WMCO sampling

CHEMICAL CONCENTRATION REPORT FOR SILOS 1, 2, AND 3
OPERABLE UNIT 4

Volatile Organics Analysis Data (ug/kg)
SILO 1

Sample Location	S1NE1A	S1NE1B	S1NE1C	S1NEW1	S1SE1	S1SE2	S1SW1
Parameter							
Methylene Chloride	2100 (B)	1200(B)	1200(B)	3400(B)	4100(B)	840(B)	NA
Acetone	5300	140(BJ)	2200	1200(BJ)	1700(B)	2600(B)	NA
Chloroform	500(BJ)	1500(B)	490(BJ)	660(B)	660(B)	480(BJ)	NA
2-Butanone	10,000(B)	21,000(B)	10,000(B)	7100(B)	9200(B)	12,000(B)	NA
4-Methyl-2-Pentanone	ND	ND	ND	950(BJ)	1400	ND	NA
Toluene	ND	220(J)	ND	130(J)	140(J)	430(BJ)	NA
Styrene	ND	350	ND	ND	ND	ND	NA
Blank Reference	Blank 3	Blank 4	Blank 3	Blank 1	Blank 1	Blank 3	NA

SILO 2

Sample Location	S2NE1A	S2NE2B	S2NW1C	S2NW2	S2SW1	S2SW2	SWSW1
Parameter							
Chloroemethane	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	3600(B)	1500(B)	3600(B)	6300(B)	1100(B)	3400(B)	3700(B)
Acetone	ND	1400(B)	1600(B)	ND	ND	1200(BJ)	1600(B)
Chloroform	910(B)	720(B)	670(B)	1300(B)	700(B)	820(B)	660(B)
2-Butanone	15,000(B)	8700(B)	7800(B)	15,000(B)	8900(B)	11,000(B)	9900(B)
4-Methyl-2-Pentanone	ND	ND	2700	ND	ND	ND	870(J)
Toluene	200(J)	250(J)	130(J)	240(J)	130(J)	200(J)	ND
Trichloroethane	ND	ND	ND	ND	ND	ND	120
Toluene	200	250	130	240	130	200	ND
Styrene	ND	ND	ND	ND	200	ND	ND
Total Xylenes	ND	130	ND	ND	200	ND	ND
Blank Reference	Blank 4	Blank 4	Blank 1	Blank 4	Blank 4	Blank 4	Blank 1

Organic Qualifiers
J - Compound detected below the contract required quantification limit (CRQL)
ND - Compound analyzed for but not detected
B - Compound was found in the method blank
NA - Not analyzed
Note 1: S1 indicates Silo 1, S2 indicates Silo 2, 21-33 indicate Silo 3
Note 2: Data validation is currently in progress

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CHEMICAL CONCENTRATION REPORT FOR SILOS 1, 2, AND 3
OPERABLE UNIT 4

Volatile Organics Analysis Data (µg/kg)
SILO 3

Sample Location	26	27	27R	28	29
Chloromethane	ND	140	ND	ND	ND
Methylene Chloride	1800(B)	1200(B)	2800	1000(B)	1600(B)
Acetone	4800	3900	5200	12,000	3400(B)
Chloroform	680(B)	680(B)	740	560(BJ)	810(B)
2-Butanone	13,000(B)	13,004(B)	15,000	16,000(B)	9700(B)
4-Methyl-2-Pentanone	ND	ND	6800	ND	ND
Toluene	210(J)	6800		3400(B)	180(BJ)
Blank Reference	Blank 2	Blank 2		Blank 3	Blank 5

BLANKS

Sample Location	Blank 1	Blank 2	Blank 3	Blank 4	Blank 5
Methylene Chloride	1700	1600	1300	2400	1100
Acetone	1200(J)	ND	4800	570(J)	1000(J)
Chloroform	720	680	470(J)	370(J)	310(J)
2-Butanone	8500	11,000	8100	6400	6500
4-Methyl-2-Pentanone	ND	ND	ND	ND	ND
Toluene	ND	ND	140(J)	ND	160(J)
Styrene	ND	ND	ND	810	ND
Total Xylenes	ND	ND	ND	720	ND

Organic Qualifiers
J - Compound detected below the contract required quantification limit (CRQL)
ND - Compound analyzed for but not detected
B - Compound was found in the method blank

Note 1: S1 indicates Silo 1, S2 indicates Silo 2, 21-33 indicate Silo 3
Note 2: Data validation is currently in progress

CHEMICAL CONCENTRATION REPORT FOR SILOS 1, 2, AND 3
OPERABLE UNIT 4

Semivolatile Organics Analysis Data (ug/kg)
SILO 1

Sample Location	S1NE1A	S1NE1B	S1NE1C	S1NEW1	S1SE1	S1SE2	S1SW1
bis(2-Ethylhexyl)Phthalate	220(J)	93(J)	210(J)	630	800	6000	560
Di-n-Octyl Phthalate	ND	ND	ND	500	ND	820	45(J)
Blank Reference	Blank 1	Blank 1	Blank 1	Blank 2	Blank 1	Blank 1	Blank 1

SILO 2

Sample Location	S2NE1	S2NE2	S2NW1	S2NW2	S2SW1	S2SW2
bis(2-Ethylhexyl)Pthalate	520	ND	560	560	270(J)	520
Di-n-Octyl Phthalate	ND	ND	ND	ND	ND	ND
Blank Reference	Blank 2	Blank 2	Blank 2	Blank 2	Blank 1	Blank 2

SILO 3

Sample Location	26	27	28	29	Blank 1	Blank 2
bis(2-Ethylhexyl)Phthalate	40(J)	ND	ND	ND	ND	ND
Di-n-Octyl Phthalate	ND	ND	ND	ND	ND	ND
Blank Reference	Blank 1	Blank 1	Blank 1	Blank 1		

Organic Qualifiers
J - Compound detected below the contract required quantification limit (CRQL)
ND - Compound analyzed for but not detected
B - Compound was found in the method blank

Note 1: S1 indicates Silo 1, S2 indicates Silo 2, 21-33 indicate Silo 3
Note 2: Data validation is currently in progress

CHEMICAL CONCENTRATION REPORT FOR SILOS 1, 2, AND 3
OPERABLE UNIT 4

Pesticide Organics Analysis Data (ug/kg)
SILO 1

Sample Location	S1NE1A	S1NE1B	S1NE1C	S1NW1	S1SE1	S1SE2	S1SW1
Aroclor-1248	3700	ND	ND	1700	2500	7300	2400
Aroclor-1254	8100	1100(J)	1300(J)	3900	3500	10,000	5600
Second Dilution			**Second Dilution**				
Aroclor-1248	4100(J)	NA	NA	2800(J)	4000(J)	8000	3200(J)
Aroclor-1254	8700(J)	NA	NA	5700(J)	5800(J)	12,000	6600(J)
Blank Reference	Blank 1	Blank 1	Blank 2	Blank 1	Blank 1	Blank 1	Blank 1

SILO 2

Sample Location	S2NE1	S2NE2	S2NW1	S2NW2	S2SW1	S2SW2
Aroclor-1248	ND	ND	ND	ND	ND	ND
Aroclor-1254	1900	420(J)	3000	1300(J)	3300	3900
Second Dilution				**Second Dilution**		
Aroclor-1248	ND	NA	ND	ND	ND	ND
Aroclor-1254	2000(J)	NA	5400(J)	1500(J)	3700(J)	6000(J)
Blank Reference	Blank 2	Blank 2	Blank 2	Blank 2	Blank 1	Blank 2

SILO 3 and BLANKS

Sample Location	26	27	28	29	Blank 1	Blank 2
Aroclor-1248	ND	ND	ND	ND	ND	ND
Aroclor-1254	ND	ND	ND	ND	ND	ND
Second Dilution		**Second Dilution**				
Arcolor-1248	NA	NA	NA	NA		
Aroclor-1254	NA	NA	NA	NA		
Blank Reference	Blank 1	Blank 1	Blank 1	Blank 1		

Organic Qualifiers
J - Copmpound detected below the contract required quantification limit (CRQL)
ND - Compound analyzed for but not detected
B - Compound was found in the method blank
NA - Not analyzed
Note 1: S1 indicates Silo 1, S2 indicates Silo 2, 21-33 indicate Silo 3
Note 2: Data validation is currently in progress
Source: Winter 1989 WMCO sampling.

SURFACE SOILS

RADIOLOGICAL RESULTS

SURFACE SOIL RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picocuries per gram (pCi/g).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETERS	N 481000 E 1378000 05049 0 - 2	N 480000 E 1378000 05146 0 - 2	N 480000 E 1379000 05149 0 - 2	N 480260 E 1378340 05644 0 - 2
Cesium 137	< 0.2	< 0.2	1.0 ± 0.2	NA
Neptunium 237	< 0.6	< 0.6	< 0.6	NA
Plutonium 238	< 0.6	< 0.6	< 0.6	NA
Plutonium 239/240	< 0.6	< 0.6	< 0.6	NA
Radium 226	< 0.3	< 0.4	1.0 ± 0.2	NA
Radium 228	< 1.1	< 0.7	< 0.9	NA
Ruthenium 106	< 1.5	< 1.0	< 1.2	NA
Strontium 90	< 0.5	< 0.5	1.1 ± 0.2	NA
Technetium 99	< 0.9	< 0.9	< 2.2	NA
Thorium 228	0.7 ± 0.2	0.7 ± 0.3	1.4 ± 0.4	NA
Thorium 230	1.0 ± 0.3	1.2 ± 0.4	8.4 ± 1.5	NA
Thorium 232	0.8 ± 0.3	< 0.6	5.2 ± 1.0	NA
Total Thorium **	NA	NA	NA	NA
Uranium 234	1.7 ± 0.6	1.3 ± 0.4	21.0 ± 3.8	2.5 ± 0.5
Uranium 235/236	< 0.6	< 0.6	1.4 ± 0.5	< 0.6
Uranium 238	2.6 ± 0.7	1.7 ± 0.5	21.1 ± 3.8	4.8 ± 0.8
Total Uranium **	7.8 ± 2.1	NA	NA	NA

* Data validation in progress.

** Results reported in ug/g

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SURFACE SOIL RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picocuries per gram (pCi/g).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETERS	N 480260 E 1378340 05645 2 - 4	N 480260 E 1378340 05646 4 - 6	N 480540 E 1378350 05647 0 - 2	N 480540 E 1378350 05648 2 - 4
Cesium 137	< 0.2	< 0.2	NA	< 0.2
Neptunium 237	< 0.6	< 0.6	NA	< 0.6
Plutonium 238	< 0.6	< 0.6	NA	< 0.6
Plutonium 239/240	< 0.6	< 0.6	NA	< 0.6
Radium 226	1.0 ± 0.2	1.0 ± 0.2	NA	2.3 ± 0.2
Radium 228	1.7 ± 0.3	1.3 ± 0.3	NA	1.4 ± 0.2
Ruthenium 106	< 1.5	< 1.8	NA	< 1.1
Strontium 90	0.9 ± 0.2	0.8 ± 0.3	NA	0.8 ± 0.3
Technetium 99	< 0.9	< 0.9	NA	< 1.1
Thorium 228	1.4 ± 0.3	1.2 ± 0.3	NA	1.2 ± 0.2
Thorium 230	2.5 ± 0.4	1.9 ± 0.4	NA	3.9 ± 0.6
Thorium 232	1.7 ± 0.3	1.2 ± 0.3	NA	1.2 ± 0.3
Total Thorium **	NA	NA	NA	NA
Uranium 234	NA	NA	6.9 ± 1.3	NA
Uranium 235/236	NA	NA	< 0.6	NA
Uranium 238	NA	NA	20.8 ± 3.5	NA
Total Uranium **	4.0 ± 3.0	4.0 ± 3.0	NA	64.0 ± 7.0

* Data validation in progress.

** Results reported in ug/g

SURFACE SOIL RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picocuries per gram (pCi/g).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETERS	N 480540 E 1378350 05649 4 - 6	N 480700 E 1378400 05650 0 - 2	N 480700 E 1378400 05651 2 - 4	N 480700 E 1378400 05652 4 - 6
Cesium 137	< 0.2	NA	< 0.2	< 0.2
Neptunium 237	< 0.6	NA	< 0.6	< 0.6
Plutonium 238	< 0.6	NA	< 0.6	< 0.6
Plutonium 239/240	< 0.6	NA	< 0.6	< 0.6
Radium 226	4.2 ± 0.4	NA	1.1 ± 0.1	1.2 ± 0.1
Radium 228	1.3 ± 0.2	NA	1.0 ± 0.2	1.2 ± 0.2
Ruthenium 106	< 1.0	NA	< 1.0	< 1.1
Strontium 90	1.0 ± 0.3	NA	2.6 ± 0.4	1.6 ± 0.3
Technetium 99	1.2 ± 0.7	NA	< 0.9	< 0.9
Thorium 228	1.1 ± 0.2	NA	0.9 ± 0.2	1.0 ± 0.2
Thorium 230	4.3 ± 0.6	NA	3.3 ± 0.5	3.3 ± 0.5
Thorium 232	0.9 ± 0.2	NA	1.3 ± 0.3	1.0 ± 0.2
Total Thorium **	NA	NA	NA	NA
Uranium 234	NA	4.7 ± 0.7	NA	NA
Uranium 235/236	NA	< 0.6	NA	NA
Uranium 238	NA	7.3 ± 1.1	NA	NA
Total Uranium **	46.0 ± 7.0	NA	10.0 ± 2.0	12.0 ± 3.0

* Data validation in progress.

** Results reported in ug/g

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SURFACE SOIL RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picocuries per gram (pCi/g).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETERS	N 481000 E 1378300 05423 0 - 2	N 481000 E 1378000 05496 0 - 2	N 480250 E 1378500 05884 0 - 6	N 480245 E 1378750 05887 0 - 6
Cesium 137	< 0.2	< 0.2	< 0.2	0.2 ± 0.1
Neptunium 237	< 0.6	< 0.6	< 0.6	< 0.6
Plutonium 238	< 0.6	< 0.6	< 0.6	< 0.6
Plutonium 239/240	< 0.6	< 0.6	< 0.6	< 0.6
Radium 226	0.6 ± 0.1	0.6 ± 0.1	1.1 ± 0.1	0.9 ± 0.1
Radium 228	0.5 ± 0.2	0.6 ± 0.1	1.3 ± 0.1	0.8 ± 0.1
Ruthenium 106	< 1.0	< 1.0	< 1.0	< 1.0
Strontium 90	< 0.5	< 0.5	< 0.5	1.8 ± 0.3
Technetium 99	< 0.9	< 0.9	< 0.9	< 0.9
Thorium 228	< 0.6	< 0.6	0.9 ± 0.2	1.1 ± 0.2
Thorium 230	3.4 ± 0.5	1.1 ± 0.2	2.2 ± 0.4	1.4 ± 0.3
Thorium 232	< 0.6	< 0.6	0.9 ± 0.2	1.0 ± 0.2
Total Thorium **	NA	NA	NA	NA
Uranium 234	3.2 ± 0.5	1.5 ± 0.3	2.4 ± 0.4	2.8 ± 0.4
Uranium 235/236	< 0.6	< 0.6	< 0.6	< 0.6
Uranium 238	4.5 ± 0.6	3.2 ± 0.5	2.4 ± 0.4	3.3 ± 0.5
Total Uranium **	11.0 ± 2.0	9.0 ± 1.0	11.0 ± 2.0	8.0 ± 2.0

* Data validation in progress.

** Results reported in ug/g

SURFACE SOIL RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picocuries per gram (pCi/g).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETERS	N 480239 E 1379000 05890 0 - 6
Cesium 137	0.3 ± 0.1
Neptunium 237	< 0.6
Plutonium 238	< 0.6
Plutonium 239/240	< 0.6
Radium 226	1.3 ± 0.1
Radium 228	0.9 ± 0.1
Ruthenium 106	< 1.0
Strontium 90	0.9 ± 0.3
Technetium 99	< 0.9
Thorium 228	1.0 ± 0.2
Thorium 230	3.5 ± 0.5
Thorium 232	1.0 ± 0.2
Total Thorium **	NA
Uranium 234	4.5 ± 0.6
Uranium 235/236	< 0.6
Uranium 238	5.1 ± 0.7
Total Uranium **	15.0 ± 2.0

* Data validation in progress.

** Results reported in ug/g

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SURFACE SOILS

CIS - DATA

SOURCE: ROY F. WESTON 1987

ON-SITE LABORATORY RADIONUCLIDE RESULTS

SAMPLE ID	EAST COORDINATE (Feet)	NORTH COORDINATE (Feet)	BEGIN DEPTH (Feet)	END DEPTH (Feet)	RADIONUCLIDE	VQ	ACTIVITY CONCENTRATION (pCi/g)	UNCERTAINTY VALUE (pCi/g)
FMP-SS-23-046	1378796.30	480442.13	0.00	0.50	CS-137	<	0.60	
FMP-SS-23-046	1378796.30	480442.13	0.00	0.50	RA-226	=	3.90	0.70
FMP-SS-23-046	1378796.30	480442.13	0.00	0.50	RU-106	<	6.10	
FMP-SS-23-046	1378796.30	480442.13	0.00	0.50	TH-232	<	3.70	
FMP-SS-23-046	1378796.30	480442.13	0.00	0.50	U-238	<	16.70	
FMP-SS-23-047	1378776.78	480459.67	0.00	0.50	CS-137	<	0.30	
FMP-SS-23-047	1378776.78	480459.67	0.00	0.50	RA-226	=	0.80	0.40
FMP-SS-23-047	1378776.78	480459.67	0.00	0.50	RU-106	<	8.20	
FMP-SS-23-047	1378776.78	480459.67	0.00	0.50	TH-232	=	1.00	0.70
FMP-SS-23-047	1378776.78	480459.67	0.00	0.50	U-238	=	5.20	1.30
FMP-SS-23-048	1378757.37	480445.19	0.00	0.50	CS-137	=	0.40	0.30
FMP-SS-23-048	1378757.37	480445.19	0.00	0.50	RA-226	=	0.90	0.30
FMP-SS-23-048	1378757.37	480445.19	0.00	0.50	RU-106	<	0.60	
FMP-SS-23-048	1378757.37	480445.19	0.00	0.50	TH-232	<	2.00	
FMP-SS-23-048	1378757.37	480445.19	0.00	0.50	U-238	<	12.70	
FMP-SS-23-049	1378739.73	480458.68	0.00	0.50	CS-137	=	0.60	0.20
FMP-SS-23-049	1378739.73	480458.68	0.00	0.50	RA-226	=	0.80	0.60
FMP-SS-23-049	1378739.73	480458.68	0.00	0.50	RU-106	<	6.70	
FMP-SS-23-049	1378739.73	480458.68	0.00	0.50	TH-232	<	0.30	
FMP-SS-23-049	1378739.73	480458.68	0.00	0.50	U-238	=	6.90	3.40
FMP-SS-23-050	1378715.41	480447.34	0.00	0.50	CS-137	<	0.40	
FMP-SS-23-050	1378715.41	480447.34	0.00	0.50	RA-226	=	1.90	0.50
FMP-SS-23-050	1378715.41	480447.34	0.00	0.50	RU-106	<	7.80	
FMP-SS-23-050	1378715.41	480447.34	0.00	0.50	TH-232	=	3.60	1.00
FMP-SS-23-050	1378715.41	480447.34	0.00	0.50	U-238	<	9.00	
FMP-SS-23-050QC	1378715.41	480447.34	0.00	0.50	CS-137	<	1.10	
FMP-SS-23-050QC	1378715.41	480447.34	0.00	0.50	RA-226	=	2.40	0.50
FMP-SS-23-050QC	1378715.41	480447.34	0.00	0.50	RU-106	<	6.50	
FMP-SS-23-050QC	1378715.41	480447.34	0.00	0.50	TH-232	=	1.70	1.20
FMP-SS-23-050QC	1378715.41	480447.34	0.00	0.50	U-238	=	6.20	4.00

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ON-SITE LABORATORY RADIONUCLIDE RESULTS

SAMPLE ID	EAST COORDINATE (Feet)	NORTH COORDINATE (Feet)	BEGIN DEPTH (Feet)	END DEPTH (Feet)	RADIONUCLIDE	VQ	ACTIVITY CONCENTRATION (pCi/g)	UNCERTAINTY VALUE (pCi/g)
FMP-SS-23-051	1378695.81	480461.88	0.00	0.50	CS-137	<	0.40	
FMP-SS-23-051	1378695.81	480461.88	0.00	0.50	RA-226	=	2.40	0.40
FMP-SS-23-051	1378695.81	480461.88	0.00	0.50	RU-106	<	0.40	
FMP-SS-23-051	1378695.81	480461.88	0.00	0.50	TH-232	<	0.30	
FMP-SS-23-051	1378695.81	480461.88	0.00	0.50	U-238	<	8.00	
FMP-SS-23-052	1378674.43	480448.46	0.00	0.50	CS-137	<	0.80	
FMP-SS-23-052	1378674.43	480448.46	0.00	0.50	RA-226	=	0.40	0.20
FMP-SS-23-052	1378674.43	480448.46	0.00	0.50	RU-106	<	0.60	
FMP-SS-23-052	1378674.43	480448.46	0.00	0.50	TH-232	<	2.10	
FMP-SS-23-052	1378674.43	480448.46	0.00	0.50	U-238	<	10.10	
FMP-SS-23-053	1378635.42	480448.53	0.00	0.50	CS-137	<	0.70	
FMP-SS-23-053	1378635.42	480448.53	0.00	0.50	RA-226	=	0.60	0.40
FMP-SS-23-053	1378635.42	480448.53	0.00	0.50	RU-106	<	0.80	
FMP-SS-23-053	1378635.42	480448.53	0.00	0.50	TH-232	=	0.90	0.40
FMP-SS-23-053	1378635.42	480448.53	0.00	0.50	U-238	=	4.50	2.80
FMP-SS-23-053D	1378635.42	480448.53	0.00	0.50	CS-137	<	0.50	
FMP-SS-23-053D	1378635.42	480448.53	0.00	0.50	RA-226	<	0.40	
FMP-SS-23-053D	1378635.42	480448.53	0.00	0.50	RU-106	<	4.80	
FMP-SS-23-053D	1378635.42	480448.53	0.00	0.50	TH-232	=	0.90	0.40
FMP-SS-23-053D	1378635.42	480448.53	0.00	0.50	U-238	=	4.10	3.50
FMP-SS-23-054	1378717.55	480525.31	0.00	0.50	CS-137	<	0.90	
FMP-SS-23-054	1378717.55	480525.31	0.00	0.50	RA-226	=	0.70	0.30
FMP-SS-23-054	1378717.55	480525.31	0.00	0.50	RU-106	<	5.60	
FMP-SS-23-054	1378717.55	480525.31	0.00	0.50	TH-232	<	0.30	
FMP-SS-23-054	1378717.55	480525.31	0.00	0.50	U-238	<	6.80	
FMP-SS-23-055	1378714.81	480425.35	0.00	0.50	CS-137	<	0.60	
FMP-SS-23-055	1378714.81	480425.35	0.00	0.50	RA-226	=	1.00	0.30
FMP-SS-23-055	1378714.81	480425.35	0.00	0.50	RU-106	<	5.40	
FMP-SS-23-055	1378714.81	480425.35	0.00	0.50	TH-232	=	1.10	0.30
FMP-SS-23-055	1378714.81	480425.35	0.00	0.50	U-238	<	6.70	

ON-SITE LABORATORY RADIONUCLIDE RESULTS

SAMPLE ID	EAST COORDINATE (Feet)	NORTH COORDINATE (Feet)	BEGIN DEPTH (Feet)	END DEPTH (Feet)	RADIONUCLIDE	VQ	ACTIVITY CONCENTRATION (pCi/g)	UNCERTAINTY VALUE (pCi/g)
FMP-SS-23-056	1378712.08	480325.39	0.00	0.50	CS-137	<	0.30	
FMP-SS-23-056	1378712.08	480325.39	0.00	0.50	RA-226	=	1.10	0.30
FMP-SS-23-056	1378712.08	480325.39	0.00	0.50	RU-106	<	7.90	
FMP-SS-23-056	1378712.08	480325.39	0.00	0.50	TH-232	=	0.50	0.30
FMP-SS-23-056	1378712.08	480325.39	0.00	0.50	U-238	<	10.20	
FMP-SS-23-056D	1378712.08	480325.39	0.00	0.50	CS-137	<	0.30	
FMP-SS-23-056D	1378712.08	480325.39	0.00	0.50	RA-226	=	1.10	0.30
FMP-SS-23-056D	1378712.08	480325.39	0.00	0.50	RU-106	<	0.50	
FMP-SS-23-056D	1378712.08	480325.39	0.00	0.50	TH-232	<	0.30	
FMP-SS-23-056D	1378712.08	480325.39	0.00	0.50	U-238	<	3.40	
FMP-SS-23-057	1378709.34	480225.42	0.00	0.50	CS-137	<	0.10	
FMP-SS-23-057	1378709.34	480225.42	0.00	0.50	RA-226	=	0.50	0.30
FMP-SS-23-057	1378709.34	480225.42	0.00	0.50	RU-106	<	6.90	
FMP-SS-23-057	1378709.34	480225.42	0.00	0.50	TH-232	=	0.80	0.40
FMP-SS-23-057	1378709.34	480225.42	0.00	0.50	U-238	<	5.10	
FMP-SS-23-061	1378809.30	480222.69	0.00	0.50	CS-137	<	1.10	
FMP-SS-23-061	1378809.30	480222.69	0.00	0.50	RA-226	=	0.60	0.30
FMP-SS-23-061	1378809.30	480222.69	0.00	0.50	RU-106	<	4.90	
FMP-SS-23-061	1378809.30	480222.69	0.00	0.50	TH-232	<	3.40	
FMP-SS-23-061	1378809.30	480222.69	0.00	0.50	U-238	<	8.60	
FMP-SD-40-014	1378446.00	480059.00	0.00	0.16	CS-137	<	0.10	
FMP-SD-40-014	1378446.00	480059.00	0.00	0.16	RA-226	=	0.80	0.50
FMP-SD-40-014	1378446.00	480059.00	0.00	0.16	RU-106	<	7.30	
FMP-SD-40-014	1378446.00	480059.00	0.00	0.16	TH-232	<	2.30	
FMP-SD-40-014	1378446.00	480059.00	0.00	0.16	U-238	=	7.40	2.90
FMP-SD-40-015	1378369.00	480023.00	0.00	0.42	CS-137	<	0.10	
FMP-SD-40-015	1378369.00	480023.00	0.00	0.42	RA-226	<	0.50	
FMP-SD-40-015	1378369.00	480023.00	0.00	0.42	RU-106	<	5.30	
FMP-SD-40-015	1378369.00	480023.00	0.00	0.42	TH-232	<	1.70	
FMP-SD-40-015	1378369.00	480023.00	0.00	0.42	U-238	=	8.10	2.40

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ON-SITE LABORATORY RADIONUCLIDE RESULTS

SAMPLE ID	EAST COORDINATE (Feet)	NORTH COORDINATE (Feet)	BEGIN DEPTH (Feet)	END DEPTH (Feet)	RADIONUCLIDE	VQ	ACTIVITY CONCENTRATION (pCi/g)	UNCERTAINTY VALUE (pCi/g)
FMP-SD-40-016	1378298.00	479984.00	0.00	0.50	CS-137	<	0.50	
FMP-SD-40-016	1378298.00	479984.00	0.00	0.50	RA-226	<	1.60	
FMP-SD-40-016	1378298.00	479984.00	0.00	0.50	RU-106	<	0.40	
FMP-SD-40-016	1378298.00	479984.00	0.00	0.50	TH-232	<	0.20	
FMP-SD-40-016	1378298.00	479984.00	0.00	0.50	U-238	=	5.60	2.20
FMP-SD-40-017	1378196.00	479964.00	0.00	0.20	CS-137	<	0.10	
FMP-SD-40-017	1378196.00	479964.00	0.00	0.20	RA-226	=	0.70	0.30
FMP-SD-40-017	1378196.00	479964.00	0.00	0.20	RU-106	<	4.90	
FMP-SD-40-017	1378196.00	479964.00	0.00	0.20	TH-232	<	1.90	
FMP-SD-40-017	1378196.00	479964.00	0.00	0.20	U-238	<	5.20	
FMP-SD-40-010	1378785.00	480059.00	0.00	0.30	CS-137	<	0.40	
FMP-SD-40-010	1378785.00	480059.00	0.00	0.30	RA-226	=	0.70	0.30
FMP-SD-40-010	1378785.00	480059.00	0.00	0.30	RU-106	<	4.60	
FMP-SD-40-010	1378785.00	480059.00	0.00	0.30	TH-232	<	1.80	
FMP-SD-40-010	1378785.00	480059.00	0.00	0.30	U-238	=	4.80	3.00
FMP-SD-40-011	1378704.00	480081.00	0.00	0.50	CS-137	<	0.40	
FMP-SD-40-011	1378704.00	480081.00	0.00	0.50	RA-226	=	0.80	0.40
FMP-SD-40-011	1378704.00	480081.00	0.00	0.50	RU-106	<	3.50	
FMP-SD-40-011	1378704.00	480081.00	0.00	0.50	TH-232	<	0.80	
FMP-SD-40-011	1378704.00	480081.00	0.00	0.50	U-238	=	4.70	2.90
FMP-SD-40-012	1378614.00	480081.00	0.00	0.50	CS-137	<	0.40	
FMP-SD-40-012	1378614.00	480081.00	0.00	0.50	RA-226	<	1.50	
FMP-SD-40-012	1378614.00	480081.00	0.00	0.50	RU-106	<	0.50	
FMP-SD-40-012	1378614.00	480081.00	0.00	0.50	TH-232	<	2.10	
FMP-SD-40-012	1378614.00	480081.00	0.00	0.50	U-238	=	6.80	2.90
FMP-SD-40-013	1378536.00	480099.00	0.00	0.42	CS-137	<	0.90	
FMP-SD-40-013	1378536.00	480099.00	0.00	0.42	RA-226	=	0.70	0.20
FMP-SD-40-013	1378536.00	480099.00	0.00	0.42	RU-106	<	6.20	
FMP-SD-40-013	1378536.00	480099.00	0.00	0.42	TH-232	=	0.60	0.50
FMP-SD-40-013	1378536.00	480099.00	0.00	0.42	U-238	=	3.30	2.00

ON-SITE LABORATORY RADIONUCLIDE RESULTS

SAMPLE ID	EAST COORDINATE (Feet)	NORTH COORDINATE (Feet)	BEGIN DEPTH (Feet)	END DEPTH (Feet)	RADIONUCLIDE	VQ	ACTIVITY CONCENTRATION (pCi/g)	UNCERTAINTY VALUE (pCi/g)
FMP-SD-40-013D	1378536.00	480099.00	0.00	0.42	CS-137	<	0.80	
FMP-SD-40-013D	1378536.00	480099.00	0.00	0.42	RA-226	=	0.70	0.40
FMP-SD-40-013D	1378536.00	480099.00	0.00	0.42	RU-106	<	7.40	
FMP-SD-40-013D	1378536.00	480099.00	0.00	0.42	TH-232	=	0.60	0.40
FMP-SD-40-013D	1378536.00	480099.00	0.00	0.42	U-238	=	7.60	3.00
FMP-SL-46-326	1378423.13	480733.44	0.16	0.50	CS-137	<	0.90	
FMP-SL-46-326	1378423.13	480733.44	0.16	0.50	RA-226	=	3.20	0.60
FMP-SL-46-326	1378423.13	480733.44	0.16	0.50	RU-106	<	4.90	
FMP-SL-46-326	1378423.13	480733.44	0.16	0.50	TH-232	<	4.30	
FMP-SL-46-326	1378423.13	480733.44	0.16	0.50	U-238	<	13.70	
FMP-SL-46-327	1378623.06	480727.97	0.16	0.50	CS-137	<	0.10	
FMP-SL-46-327	1378623.06	480727.97	0.16	0.50	RA-226	=	1.00	0.30
FMP-SL-46-327	1378623.06	480727.97	0.16	0.50	RU-106	<	4.90	
FMP-SL-46-327	1378623.06	480727.97	0.16	0.50	TH-232	=	0.40	0.20
FMP-SL-46-327	1378623.06	480727.97	0.16	0.50	U-238	=	3.00	2.20
FMP-SL-46-571	1378446.76	480682.78	0.50	1.00	CS-137	<	0.50	
FMP-SL-46-571	1378446.76	480682.78	0.50	1.00	RA-226	=	11.60	0.90
FMP-SL-46-571	1378446.76	480682.78	0.50	1.00	RU-106	<	8.20	
FMP-SL-46-571	1378446.76	480682.78	0.50	1.00	TH-232	<	2.20	
FMP-SL-46-571	1378446.76	480682.78	0.50	1.00	U-238	<	23.00	
FMP-SL-46-572	1378446.76	480682.78	0.50	1.00	CS-137	<	0.60	
FMP-SL-46-572	1378446.76	480682.78	0.50	1.00	RA-226	=	2.30	0.40
FMP-SL-46-572	1378446.76	480682.78	0.50	1.00	RU-106	<	2.40	
FMP-SL-46-572	1378446.76	480682.78	0.50	1.00	TH-232	<	2.30	
FMP-SL-46-572	1378446.76	480682.78	0.50	1.00	U-238	<	11.20	
FMP-SS-46-194	1378431.34	481033.33	0.00	0.16	CS-137	<	0.60	
FMP-SS-46-194	1378431.34	481033.33	0.00	0.16	RA-226	=	0.70	0.30
FMP-SS-46-194	1378431.34	481033.33	0.00	0.16	RU-106	<	0.60	
FMP-SS-46-194	1378431.34	481033.33	0.00	0.16	TH-232	<	0.30	
FMP-SS-46-194	1378431.34	481033.33	0.00	0.16	U-238	=	30.10	4.20

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ON-SITE LABORATORY RADIONUCLIDE RESULTS

SAMPLE ID	EAST COORDINATE (Feet)	NORTH COORDINATE (Feet)	BEGIN DEPTH (Feet)	END DEPTH (Feet)	RADIONUCLIDE	VQ	ACTIVITY CONCENTRATION (pCi/g)	UNCERTAINTY VALUE (pCi/g)
FMP-SS-46-195Q	1378431.34	481033.33	0.00	0.16	CS-137	<	0.60	
FMP-SS-46-195Q	1378431.34	481033.33	0.00	0.16	RA-226	=	0.70	0.30
FMP-SS-46-195Q	1378431.34	481033.33	0.00	0.16	RU-106	<	0.60	
FMP-SS-46-195Q	1378431.34	481033.33	0.00	0.16	TH-232	<	0.30	
FMP-SS-46-195Q	1378431.34	481033.33	0.00	0.16	U-238	=	26.90	5.50
FMP-SS-46-196	1378531.30	481030.60	0.00	0.16	CS-137	<	0.30	
FMP-SS-46-196	1378531.30	481030.60	0.00	0.16	RA-226	=	1.70	0.40
FMP-SS-46-196	1378531.30	481030.60	0.00	0.16	RU-106	<	3.60	
FMP-SS-46-196	1378531.30	481030.60	0.00	0.16	TH-232	<	0.30	
FMP-SS-46-196	1378531.30	481030.60	0.00	0.16	U-238	=	8.70	3.50
FMP-SS-46-196D	1378531.30	481030.60	0.00	0.16	CS-137	<	0.70	
FMP-SS-46-196D	1378531.30	481030.60	0.00	0.16	RA-226	=	1.70	0.40
FMP-SS-46-196D	1378531.30	481030.60	0.00	0.16	RU-106	<	4.90	
FMP-SS-46-196D	1378531.30	481030.60	0.00	0.16	TH-232	=	0.70	0.30
FMP-SS-46-196D	1378531.30	481030.60	0.00	0.16	U-238	=	10.60	3.50
FMP-SS-46-197	1378631.27	481027.86	0.00	0.16	CS-137	<	0.10	
FMP-SS-46-197	1378631.27	481027.86	0.00	0.16	RA-226	=	0.70	0.30
FMP-SS-46-197	1378631.27	481027.86	0.00	0.16	RU-106	<	4.30	
FMP-SS-46-197	1378631.27	481027.86	0.00	0.16	TH-232	<	1.20	
FMP-SS-46-197	1378631.27	481027.86	0.00	0.16	U-238	=	4.10	2.00
FMP-SS-46-198	1378731.23	481025.12	0.00	0.16	CS-137	<	0.30	
FMP-SS-46-198	1378731.23	481025.12	0.00	0.16	RA-226	=	1.00	0.30
FMP-SS-46-198	1378731.23	481025.12	0.00	0.16	RU-106	<	3.20	
FMP-SS-46-198	1378731.23	481025.12	0.00	0.16	TH-232	=	0.70	0.30
FMP-SS-46-198	1378731.23	481025.12	0.00	0.16	U-238	=	4.10	0.90
FMP-SS-46-199	1378428.61	480933.37	0.00	0.16	CS-137	<	0.40	
FMP-SS-46-199	1378428.61	480933.37	0.00	0.16	RA-226	<	0.30	
FMP-SS-46-199	1378428.61	480933.37	0.00	0.16	RU-106	<	0.50	
FMP-SS-46-199	1378428.61	480933.37	0.00	0.16	TH-232	<	2.80	
FMP-SS-46-199	1378428.61	480933.37	0.00	0.16	U-238	<	8.80	

ON-SITE LABORATORY RADIONUCLIDE RESULTS

SAMPLE ID	EAST COORDINATE (Feet)	NORTH COORDINATE (Feet)	BEGIN DEPTH (Feet)	END DEPTH (Feet)	RADIONUCLIDE	VQ	ACTIVITY CONCENTRATION (pCi/g)	UNCERTAINTY VALUE (pCi/g)
FMP-SS-46-200	1378628.53	480927.90	0.00	0.16	CS-137	<	0.20	
FMP-SS-46-200	1378628.53	480927.90	0.00	0.16	RA-226	=	0.50	0.20
FMP-SS-46-200	1378628.53	480927.90	0.00	0.16	RU-106	<	3.60	
FMP-SS-46-200	1378628.53	480927.90	0.00	0.16	TH-232	<	1.80	
FMP-SS-46-200	1378628.53	480927.90	0.00	0.16	U-238	<	9.00	
FMP-SS-46-201	1378728.49	480925.16	0.00	0.16	CS-137	<	0.30	
FMP-SS-46-201	1378728.49	480925.16	0.00	0.16	RA-226	=	1.00	0.30
FMP-SS-46-201	1378728.49	480925.16	0.00	0.16	RU-106	<	3.00	
FMP-SS-46-201	1378728.49	480925.16	0.00	0.16	TH-232	<	0.70	
FMP-SS-46-201	1378728.49	480925.16	0.00	0.16	U-238	<	8.70	
FMP-SS-46-202	1378425.87	480833.41	0.00	0.16	CS-137	<	0.20	
FMP-SS-46-202	1378425.87	480833.41	0.00	0.16	RA-226	=	0.90	0.40
FMP-SS-46-202	1378425.87	480833.41	0.00	0.16	RU-106	<	0.40	
FMP-SS-46-202	1378425.87	480833.41	0.00	0.16	TH-232	=	0.70	0.30
FMP-SS-46-202	1378425.87	480833.41	0.00	0.16	U-238	=	2.60	1.70
FMP-SS-46-203	1378525.83	480830.67	0.00	0.16	CS-137	=	0.80	0.30
FMP-SS-46-203	1378525.83	480830.67	0.00	0.16	RA-226	=	1.10	0.50
FMP-SS-46-203	1378525.83	480830.67	0.00	0.16	RU-106	<	3.80	
FMP-SS-46-203	1378525.83	480830.67	0.00	0.16	TH-232	<	0.50	
FMP-SS-46-203	1378525.83	480830.67	0.00	0.16	U-238	=	12.30	2.90
FMP-SS-46-204	1378625.79	480827.93	0.00	0.16	CS-137	<	0.40	
FMP-SS-46-204	1378625.79	480827.93	0.00	0.16	RA-226	=	4.50	0.60
FMP-SS-46-204	1378625.79	480827.93	0.00	0.16	RU-106	<	3.50	
FMP-SS-46-204	1378625.79	480827.93	0.00	0.16	TH-232	<	0.30	
FMP-SS-46-204	1378625.79	480827.93	0.00	0.16	U-238	=	5.60	3.40
FMP-SS-46-205	1378725.76	480825.20	0.00	0.16	CS-137	<	0.40	
FMP-SS-46-205	1378725.76	480825.20	0.00	0.16	RA-226	<	0.50	
FMP-SS-46-205	1378725.76	480825.20	0.00	0.16	RU-106	<	3.10	
FMP-SS-46-205	1378725.76	480825.20	0.00	0.16	TH-232	=	0.70	0.30
FMP-SS-46-205	1378725.76	480825.20	0.00	0.16	U-238	<	3.10	

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ON-SITE LABORATORY RADIONUCLIDE RESULTS

SAMPLE ID	EAST COORDINATE (Feet)	NORTH COORDINATE (Feet)	BEGIN DEPTH (Feet)	END DEPTH (Feet)	RADIONUCLIDE	VQ	ACTIVITY CONCENTRATION (pCi/g)	UNCERTAINTY VALUE (pCi/g)
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	CS-137	=	0.90	0.40
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	RA-226	=	4.40	0.60
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	RU-106	<	0.60	
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	TH-232	<	1.00	
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	U-238	<	19.40	
FMP-SS-46-206D	1378423.13	480733.44	0.00	0.16	CS-137	=	0.90	0.40
FMP-SS-46-206D	1378423.13	480733.44	0.00	0.16	RA-226	=	4.00	0.50
FMP-SS-46-206D	1378423.13	480733.44	0.00	0.16	RU-106	<	4.20	
FMP-SS-46-206D	1378423.13	480733.44	0.00	0.16	TH-232	<	2.60	
FMP-SS-46-206D	1378423.13	480733.44	0.00	0.16	U-238	<	18.40	
FMP-SS-46-207	1378623.06	480727.97	0.00	0.16	CS-137	<	0.90	
FMP-SS-46-207	1378623.06	480727.97	0.00	0.16	RA-226	=	5.30	0.60
FMP-SS-46-207	1378623.06	480727.97	0.00	0.16	RU-106	<	6.00	
FMP-SS-46-207	1378623.06	480727.97	0.00	0.16	TH-232	<	0.80	
FMP-SS-46-207	1378623.06	480727.97	0.00	0.16	U-238	=	6.20	3.40
FMP-SS-46-208QC	1378623.06	480727.97	0.00	0.16	CS-137	<	0.50	
FMP-SS-46-208QC	1378623.06	480727.97	0.00	0.16	RA-226	=	8.40	0.70
FMP-SS-46-208QC	1378623.06	480727.97	0.00	0.16	RU-106	<	6.00	
FMP-SS-46-208QC	1378623.06	480727.97	0.00	0.16	TH-232	<	1.40	
FMP-SS-46-208QC	1378623.06	480727.97	0.00	0.16	U-238	=	7.70	5.00
FMP-SS-46-209	1378723.02	480725.24	0.00	0.16	CS-137	<	0.20	
FMP-SS-46-209	1378723.02	480725.24	0.00	0.16	RA-226	=	1.10	0.40
FMP-SS-46-209	1378723.02	480725.24	0.00	0.16	RU-106	<	0.50	
FMP-SS-46-209	1378723.02	480725.24	0.00	0.16	TH-232	<	0.60	
FMP-SS-46-209	1378723.02	480725.24	0.00	0.16	U-238	=	6.20	3.40
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	CS-137	=	1.20	0.30
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	RA-226	=	10.30	0.90
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	RU-106	<	11.00	
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	TH-232	<	0.90	
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	U-238	<	14.90	

ON-SITE LABORATORY RADIONUCLIDE RESULTS

SAMPLE ID	EAST COORDINATE (Feet)	NORTH COORDINATE (Feet)	BEGIN DEPTH (Feet)	END DEPTH (Feet)	RADIONUCLIDE	VQ	ACTIVITY CONCENTRATION (pCi/g)	UNCERTAINTY VALUE (pCi/g)
FMP-SS-46-319	1378648.05	480727.29	0.00	0.16	CS-137	<	1.40	
FMP-SS-46-319	1378648.05	480727.29	0.00	0.16	RA-226	=	7.90	0.90
FMP-SS-46-319	1378648.05	480727.29	0.00	0.16	RU-106	<	0.50	
FMP-SS-46-319	1378648.05	480727.29	0.00	0.16	TH-232	<	2.50	
FMP-SS-46-319	1378648.05	480727.29	0.00	0.16	U-238	<	12.10	
FMP-SS-46-320	1378471.75	480682.09	0.00	0.16	CS-137	<	0.80	
FMP-SS-46-320	1378471.75	480682.09	0.00	0.16	RA-226	=	1.30	0.50
FMP-SS-46-320	1378471.75	480682.09	0.00	0.16	RU-106	<	5.80	
FMP-SS-46-320	1378471.75	480682.09	0.00	0.16	TH-232	<	4.30	
FMP-SS-46-320	1378471.75	480682.09	0.00	0.16	U-238	=	3.20	1.90
FMP-SS-46-320D	1378471.75	480682.09	0.00	0.16	CS-137	<	0.40	
FMP-SS-46-320D	1378471.75	480682.09	0.00	0.16	RA-226	=	1.60	0.60
FMP-SS-46-320D	1378471.75	480682.09	0.00	0.16	RU-106	<	0.90	
FMP-SS-46-320D	1378471.75	480682.09	0.00	0.16	TH-232	=	0.60	0.40
FMP-SS-46-320D	1378471.75	480682.09	0.00	0.16	U-238	=	6.40	3.10
FMP-SS-46-321	1378449.49	480782.74	0.00	0.16	CS-137	=	0.50	0.30
FMP-SS-46-321	1378449.49	480782.74	0.00	0.16	RA-226	=	4.70	0.80
FMP-SS-46-321	1378449.49	480782.74	0.00	0.16	RU-106	<	0.60	
FMP-SS-46-321	1378449.49	480782.74	0.00	0.16	TH-232	<	4.20	
FMP-SS-46-321	1378449.49	480782.74	0.00	0.16	U-238	<	14.90	
FMP-SS-46-322	1378422.45	480708.45	0.00	0.16	CS-137	<	1.00	
FMP-SS-46-322	1378422.45	480708.45	0.00	0.16	RA-226	=	2.00	0.60
FMP-SS-46-322	1378422.45	480708.45	0.00	0.16	RU-106	<	3.40	
FMP-SS-46-322	1378422.45	480708.45	0.00	0.16	TH-232	<	4.40	
FMP-SS-46-322	1378422.45	480708.45	0.00	0.16	U-238	=	6.10	3.60
FMP-SS-46-323	1378474.48	480782.06	0.00	0.16	CS-137	=	1.00	0.40
FMP-SS-46-323	1378474.48	480782.06	0.00	0.16	RA-226	=	4.40	0.60
FMP-SS-46-323	1378474.48	480782.06	0.00	0.16	RU-106	<	0.60	
FMP-SS-46-323	1378474.48	480782.06	0.00	0.16	TH-232	<	4.60	
FMP-SS-46-323	1378474.48	480782.06	0.00	0.16	U-238	=	8.50	4.30

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ON-SITE LABORATORY RADIONUCLIDE RESULTS

SAMPLE ID	EAST COORDINATE (Feet)	NORTH COORDINATE (Feet)	BEGIN DEPTH (Feet)	END DEPTH (Feet)	RADIONUCLIDE	VQ	ACTIVITY CONCENTRATION (pCi/g)	UNCERTAINTY VALUE (pCi/g)
FMP-SS-46-324	1378446.76	480682.78	0.00	0.16	CS-137	<	2.40	
FMP-SS-46-324	1378446.76	480682.78	0.00	0.16	RA-226	=	35.80	1.60
FMP-SS-46-324	1378446.76	480682.78	0.00	0.16	RU-106	<	9.00	
FMP-SS-46-324	1378446.76	480682.78	0.00	0.16	TH-232	<	4.00	
FMP-SS-46-324	1378446.76	480682.78	0.00	0.16	U-238	<	7.20	
FMP-SS-46-325	1378423.82	480758.43	0.00	0.16	CS-137	=	0.40	0.20
FMP-SS-46-325	1378423.82	480758.43	0.00	0.16	RA-226	=	1.70	0.50
FMP-SS-46-325	1378423.82	480758.43	0.00	0.16	RU-106	<	3.20	
FMP-SS-46-325	1378423.82	480758.43	0.00	0.16	TH-232	<	2.70	
FMP-SS-46-325	1378423.82	480758.43	0.00	0.16	U-238	=	5.50	2.00
FMP-SS-46-566	1378674.41	480776.59	0.00	0.16	CS-137	<	0.60	
FMP-SS-46-566	1378674.41	480776.59	0.00	0.16	RA-226	=	3.50	0.60
FMP-SS-46-566	1378674.41	480776.59	0.00	0.16	RU-106	<	6.70	
FMP-SS-46-566	1378674.41	480776.59	0.00	0.16	TH-232	<	6.50	
FMP-SS-46-566	1378674.41	480776.59	0.00	0.16	U-238	=	8.70	4.90
FMP-SS-46-567	1378574.44	480779.32	0.00	0.16	CS-137	<	1.90	
FMP-SS-46-567	1378574.44	480779.32	0.00	0.16	RA-226	=	22.50	1.90
FMP-SS-46-567	1378574.44	480779.32	0.00	0.16	RU-106	<	13.00	
FMP-SS-46-567	1378574.44	480779.32	0.00	0.16	TH-232	<	3.20	
FMP-SS-46-567	1378574.44	480779.32	0.00	0.16	U-238	=	37.40	10.20
FMP-SS-46-568	1378673.04	480726.60	0.00	0.16	CS-137	<	0.50	
FMP-SS-46-568	1378673.04	480726.60	0.00	0.16	RA-226	=	2.60	0.70
FMP-SS-46-568	1378673.04	480726.60	0.00	0.16	RU-106	<	6.40	
FMP-SS-46-568	1378673.04	480726.60	0.00	0.16	TH-232	<	3.30	
FMP-SS-46-568	1378673.04	480726.60	0.00	0.16	U-238	=	6.90	3.80
FMP-SS-46-569	1378624.43	480777.95	0.00	0.16	CS-137	=	1.10	0.50
FMP-SS-46-569	1378624.43	480777.95	0.00	0.16	RA-226	=	3.60	0.80
FMP-SS-46-569	1378624.43	480777.95	0.00	0.16	RU-106	<	1.40	
FMP-SS-46-569	1378624.43	480777.95	0.00	0.16	TH-232	<	0.70	
FMP-SS-46-569	1378624.43	480777.95	0.00	0.16	U-238	=	18.60	4.90

RADIOCHEMISTRY RESULTS

SAMPLE ID	EAST COORDINATE (Feet)	NORTH COORDINATE (Feet)	BEGIN DEPTH (Feet)	END DEPTH (Feet)	DRY WEIGHT (g)	RADIONUCLIDE	VQ	ACTIVITY CONCENTRATION (pCi/g)	UNCERTAINTY VALUE (pCi/g)
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	486.00	CS-137	=	2.60	0.50
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	486.00	NP-237	<	0.30	0.60
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	486.00	PB-210	=		
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	486.00	PU-238	<	0.10	
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	486.00	PU-239/240	<	0.10	
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	486.00	RA-226	=	7.00	0.95
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	486.00	RA-228	=		
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	486.00	RU-106	<	2.00	
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	486.00	SR-90	<	0.30	
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	486.00	TC-99	<	4.00	
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	486.00	TH-228	=	0.80	0.50
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	486.00	TH-230	=	295.00	9.00
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	486.00	TH-232	=	1.00	0.60
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	486.00	U-234	=	6.10	0.40
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	486.00	U-235	=	0.40	0.10
FMP-SS-46-206	1378423.13	480733.44	0.00	0.16	486.00	U-238	=	9.30	0.50
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	463.00	CS-137	<	0.40	
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	463.00	NP-237	<	0.08	
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	463.00	PB210	=		
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	463.00	PU-238	<	0.20	
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	463.00	PU-239/240	<	0.10	
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	463.00	RA-226	=	17.02	1.49
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	463.00	RA-228	=		
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	463.00	RU-106	<	2.00	
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	463.00	SR-90	<	0.90	
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	463.00	TC-99	<	0.90	
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	463.00	TH-228	=	1.10	0.30
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	463.00	TH-230	=	14.00	1.00
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	463.00	TH-232	=	1.70	0.30
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	463.00	U-234	=	11.00	1.00
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	463.00	U-235	=	0.60	0.10
FMP-SS-46-318	1378623.74	480752.96	0.00	0.16	463.00	U-238	=	23.00	1.00

SUBSURFACE SOILS

SAMPLING LOGS

SUBSURFACE SOIL SAMPLING LOG
RI/FS DATA

Well Number	Sample Number	Sample Interval	Requested Parameters
1018	07309	0.0 - 1.5	ARCHIVE
1018	07310	1.5 - 3.0	ARCHIVE
1018	07311	3.0 - 4.5	FULL RAD
1018	07312	4.5 - 6.0	ARCHIVE
1018	07313	6.0 - 7.5	ARCHIVE
1018	07314	7.5 - 9.0	ARCHIVE
1018	07315	9.0 - 10.5	ARCHIVE
1018	07316	10.5 - 12.0	ARCHIVE
1018	07317	12.0 - 13.5	ARCHIVE
1018	07318	13.5 - 15.0	ARCHIVE
1018	07319	15.0 - 16.5	ARCHIVE
1018	07320	16.5 - 18.0	ARCHIVE
1018	07321	18.0 - 19.5	ARCHIVE
1018	07322	19.5 - 21.0	ARCHIVE
1018	07323	21.0 - 22.5	ARCHIVE
1018	07324	22.5 - 24.0	ARCHIVE
1018	07325	24.0 - 25.5	ARCHIVE
1018	07326	25.5 - 27.0	ARCHIVE
1018	07327	27.0 - 28.5	ARCHIVE
1018	07328	28.5 - 30.0	ARCHIVE
1018	07329	30.0 - 31.5	ARCHIVE
1018	07330	31.5 - 32.5	ARCHIVE
1018	07331	32.5 - 33.5	ARCHIVE
1029	07398	0.0 - 1.5	ARCHIVE
1029	07399	1.5 - 3.0	ARCHIVE
1029	07400	3.0 - 4.5	ARCHIVE
1029	07401	4.5 - 6.0	ARCHIVE
1029	07402	6.0 - 7.5	ARCHIVE
1029	07403	7.5 - 9.0	ARCHIVE
1029	07404	9.0 - 10.5	ARCHIVE
1029	07405	10.5 - 12.5	ARCHIVE
1029	07406	12.0 - 13.5	ARCHIVE
1029	07407	13.5 - 15.0	FULL RAD
1029	07409	15.0 - 16.5	ARCHIVE
1029	07410	16.5 - 18.0	ARCHIVE
1029	07412	18.5 - 21.0	ARCHIVE
1029	07413	21.0 - 22.5	ARCHIVE
1029	07414	22.5 - 24.0	ARCHIVE
1029	07415	24.0 - 25.5	ARCHIVE
1029	07416	25.5 - 27.0	ARCHIVE
1029	07417	27.0 - 28.5	ARCHIVE
1029	07418	28.5 - 30.0	ARCHIVE
1029	07419	30.0 - 31.5	ARCHIVE
1029	07490	31.5 - 33.0	ARCHIVE
1029	07491	33.0 - 34.5	ARCHIVE
1029	07492	34.5 - 36.0	ARCHIVE
1032	07494	0.0 - 1.5	ARCHIVE
1032	07495	1.5 - 3.0	ARCHIVE
1032	07496	3.0 - 4.5	ARCHIVE

SUBSURFACE SOIL SAMPLING LOG
RI/FS DATA

Well Number	Sample Number	Sample Interval	Requested Parameters
1032	07497	4.5 - 6.0	ARCHIVE
1032	07498	6.0 - 7.5	ARCHIVE
1032	07499	7.5 - 9.0	ARCHIVE
1032	07500	9.0 - 10.5	ARCHIVE
1032	07501	10.5 - 12.0	ARCHIVE
1032	07502	12.0 - 13.5	ARCHIVE
1032	07503	13.5 - 15.0	ARCHIVE
1032	07506	15.0 - 15.5	ARCHIVE
1032	07504	15.0 - 16.5	FULL RAD
1032	07505	16.5 - 18.0	ARCHIVE
1032	07507	18.0 - 19.5	ARCHIVE
1032	07508	19.5 - 21.0	ARCHIVE
1032	07509	21.0 - 22.5	ARCHIVE
1032	07510	22.5 - 24.0	ARCHIVE
1033	08853	0.0 - 1.5	ARCHIVE
1033	08854	1.5 - 3.0	FULL RAD
1033	08855	3.0 - 4.5	ARCHIVE
1033	08856	4.5 - 6.0	ARCHIVE
1033	08857	6.0 - 7.5	ARCHIVE
1033	08858	7.5 - 9.0	ARCHIVE
1033	08859	9.0 - 10.5	ARCHIVE
1033	08860	10.5 - 12.0	ARCHIVE
1033	08861	12.0 - 13.5	ARCHIVE
1033	08862	13.5 - 15.0	ARCHIVE
1033	08863	15.0 - 16.5	ARCHIVE
1033	08864	16.5 - 18.0	ARCHIVE
1033	08865	18.0 - 19.5	ARCHIVE
1033	08866	19.5 - 21.0	ARCHIVE
1034	08307	18.0 - 19.0	ARCHIVE
1072	08188	0.0 - 1.5	FULL RAD
1072	08189	1.5 - 3.0	ARCHIVE
1072	08190	3.0 - 4.5	ARCHIVE
1072	08191	4.5 - 6.0	ARCHIVE
1072	08192	6.0 - 7.0	ARCHIVE
1072	08193	7.0 - 9.0	ARCHIVE
1072	08194	9.0 - 10.5	ARCHIVE
1072	08195	10.5 - 12.0	ARCHIVE
1072	08196	12.0 - 13.5	ARCHIVE
1072	08197	13.5 - 15.0	ARCHIVE
1072	08198	15.0 - 16.5	ARCHIVE
1072	08199	16.5 - 18.0	ARCHIVE
1072	08200	18.0 - 19.5	ARCHIVE
1072	08201	19.5 - 21.0	ARCHIVE
1072	08202	21.0 - 23.0	ARCHIVE
1072	08203	23.0 - 24.0	ARCHIVE
1072	08204	24.0 - 25.5	ARCHIVE
1072	08205	25.5 - 27.0	ARCHIVE
1072	08206	27.0 - 28.5	ARCHIVE
1072	08207	28.5 - 30.0	ARCHIVE
1072	08208	30.0 - 31.5	ARCHIVE
1072	08209	31.5 - 33.0	ARCHIVE
1072	08210	38.0 - 39.5	ARCHIVE
1072	08211	43.0 - 44.5	ARCHIVE
1072	08212	48.0 - 50.0	ARCHIVE

SUBSURFACE SOIL SAMPLING LOG
RI/FS DATA

Well Number	Sample Number	Sample Interval	Requested Parameters
2008	08241	0.0 - 1.5	ARCHIVE
2008	08242	1.5 - 3.0	ARCHIVE
2008	08243	3.0 - 4.5	ARCHIVE
2008	08244	4.5 - 6.0	ARCHIVE
2008	08805	6.0 - 7.5	ARCHIVE
2008	08806	7.5 - 9.0	ARCHIVE
2008	08807	9.0 - 10.5	ARCHIVE
2008	08808	10.5 - 12.0	ARCHIVE
2008	08809	12.0 - 13.5	ARCHIVE
2008	08810	13.5 - 15.0	FULL RAD
2008	08811	15.0 - 16.5	ARCHIVE
2008	08812	16.5 - 18.0	ARCHIVE
2008	08813	18.0 - 19.0	ARCHIVE
2008	08814	19.0 - 20.5	ARCHIVE
2008	08815	20.5 - 22.0	ARCHIVE
2008	08816	22.0 - 23.5	ARCHIVE
2008	08817	23.5 - 25.0	ARCHIVE
2008	08818	25.0 - 26.5	ARCHIVE
2008	08819	26.5 - 28.0	ARCHIVE
2008	08820	28.0 - 29.5	ARCHIVE
2008	08821	29.5 - 31.0	ARCHIVE
2008	08822	31.0 - 32.5	ARCHIVE
2008	08823	32.5 - 34.0	ARCHIVE
2008	08824	39.0 - 40.5	ARCHIVE
2008	08825	45.0 - 46.5	ARCHIVE
2008	08826	50.0 - 51.5	ARCHIVE
2008	08827	55.0 - 56.5	FULL RAD
2008	08828	60.0 - 61.5	ARCHIVE
2008	08829	65.0 - 66.5	ARCHIVE
2008	08830	70.0 - 71.5	ARCHIVE
2009	07070	0.0 - 1.5	ARCHIVE
2009	07071	1.5 - 3.0	ARCHIVE
2009	07072	3.0 - 4.5	ARCHIVE
2009	07073	4.5 - 6.0	FULL RAD
2009	07074	6.0 - 7.5	ARCHIVE
2009	07075	7.5 - 8.5	ARCHIVE
2009	07076	9.0 - 10.5	ARCHIVE
2009	07077	10.5 - 12.0	ARCHIVE
2009	07078	12.0 - 13.5	ARCHIVE
2009	07079	13.5 - 15.0	ARCHIVE
2009	07080	18.5 - 20.5	ARCHIVE
2009	07081	23.5 - 25.0	ARCHIVE
2009	07082	28.5 - 30.0	ARCHIVE
2009	07083	33.5 - 35.0	ARCHIVE
2009	07084	38.5 - 40.0	ARCHIVE
2009	07085	43.5 - 45.0	ARCHIVE
2009	07086	48.0 - 49.5	ARCHIVE
2009	07087	53.0 - 54.5	FULL RAD
3034	08265	0.0 - 1.5	ARCHIVE
3034	08266	1.5 - 3.0	ARCHIVE
3034	08267	3.0 - 4.5	ARCHIVE
3034	08268	4.5 - 6.0	ARCHIVE
3034	08269	6.0 - 7.5	ARCHIVE
3034	08270	7.5 - 9.0	ARCHIVE
3034	08271	9.0 - 10.5	ARCHIVE
3034	08272	10.5 - 12.0	FULL RAD
3034	08273	12.0 - 13.5	ARCHIVE

SUBSURFACE SOIL SAMPLING LOG
RI/FS DATA

Well Number	Sample Number	Sample Interval	Requested Parameters
3034	08274	13.5 - 15.0	ARCHIVE
3034	08275	15.0 - 16.5	ARCHIVE
3034	08276	16.5 - 18.0	ARCHIVE
3034	08277	18.0 - 19.5	ARCHIVE
3034	08278	19.5 - 21.0	ARCHIVE
3034	08279	21.0 - 22.5	FULL RAD
3034	08280	22.5 - 24.0	ARCHIVE
3034	08281	24.0 - 25.5	ARCHIVE
3034	08282	30.0 - 31.5	ARCHIVE
3034	08283	35.0 - 36.5	ARCHIVE
3034	08284	40.0 - 41.5	ARCHIVE
3034	08285	45.0 - 46.5	ARCHIVE
3034	08286	50.0 - 51.5	ARCHIVE
3034	08287	55.0 - 56.5	ARCHIVE
3034	08288	60.0 - 61.5	ARCHIVE
3034	08289	65.0 - 66.5	ARCHIVE
3034	08290	70.0 - 71.5	ARCHIVE
3034	08291	75.0 - 76.5	ARCHIVE
3034	08292	80.0 - 81.5	ARCHIVE
3034	08293	85.0 - 86.5	ARCHIVE
3034	08294	90.0 - 91.5	ARCHIVE
3034	08295	95.0 - 96.5	FULL RAD
3034	08296	100.0 -101.5	ARCHIVE
3034	08297	105.0 -106.5	ARCHIVE
3034	08298	110.0 -111.5	ARCHIVE
3034	08299	112.1 -114.1	ARCHIVE
3034	08300	115.0 -116.5	ARCHIVE
3034	08301	120.0 -121.5	ARCHIVE
3034	08302	125.0 -126.5	ARCHIVE
3034	08303	130.0 -131.5	ARCHIVE
3034	08304	135.0 -136.5	ARCHIVE
3034	08305	140.0 -141.5	ARCHIVE

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SUBSURFACE SOILS

RADIOLOGICAL RESULTS

SUBSURFACE SOIL RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per gram (pCi/g).
Data presented by well id, sample number, and depth in feet.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETERS	1018 07311 (3.0 - 4.5)			
Cesium 137	<	0.2		
Neptunium 237	<	0.6		
Plutonium 238	<	0.6		
Plutonium 239/240	<	0.6		
Radium 226		1.1	±	0.2
Radium 228	<	0.8		
Ruthenium 106	<	1.4		
Strontium 90	<	0.5		
Technetium 99	<	0.9		
Thorium 228		1.4	±	0.4
Thorium 230		1.8	±	0.5
Thorium 232		0.8	±	0.3
Total Thorium **		NA		
Uranium 234		1.0	±	0.4
Uranium 235/236	<	0.6		
Uranium 238		1.1	±	0.4
Total Uranium **		NA		

* Data validation in progress.

** Results reported in ug/g

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SUBSURFACE SOIL RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per gram (pCi/g).
Data presented by well id, sample number, and depth in feet.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETERS	1029 07407 (13.5 - 15.0)	1029 07490 (31.5 - 33.0)
Cesium 137	< 0.2	NA
Neptunium 237	< 0.6	NA
Plutonium 238	< 0.6	NA
Plutonium 239/240	< 0.6	NA
Radium 226	0.6 ± 0.1	NA
Radium 228	0.5 ± 0.1	NA
Ruthenium 106	< 1.0	NA
Strontium 90	< 0.5	NA
Technetium 99	< 0.9	NA
Thorium 228	< 0.6	NA
Thorium 230	1.0 ± 0.3	NA
Thorium 232	< 0.6	NA
Total Thorium **	NA	NA
Uranium 234	< 0.6	NA
Uranium 235/236	< 0.6	NA
Uranium 238	0.6 ± 0.2	NA
Total Uranium **	NA	< 5.0

* Data validation in progress.

** Results reported in ug/g

SUBSURFACE SOIL RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per gram (pCi/g).
Data presented by well id, sample number, and depth in feet.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETERS	1032 07504 (15.0 - 16.5)			
Cesium 137	<	0.2		
Neptunium 237	<	0.6		
Plutonium 238	<	0.6		
Plutonium 239/240	<	0.6		
Radium 226		1.0	±	0.3
Radium 228		0.6	±	0.2
Ruthenium 106	<	1.0		
Strontium 90	<	0.5		
Technetium 99	<	0.9		
Thorium 228		0.8	±	0.3
Thorium 230		1.6	±	0.4
Thorium 232		0.7	±	0.3
Total Thorium **		NA		
Uranium 234		2.1	±	0.5
Uranium 235/236	<	0.6		
Uranium 238		1.3	±	0.4
Total Uranium **		NA		

* Data validation in progress.

** Results reported in ug/g

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SUBSURFACE SOIL RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per gram (pCi/g).
Data presented by well id, sample number, and depth in feet.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETERS	1033 08854 (1.5 - 3.0)		
Cesium 137	< 0.2		
Neptunium 237	< 0.6		
Plutonium 238	< 0.6		
Plutonium 239/240	< 0.6		
Radium 226	1.3	±	0.1
Radium 228	1.1	±	0.1
Ruthenium 106	< 1.0		
Strontium 90	0.5	±	0.2
Technetium 99	< 1.3		
Thorium 228	1.3	±	0.4
Thorium 230	1.6	±	0.5
Thorium 232	1.3	±	0.4
Total Thorium **	NA		
Uranium 234	1.2	±	0.4
Uranium 235/236	< 0.6		
Uranium 238	1.4	±	0.4
Total Uranium **	NA		

* Data validation in progress.

** Results reported in ug/g

SUBSURFACE SOIL RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per gram (pCi/g).
Data presented by well id, sample number, and depth in feet.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETERS	1072 08188 (0.0 - 1.5)
Cesium 137	< 0.2
Neptunium 237	< 0.6
Plutonium 238	< 0.6
Plutonium 239/240	< 0.6
Radium 226	1.5 ± 0.1
Radium 228	1.0 ± 0.1
Ruthenium 106	< 1.0
Strontium 90	< 0.5
Technetium 99	3.6 ± 1.1
Thorium 228	1.2 ± 0.4
Thorium 230	4.8 ± 0.9
Thorium 232	0.9 ± 0.3
Total Thorium **	NA
Uranium 234	3.4 ± 0.7
Uranium 235/236	< 0.6
Uranium 238	15.0 ± 2.3
Total Uranium **	NA

* Data validation in progress.

** Results reported in ug/g

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SUBSURFACE SOIL RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per gram (pCi/g).
Data presented by well id, sample number, and depth in feet.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETERS	2008 08810 (13.5 - 15.0)	2008 08827 (55.0 - 56.5)
Cesium 137	< 0.2	< 0.2
Neptunium 237	< 0.6	< 0.6
Plutonium 238	< 0.6	< 0.6
Plutonium 239/240	< 0.6	< 0.6
Radium 226	0.9 ± 0.1	0.6 ± 0.1
Radium 228	0.8 ± 0.1	< 0.5
Ruthenium 106	< 1.0	< 1.0
Strontium 90	< 0.5	< 0.5
Technetium 99	3.6 ± 0.9	< 0.9
Thorium 228	1.1 ± 0.4	< 0.6
Thorium 230	1.7 ± 0.5	1.5 ± 0.5
Thorium 232	0.9 ± 0.3	< 0.6
Total Thorium **	NA	NA
Uranium 234	1.0 ± 0.3	0.8 ± 0.3
Uranium 235/236	< 0.6	< 0.6
Uranium 238	0.9 ± 0.3	0.8 ± 0.3
Total Uranium **	NA	NA

* Data validation in progress.

** Results reported in ug/g

SUBSURFACE SOIL RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per gram (pCi/g).
Data presented by well id, sample number, and depth in feet.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETERS	2009 07073 (4.5 - 6.0)				2009 07087 (53.0 - 54.5)			
Cesium 137	<	0.2			<	0.2		
Neptunium 237	<	0.6			<	0.6		
Plutonium 238	<	0.6			<	0.6		
Plutonium 239/240	<	0.6			<	0.6		
Radium 226		0.7	±	0.1		0.5	±	0.1
Radium 228		0.5	±	0.2		0.3	±	0.1
Ruthenium 106	<	1.0			<	1.0		
Strontium 90	<	0.5				0.7	±	0.2
Technetium 99	<	0.9			<	0.9		
Thorium 228		0.6	±	0.3	<	0.6		
Thorium 230		1.5	±	0.4		1.0	±	0.3
Thorium 232	<	0.6			<	0.6		
Total Thorium **		NA				NA		
Uranium 234	<	0.6				1.0	±	0.4
Uranium 235/236	<	0.6			<	0.6		
Uranium 238	<	0.6				0.8	±	0.3
Total Uranium **		NA				NA		

* Data validation in progress.

** Results reported in ug/g

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SUBSURFACE SOIL RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per gram (pCi/g).
Data presented by well id, sample number, and depth in feet.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETERS	3034 08272 (10.5 - 12.0)	3034 08279 (21.0 - 22.5)	3034 08286 (50.0 - 51.5)	3034 08295 (95.0 - 96.5)
Cesium 137	< 0.2	< 0.2	NA	< 0.2
Neptunium 237	< 0.6	< 0.6	NA	< 0.6
Plutonium 238	< 0.6	< 0.6	NA	< 0.6
Plutonium 239/240	< 0.6	< 0.6	NA	< 0.6
Radium 226	< 0.3	0.7 ± 0.1	NA	0.6 ± 0.1
Radium 228	< 0.5	0.6 ± 0.1	NA	< 0.5
Ruthenium 106	< 1.0	< 1.0	NA	< 1.0
Strontium 90	< 0.5	< 0.5	NA	< 0.5
Technetium 99	< 0.9	2.1 ± 0.7	NA	< 0.9
Thorium 228	0.9 ± 0.3	0.8 ± 0.3	NA	< 0.6
Thorium 230	0.9 ± 0.3	3.8 ± 0.9	NA	0.7 ± 0.2
Thorium 232	0.6 ± 0.3	0.7 ± 0.3	NA	< 0.6
Total Thorium **	NA	NA	NA	NA
Uranium 234	0.6 ± 0.2	0.8 ± 0.3	NA	< 0.6
Uranium 235/236	< 0.6	< 0.6	NA	< 0.6
Uranium 238	0.6 ± 0.2	0.9 ± 0.3	NA	< 0.6
Total Uranium **	NA	NA	12.3 ± 3.2	NA

* Data validation in progress.

** Results reported in ug/g

SUBSURFACE SOILS

BORING/WELL LOGS

NOTE: Only one boring log, corresponding to the deepest well is displayed for wells installed in clusters. Therefore:

- Well 1008 is covered by 2008.
- Well 1009 is covered by 2009.
- Well 2034 is covered by 3034.

Wells 2018 and 3018 were installed by Dames & Moore. Well 3009 was installed by NLO.

BORING/WELL LOGS
LEGEND

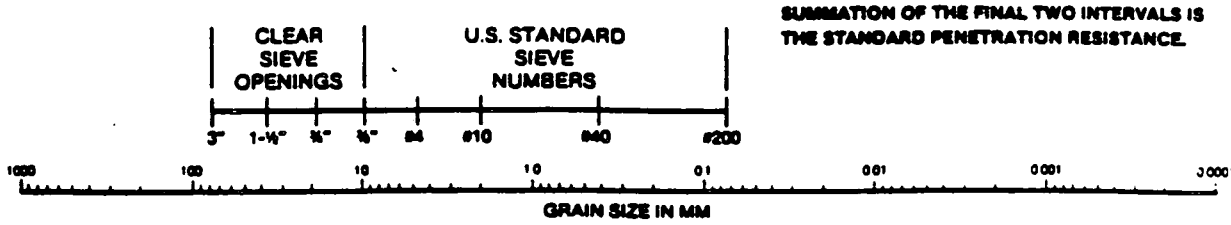
CONSISTENCY OF COHESIVE SOILS

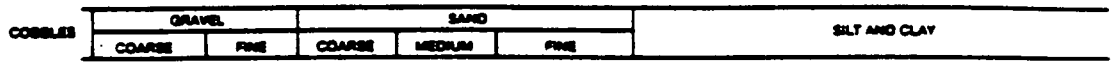
CONSISTENCY	UNCONFINED COMPRESSIVE STRENGTH (TONS PER SQUARE FOOT)
VERY SOFT	LESS THAN 0.25
SOFT	0.25 to 0.50
MEDIUM STIFF	0.50 to 1.0
STIFF	1.0 TO 2.0
VERY STIFF	2.0 TO 4.0
HARD	MORE THAN 4.0

DENSITY OF GRANULAR SOILS

DENSITY	STANDARD PENETRATION RESISTANCE[1]
VERY LOOSE	0 - 4
LOOSE	5 - 10
MEDIUM DENSE	11 - 30
DENSE	31 - 50
VERY DENSE	OVER 50

[1] STANDARD PENETRATION RESISTANCE IS THE NUMBER OF BLOWS REQUIRED TO DRIVE A 2-INCH O.D. SPLIT BARREL SAMPLER 12 INCHES USING A 140-POUND HAMMER FALLING FREELY THROUGH 30 INCHES. THE SAMPLER IS DRIVEN 18 INCHES AND THE NUMBER OF BLOWS RECORDED FOR EACH 6-INCH INTERVAL. THE SUMMATION OF THE FINAL TWO INTERVALS IS THE STANDARD PENETRATION RESISTANCE.





USCS CLASSIFICATION FOR SOILS

COARSE-GRAINED SOILS

CLEAN GRAVELS (LITTLE OR NO FINES)	GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
	GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)	GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
	GC	CLAYEY GRAVELS GRAVEL-SAND-CLAY MIXTURES
CLEAN SANDS (LITTLE OR NO FINES)	SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
	SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)	SM	SILTY SANDS, SAND-SILT MIXTURES
	SC	CLAYEY SANDS, SAND—CLAY MIXTURES

FINE-GRAINED/HIGHLY ORGANIC SOILS

SILTS AND CLAYS LIQUID LIMIT (LESS THAN 50)	ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
	CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
	OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
SILTS AND CLAYS LIQUID LIMIT (GREATER THAN 50)	MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS
	CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
	OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS	PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

VISUAL CLASSIFICATION OF SOILS

ECT NUMBER: 602 - 3.2
NEW WELL ID : 118/1018

N./GEOLOGIST: LOWELL WILLE
LLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378661.69, 479450.19

TODAY'S DATE 07/09/90

SAMPLE DATE: 10/19/87

PAGE NUMBER 1

SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
07309	2 8 10	14	SOFT BROWN (10YR, 6/4) SILTY CLAY - TRACE SAND, SOME ORGANIC PLANT MATERIAL - MOIST. STIFF BROWN (10YR, 6/0) SILTY CLAY, TRACE SAND - DRY	OL CL	3.5 1.8	HNU : ALPHA : 2 BETA-GAMMA : 80
07310	3 6 15	10	HARD BROWN (10YR, 6/8) CLAY, TRACE SILT AND FINE SAND - DRY.	CL	>5	HNU : ALPHA : 2 BETA-GAMMA : 80
07311	7 15 21	12	HARD BROWN (10YR, 5/8) MOTTLED GRAY CLAY, TRACE SILT AND FINE SAND - DRY. LOOSE BROWN (10YR, 4/6) FINE SAND, SOME MEDIUM SAND AND SILT, TRACE CLAY - DRY.	CL SW	4.5	HNU : ALPHA : 2 BETA-GAMMA : 80
07312	8 10 10	14	HARD BROWN (10YR, 6/8) CLAY, TRACE SILT AND FINE SAND - MOIST. HARD BORWN (10YR, 6/8) CLAYEY SILT, SOME FINE SAND - MOIST.	CL CL	3.5 2.8	HNU : ALPHA : 2 BETA-GAMMA : 80
07313		13	HARD BROWN (10YR, 6/6) SILTY SAND, SOME CLAY, TRACE GRAVEL AND PEBBLES - DRY.	SM	>5	HNU : ALPHA : 2 BETA-GAMMA : 80
07314	6 8 10	11	DENSE BROWN (10YR, 5/8) AND GRAY 10YR 6/2 INTERLAYERED SAND, SOME SILT, TRACE CLAY AND FINE GRAVEL - DRY.	SM		HNU : ALPHA : 2 BETA-GAMMA : 80
07315	16 42 36	13	DENSE BROWN (10YR, 5/8) FINE TO MEDIUM SAND, SOME SILT, CLAY, TRACE GRAVEL - MOIST, SLIGHTLY BONDED	SM		HNU : ALPHA : 2 BETA-GAMMA : 80

VISUAL CLASSIFICATION OF SOILS (CONTINUED)

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 118/1018

ENGIN./GEOLOGIST: LOWELL WILLE
DRILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378661.69, 479450.19

TODAY'S DATE 07/09/90

SAMPLE DATE: 10/19/87

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DEPTH Feet	SAMPLER	SAMPLE NUMBER	BLOWS ON SAMPLER	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
10.5 12.0		07316	18 28 37	17	DENSE GRAY (10YR, 5/1) FINE SAND, SOME SILT AND CLAY - MOIST	SM	0.5	HNU : ALPHA : 2 BETA-GAMMA : 80
12.0 13.5		07317	45 17 15	17	DENSE GRAY (10YR, 6/0) SAND AND GRAVEL, SOME SILT AND CLAY - DRY. HARD GRAY (10YR, 6/1) CLAY - SOME SILT, MOIST. DENSE GRAY (10YR, 6/0) FINE SAND, SOME SILT, TRACE CLAY - DRY.	GC CL SM	1.0 0.5	HNU : ALPHA : 2 BETA-GAMMA : 80
13.5 15.0		07318	16 44 50	17	HARD GRAY (10YR, 5/1) CLAY - SOME SILT - MOIST. DENSE GRAY (10YR, 5/1) SAND - SOME SILT AND CLAY - DRY. HARD GRAY (10YR, 5/1) CLAY, SOME SILT - MOIST. DENSE GRAY (10YR, 5/1) SAND AND GRAVEL - SOME	CL SM CL	4.0 3.5	HNU : ALPHA : 2 BETA-GAMMA : 80
15.0 16.5		07319	4 7 12	10	STIFF GRAY (7.5YR, 6/2) CLAY, SOME SILT, TRACE FINE SAND - MOIST.	CL	3.5	HNU : ALPHA : 2 BETA-GAMMA : 75
16.5 18.0		07320	3 5 23	10	STIFF GRAY 10YR, 6/1 CLAY, SOME SILT, SAND AND GRAVEL - DRY.	CL	3.5	HNU : ALPHA : 2 BETA-GAMMA : 75
18.0 19.5		07321	8 10 23	11	STIFF GRAY 10YR 6/1 CLAY, SOME SILT AND SAND, TRACE GRAVEL - DRY.	CL	3.2	HNU : ALPHA : 2 BETA-GAMMA : 75
19.5 21.0		07322	43 27 32	12	HARD GRAY 10YR 5/1 GRAVELLY CLAY, SOME SILT AND CLAY, TRACE PEBBLES - DRY.	CL	>5	HNU : ALPHA : 2 BETA-GAMMA : 75

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VISUAL CLASSIFICATION OF SOILS (CONTINUED)

ROJECT NUMBER: 602 - 3.2
D/NEW WELL ID : 118/1018

IGIN./GEOLOGIST: LOWELL WILLE
ILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378661.69, 479450.19

TODAY'S DATE 07/09/90

SAMPLE DATE: 10/19/87

PAGE NUMBER 3

et	SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
.0 .5	07323	50	6	HARD GRAY 10YR 5/1 CLAY, SOME GRAVEL, TRACE SAND AND SILT, DRY.	CL	>5	HNU : ALPHA : 2 BETA-GAMMA : 75
.5 .0	07324	8 14 50	18	HARD GRAY 10YR 6/1 CLAY, TRACE GRAVEL AND SAND, SOME SILT, DRY	CL	>5	HNU : ALPHA : 2 BETA-GAMMA : 75
.0 .5	07325	6 16 36	14	HARD GRAY 10YR 6/1 CLAY, TRACE GRAVEL AND SILT, DRY.	CL	3.5	HNU : ALPHA : 2 BETA-GAMMA : 75
5 0	07326	5 13 30	9	HARD GRAY 10YR 6/1 GRAVELLY CLAY, SOME SAND AND SLIT, MOIST.	CL	3.5	HNU : ALPHA : 2 BETA-GAMMA : 75
0 5	07327	11 21 36	18	STIFF GRAY 10YR 6/1 CLAY, TRACE SAND, GRAVEL, AND SILT, DRY.	CL	2.5	HNU : ALPHA : 2 BETA-GAMMA : 75
5 0	07328	12 9 12	13	LOOSE BROWN 10YR 6/6 SAND, SOME SILT AND CLAY - TRACE GRAVEL - DRY.	SM		HNU : ALPHA : 2 BETA-GAMMA : 75
0 5	07329	5 16 26	14	DENSE BROWN 10YR 6/6 SAND, SOME SILT AND CLAY, TRACE GRAVEL - DRY.	SM		HNU : ALPHA : 2 BETA-GAMMA : 75

VISUAL CLASSIFICATION OF SOILS (CONTINUED)

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 118/1018

ENGIN./GEOLOGIST: LOWELL WILLE
DRILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378661.69, 479450.19

TODAY'S DATE 07/09/90

SAMPLE DATE: 10/19/87

PAGE NUMBER 4

DEPTH Feet	SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
31.5 32.5	07330	33 71	12	DENSE BROWN 10YR 5/6 SAND AND GRAVEL, SOME SILT AND CLAY - TRACE PEBBLES - DRY.	GC		HNU : ALPHA : 2 BETA-GAMMA : 75
32.5 33.5	07331	50	6	DENSE BROWN 10YR 5/6 SAND AND GRAVEL, SOME SILT AND CLAY - TRACE PEBBLES - DRY.	GM		HNU : ALPHA : 2 BETA-GAMMA : 75
.0 .0	07332			RINSATE SAMPLE			HNU : ALPHA : BETA-GAMMA :

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VISUAL CLASSIFICATION OF SOILS (CONTINUED)

'ROJECT NUMBER: 602 - 3.2
ILD/NEW WELL ID : 129/1029
'NGIN./GEOLOGIST: D. OAKLEY
RILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378398.38, 480826.11

TODAY'S DATE 07/09/90
SAMPLE DATE: 10/28/87
PAGE NUMBER 5

DEPTH eet	SAMPLER	SAMPLE NUMBER	BLOWS ON	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
.0 1.5	07398	9 7 14		15	VERY STIFF YELLOWISH BROWN SILT, SOME CLAY, TRACE SAND - DRY. MEDIUM DENSE YELLOWISH BROWN SILTY SAND, SOME GRAVEL, TRACE CLAY - DRY.	ML SP	4.5+	HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80
1.5 3.0	07399	11 8 9		14	MEDIUM DENSE YELLOWISH BROWN SILTY SAND, SOME GRAVEL, TRACE CLAY - DRY. MEDIUM DENSE YELLOWISH BROWN FINE SAND, TRACE SILT - DRY. VERY STIFF BROWNISH YELLOW SILT, SOME SAND AND CLAY - DRY, LIMESTONE	SP SP ML	3.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80
3.0 4.5	07400	20 27 21		18	HARD BROWNISH YELLOW SANDY CLAY, TRACE SILT - DRY. DENSE BROWNISH YELLOW SILTY SAND, SOME GRAVEL, TRACE CLAY, DRY.	CL SP	2.75	HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80
4.5 6.0	07401	21 28 20		16	HARD BROWNISH YELLOW SILTY CLAY, TRACE GRAVEL AND SAND - DRY, LIMESTONE GRAVEL.	CL	2.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80
6.0 7.5	07402	14 16 21		18	HARD GRAY SILTY CLAY, TRACE SAND AND GRAVEL - DRY. LIMESTONE GRAVEL.	CL	3.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80
7.5 9.0	07403	11 7 14		5	HARD GRAY SILTY CLAY, TRACE SAND AND GRAVEL - DRY. LIMESTONE GRAVEL. VERY STIFF PALE OLIVE GRAVELLY CLAY, TRACE SAND AND SILT - MOIST.	CL CL	3.0 1.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80
9.0 9.5	07404	5 9 12		9	VERY STIFF PALE OLIVE CLAY, SOME GRAVEL AND SAND, TRACE SILT - MOIST.	CL	1.25	HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80

VISUAL CLASSIFICATION OF SOILS (CONTINUED)

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 129/1029

ENGIN./GEOLOGIST: D. OAKLEY
DRILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378398.38, 480826.11

TODAY'S DATE 07/09/90

SAMPLE DATE: 10/28/87

PAGE NUMBER 6

DEPTH Feet	SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
10.5 12.5	07405	2 2 11	0	SHELBY TUBE			HNU : ALPHA : BETA-GAMMA :
12.0 13.5	07406	6 6 10	5	VERY STIFF OLIVE GRAY CLAY, SOME GRAVEL, TRACE SAND AND SILT - MOIST.	CL	1.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80
13.5 15.0	07407	4 6 8	12	STIFF OLIVE GRAY CLAY, SOME GRAVEL, TRACE SAND AND SILT - MOIST	CL	.75	HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80
15.0 16.5	07409	6 4 6	11	STIFF OLIVE GRAY CLAY, SOME GRAVEL, TRACE SILT AND SAND - MOIST.	CL	.75	HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80
16.5 18.0	07410	2 2 4	4	MEDIUM STIFF OLIVE GRAY GRAVELLY CLAY, TRACE SAND AND SILT - WET.	CL		HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80
18.5 21.0	07412	4 4 5	12	STIFF OLIVE GRAY GRAVELLY CLAY, TRACE SILT AND SAND - DRY	CL		HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80
21.0 22.5	07413	3 4 6	4	STIFF OLIVE GRAY GRAVELLY CLAY, TRACE SAND AND SILT - DRY.	CL		HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80

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VISUAL CLASSIFICATION OF SOILS (CONTINUED)

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 129/1029

ENGIN./GEOLOGIST: D. OAKLEY
DRILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378398.38, 480826.11

TODAY'S DATE 07/09/90

SAMPLE DATE: 10/28/87

PAGE NUMBER 7

DEPTH Feet	SAMPLER	SAMPLE NUMBER	BLOWS ON	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
22.5 24.0		07414	5 15 25	4	HARD GRAY GRAVELLY CLAY - TRACE SAND - DRY.	CL	1.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80
24.0 25.5		07415	15 32 40	15	HARD OLIVE GRAY GRAVELLY CLAY - WET	CL	4.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80
25.5 27.0		07416	8 12 18	3	VERY STIFF OLIVE GRAY GRAVELLY CLAY - WET	CL	.1	HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80
27.0 28.5		07417	8 9 14	18	OLIVE GRAY GRAVELLY CLAY - WET. GRAYISH BROWN FINE SAND, TRACE CLAY - WET. VERY STIFF OLIVE GRAY CLAY, SOME GRAVEL AND SAND, TRACE SILT - MOIST	CL SP CL	1.5 1.50	HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80
28.5 30.0		07418	4 8 13	18	VERY STIFF OLIVE GRAY CLAY, SOME FINE GRAVEL AND SAND, TRACE SILT - MOIST.	CL	1.25	HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80
30.0 31.5		07419	6 7 15	9	VERY STIFF GRAY CLAY, SOME GRAVEL, TRACE SILT AND SAND, MOIST.	CL	1.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80
31.5 33.0		07490	7 10 16	7	VERY STIFF LIGHT OLIVE GRAY GRAVELLY CLAY, TRACE SAND AND SILT - WET.	CL		HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80

VISUAL CLASSIFICATION OF SOILS (CONTINUED)

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 129/1029

ENGIN./GEOLOGIST: D. OAKLEY
DRILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378398.38, 480826.11

TODAY'S DATE 07/09/90

SAMPLE DATE: 10/28/87

PAGE NUMBER 8

DEPTH Feet	SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
33.0 34.5	07491	6 16 18	14	SOFT GRAY MOTTLED GRAVELLY CLAY TRACE SAND. DENSE BROWNISH YELLOW SAND - DRY.	CL GP	.25	HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80
34.5 36.0	07492	15 20 21	12	DENSE LIGHT YELLOWISH BROWN SAND - DRY.	GP		HNU : 0 ALPHA : 0 BETA-GAMMA : 40-80
.0 .0	07493			RINSATE SAMPLE			HNU : ALPHA : BETA-GAMMA :

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VISUAL CLASSIFICATION OF SOILS (CONTINUED)

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 132/1032

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378296.81, 480515.31

TODAY'S DATE 07/09/90

SAMPLE DATE: 10/31/87

'NGIN./GEOLOGIST: D. OAKLEY
RILLING METHODS : CABLE-TOOL

PAGE NUMBER 9

DEPTH Feet	SAMPLER	SAMPLE NUMBER	BLOWS ON	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
.0 1.5	07494	4 3 3		14	MEDIUM STIFF LIGHT YELLOWISH BROWN (2.5Y , 6/4) SILT, SOME CLAY, TRACE SAND AND G RAVEL. OLIVE GRAY (5Y, 5/2) CLAY, SOME SILT, TRACE SAND AND GRAVEL - DRY.	ML CL	3.0 1.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 80
1.5 3.0	07495	3 4 4		12	MEDIUM STIFF OLIVE (5Y, 5/3) CLAY, SOME SILT, TRACE GRAVEL AND SAND - DRY. LIGH T YELLOWISH BROWN (2.5Y, 6/4) SILT, SOME SAND AND CLAY - DRY.	CL ML	1.5 1.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 70
3.0 4.5	07496	3 4 4		10	MEDIUM STIFF YELLOWISH BROWN (10YR, 5/4) CLAY AND SILT, TRACE SAND AND GRAVEL - DRY. DARK BROWN (10YR, 3/3) SILT, SOME CLAY, TRACE SAND AND GRAVEL - DRY.	CL ML	3.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 70
4.5 6.0	07497	8 8 11		14	VERY STIFF YELLOWISH BROWN (10YR, 5/4) C LAY, SOME SILT, TRACE SAND AND GRAVEL - DRY. VERY STIFF BROWNISH YELLOW (10YR, 6/6) SILT, TRACE SAND AND CLAY AND GRAVE L - DRY.	CL ML	3.5 1.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 70
6.0 7.5	07498	9 7 11		14	VERY STIFF BROWNISH YELLOW (10YR, 6/8) S ILT, SOME GRAVEL AND SAND, TRACE CLAY - DRY.	ML	1.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 80
7.5 9.0	07499	13 14 17		12	MEDIUM DENSE BROWNISH YELLOW (10YR, 6/8) GRAVEL, SOME SAND AND SILT - DRY.	GM		HNU : 0 ALPHA : 0 BETA-GAMMA : 60
9.0 10.5	07500	8 7 10		10	BROWNISH YELLOW GRAVEL (10YR, 6/8), SOME SAND AND SILT. VERY STIFF YELLOWISH BR OWN (10YR, 5/4) CLAY, TRACE SILT AND SAN D - MOIST.	CL	4.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 70

VISUAL CLASSIFICATION OF SOILS (CONTINUED)

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 132/1032

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378296.81, 480515.31

TODAY'S DATE 07/09/90

SAMPLE DATE: 10/31/87

'IGIN./GEOLOGIST: D. OAKLEY
.ILLING METHODS : CABLE-TOOL

PAGE NUMBER 10

DEPTH Feet	SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
10.5 12.0	07501	3 5 7	14	MEDIUM DENSE LIGHT YELLOWISH BROWN (2.5Y R, 6/4) GRAVEL, SOME CLAY, TRACE SAND AN D SILT - MOIST. STIFF YELLOWISH BROWN (10YR, 5/4) CLAY, SOME SILT, TRACE SAND - MOIST.	GC CL	2.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 80
12.0 13.5	07502	1 2 2	8	SOFT BROWN (10YR, 5/3) CLAY, SOME SAND, TRACE GRAVEL AND SILT - WET.	CH	.25	HNU : 0 ALPHA : 0 BETA-GAMMA : 70
13.5 15.0	07503	5 11 14	5	VERY STIFF BROWN CLAY (10YR, 5/3) SOME G RAVEL, TRACE SAND AND SILT - DRY.	CH	.25	HNU : 0 ALPHA : 0 BETA-GAMMA : 70
15.0 16.5	07504	5 11 18	13	VERY STIFF OLIVE GRAY (5Y, 5/2) CLAY, SO ME GRAVEL, TRACE SAND AND SILT - MOIST.	CL	4.25	HNU : 0 ALPHA : 0 BETA-GAMMA : 60-80
16.5 18.0	07505	9 12 42	12	HARD OLIVE GRAY (5Y, 5/2) CLAY, SOME GRA VEL, TRACE SAND AND SILT - MOIST.	CL	4.25	HNU : 0 ALPHA : 0 BETA-GAMMA : 60-80
15.0 15.5	07506			HARD OLIVE GRAY (5Y, 5/2) CLAY, SOME GRA VEL, TRACE SAND AND SILT - MOIST.	CL	4.25	HNU : 0 ALPHA : 0 BETA-GAMMA : 60-80
18.0 19.5	07507	11 13 15	11	HARD OLIVE GRAY (5Y, 5/2) CLAY, SOME GRA VEL, TRACE SAND AND SILT - MOIST. VERY STIFF YELLOWISH RED (5YR, 5/8) CLAY, SOM E SAND, GRAVEL, AND SILT - DRY.	CL CL	4.25 4.00	HNU : 0 ALPHA : 0 BETA-GAMMA : 60

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VISUAL CLASSIFICATION OF SOILS (CONTINUED)

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 132/1032
ENGIN./GEOLOGIST: D. OAKLEY
DRILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378296.81, 480515.31

TODAY'S DATE 07/09/90
SAMPLE DATE: 10/31/87
PAGE NUMBER 11

DEPTH feet	SAMPLER	SAMPLE NUMBER	BLOWS ON	RECOVERY	DESCRIPTION	USCS	TSF	REMARKS
9.5 1.0		07508	11 11 15	14	BROWNISH YELLOW (10YR, 6/8) SILT, SOME SAND - DRY. MEDIUM DENSE YELLOWISH BROWN (10YR, 5/6) FINE SAND, TRACE SILT AND CLAY - DRY. BROWNISH YELLOW (10YR, 6/8) SILT, SOME SAND - DRY.	ML SP ML	.20 .2	HNU : 0 ALPHA : 0 BETA-GAMMA : 80
1.0 2.5		07509	8 11 17	12	BROWNISH YELLOW (10YR, 6/8) SILT, SOME SAND - DRY. MEDIUM DENSE YELLOWISH BROWN (10YR, 5/6) FINE SAND - DRY.	ML SP	.20	HNU : 0 ALPHA : 5 BETA-GAMMA : 80
2.5 4.0		07510	12 14 18	14	MEDIUM DENSE YELLOWISH BROWN (10YR, 5/6) FINE SAND - DRY.	SP		HNU : 0 ALPHA : 0 BETA-GAMMA : 60
.0 .0		07511			RINSATE SAMPLE			HNU : ALPHA : BETA-GAMMA :

VISUAL CLASSIFICATION OF SOILS (CONTINUED)

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 133/1033

ENGIN./GEOLOGIST: M. GOLDBERG
DRILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378675.14, 480412.89

TODAY'S DATE 07/09/90

SAMPLE DATE: 04/10/88

PAGE NUMBER 12

DEPTH Feet	SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
.0 1.5	08853	3 4 6	18	STIFF DARK YELLOWISH BROWN CLAY (10YR, 4/6), DRY.	CL	1.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 600
1.5 3.0	08854	9 7 11	12	STIFF YELLOWISH BROWN CLAY (10YR, 5/8) DRY.	CL	1.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 600
3.0 4.5	08855	10 11 14	18	VERY STIFF YELLOWISH BROWN CLAY (10YR, 5/8), TRACE SILT.	ML	2.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 600
4.5 6.0	08856	10 10 10	18	VERY STIFF YELLOWISH BROWN CLAY (10YR, 5/8), VERY SILTY - MOIST.	ML	2.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 600
6.0 7.5	08857		18	SHELBY TUBE			HNU : ALPHA : BETA-GAMMA :
7.5 9.0	08858	1 1 1	12	SOFT OLIVE GRAY CLAY (5Y, 5/2) DRY, HIGH PLASTICITY.	CL	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 600
9.0 10.5	08859	1 2 2	18	SOFT OLIVE GRAY SILTY CLAY (5Y, 5/2) DRY, PLASTIC.	CL	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 600

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VISUAL CLASSIFICATION OF SOILS (CONTINUED)

ROJECT NUMBER: 602 - 3.2
LD/NEW WELL ID : 133/1033

NGIN./GEOLOGIST: M. GOLDBERG
RILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378675.14, 480412.89

TODAY'S DATE 07/09/90

SAMPLE DATE: 04/10/88

PAGE NUMBER 13

DEPTH eet	SAMPLER	SAMPLE NUMBER	BLOWS ON	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
0.5 2.0		08860	4 5 3	18	SOFT GRAY SILTY CLAY (5Y, 5/1) TRACE SAND, MOIST, WET. MEDIUM DENSE GRAY SILTY SAND (5Y, 5/1) WET.	CL SM	<1 <1	HNU : 0 ALPHA : 0 BETA-GAMMA : 600
2.0 3.5		08861	4 7 7	12	MEDIUM DENSE GRAY SILTY SAND (5Y, 5/1), WET.	SM	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 450
3.5 5.0		08862	12 10 11	14	MEDIUM DENSE GRAY SILTY SAND (5Y, 5/1) WET, TRACE GRAVEL.	SM	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 400
5.0 6.5		08863	5 5 6	10	MEDIUM DENSE GRAY SILTY SAND (5Y, 5/1) WET, TRACE GRAVEL. MEDIUM STIFF DARK GRAY SANDY CLAY (5Y, 5/1) WET, TRACE GRAVEL.	SM CL	<1 <1	HNU : 0 ALPHA : 0 BETA-GAMMA : 400
6.5 8.0		08864	6 9 11	8	STIFF DARK GRAY CLAY (5Y, 5/1) TRACE GRAVEL, MOIST.	CL	1.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 400
8.0 9.5		08865	7 9 6	12	MEDIUM DENSE SANDY SILT WITH TRACE OF GRAVEL (5Y, 5/1), MOIST.	SM	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 380
9.5 11.0		08866	6 6 8	12	STIFF DARK GRAY CLAY (5Y, 5/1), TRACE OF GRAVEL - DRY.	CL	2.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 380

VISUAL CLASSIFICATION OF SOILS (CONTINUED)

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 134/1034

ENGIN./GEOLOGIST: W. MONTGOMERY
DRILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378410.28, 480240.85

TODAY'S DATE 07/09/90

SAMPLE DATE: 04/06/88

PAGE NUMBER 14

DEPTH Feet	SAMPLE	SAMPLE NUMBER	BLOWS ON	RECOVERY	DESCRIPTION	USCS	TSF	REMARKS
18.0 19.0		08307			MEDIUM DENSE DARK GRAY (5Y, 4/1) SANDY CLAY WITH SOME GRAVEL AND TRACE SILT, MOIST.		3.0	HNU : ALPHA : BETA-GAMMA :

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VISUAL CLASSIFICATION OF SOILS (CONTINUED)

ROJECT NUMBER: 602 - 3.2
LD/NEW WELL ID : 1072/1072
NGIN./GEOLOGIST: M. GOLDBERG
RILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378476.33, 481025.93

TODAY'S DATE 07/09/90
SAMPLE DATE: 03/15/88
PAGE NUMBER 15

DEPTH feet	SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
.0 1.5	08188	3 5 7	12	VERY STIFF LIGHT OLIVE BROWN CLAY (2.5Y, 5/4) DRY	CL	2.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 120
1.5 3.0	08189	3 6 6	14	STIFF DARK GRAYISH BROWN CLAY (10YR, 4/2) DRY	CL	2.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 100
3.0 4.5	08190	7 13 14	14	STIFF YELLOWISH BROWN CLAY (10YR, 5/6) D RY, TRACE SAND AND SILT	ML	1.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 120
4.5 6.0	08191	14 34 43	18	VERY STIFF YELLOWISH BROWN CLAY (10YR, 5 /6), TRACE SAND AND SILT	ML	2.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 120
6.0 7.0	08192		12	SHELBY TUBE			HNU : ALPHA : BETA-GAMMA :
7.0 9.0	08193	2 3 2	12	STIFF YELLOWISH BROWN CLAY (10YR, 5/6) W ET	CL	2.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 140
9.0 10.5	08194	3 4 3	18	VERY SOFT YELLOWISH BROWN CLAY (10YR, 5/ 4) WET	CH	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 160

VISUAL CLASSIFICATION OF SOILS (CONTINUED)

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 1072/1072

ENGIN./GEOLOGIST: M. GOLDBERG
DRILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD R1/FS
COORDINATES: 1378476.33, 481025.93

TODAY'S DATE 07/09/90

SAMPLE DATE: 03/15/88

PAGE NUMBER 16

DEPTH Feet	SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
10.5 12.0	08195	13 16 23	18	VERY STIFF YELLOWISH BROWN CLAY (10YR, 5/8) DRY	CL	2.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 150
12.0 13.5	08196	20 23 26	18	VERY STIFF REDDISH BROWN CLAY (5YR, 4/4), TRACE GRAVEL, DRY	CL	2.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 150
13.5 15.0	08197	11 12 16	18	VERY STIFF REDDISH BROWN CLAY (5YR, 4/4), TRACE GRAVEL, DRY. STIFF GRAY CLAY (5Y, 5/1) DRY, TRACE GRAVEL	CL CL	2.5 1.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 130
15.0 16.5	08198	3 5 7	12	STIFF GRAY CLAY (5Y, 5/1) DRY, TRACE GRAVEL	CL	1.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 130
16.5 18.0	08199	6 7 9	18	MEDIUM STIFF GRAY CLAY (5Y, 5/1) DRY, TRACE GRAVEL	CL	1.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 120
18.0 19.5	08200	2 6 6	18	SOFT GRAY CLAY (5Y, 5/1) DRY, TRACE GRAVEL	CL	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 140
19.5 21.0	08201	6 7 12	18	SOFT GRAY CLAY (5Y, 5/1) DRY, TRACE GRAVEL	CL	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 140

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VISUAL CLASSIFICATION OF SOILS (CONTINUED)

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 1072/1072
ENGIN./GEOLOGIST: M. GOLDBERG
DRILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378476.33, 481025.93

TODAY'S DATE 07/09/90
SAMPLE DATE: 03/15/88
PAGE NUMBER 17

DEPTH feet	SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
1.0 3.0	08202		24	SHELBY TUBE			HNU : ALPHA : BETA-GAMMA :
3.0 4.0	08203	3 6	12	MEDIUM STIFF GRAY CLAY (5Y, 5/1) DRY, TRACE GRAVEL	CL	1.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 140
4.0 5.5	08204	5 6 13	12	MEDIUM STIFF DARK GRAY CLAY (5Y, 5/1) DRY, TRACE GRAVEL			HNU : 0 ALPHA : 0 BETA-GAMMA : 110
5.5 7.0	08205	3 4 6	10	STIFF DARK GRAY CLAY (5Y, 5/1) DRY, TRACE GRAVEL	CL	1.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 100
7.0 8.5	08206	4 6 18	16	STIFF DARK GRAY CLAY (5Y, 5/1) DRY, TRACE GRAVEL		1.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 100
8.5 10.0	08207	22 30 41	18	HARD DARK GRAY CLAY (5Y, 5/1) DRY, TRACE GRAVEL. BLUE GRAVEL AND CLAY STRINGERS.	CL	4.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 120
10.0 11.5	08208	12 22 41	18	VERY STIFF DARK OLIVE GREY CLAY (5Y, 3/2), ABUNDANT GRAVEL, DRY.	CL	3.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 100

VISUAL CLASSIFICATION OF SOILS (CONTINUED)

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 1072/1072

ENGIN./GEOLOGIST: M. GOLDBERG
DRILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378476.33, 481025.93

TODAY'S DATE 07/09/90

SAMPLE DATE: 03/15/88

PAGE NUMBER 18

DEPTH Feet	SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
31.5 33.0	08209	12 22 38	18	VERY STIFF DARK OLIVE GREY CLAY (5Y, 3/2), ABUNDANT GRAVEL, DRY. VERY STIFF YEL LOWISH BROWN SILTY CLAY (10YR, 6/8), DRY . DENSE YELLOWISH BROWN SAND (10YR, 6/6), DRY.	CL CL SW	3.5 2.5 <1	HNU : 0 ALPHA : 0 BETA-GAMMA : 100
38.0 39.5	08210	17 31 37	18	VERY DENSE YELLOWISH BROWN SAND (10YR, 6 /6), DRY.	SW	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 140
43.0 44.5	08211	26 28 34	18	VERY DENSE YELLOWISH BROWN SAND (10YR, 6 /6), DRY, TRACE GRAVEL.	SW	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 160
48.0 50.0	08212	10 28 50	20	VERY DENSE YELLOWISH BROWN SAND (10YR, 6 /6), DRY, TRACE GRAVEL.	SW	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 140
.0 .0	08213			RINSATE SAMPLE			HNU : ALPHA : BETA-GAMMA :

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VISUAL CLASSIFICATION OF SOILS (CONTINUED)

OJECT NUMBER: 602 - 3.2
D/NEW WELL ID : 208/2008

GIN./GEOLOGIST: M. GOLDBERG
ILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378918.03, 480661.42

TODAY'S DATE 07/09/90

SAMPLE DATE: 03/28/88

PAGE NUMBER 19

et	SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
.0 .5	08241	2 2 4	12	STIFF YELLOWISH BROWN SILTY CLAY (10YR, 5/6), DRY.	CL	1.5	HNU : 3 ALPHA : 0 BETA-GAMMA : 260
.5 .0	08242	6 7 11	9	VERY STIFF DARK YELLOWISH BROWN SILTY CL AY (10YR, 4/6), DRY.	CL		HNU : 2 ALPHA : 0 BETA-GAMMA : 270
.0 .5	08243	5 8 9	6	MEDIUM STIFF YELLOWISH BROWN CLAYEY SILT (10YR, 5/4), DRY.	ML	0.5	HNU : 2 ALPHA : 0 BETA-GAMMA : 250
.5 .0	08244	3 4 4	11	STIFF DARK YELLOWISH BROWN SANDY CLAY (1 0YR, 5/4), MOIST.	CL	1.25	HNU : 1 ALPHA : 0 BETA-GAMMA : 240
.0 .5	08805		18	SHELBY TUBE			HNU : ALPHA : BETA-GAMMA :
.5 .0	08806	4 8 8	10	LOOSE YELLOWISH BROWN SAND (10YR, 5/8), WET, TRACE SILT.	SP	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 200
.0 .5	08807	6 9 10	14	LOOSE YELLOWISH BROWN SAND (10YR, 5/8), WET, TRACE SILT.	SP	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 200

VISUAL CLASSIFICATION OF SOILS (CONTINUED)

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 208/2008

ENGIN./GEOLOGIST: M. GOLDBERG
DRILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378918.03, 480661.42

TODAY'S DATE 07/09/90

SAMPLE DATE: 03/28/88

PAGE NUMBER 20

DEPTH Feet	SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
10.5 12.0	08808	7 9 10	14	STIFF DARK GRAY CLAY (5Y, 4/1) WITH SAND AND SILT.	CL	1.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 200
12.0 13.5	08809	10 10 9	14	STIFF DARK GRAY SILT (5Y, 4/1) WITH SAND , TRACE CLAY, WET.	ML	1.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 200
13.5 15.0	08810	2 3 4	16	MEDIUM STIFF DARK GRAY CLAY (5Y, 4/1), TRACE SILT, MOIST.	CL	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 200
15.0 16.5	08811	5 7 6	18	MEDIUM STIFF DARK GRAY SILTY CLAY (5Y, 4/1), TRACE SAND AND SILT, WET.	ML	1.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 200
16.5 18.0	08812	6 7 10	18	MEDIUM STIFF DARK GRAY SILTY CLAY (5Y, 4/1), TRACE SAND AND GRAVEL, WET.	ML	1.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 210
18.0 19.0	08813		12	SHELBY TUBE			HNU : ALPHA : BETA-GAMMA :
19.0 20.5	08814	13 13 15	12	STIFF DARK GRAY SILTY CLAY (5Y, 4/1), TRACE GRAVEL, MOIST.	CL	2.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 210

VISUAL CLASSIFICATION OF SOILS (CONTINUED)

ROJECT NUMBER: 602 - 3.2
LD/NEW WELL ID : 208/2008

NGIN./GEOLOGIST: M. GOLDBERG
RILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378918.03, 480661.42

TODAY'S DATE 07/09/90

SAMPLE DATE: 03/28/88

PAGE NUMBER 21

DEPTH feet	SAMPLE NUMBER	BLOWS ON	SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
0.5 2.0	08815	7 7 9		10	STIFF DARK GRAY CLAY (5Y, 4/1), TRACE GRAVEL, DRY.	CL	2.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 210
2.0 5.5	08816	5 6 9		12	VERY STIFF DARK GRAY CLAY (5Y, 4/1), TRACE GRAVEL, MOIST.	CL	2.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 210
5.5 5.0	08817	4 6 10		12	VERY STIFF DARK GRAY CLAY (5Y, 4/1), TRACE GRAVEL, MOIST.	CL	2.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 180
5.0 5.5	08818	4 5 7		8	VERY STIFF DARK GRAY CLAY (5Y, 4/1), TRACE GRAVEL, DRY.	CL	2.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 180
5.5 8.0	08819	2 4 3		12	STIFF DARK GRAY CLAY (5Y, 4/1), TRACE GRAVEL, DRY.	CL	1.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 180
8.0 9.5	08820	5 7 50		14	STIFF DARK GRAY CLAY (5Y, 4/1), TRACE GRAVEL, DRY.	CL	1.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 190
9.5 1.0	08821	50 50		18	VERY HARD OLIVE GRAY CLAY (5Y, 4/2), TRACE GRAVEL, DRY.	CL	>4.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 190

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 208/2008

ENGIN./GEOLOGIST: M. GOLDBERG
DRILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378918.03, 480661.42

TODAY'S DATE 07/09/90

SAMPLE DATE: 03/28/88

PAGE NUMBER 22

DEPTH Feet	SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
31.0 32.5	08822	14 34 50	18	VERY HARD DARK GRAY CLAY (5Y, 4/1), TRACE GRAVEL, DRY.	CL	>4.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 190
32.5 34.0	08823	14 24 35	18	VERY HARD DARK GRAY CLAY (5Y, 4/1), TRACE GRAVEL. DENSE YELLOWISH BROWN SAND (10YR, 5/6), DRY.	CL SW	>4.0 <1	HNU : 0 ALPHA : 0 BETA-GAMMA : 180
39.0 40.5	08824	14 47 50	18	VERY DENSE YELLOWISH BROWN SAND (10YR, 5/6), DRY.	SW	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 190
45.0 46.5	08825	40 50 50	16	VERY DENSE YELLOWISH BROWN SAND (10YR, 5/6), TRACE GRAVEL, DRY.	SW	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 190
50.0 51.5	08826	15 20 25	18	DENSE YELLOWISH BROWN SAND (10YR, 5/6), DRY.	SP	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 120
55.0 56.5	08827	7 14 22	18	DENSE DARK GRAY SAND (2.5Y, 4/1), MOIST.	SP	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 120
60.0 61.5	08828	5 7 11	14	MEDIUM DENSE YELLOWISH BROWN SAND (10YR, 5/6), WET.	SW	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 120

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VISUAL CLASSIFICATION OF SOILS (CONTINUED)

OJECT NUMBER: 602 - 3.2
D/NEW WELL ID : 208/2008

GIN./GEOLOGIST: M. GOLDBERG
ILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378918.03, 480661.42

TODAY'S DATE 07/09/90

SAMPLE DATE: 03/28/88

PAGE NUMBER 23

et	SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
.0 .5	08829	12 10 16	18	MEDIUM DENSE YELLOWISH BROWN SAND (10YR, 5/6), WET, TRACE GRAVEL.	SW	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 120
.0 .5	08830	11 12 21	18	MEDIUM DENSE YELLOWISH BROWN SAND (10YR, 5/6), WITH GRAVEL, WET.	SW	<1	HNU : 0 ALPHA : 0 BETA-GAMMA : 110
.0 .0	08831			RINSATE SAMPLE			HNU : ALPHA : BETA-GAMMA :

VISUAL CLASSIFICATION OF SOILS (CONTINUED)

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 209/2009

ENGIN./GEOLOGIST: B. DUNNING
DRILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378007.77, 479540.71

TODAY'S DATE 07/09/90

SAMPLE DATE: 09/08/87

PAGE NUMBER 24

DEPTH Feet	SAMPLE NUMBER	BLOWS ON SAMPLER	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
.0 1.5	07070	7 16 26	6	DENSE, DARK BROWN, FINE TO COARSE SAND, SOME FINE TO COARSE GRAVEL, TRACE SILT, MOIST.	SP		HNU : 0 ALPHA : 80-110 BETA-GAMMA : 0
1.5 3.0	07071	13 9 13	6	MEDIUM DENSE, DARK BROWN FINE SAND, TRACE SILT, SOME GRAVEL, DRY.	SP		HNU : 0 ALPHA : 80-110 BETA-GAMMA : 0
3.0 4.5	07072	14 23 26	8	DENSE, DARK BROWN FINE TO COARSE SILTY SAND, SOME SILTY CLAY, TRACE FINE TO COARSE GRAVEL, DRY.	SP		HNU : 0 ALPHA : 80-110 BETA-GAMMA : 0
4.5 6.0	07073	25 36 41	18	HARD LIGHT GRAY SILTY CLAY, TRACE FINE SAND AND FINE TO COARSE GRAVEL, DRY.	CL		HNU : 0 ALPHA : 80-110 BETA-GAMMA : 0
6.0 7.5	07074	20 29 38	16	HARD, LIGHT YELLOWISH BROWN, SILTY CLAY, TRACE FINE TO MEDIUM SAND AND FINE GRAVEL, MOIST.	CL		HNU : 0 ALPHA : 80-110 BETA-GAMMA : 0
7.5 8.5	07075	33 53	13	HARD DARK BROWN SILTY CLAY, TRACE FINE TO COARSE SAND AND FINE GRAVEL, MOIST.	CL		HNU : 0 ALPHA : 80-110 BETA-GAMMA : 0
9.0 10.5	07076	7 11 21	16	HARD DARK BROWN SILTY CLAY, TRACE FINE TO COARSE SAND AND FINE GRAVEL, MOIST. DENSE BROWN FINE TO MEDIUM SAND, TRACE FINE GRAVEL, MOIST.	CL SP		HNU : 0 ALPHA : 80-110 BETA-GAMMA : 0

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VISUAL CLASSIFICATION OF SOILS (CONTINUED)

ROJECT NUMBER: 602 - 3.2
LD/NEW WELL ID : 209/2009

NGIN./GEOLOGIST: B. DUNNING
RILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378007.77, 479540.71

TODAY'S DATE 07/09/90

SAMPLE DATE: 09/08/87

PAGE NUMBER 25

DEPTH eet	SAMPLER	SAMPLE NUMBER	BLOWS ON	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
0.5 2.0	07077		26 23 21	12	DENSE, BROWN, FINE TO MEDIUM SAND, TRACE FINE GRAVEL, MOIST. VERY STIFF, LIGHT BROWN SILTY CLAY, MOIST. DENSE, BROWN FINE TO MEDIUM SAND, MOIST.	SP CL SP		HNU : 0 ALPHA : 80-110 BETA-GAMMA : 0
2.0 3.5	07078		9 11 17	17	MEDIUM DENSE, BROWN FINE SAND, TRACE SILT, MOIST.	SP		HNU : 0 ALPHA : 80-110 BETA-GAMMA : 0
3.5 5.0	07079		23 29 29	16	VERY DENSE BROWN FINE SAND, TRACE SILT, MOIST.	SP		HNU : 0 ALPHA : 80-110 BETA-GAMMA : 0
8.5 0.5	07080		21 23 26	18	DENSE, DARK BROWN FINE TO COARSE SAND, TRACE SILT, MOIST.	SP		HNU : 0 ALPHA : 80-120 BETA-GAMMA : 0
3.5 5.0	07081		11 20 31	15	DENSE, DARK BROWN FINE TO MEDIUM SAND, SOME SILT, MOIST.	SW		HNU : 0 ALPHA : 80-120 BETA-GAMMA : 0
8.5 0.0	07082		10 21 31	18	DENSE, DARK BROWN FINE TO MEDIUM SILTY SAND, MOIST.	SP		HNU : 0 ALPHA : 80-120 BETA-GAMMA : 0
3.5 5.0	07083		14 15 19	18	DENSE, DARK BROWN FINE TO COARSE SAND, TRACE GRAVELS, TRACE SILT, MOIST.	SP		HNU : 0 ALPHA : 80 BETA-GAMMA : 0

VISUAL CLASSIFICATION OF SOILS (CONTINUED)

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 209/2009

ENGIN./GEOLOGIST: B. DUNNING
DRILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378007.77, 479540.71

TODAY'S DATE 07/09/90

SAMPLE DATE: 09/08/87

PAGE NUMBER 26

DEPTH Feet	SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
38.5 40.0	07084	17 20 28	18	DENSE DARK BROWN FINE TO COARSE SAND TRACE GRAVELS TRACE SILT - MOIST; VERY STIFF LIGHT BROWN SILTY CLAY, MOIST.	SP		HNU : 0 ALPHA : 80-100 BETA-GAMMA : 0
43.5 45.0	07085	17 26 40	18	DENSE, DARK YELLOW BROWN FINE TO COARSE SAND, SOME GRAVEL, TRACE SILT, MOIST.	SP		HNU : 0 ALPHA : 80-100 BETA-GAMMA : 0
48.0 49.5	07086	13 23 22	18	DENSE, PALE BROWN FINE TO COARSE SAND, TRACE FINE GRAVEL, WET.	SW		HNU : 0 ALPHA : 60-100 BETA-GAMMA : 0
53.0 54.5	07087	16 36 50	18	VERY DENSE, PALE BROWN FINE TO COARSE SAND, SOME FINE GRAVEL, WET.	SW		HNU : 0 ALPHA : 60-110 BETA-GAMMA : 0

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VISUAL CLASSIFICATION OF SOILS (CONTINUED)

OJECT NUMBER: 602 - 3.2
D/NEW WELL ID : 334/3034
GIN./GEOLOGIST: F. MARKERT
ILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378431.39, 480240.23

TODAY'S DATE 07/09/90
SAMPLE DATE: 03/30/88
PAGE NUMBER 31

et	SAMPLER	SAMPLE NUMBER	BLOWS ON	RECOVERY	DESCRIPTION	USCS	TSF	REMARKS
.0 .5		08265	2 5 6	17	MEDIUM DENSE, DARK BROWN (10YR, 3/3) SOIL, SOME SILT, SOME CLAY, ORGANIC RICH, ROOTS, DRY. MEDIUM DENSE, BROWN (10YR, 4/4) CLAY, TRACE SILT, TRACE ORGANICS, MOTTLED, DRY.	OH CL	2.0 4.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 250-300
.5 .0		08266	3 8 15	15	MEDIUM DENSE, GREY (10YR, 6/2) CLAY, SOME SILT, TRACE ORGANICS AT TOP, MOTTLED, DRY.	CL	>4.5	HNU : 0 ALPHA : 2 BETA-GAMMA : 250-300
.0 .5		08267	15 18 21	18	DENSE, GRAY (10YR, 5/2) CLAY, SOME SILT WITH SILT LENSES, TRACE ORGANICS, MOTTLED TAN AT BOTTOM, DRY.	CL	>4.5	HNU : 0 ALPHA : 1 BETA-GAMMA : 250-300
.5 .0		08268	15 18 21	17	DENSE, GREY (10YR, 5/1) CLAY, TRACE SILT WITH SILT LENSES, MOTTLED TAN, DRY.	CL	>4.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 250-300
.0 .5		08269	21 23 19	18	DENSE, GREY (10YR, 6/2) CLAY, SOME SILT W/ SILT LENSES, MOTTLED TAN, DRY. DENSE, BROWN (10YR, 5/4) FINE SAND, SOME SILT, SOME ANGULAR GRAVEL, MOTTLED DARK GREY, MOIST.	CL SM	3.5	HNU : 0 ALPHA : 1 BETA-GAMMA : 250-300
.5 .0		08270	1 3 7	7	LOOSE, BROWN (2.5Y, 4/2) FINE SAND, SOME GRAVEL, TRACE CLAY, TRACE SILT, POORLY GRADED, UNSTRATIFIED, MOIST.	SP		HNU : 0 ALPHA : BETA-GAMMA : 250-300
.0 .5		08271	5 9 10	9	MEDIUM DENSE, BROWN (10YR, 4/4) FINE SAND, SOME GRAVEL, TRACE CLAY, TRACE SILT, POORLY GRADED, UNSTRATIFIED, MOIST. MEDIUM DENSE, GREY (10YR, 4/2) CLAY, SOME SILT, MOIST.	SP CH	1.0	HNU : 0 ALPHA : BETA-GAMMA : 250-300

VISUAL CLASSIFICATION OF SOILS (CONTINUED)

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 334/3034

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378431.39, 480240.23

TODAY'S DATE 07/09/90

SAMPLE DATE: 03/30/88

ENGIN./GEOLOGIST: F. MARKERT
DRILLING METHODS : CABLE-TOOL

PAGE NUMBER 32

DEPTH Feet	SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
10.5 12.0	08272	4 5 9	10	MEDIUM DENSE, GREY (10YR, 5/1) CLAY, SOME SILT, DRY.	CL	1.25	HNU : 0 ALPHA : 0 BETA-GAMMA : 250-300
12.0 13.5	08273	5 6 10	12	MEDIUM DENSE, GREY (5Y, 4/1) CLAY, TRACE ANGULAR GRAVEL, SOME SILT, DRY. MEDIUM DENSE, GREY (5Y, 3/1) FINE SAND LENS, SOME GRAVEL, SOME SILT, MOIST.	CL SM	2.75	HNU : 0 ALPHA : 0 BETA-GAMMA : 250-300
13.5 15.0	08274	3 5 9	9	MEDIUM DENSE, GREY (5Y, 4/1) CLAY, TRACE ANGULAR GRAVEL, SOME SILT, DRY.	CL	2.5	HNU : 0 ALPHA : 1 BETA-GAMMA : 250-300
15.0 16.5	08275	2 2 5	9	LOOSE, GREY (5Y, 4/1) CLAY, SOME ANGULAR GRAVEL, TRACE SAND, SOME SILT, DRY.	CL	0.75	HNU : 0 ALPHA : 0 BETA-GAMMA : 200-250
16.5 18.0	08276	7 19 22	15	DENSE, GREY (5Y, 3/1) CLAY, SOME ANGULAR GRAVEL, TRACE SAND, SOME SILT, DRY.	CL	4.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 200-250
18.0 19.5	08277	8 13 31	6	DENSE, GREY (5Y, 4/1) CLAY, SOME ANGULAR GRAVEL, SOME SAND, SOME SILT, DRY.	CL	3.5	HNU : 0 ALPHA : 0 BETA-GAMMA : 200-250
19.5 21.0	08278	9 13 25	9	DENSE, GREY (5Y, 4/1) CLAY, SOME ROUNDED GRAVEL, SOME SAND, SOME SILT, DRY.	CL	3.0	HNU : 0 ALPHA : 0 BETA-GAMMA : 200-250

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VISUAL CLASSIFICATION OF SOILS (CONTINUED)

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 334/3034
ENGIN./GEOLOGIST: F. MARKERT
DRILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378431.39, 480240.23

TODAY'S DATE 07/09/90
SAMPLE DATE: 03/30/88
PAGE NUMBER 33

DEPTH feet	SAMPLER NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
1.0 2.5	08279	8 11 21	16	DENSE, GREY (5Y, 3/1) CLAY, SOME ROUNDED GRAVEL, SOME SILT, TRACE SAND, DRY.	CL	2.75	HNU : 0 ALPHA : 0 BETA-GAMMA : 200-250
2.5 4.0	08280	9 15 22	14	DENSE, TAN (10YR, 6/4) FINE SAND, EXTREMELY WELL GRADED, UNSTRATIFIED, DRY.	SW		HNU : 0 ALPHA : 0 BETA-GAMMA : 200-250
4.0 5.5	08281	8 21 23	15	DENSE, TAN (10YR, 7/4) FINE SAND, WELL GRADED, STRATIFIED, SOME SILT IN LENSES OF DARKER (10YR, 5/6) 1/2" TO 1" THICK, DRY.	SM		HNU : 0 ALPHA : 0 BETA-GAMMA : 200-250
0.0 1.5	08282	5 9 14	12	MEDIUM DENSE, TAN (10YR, 5/6) FINE SAND, TRACE SILT, EXTREMELY WELL GRADED, PARTIALLY STRATIFIED, DRY.	SW		HNU : 0 ALPHA : 0 BETA-GAMMA : 300-350
5.0 6.5	08283	14 49	14	VERY DENSE, TAN (10YR, 5/4) FINE SAND, TRACE ROUNDED GRAVEL, TRACE SILT, WELL GRADED, UNSTRATIFIED, DRY.	SW		HNU : 0 ALPHA : 0 BETA-GAMMA : 300-350
0.0 1.5	08284	12 15 17	13	DENSE, TAN (10YR, 6/4) FINE SAND, TRACE SILT, EXTREMELY WELL GRADED, UNSTRATIFIED, DRY.	SW		HNU : 0 ALPHA : 0 BETA-GAMMA : 300-350
5.0 6.5	08285	8 22 20	13	DENSE, LIGHT TAN (10YR, 6/2) FINE SAND, TRACE SILT, EXTREMELY WELL GRADED, PARTIALLY STRATIFIED, DRY.	SW		HNU : 0 ALPHA : 1 BETA-GAMMA : 300-350

VISUAL CLASSIFICATION OF SOILS (CONTINUED)

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 334/3034

ENGIN./GEOLOGIST: F. MARKERT
DRILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378431.39, 480240.23

TODAY'S DATE 07/09/90

SAMPLE DATE: 03/30/88

PAGE NUMBER 34

DEPTH Feet	SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
50.0 51.5	08286	9 14 17	11	DENSE, BROWN (10YR, 4/2) MEDIUM TO COARSE SAND, TRACE ROUNDED GRAVEL, TRACE SILT, FAIR-POOR GRADING, UNSTRATIFIED, WET.	SP		HNU : 0 ALPHA : 0 BETA-GAMMA : 300-350
55.0 56.5	08287	5 10 21	9	DENSE, BROWN (10YR, 4/2) MED. TO CSE. SAND, SOME ROUNDED GRAVEL, TRACE SILT, POORLY GRADED, UNSTRATIFIED, WET. DENSE, BROWN (10YR, 4/2) ROUNDED GRAVEL, SOME MED. TO CSE. SAND, SOME SILT, POORLY GRADE	SP GM		HNU : 0 ALPHA : 0 BETA-GAMMA : 300-350
60.0 61.5	08288	9 15 19	12	DENSE, BROWN (10YR, 3/3) FINE TO COARSE GRAVELLY SAND, SOME ROUNDED GRAVEL, POORLY GRADED, UNSTRATIFIED, WET.	GP		HNU : 0 ALPHA : 0 BETA-GAMMA : 300-350
65.0 66.5	08289	10 20 24	14	DENSE, BROWN (10YR, 3/3) FINE TO COARSE GRAVELLY SAND, SOME ROUNDED GRAVEL, POORLY GRADED, UNSTRATIFIED, WET.	GP		HNU : 0 ALPHA : 0 BETA-GAMMA : 300-350
70.0 71.5	08290	12 33 28	11	VERY DENSE, BROWN (10YR, 4/2) MED. TO CSE. GRAVELLY SAND, SOME ROUND GRAVEL (PEBBLES), SOME SILT, POORLY GRADED, UNSTRATIFIED, WET.	GM		HNU : 0 ALPHA : 0 BETA-GAMMA : 300-350
75.0 76.5	08291	13 24 36	14	VERY DENSE, BROWN (10YR, 4/3) GRAVELLY MEDIUM SAND, SOME ROUND GRAVEL (PEBBLES), TRACE SILT, POORLY GRADED, UNSTRATIFIED, WET.	GM		HNU : ALPHA : 0 BETA-GAMMA : 200-250
80.0 81.5	08292	15 29 26	12	VERY DENSE, BROWN (10YR, 3/3) MED. TO CSE. SAND, SOME ROUNDED GRAVEL, SOME SILT, POORLY GRADED, UNSTRATIFIED, WET. VERY DENSE, BROWN (10YR, 4/3) FINE SAND, SOME SILT, WELL GRADED, UNSTRATIFIED, WET.	GM SM		HNU : ALPHA : 2 BETA-GAMMA : 200-250

VISUAL CLASSIFICATION OF SOILS (CONTINUED)

OJECT NUMBER: 602 - 3.2
D/NEW WELL ID : 334/3034
GIN./GEOLOGIST: F. MARKERT
ILLING METHODS : CABLE-TOOL

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378431.39, 480240.23

TODAY'S DATE 07/09/90
SAMPLE DATE: 03/30/88
PAGE NUMBER 35

et	SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
.0 .5	08293	6 13 17	11	MEDIUM DENSE, BROWN (10YR, 3/3) FINE TO MED. SAND, SOME SILT, WELL GRADED, UNSTRATIFIED, WET.	SM		HNU : ALPHA : 0 BETA-GAMMA : 200-250
.0 .5	08294	5 12 18	8	MEDIUM DENSE, BROWN (10YR, 3/2) FINE TO MED. SAND, SOME SILT, FAIR GRADING, UNSTRATIFIED, WET.	SM		HNU : ALPHA : 0 BETA-GAMMA : 200-250
.0 .5	08295	5 10 15	9	MEDIUM DENSE, BROWN (10YR, 3/2) MED. TO CSE. SAND, SOME SILT, TRACE ROUNDED GRAVEL, FAIR GRADING, UNSTRATIFIED, WET.	SM		HNU : ALPHA : 0 BETA-GAMMA : 200-250
.0 .5	08296	2 3 8	9	MEDIUM DENSE, BROWN (10YR, 4/2) FINE TO CSE. SAND, TRACE SILT, TRACE ROUNDED GRAVEL, FAIR GRADING, PARTIALLY STRATIFIED, WET.	SM		HNU : ALPHA : 0 BETA-GAMMA : 200-250
.0 .5	08297	12 19 27	12	DENSE, BROWN (10YR, 4/2) MEDIUM SAND, WELL GRADED, UNSTRATIFIED, WET. DENSE, BROWN (10YR, 5/2) VERY FINE SAND, SOME SILT, EXTREMELY WELL GRADED, PARTIALLY STRATIFIED, WET.	SW SM		HNU : ALPHA : 0 BETA-GAMMA : 200-250
.0 .5	08298	3 9 13	7	MEDIUM DENSE, GRAY - BLACK (5Y, 2.5/1) CLAY, SOME SILT, TRACE SAND, MOIST.	CL	2.75	HNU : ALPHA : 1 BETA-GAMMA : 200-250
.1 .1	08299			SHELBY TUBE			HNU : ALPHA : BETA-GAMMA :

PROJECT NUMBER: 602 - 3.2
OLD/NEW WELL ID : 334/3034

PROJECT NAME: FERNALD RI/FS
COORDINATES: 1378431.39, 480240.23

TODAY'S DATE 07/09/90
SAMPLE DATE: 03/30/88

ENGIN./GEOLOGIST: F. MARKERT
DRILLING METHODS : CABLE-TOOL

DEPTH Feet	SAMPLE NUMBER	BLOWS ON SAMPLE	RECOVERY INCHES	DESCRIPTION	USCS	TSF	REMARKS
115.0 116.5	08300	4 5 5	16	LOOSE, GREY (5Y, 3/1) FINE SAND, SOME SILT, SOME CLAY, WELL GRADED, UNSTRATIFIED, WET. MORE CLAY RICH IN LAST 4".	SM		HNU : ALPHA : 0 BETA-GAMMA : 250-300
120.0 121.5	08301	5 8 15	11	MEDIUM DENSE GREY (5Y, 4/1) FINE TO CSE. GRAVELLY SAND, SOME CSE. ROUND GRAVEL, SOME SILT, TRACE CLAY, POORLY GRADED, UNSTRATIFIED, WET.	GM		HNU : 0 ALPHA : 1 BETA-GAMMA : 250-300
125.0 126.5	08302	32 48 37	11	DENSE, GREY (5Y, 3/2) MED. TO CSE. GRAVELLY SAND, SOME CSE. ROUND GRAVEL, SOME SILT, POORLY GRADED, UNSTRATIFIED, WET.	GM		HNU : 0 ALPHA : 0 BETA-GAMMA : 250-300
130.0 131.5	08303	70	8	DENSE, GREY (2.5Y, 5/2) COARSE GRAVELLY SAND, SOME COARSE ROUND GRAVEL, TRACE SILT, POORLY GRADED, UNSTRATIFIED, WET.	GP		HNU : 0 ALPHA : 0 BETA-GAMMA : 250-300
135.0 136.5	08304	10 14 18	10	DENSE, GREY-BROWN (10YR, 5/2) MED. TO CSE. SAND, TRACE ROUNDED GRAVEL, TRACE SILT, FAIR GRADING, UNSTRATIFIED, WET.	SP		HNU : 0 ALPHA : 0 BETA-GAMMA : 250-300
140.0 141.5	08305	5 11 19	9	MEDIUM DENSE, GREY-BROWN (10YR, 5/2) FINE TO MED. SAND, TRACE SILT, FAIR GRADING, UNSTRATIFIED, WET.	SP		HNU : 0 ALPHA : 0 BETA-GAMMA : 250-300
.0 .0	08306			RINSATE SAMPLE			HNU : ALPHA : BETA-GAMMA :

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APPENDIX C

SURFACE WATER AND SEDIMENTS DATA

SURFACE WATER/ANALYTICAL RESULTS

SURFACE WATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picocuries per liter (pCi/L).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETERS	ASIT-010 01047 06-28-1988	ASIT-010 01117 03-10-1989	DUPLICATE ASIT-010 01118 03-10-1989	ASIT-023 01150 02-21-1989
Cesium 137	NA	NA	NA	< 20.0
Neptunium 237	NA	NA	NA	< 1.0
Plutonium 238	NA	NA	NA	< 1.0
Plutonium 239/240	NA	NA	NA	< 1.0
Radium 226	< 1.0	< 1.0	< 1.0	< 1.0
Radium 228	< 3.0	< 3.0	< 3.0	< 3.0
Ruthenium 106	NA	NA	NA	< 150.0
Strontium 90	NA	NA	NA	< 5.0
Technetium 99	NA	NA	NA	34.9 ± 16.5
Thorium 228	NA	NA	NA	< 1.0
Thorium 230	NA	NA	NA	< 1.0
Thorium 232	NA	NA	NA	< 1.0
Total Thorium **	NA	NA	NA	NA
Uranium 234	NA	NA	NA	80.3 ± 12.7
Uranium 235/236	NA	NA	NA	4.9 ± 1.4
Uranium 238	NA	NA	NA	165.0 ± 25.0
Total Uranium **	2199.0 ± 352.0	282.0 ± 46.0	231.0 ± 38.0	465.0 ± 82.0

* Data validation in progress.

** Results reported in ug/L

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SURFACE WATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picocuries per liter (pCi/L).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETERS	DUPLICATE ASIT-023 01151 02-21-1989	ASIT-024 01152 02-21-1989	DUPLICATE ASIT-024 01153 02-21-1989	ASIT-025 01114 03-10-1989
Cesium 137	< 20.0	< 20.0	< 20.0	NA
Neptunium 237	< 1.0	< 1.0	< 1.0	NA
Plutonium 238	< 1.0	< 1.0	< 1.0	NA
Plutonium 239/240	< 1.0	< 1.0	< 1.0	NA
Radium 226	< 1.0	< 1.0	< 1.0	< 1.0
Radium 228	< 3.0	< 3.0	< 3.0	< 3.0
Ruthenium 106	< 150.0	< 150.0	< 150.0	NA
Strontium 90	< 5.0	< 5.0	< 5.0	NA
Technetium 99	< 30.0	< 30.0	36.9 ± 18.6	NA
Thorium 228	< 1.0	< 1.0	< 1.0	NA
Thorium 230	< 1.0	< 1.0	< 1.0	NA
Thorium 232	< 1.0	< 1.0	< 1.0	NA
Total Thorium **	NA	NA	NA	NA
Uranium 234	76.9 ± 11.8	86.4 ± 13.8	85.8 ± 13.7	NA
Uranium 235/236	6.0 ± 1.5	6.7 ± 1.8	6.7 ± 1.8	NA
Uranium 238	165.0 ± 24.0	205.0 ± 32.0	195.0 ± 30.0	NA
Total Uranium **	433.0 ± 72.0	517.0 ± 83.0	576.0 ± 93.0	247.0 ± 41.0

* Data validation in progress.

** Results reported in ug/L

SURFACE WATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picocuries per liter (pCi/L).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETERS	ASIT-026 01115 03-10-1989	DUPLICATE ASIT-026 01116 03-10-1989	W-10 01108 01-12-1989	W-10 01216 05-23-1989
Cesium 137	NA	NA	< 20.0	< 20.0
Neptunium 237	NA	NA	< 1.0	< 1.0
Plutonium 238	NA	NA	< 1.0	< 1.0
Plutonium 239/240	NA	NA	< 1.0	< 1.0
Radium 226	< 1.0	< 1.0	< 1.0	< 1.0
Radium 228	< 3.0	< 3.0	< 3.0	< 3.0
Ruthenium 106	NA	NA	< 150.0	< 150.0
Strontium 90	NA	NA	< 5.0	< 5.0
Technetium 99	NA	NA	< 30.0	< 30.0
Thorium 228	NA	NA	< 1.0	< 1.0
Thorium 230	NA	NA	< 1.0	< 1.0
Thorium 232	NA	NA	< 1.0	< 1.0
Total Thorium **	NA	NA	NA	< 6.0
Uranium 234	NA	NA	2.7 ± 0.6	1.2 ± 0.5
Uranium 235/236	NA	NA	< 1.0	< 1.0
Uranium 238	NA	NA	4.8 ± 0.8	4.5 ± 0.9
Total Uranium **	216.0 ± 36.0	201.0 ± 33.0	12.0 ± 2.0	25.0 ± 4.0

* Data validation in progress.

** Results reported in ug/L

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SURFACE WATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picocuries per liter (pCi/L).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETERS	DUPLICATE W-10 01217 05-23-1989	W-11 01107 01-12-1989	W-11 01209 05-14-1989
Cesium 137	< 20.0	< 20.0	< 20.0
Neptunium 237	< 1.0	< 1.0	< 1.0
Plutonium 238	< 1.0	< 1.0	< 1.0
Plutonium 239/240	< 1.0	< 1.0	< 1.0
Radium 226	< 1.0	< 1.0	< 1.0
Radium 228	< 3.0	< 3.0	< 3.0
Ruthenium 106	< 150.0	< 150.0	< 150.0
Strontium 90	< 5.0	< 5.0	< 5.0
Technetium 99	< 30.0	< 30.0	< 30.0
Thorium 228	< 1.0	< 1.0	< 1.0
Thorium 230	< 1.0	< 1.0	< 1.0
Thorium 232	< 1.0	< 1.0	< 1.0
Total Thorium **	< 3.0	NA	< 6.0
Uranium 234	1.3 ± 0.3	3.2 ± 0.5	2.5 ± 0.5
Uranium 235/236	< 1.0	< 1.0	< 1.0
Uranium 238	2.0 ± 0.4	6.2 ± 0.9	2.6 ± 0.5
Total Uranium **	5.0 ± 1.0	19.0 ± 3.0	9.0 ± 2.0

* Data validation in progress.

** Results reported in ug/L

DATA QUALIFIERS

EXPLANATION FOR DATA QUALIFIERS SHOWN ON THE FOLLOWING GENERAL CHEMICAL RESULTS

On the data tables that follow, an individual analytical result may include one or more data qualifiers. The list below presents all possible qualifiers and can be used as a reference when looking at the data. The qualifiers are standard Contract Laboratory Program (CLP) data qualifiers.

One note of caution; two types of chemical results tables are presented in this appendix: general chemical results and hazardous substance list results. There are two separate lists of data qualifiers for these separate tables and, although some of the symbols are the same for each, they may have different definitions.

Concentration Qualifiers

B = Reported value was obtained from a reading that was less than the Contract Laboratory Program (CLP) Contract Required Detection Limit (CRQL), but greater than or equal to the Instrument Detection Limit (IDL).

Quality Qualifiers

E = The reported value is estimated because of the presence of interference.

M = Duplicate injection precision not met.

N = Spiked sample recovery not within controls limits.

S = The reported value was determined by the Method of Standard Additions.

W = Post-digestion spike for Furnace AA analysis is out of control limits (85-115%), while sample absorbance is less than 50% of spike absorbance.

G = Native analyte > 4 times spike added; therefore acceptance criteria do not apply.

X = Detection limit is higher than normal due to sample matrix interferences.

* = Duplicate analysis not within control limits.

+ = Correlation coefficient for the MSA is less than 0.955.

EXPLANATION FOR DATA QUALIFIERS SHOWN ON THE FOLLOWING HAZARDOUS SUBSTANCE LIST RESULTS

On the data tables that follow, an individual analytical result may include one or more data qualifiers. The list below presents all possible qualifiers and can be used as a reference when looking at the data. The qualifiers are standard Contract Laboratory Program (CLP) data qualifiers.

One note of caution; two types of chemical results tables are presented in this appendix: general chemical results and hazardous substance list results. There are two separate lists of data qualifiers for these separate tables and, although some of the symbols are the same for each, they may have different definitions.

J = Indicates an estimated value. This flag is used when the mass spectral data indicate the presence of a compound that meets the identification criteria, but the result is less than the sample quantitation limit but greater than zero.

C = This flag applies to pesticide results where the identification has been confirmed by GC/MS.

B = This flag is used when the analyte is found in the associated blank as well as in the sample. It indicates possible/probable blank contamination and warns the data user to take appropriate action.

E = This flag identifies compounds whose concentrations exceed the calibration range of the GC/MS instrument for that specific analysis. This flag will <u>not</u> apply to pesticides/PCBs analyzed by GC/EC methods.

D = This flag identifies all compounds identified in an analysis at a secondary dilution factor.

F = Estimated value due to a confirmed compound which is off-scale in both columns.

X = A flag that FORMASTER III CLP software automatically inserts to indicate that the data was entered manually.

Z = No estimated value reported, or an elevated CRQL reported because matrix effects interfere with or obscure the compound on one or both columns. In either situation, the compound does not confirm as a positive identification.

* = Values outside of contract laboratory-required QC limits.

SURFACE WATER GENERAL CHEMICAL RESULTS
RI/FS DATA*

Results in parts per million (ppm).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	W-10 01108 01-12-1989	W-10 01217 05-23-1989	W-11 01107 01-12-1989	W-11 01209 05-14-1989
GENERAL CHEMISTRY				
Ammonia	0.1000	0.4090	0.4520	< 0.1000
Chloride	14.5000	12.0000	16.5000	19.9900
Fluoride	0.2250	0.2000	0.2150	0.1800
Hydrogen ion	NA	NA	NA	NA
Nitrates	NA	NA	NA	NA
Phenols	< 0.0100	< 0.0100	< 0.0100	< 0.0100
Phosporus (black, white, red,	NA	NA	NA	NA
Phosphate as P	NA	NA	NA	NA
Sulfate	39.5000	52.2000	37.0000	57.3600
Total Kjeldahl Nitrogen	1.0900	1.6800	1.8100	0.3470
Total Organic Carbon	NA	< 1.0000	NA	< 1.0000
Total Organic Halides	NA	0.0310	NA	0.0100
Total Organic Nitrogen	0.9900	1.2700	1.3600	0.3470
METALS				
Aluminum	0.4510	NA	0.1500 B	0.0764
Antimony	0.0025 B	NA	< 0.0005	NA
Arsenic	< 0.0020	0.0188	< 0.0020	< 0.0020
Barium	0.0658 B	0.0288	0.0552 B	0.0313
Beryllium	0.0012 B	NA	0.0011 B	NA
Cadmium	0.0032 B	0.0032	0.0028 B	< 0.0020
Calcium	56.6000	45.2000	52.3000	71.8000
Chromium	0.0173	0.0243	0.0139	< 0.0100
Cobalt	< 0.0100	NA	< 0.0100	NA
Copper	0.0147 B	< 0.0100	0.0100 B	< 0.0100
Cyanides (soluble salts and co	NA	NA	NA	NA
Hexavalent Chromium	NA	NA	NA	NA
Iron	0.5560	0.4640	0.2000 E	0.0415
Lead	0.0027 B	0.0021	< 0.0020	0.0093
Magnesium	13.7000	9.9700	12.7000	20.9000
Manganese	0.0265	0.0278	0.0199	0.0121
Mercury	< 0.0002	0.0003	< 0.0002	0.0003
Molybdenum	0.0205 B	< 0.0100	< 0.0200	< 0.0100
Nickel	< 0.0200	< 0.0200	< 0.0200	< 0.0200
Potassium	3.1900 B	2.7200	2.7700 B	1.6800
Selenium	< 0.0020	0.0169	< 0.0020	< 0.0020
Silicon	NA	NA	NA	2.2500
Silver	< 0.0005	< 0.0100	< 0.0005	< 0.0100
Sodium	9.2300	5.9030	8.3900	9.6900

*Data validation in progress

SURFACE WATER GENERAL CHEMICAL RESULTS
RI/FS DATA*

Results in parts per million (ppm).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	W-11 01247 07-15-1990
GENERAL CHEMISTRY	
Ammonia	< 0.1000
Chloride	9.2100
Fluoride	0.2200
Hydrogen ion	NA
Nitrates	NA
Phenols	0.0200
Phosporus (black, white, red,	NA
Phosphate as P	NA
Sulfate	44.8000
Total Kjeldahl Nitrogen	NA
Total Organic Carbon	5.5900
Total Organic Halides	< 0.0100
Total Organic Nitrogen	0.5800
METALS	
Aluminum	< 0.0600
Antimony	NA
Arsenic	< 0.0020
Barium	0.0470
Beryllium	NA
Cadmium	0.0030
Calcium	86.9000
Chromium	0.0260
Cobalt	NA
Copper	< 0.0100
Cyanides (soluble salts and co	NA
Hexavalent Chromium	NA
Iron	0.0240
Lead	0.0060
Magnesium	20.6000
Manganese	0.0090
Mercury	< 0.0002
Molybdenum	< 0.0100
Nickel	0.0250
Potassium	3.0300
Selenium	< 0.0020
Silicon	4.6100
Silver	0.0130
Sodium	9.7500

*Data validation in progress

SURFACE WATER
HAZARDOUS SUBSTANCE LIST RESULTS
RI/FS DATA*

Results in parts per million (ppm).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	W-10 01108 01-12-1989	W-11 01107 01-12-1989
VOLATILE ORGANICS		
1,1,1-Trichloroethane	< 0.0050	< 0.0050
1,1,2,2-Tetrachloroethane	< 0.0050	< 0.0050
1,1,2-Trichloroethane	< 0.0050	< 0.0050
1,1-Dichloroethane	< 0.0050	< 0.0050
1,1-Dichloroethene	< 0.0050	< 0.0050
1,2-Dichloroethane	< 0.0050	< 0.0050
1,2-Dichloroethylene	< 0.0050	< 0.0050
1,2-Dichloropropane	< 0.0050	< 0.0050
2-Butanone	< 0.0100	< 0.0100
2-Hexanone	< 0.0100	< 0.0100
4-Methyl-2-pentanone	< 0.0100	< 0.0100
Acetone	< 0.0100	< 0.0100
Benzene	< 0.0050	< 0.0050
Bromodichloromethane	< 0.0050	< 0.0050
Bromoform	< 0.0050	< 0.0050
Bromomethane	< 0.0100	< 0.0100
Carbon Tetrachloride	< 0.0050	< 0.0050
Carbon disulfide	< 0.0050	< 0.0050
Chlorobenzene	< 0.0050	< 0.0050
Chloroethane	< 0.0100	< 0.0100
Chloroform	< 0.0050	< 0.0050
Chloromethane	< 0.0100	< 0.0100
Dibromochloromethane	< 0.0050	< 0.0050
Ethylbenzene	< 0.0050	< 0.0050
Methylene chloride	< 0.0050	< 0.0050
Styrene	< 0.0050	< 0.0050
Tetrachlorethene	< 0.0050	< 0.0050
Toluene	< 0.0050	< 0.0050
Total xylenes	< 0.0050	< 0.0050
Trichloroethene	< 0.0050	< 0.0050
Vinyl Acetate	< 0.0100	< 0.0100
Vinyl chloride	< 0.0100	< 0.0100
cis-1,3-Dichloropropene	< 0.0050	< 0.0050
trans-1,3-Dichloropropene	< 0.0050	NA
trans-1,3-Dichloropropene	NA	< 0.0050

*Data validation in progress

SURFACE WATER
HAZARDOUS SUBSTANCE LIST RESULTS
RI/FS DATA*

Results in parts per million (ppm).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	W-10 01108 01-12-1989	W-11 01107 01-12-1989
ORGANOPHOSPOROUS PESTICIDES		
Azinphosmethyl	< 0.0025	< 0.0025
Demeton	< 0.0003	< 0.0003
Diazinon	< 0.0003	< 0.0003
Disulfoton	< 0.0003	< 0.0003
Ethion	< 0.0003	< 0.0003
Malathion	< 0.0010	< 0.0003
Parathion, ethyl	< 0.0003	< 0.0003
Parathion, methyl	< 0.0003	< 0.0003
PESTICIDES		
4,4'-DDD	< 0.0001	< 0.0001
4,4'-DDE	< 0.0001	< 0.0001
4,4'-DDT	< 0.0001	< 0.0001
Aldrin	< 0.0000	< 0.0000
Aroclor-1016	< 0.0005	< 0.0005
Aroclor-1221	< 0.0005	< 0.0005
Aroclor-1232	< 0.0005	< 0.0005
Aroclor-1242	< 0.0005	< 0.0005
Aroclor-1248	< 0.0005	< 0.0005
Aroclor-1254	< 0.0010	< 0.0010
Aroclor-1260	< 0.0010	< 0.0010
Dieldrin	< 0.0001	< 0.0001
Endosulfan II	< 0.0001	< 0.0001
Endosulfan sulfate	< 0.0001	< 0.0001
Endosulfan-I	< 0.0000	< 0.0000
Endrin	< 0.0001	< 0.0001
Endrin ketone	< 0.0001	< 0.0001
Heptachlor	< 0.0000	< 0.0000
Heptachlor epoxide	< 0.0000	< 0.0000
Methoxychlor	< 0.0005	< 0.0005
Toxaphene	< 0.0010	< 0.0010
alpha-BHC	< 0.0000	< 0.0000
alpha-Chlordane	< 0.0005	< 0.0005
beta-BHC	< 0.0000	< 0.0000
delta-BHC	< 0.0000	< 0.0000
gamma-BHC (Lindane)	< 0.0000	< 0.0000
gamma-Chlordane	< 0.0005	< 0.0005
SEMI-VOLATILE ORGANICS		

*Data validation in progress

SURFACE WATER
HAZARDOUS SUBSTANCE LIST RESULTS
RI/FS DATA*

Results in parts per million (ppm).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	ASIT-021 01161 02-21-1989	W-11 01107 01-12-1989
SEMI-VOLATILE ORGANICS		
1,2,4-Trichlorobenzene	< 0.0100	< 0.0100
1,2-Dichlorobenzene	< 0.0100	< 0.0100
1,3-Dichlorobenzene	< 0.0100	< 0.0100
1,4-Dichlorobenzene	< 0.0100	< 0.0100
2,4,5-Trichlorophenol	< 0.0500	< 0.0500
2,4,6-Trichlorophenol	< 0.0100	< 0.0100
2,4-Dichlorophenol	< 0.0100	< 0.0100
2,4-Dimethylphenol	< 0.0100	< 0.0100
2,4-Dinitrophenol	< 0.0500	< 0.0500
2,4-Dinitrotoluene	< 0.0100	< 0.0100
2,6-Dinitrotoluene	< 0.0100	< 0.0100
2-Chloronaphthalene	< 0.0100	< 0.0100
2-Chlorophenol	< 0.0100	< 0.0100
2-Methylnaphthalene	< 0.0100	< 0.0100
2-Nitroaniline	< 0.0500	< 0.0500
2-Nitrophenol	< 0.0100	< 0.0100
3,3'-Dichlorobenzidine	< 0.0200	< 0.0200
3-Nitroaniline	< 0.0500	< 0.0500
4-Bromophenyl phenyl ether	< 0.0100	< 0.0100
4-Chloro-3-methylphenol	< 0.0100	< 0.0100
4-Chlorophenylphenyl ether	< 0.0100	< 0.0100
4-Nitrophenol	< 0.0500	< 0.0500
Acenaphthene	< 0.0100	< 0.0100
Acenaphthylene	< 0.0100	< 0.0100
Anthracene	< 0.0100	< 0.0100
Benzenamine, 4-chloro-	< 0.0100	< 0.0100
Benzo(a)anthracene	< 0.0100	< 0.0100
Benzo(a)pyrene	< 0.0100	< 0.0100
Benzo(b)fluoranthene	< 0.0100	< 0.0100
Benzo(ghi)perylene	< 0.0100	< 0.0100
Benzo(k)fluoranthene	< 0.0100	< 0.0100
Benzoic acid	< 0.0500	< 0.0500
Benzyl alcohol	< 0.0100	< 0.0100
Butyl benzyl phthalate	< 0.0100	< 0.0100
Chrysene	< 0.0100	< 0.0100
Di-n-butyl phthalate \ dibut	0.0030 J	NA
Di-n-octyl phthalate	< 0.0100	< 0.0100
Di-n-propylnitrosamine	< 0.0100	< 0.0100
Dibenzo(a,h)anthracene	< 0.0100	< 0.0100
Dibenzofuran	< 0.0100	< 0.0100

*Data validation in progress

SURFACE WATER
HAZARDOUS SUBSTANCE LIST RESULTS
RI/FS DATA*

Results in parts per million (ppm).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	ASIT-021 01161 02-21-1989	W-11 01107 01-12-1989
Diethyl phthalate	0.0030 J	0.0020 J
Dimethyl phthalate	< 0.0100	< 0.0100
Di-n-butyl phthalate \ dibut	NA	< 0.0100
Fluoranthene	< 0.0100	< 0.0100
Fluorene	< 0.0100	< 0.0100
Hexachlorobenzene	< 0.0100	< 0.0100
Hexachlorobutadiene	< 0.0100	< 0.0100
Hexachlorocyclopentadiene \	< 0.0100	NA
Hexachloroethane	< 0.0100	< 0.0100
Hexachlorocyclopentadiene \	NA	< 0.0100
Indeno(1,2,3-cd)pyrene	< 0.0100	< 0.0100
Isophorone	< 0.0100	< 0.0100
N-Nitrosodiphenylamine	< 0.0100	< 0.0100
Naphthalene	< 0.0100	< 0.0100
Nitrobenzene	< 0.0100	< 0.0100
Pentachlorophenol	< 0.0500	< 0.0500
Phenanthrene	< 0.0100	< 0.0100
Phenol	< 0.0100	< 0.0100
Phenol, 2-methyl-4,6-dinitro	< 0.0500	NA
Pyrene	< 0.0100	< 0.0100
Phenol, 2-methyl-4,6-dinitro	NA	< 0.0500
bis(2-Chloroethoxy)methane	< 0.0100	< 0.0100
bis(2-Chloroethyl) ether	< 0.0100	< 0.0100
bis(2-Chloroisopropyl) ether	< 0.0100	< 0.0100
bis(2-Ethylhexyl) phthalate	0.0040 BJ	< 0.0100
o-Cresol	< 0.0100	< 0.0100
p-Cresol	< 0.0100	< 0.0100
p-Nitroaniline	< 0.0500	< 0.0500
VOLATILE ORGANICS		
1,1,1-Trichloroethane	< 0.0050	< 0.0050
1,1,2,2-Tetrachloroethane	< 0.0050	< 0.0050
1,1,2-Trichloroethane	< 0.0050	< 0.0050
1,1-Dichloroethane	< 0.0050	< 0.0050
1,1-Dichloroethene	< 0.0050	< 0.0050
1,2-Dichloroethane	< 0.0050	< 0.0050
1,2-Dichloroethylene	< 0.0050	< 0.0050
1,2-Dichloropropane	< 0.0050	< 0.0050
2-Butanone	< 0.0100	< 0.0100
2-Hexanone	< 0.0100	< 0.0100
2-Propanone	0.0020 JB	< 0.0100
4-Methyl-2-pentanone	< 0.0100	< 0.0100

*Data validation in progress

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SURFACE WATER
HAZARDOUS SUBSTANCE LIST RESULTS
RI/FS DATA*

Results in parts per million (ppm).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	ASIT-021 01161 02-21-1989	W-11 01107 01-12-1989
Benzene	< 0.0050	< 0.0050
Bromodichloromethane	< 0.0050	< 0.0050
Bromomethane	< 0.0100	< 0.0100
Carbon disulfide	< 0.0050	< 0.0050
Chlorobenzene	< 0.0050	< 0.0050
Chloroethane	< 0.0100	< 0.0100
Chloroform	< 0.0050	< 0.0050
Chloromethane	< 0.0100	< 0.0100
Dibromochloromethane	< 0.0050	< 0.0050
Ethylbenzene	< 0.0050	< 0.0050
Methylene chloride	< 0.0050	< 0.0050
Styrene	< 0.0050	< 0.0050
Tetrachlorethene	< 0.0050	< 0.0050
Tetrachloromethane	< 0.0050	< 0.0050
Toluene	< 0.0050	< 0.0050
Total xylenes	< 0.0050	< 0.0050
Tribromomethane	< 0.0050	< 0.0050
Trichloroethene	< 0.0050	< 0.0050
Vinyl acetate	< 0.0100	< 0.0100
Vinyl chloride	< 0.0100	< 0.0100
cis-1,3-Dichloropropene	< 0.0050	< 0.0050
trans-1,3-Dichloropropene	< 0.0050	< 0.0050

*Data validation in progress

SEDIMENTS/ANALYTICAL RESULTS

SEDIMENT RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picocuries per gram (pCi/g).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETERS	ASIT-010 09050 06-28-1988	W-10 09038 06-18-1988	W-10 09153 04-17-1989	W-11 09037 06-18-1988
Cesium 137	NA	NA	NA	NA
Neptunium 237	NA	NA	NA	NA
Plutonium 238	NA	NA	NA	NA
Plutonium 239/240	NA	NA	NA	NA
Radium 226	0.7 ± 0.1	0.9 ± 0.1	1.0 ± 0.1	0.5 ± 0.1
Radium 228	0.9 ± 0.1	< 0.5	< 0.5	< 0.5
Ruthenium 106	NA	NA	NA	NA
Strontium 90	NA	NA	NA	NA
Technetium 99	NA	NA	NA	NA
Thorium 228	NA	NA	NA	NA
Thorium 230	NA	NA	NA	NA
Thorium 232	NA	NA	NA	NA
Total Thorium **	NA	NA	NA	NA
Uranium 234	NA	NA	NA	NA
Uranium 235/236	NA	NA	NA	NA
Uranium 238	NA	NA	NA	NA
Total Uranium **	30.3 ± 2.1	3.0 ± 1.0	1.0 ± 1.0	2.0 ± 1.0

* Data validation in progress.

** Results reported in ug/g

SEDIMENT RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picocuries per gram (pCi/g).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETERS	W-11 09155 04-17-1989	W-5 09036 06-18-1988	W-5 09149 04-18-1989
Cesium 137	NA	NA	NA
Neptunium 237	NA	NA	NA
Plutonium 238	NA	NA	NA
Plutonium 239/240	NA	NA	NA
Radium 226	0.6 ± 0.1	0.4 ± 0.1	0.4 ± 0.1
Radium 228	< 0.5	< 0.5	< 0.5
Ruthenium 106	NA	NA	NA
Strontium 90	NA	NA	NA
Technetium 99	NA	NA	NA
Thorium 228	NA	NA	NA
Thorium 230	NA	NA	NA
Thorium 232	NA	NA	NA
Total Thorium **	NA	NA	NA
Uranium 234	NA	NA	NA
Uranium 235/236	NA	NA	NA
Uranium 238	NA	NA	NA
Total Uranium **	< 1.0	3.0 ± 1.0	1.0 ± 1.0

* Data validation in progress.

** Results reported in ug/g

DATA QUALIFIERS

EXPLANATION FOR DATA QUALIFIERS SHOWN ON THE FOLLOWING GENERAL CHEMICAL RESULTS

On the data tables that follow, an individual analytical result may include one or more data qualifiers. The list below presents all possible qualifiers and can be used as a reference when looking at the data. The qualifiers are standard Contract Laboratory Program (CLP) data qualifiers.

One note of caution; two types of chemical results tables are presented in this appendix: general chemical results and hazardous substance list results. There are two separate lists of data qualifiers for these separate tables and, although some of the symbols are the same for each, they may have different definitions.

Concentration Qualifiers

B = Reported value was obtained from a reading that was less than the Contract Laboratory Program (CLP) Contract Required Detection Limit (CRQL), but greater than or equal to the Instrument Detection Limit (IDL).

Quality Qualifiers

E = The reported value is estimated because of the presence of interference.

M = Duplicate injection precision not met.

N = Spiked sample recovery not within controls limits.

S = The reported value was determined by the Method of Standard Additions.

W = Post-digestion spike for Furnace AA analysis is out of control limits (85-115%), while sample absorbance is less than 50% of spike absorbance.

G = Native analyte > 4 times spike added; therefore acceptance criteria do not apply.

X = Detection limit is higher than normal due to sample matrix interferences.

* = Duplicate analysis not within control limits.

+ = Correlation coefficient for the MSA is less than 0.955.

EXPLANATION FOR DATA QUALIFIERS SHOWN ON THE FOLLOWING HAZARDOUS SUBSTANCE LIST RESULTS

On the data tables that follow, an individual analytical result may include one or more data qualifiers. The list below presents all possible qualifiers and can be used as a reference when looking at the data. The qualifiers are standard Contract Laboratory Program (CLP) data qualifiers.

One note of caution; two types of chemical results tables are presented in this appendix: general chemical results and hazardous substance list results. There are two separate lists of data qualifiers for these separate tables and, although some of the symbols are the same for each, they may have different definitions.

J = Indicates an estimated value. This flag is used when the mass spectral data indicate the presence of a compound that meets the identification criteria, but the result is less than the sample quantitation limit but greater than zero.

C = This flag applies to pesticide results where the identification has been confirmed by GC/MS.

B = This flag is used when the analyte is found in the associated blank as well as in the sample. It indicates possible/probable blank contamination and warns the data user to take appropriate action.

E = This flag identifies compounds whose concentrations exceed the calibration range of the GC/MS instrument for that specific analysis. This flag will <u>not</u> apply to pesticides/PCBs analyzed by GC/EC methods.

D = This flag identifies all compounds identified in an analysis at a secondary dilution factor.

F = Estimated value due to a confirmed compound which is off-scale in both columns.

X = A flag that FORMASTER III CLP software automatically inserts to indicate that the data was entered manually.

Z = No estimated value reported, or an elevated CRQL reported because matrix effects interfere with or obscure the compound on one or both columns. In either situation, the compound does not confirm as a positive identification.

* = Values outside of contract laboratory-required QC limits.

SEDIMENT GENERAL CHEMICAL RESULTS
RI/FS DATA*

Results in parts per million (ppm).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	ASIT-010 09050 06-28-1988	W-10 09147 01-12-1989	W-11 09145 01-12-1989	W-5 09146 01-12-1989
GENERAL CHEMISTRY				
Ammonia	93.6000	NA	NA	NA
Chloride	40.0000	NA	NA	NA
Fluoride	5.6900	NA	NA	NA
Hydrogen ion	NA	NA	NA	NA
Nitrates	NA	NA	NA	NA
Phenols	< 0.5000	NA	NA	NA
Phosporus (black, white, red,	NA	NA	NA	NA
Phosphate as P	NA	NA	NA	NA
Sulfate	418.0000	NA	NA	NA
Total Kjeldahl Nitrogen	NA	NA	NA	NA
Total Organic Carbon	NA	NA	NA	NA
Total Organic Halides	NA	NA	NA	NA
Total Organic Nitrogen	794.0000	NA	NA	NA
METALS				
Aluminum	5460.0000	3920.0000 *	2080.0000 *	1970.0000 *
Antimony	< 0.1000	< 0.1000 N	< 0.1000 N	< 0.1000 N
Arsenic	3.5000 B	6.5000 N	2.7000 N	7.0000 N
Barium	49.4000	31.2000 B	21.0000 B	21.0000 B
Beryllium	0.2000 B	0.5000 B	0.5000 B	0.5000 B
Cadmium	< 0.2000	3.9000	4.5000	3.7000
Calcium	25200.0000	78700.0000	110000.0000	25900.0000
Chromium	6.9000	18.4000	17.4000	18.3000
Cobalt	3.8000 B	6.5000 B	4.7000 B	4.9000 B
Copper	9.2000	14.5000	11.7000	10.8000 B
Cyanides (soluble salts and co	NA	NA	NA	NA
Hexavalent Chromium	NA	NA	NA	NA
Iron	10000.0000	8830.0000	5940.0000	6700.0000
Lead	18.4000	11.4000 SN	4.6000 NS	9.3000 NS
Magnesium	8580.0000	18300.0000	26600.0000	18700.0000
Manganese	500.0000	415.0000	362.0000	411.0000
Mercury	1.7000	< 0.1000	< 0.1000	< 0.1000
Molybdenum	< 2.4000	< 5.0000	< 4.6000	< 4.5000
Nickel	9.4000	19.5000	16.4000	13.7000
Potassium	659.0000 B	655.0000 B	366.0000 B	307.0000 B
Selenium	< 0.2000	< 0.5000 N	< 0.5000 N	< 0.4000 N
Silicon	NA	NA	NA	NA
Silver	< 0.1000	< 0.1000	< 0.1000	< 0.1000
Sodium	111.0000	180.0000 BE	188.0000 BE	197.0000 BE

*Data validation in progress

SEDIMENT
HAZARDOUS SUBSTANCE LIST RESULTS
RI/FS DATA*

Results in parts per million (ppm).
Data presented by well id, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	ASIT-010 09050 06-28-1988	W-10 09147 01-12-1989	W-11 09145 01-12-1989	W-5 09146 01-12-1989
PESTICIDES				
4,4'-DDD	< 0.0230	< 0.0240	< 0.0200	< 0.0190
4,4'-DDE	< 0.0230	< 0.0240	< 0.0200	< 0.0190
4,4'-DDT	< 0.0230	< 0.0240	< 0.0200	< 0.0190
Aldrin	< 0.0120	< 0.0120	< 0.0099	< 0.0094
Aroclor-1016	< 0.1200	< 0.1200	< 0.0990	< 0.0940
Aroclor-1221	< 0.1200	< 0.1200	< 0.0990	< 0.0940
Aroclor-1232	< 0.1200	< 0.1200	< 0.0990	< 0.0940
Aroclor-1242	< 0.1200	< 0.1200	< 0.0990	< 0.0940
Aroclor-1248	< 0.1200	< 0.1200	< 0.0990	< 0.0940
Aroclor-1254	< 0.2300	< 0.2400	< 0.2000	< 0.1900
Aroclor-1260	< 0.2300	< 0.2400	< 0.2000	< 0.1900
Dieldrin	< 0.0230	< 0.0240	< 0.0200	< 0.0190
Endosulfan II	< 0.0230	< 0.0240	< 0.0200	< 0.0190
Endosulfan sulfate	< 0.0230	< 0.0240	< 0.0200	< 0.0190
Endosulfan-I	< 0.0120	< 0.0120	< 0.0099	< 0.0094
Endrin	< 0.0230	< 0.0240	< 0.0200	< 0.0190
Endrin ketone	< 0.0230	< 0.0240	< 0.0200	< 0.0190
Heptachlor	< 0.0120	< 0.0120	< 0.0099	< 0.0094
Heptachlor epoxide	< 0.0120	< 0.0120	< 0.0099	< 0.0094
Methoxychlor	< 0.1200	< 0.1200	< 0.0990	< 0.0940
Toxaphene	< 0.2300	< 0.2400	< 0.2000	< 0.1900
alpha-BHC	< 0.0120	< 0.0120	< 0.0099	< 0.0094
alpha-Chlordane	< 0.1200	< 0.1200	< 0.0990	< 0.0940
beta-BHC	< 0.0120	< 0.1300 X	< 0.1700 X	< 0.0094
delta-BHC	< 0.0120	< 0.0120	< 0.0099	< 0.0094
gamma-BHC (Lindane)	< 0.0120	< 0.0120	< 0.0099	< 0.0094
gamma-Chlordane	< 0.1200	< 0.1200	< 0.0990	< 0.0940
SEMI-VOLATILE ORGANICS				
1,2,4-Trichlorobenzene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
1,2-Dichlorobenzene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
1,3-Dichlorobenzene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
1,4-Dichlorobenzene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
2,4,5-Trichlorophenol	< 2.5000	< 2.3000	< 2.0000	< 1.9000
2,4,6-Trichlorophenol	< 0.4900	< 0.4800	< 0.4000	< 0.3900
2,4-Dichlorophenol	< 0.4900	< 0.4800	< 0.4000	< 0.3900
2,4-Dimethylphenol	< 0.4900	< 0.4800	< 0.4000	< 0.3900
2,4-Dinitrophenol	< 2.5000	< 2.3000	< 2.0000	< 1.9000

*Data validation in progress

SEDIMENT
HAZARDOUS SUBSTANCE LIST RESULTS
RI/FS DATA*

Results in parts per million (ppm).
Data presented by well id, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	ASIT-010 09050 06-28-1988	W-10 09147 01-12-1989	W-11 09145 01-12-1989	W-5 09146 01-12-1989
2,4-Dinitrotoluene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
2,6-Dinitrotoluene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
2-Chloronaphthalene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
2-Chlorophenol	< 0.4900	< 0.4800	< 0.4000	< 0.3900
2-Methylnaphthalene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
2-Methylphenol	< 0.4900	< 0.4800	< 0.4000	< 0.3900
2-Nitroaniline	< 2.5000	< 2.3000	< 2.0000	< 1.9000
2-Nitrophenol	< 0.4900	< 0.4800	< 0.4000	< 0.3900
3,3'-Dichlorobenzidine	< 0.9800	< 0.9600	< 0.8000	< 0.7700
3-Nitroaniline	< 2.5000	< 2.3000	< 2.0000	< 1.9000
4,6-Dinitro-2-methylphenol	< 2.5000	< 2.3000	< 2.0000	< 1.9000
4-Bromophenyl phenyl ether	< 0.4900	< 0.4800	< 0.4000	< 0.3900
4-Chloro-3-methylphenol	< 0.4900	< 0.4800	< 0.4000	< 0.3900
4-Chloroaniline	< 0.4900	< 0.4800	< 0.4000	< 0.3900
4-Chlorophenylphenyl ether	< 0.4900	< 0.4800	< 0.4000	< 0.3900
4-Methylphenol	< 0.4900	< 0.4800	< 0.4000	< 0.3900
4-Nitroaniline	< 2.5000	< 2.3000	< 2.0000	< 1.9000
4-Nitrophenol	< 2.5000	< 2.3000	< 2.0000	< 1.9000
Acenaphthene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Acenaphthylene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Anthracene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Benzo(a)anthracene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Benzo(a)pyrene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Benzo(b)fluoranthene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Benzo(g,h,i)perylene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Benzo(k)fluoranthene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Benzoic acid	< 2.5000	< 2.3000	< 2.0000	< 1.9000
Benzyl alcohol	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Butyl benzyl phthalate	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Chrysene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Di-n-butyl phthalate	< 0.4900	0.0510 BJ	0.0550 BJ	0.0390 BJ
Di-n-octyl phthalate	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Dibenzo(a,h)anthracene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Dibenzofuran	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Diethyl phthalate	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Dimethyl phthalate	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Fluoranthene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Fluorene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Hexachlorobenzene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Hexachlorobutadiene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Hexachlorocyclopentadiene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Hexachloroethane	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Indeno(1,2,3-cd)pyrene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Isophorone	< 0.4900	< 0.4800	< 0.4000	< 0.3900

*Data validation in progress

SEDIMENT
HAZARDOUS SUBSTANCE LIST RESULTS
RI/FS DATA*

Results in parts per million (ppm).
Data presented by well id, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	ASIT-010 09050 06-28-1988	W-10 09147 01-12-1989	W-11 09145 01-12-1989	W-5 09146 01-12-1989
N-Nitroso-di-n-propylamine	< 0.4900	< 0.4800	< 0.4000	< 0.3900
N-Nitrosodiphenylamine	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Naphthalene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Nitrobenzene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Pentachlorophenol	< 2.5000	< 2.3000	< 2.0000	< 1.9000
Phenanthrene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Phenol	< 0.4900	< 0.4800	< 0.4000	< 0.3900
Pyrene	< 0.4900	< 0.4800	< 0.4000	< 0.3900
bis(2-Chloroethoxy)methane	< 0.4900	< 0.4800	< 0.4000	< 0.3900
bis(2-Chloroethyl)ether	< 0.4900	< 0.4800	< 0.4000	< 0.3900
bis(2-Chloroisopropyl)ether	< 0.4900	< 0.4800	< 0.4000	< 0.3900
bis(2-Ethylhexyl) phthalate	< 0.4900	0.5900 B	0.5000 B	0.4600 B
VOLATILE ORGANICS				
1,1,1-Trichloroethane	< 0.0070	< 0.0070	< 0.0060	< 0.0060
1,1,2,2-Tetrachloroethane	< 0.0070	< 0.0070	< 0.0060	< 0.0060
1,1,2-Trichloroethane	< 0.0070	< 0.0070	< 0.0060	< 0.0060
1,1-Dichloroethane	< 0.0070	< 0.0070	< 0.0060	< 0.0060
1,1-Dichloroethene	< 0.0070	< 0.0070	< 0.0060	< 0.0060
1,2-Dichloroethane	< 0.0070	< 0.0070	< 0.0060	< 0.0060
1,2-Dichloroethylene	< 0.0070	< 0.0070	< 0.0060	< 0.0060
1,2-Dichloropropane	< 0.0070	< 0.0070	< 0.0060	< 0.0060
2-Butanone	< 0.0150	< 0.0150	< 0.0120	< 0.0120
2-Hexanone	< 0.0150	< 0.0150	< 0.0120	< 0.0120
4-Methyl-2-pentanone	< 0.0150	< 0.0150	< 0.0120	< 0.0120
Acetone	0.0940 B	< 0.0150	0.0080 BJ	0.0180 B
Benzene	< 0.0070	< 0.0070	< 0.0060	< 0.0060
Bromodichloromethane	< 0.0070	< 0.0070	< 0.0060	< 0.0060
Bromoform	< 0.0070	< 0.0070	< 0.0060	< 0.0060
Bromomethane	< 0.0150	< 0.0150	< 0.0120	< 0.0120
Carbon Tetrachloride	< 0.0070	< 0.0070	< 0.0060	< 0.0060
Carbon disulfide	< 0.0070	< 0.0070	< 0.0060	< 0.0060
Chlorobenzene	< 0.0070	< 0.0070	< 0.0060	< 0.0060
Chloroethane	< 0.0150	< 0.0150	< 0.0120	< 0.0120
Chloroform	< 0.0070	< 0.0070	< 0.0060	< 0.0060
Chloromethane	< 0.0150	< 0.0150	< 0.0120	< 0.0120
Dibromochloromethane	< 0.0070	< 0.0070	< 0.0060	< 0.0060
Ethylbenzene	< 0.0070	< 0.0070	< 0.0060	< 0.0060
Methylene chloride	0.0190 B	< 0.0070	0.0150 B	0.0070 B
Styrene	< 0.0070	< 0.0070	< 0.0060	< 0.0060
Tetrachlorethene	< 0.0070	< 0.0070	< 0.0060	< 0.0060
Toluene	< 0.0070	< 0.0070	< 0.0060	< 0.0060

*Data validation in progress

SEDIMENT
HAZARDOUS SUBSTANCE LIST RESULTS
RI/FS DATA*

Results in parts per million (ppm).
Data presented by well id, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	ASIT-010 09050 06-28-1988	W-10 09147 01-12-1989	W-11 09145 01-12-1989	W-5 09146 01-12-1989
Total xylenes	< 0.0070	< 0.0070	< 0.0060	< 0.0060
Trichloroethene	< 0.0070	< 0.0070	< 0.0060	< 0.0060
Vinyl Acetate	< 0.0150	< 0.0150	< 0.0120	< 0.0120
Vinyl chloride	< 0.0150	< 0.0150	< 0.0120	< 0.0120
cis-1,3-Dichloropropene	< 0.0070	< 0.0070	< 0.0060	< 0.0060
trans-1,3-Dichloropropene	< 0.0070	NA	< 0.0060	< 0.0060
trans-1,3-Dichloropropene	NA	< 0.0070	NA	NA

*Data validation in progress

GROUNDWATER

ELEVATION DATA

WATER ELEVATION REPORT FOR 01/01/88 - 11/01/89
REPORT DATE : 04/11/90

RI/FS WELL NUMBER	NORTH COORDINATE	EAST COORDINATE	TOP OF WELL (MSL)	TOP OF CASING (MSL)	GROUND LEVEL (MSL)	CONCRETE LEVEL (MSL)	READING	WATER ELEV. (MSL)	REF. POINT	DATE READ	TYPE OF WELL(*)
1008	480660.43	1378925.83	579.05	579.53		577.60	6.76	572.29	TOW	04/11/88	2
1008	480660.43	1378925.83	579.05	579.53		577.60	8.74	570.31	TOW	05/10/88	2
1008	480660.43	1378925.83	579.05	579.53		577.60	9.15	569.90	TOW	06/08/88	2
1008	480660.43	1378925.83	579.05	579.53		577.60	10.21	568.84	TOW	07/09/88	2
1008	480660.43	1378925.83	579.05	579.53		577.60	8.97	570.08	TOW	08/07/88	2
1008	480660.43	1378925.83	579.05	579.53		577.60	8.66	570.39	TOW	09/10/88	2
1008	480660.43	1378925.83	579.05	579.53		577.60	9.46	569.59	TOW	10/08/88	2
1008	480660.43	1378925.83	579.05	579.53		577.60	8.51	570.54	TOW	11/09/88	2
1008	480660.43	1378925.83	579.05	579.53		577.60	8.50	570.55	TOW	12/13/88	2
1008	480660.43	1378925.83	579.05	579.53		577.60	6.06	572.99	TOW	01/10/89	2
1008	480660.43	1378925.83	579.05	579.53		577.60	7.42	571.63	TOW	02/10/89	2
1008	480660.43	1378925.83	579.05	579.53		577.60	5.58	573.47	TOW	03/11/89	2
1008	480660.43	1378925.83	579.05	579.53		577.60	6.79	572.26	TOW	04/15/89	2
1008	480660.43	1378925.83	579.05	579.53		577.60	6.56	572.49	TOW	05/14/89	2
1008	480660.43	1378925.83	579.05	579.53		577.60	7.11	571.94	TOW	06/14/89	2
1008	480660.43	1378925.83	579.05	579.53		577.60	7.18	571.87	TOW	07/14/89	2
1008	480660.43	1378925.83	579.05	579.53		577.60	9.66	569.39	TOW	08/16/89	2
1008	480660.43	1378925.83	579.05	579.53		577.60	8.33	570.72	TOW	09/12/89	2
1008	480660.43	1378925.83	579.05	579.53		577.60	8.21	570.84	TOW	10/11/89	2
1009	479546.00	1378000.74	558.20	558.53		556.26	11.57	546.63	TOW	01/09/88	3
1009	479546.00	1378000.74	558.20	558.53		556.26	11.71	546.49	TOW	02/10/88	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	03/09/88	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	04/11/88	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	05/10/88	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	06/08/88	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	07/08/88	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	08/06/88	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	09/09/88	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	10/09/88	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	11/08/88	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	12/12/88	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	01/09/89	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	02/09/89	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	03/10/89	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	04/16/89	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	05/13/89	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	06/15/89	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	07/13/89	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	08/15/89	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	09/11/89	3
1009	479546.00	1378000.74	558.20	558.53		556.26	N/A	N/A	N/A	10/11/89	3
1018	479450.19	1378661.69	572.79	573.45		571.50	11.59	561.20	TOW	01/09/88	3
1018	479450.19	1378661.69	572.79	573.45		571.50	7.08	565.71	TOW	02/10/88	3
1018	479450.19	1378661.69	572.79	573.45		571.50	3.00	569.79	TOW	03/09/88	3
1018	479450.19	1378661.69	572.79	573.45		571.50	4.89	567.90	TOW	04/11/88	3
1018	479450.19	1378661.69	572.79	573.45		571.50	7.54	565.25	TOW	05/10/88	3

* 1 = PRODUCTION AREA 2 = WASTE STOR. AREA 3 = ON-SITE 4 = OFF-SITE RI/FS 5 = OFF-SITE PRIVATE 6 = OFF-SITE S.O.W.C

WATER ELEVATION REPORT FOR 01/01/88 - 11/01/89
REPORT DATE : 04/11/90

RI/FS WELL NUMBER	NORTH COORDINATE	EAST COORDINATE	TOP OF WELL (MSL)	TOP OF CASING (MSL)	GROUND LEVEL (MSL)	CONCRETE LEVEL (MSL)	READING	WATER ELEV. (MSL)	REF. POINT	DATE READ
1018	479450.19	1378661.69	572.79	573.45		571.50	9.15	563.64	TOW	06/08/88
1018	479450.19	1378661.69	572.79	573.45		571.50	10.40	562.39	TOW	07/08/88
1018	479450.19	1378661.69	572.79	573.45		571.50	11.15	561.64	TOW	08/06/88
1018	479450.19	1378661.69	572.79	573.45		571.50	11.88	560.91	TOW	09/09/88
1018	479450.19	1378661.69	572.79	573.45		571.50	12.36	560.43	TOW	10/09/88
1018	479450.19	1378661.69	572.79	573.45		571.50	12.72	560.07	TOW	11/08/88
1018	479450.19	1378661.69	572.79	573.45		571.50	12.73	560.06	TOW	11/09/88
1018	479450.19	1378661.69	572.79	573.45		571.50	12.97	559.82	TOW	12/12/88
1018	479450.19	1378661.69	572.79	573.45		571.50	11.83	560.96	TOW	01/09/89
1018	479450.19	1378661.69	572.79	573.45		571.50	10.61	562.18	TOW	02/09/89
1018	479450.19	1378661.69	572.79	573.45		571.50	4.01	568.78	TOW	03/10/89
1018	479450.19	1378661.69	572.79	573.45		571.50	3.47	569.32	TOW	04/16/89
1018	479450.19	1378661.69	572.79	573.45		571.50	2.72	570.07	TOW	05/13/89
1018	479450.19	1378661.69	572.79	573.45		571.50	5.22	567.57	TOW	06/15/89
1018	479450.19	1378661.69	572.79	573.45		571.50	8.44	564.35	TOW	07/13/89
1018	479450.19	1378661.69	572.79	573.45		571.50	9.70	563.09	TOW	08/15/89
1018	479450.19	1378661.69	572.79	573.45		571.50	10.18	562.61	TOW	09/11/89
1018	479450.19	1378661.69	572.79	573.45		571.50	10.71	562.08	TOW	10/11/89
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	25.02	553.68	TOW	01/09/88
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	23.20	555.50	TOW	02/10/88
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	21.34	557.36	TOW	02/11/88
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	23.09	555.61	TOW	02/11/88
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	21.38	557.32	TOW	03/09/88
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	24.00	554.70	TOW	04/10/88
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	27.71	550.99	TOW	04/11/88
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	27.70	551.00	TOW	04/11/88
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	24.02	554.68	TOW	05/10/88
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	21.98	556.72	TOW	06/08/88
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	21.98	556.72	TOW	06/08/88
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	21.52	557.18	TOW	07/08/88
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	21.44	557.26	TOW	07/09/88
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	25.00	553.70	TOW	08/06/88
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	24.97	553.73	TOW	08/06/88
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	24.05	554.65	TOW	09/09/88
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	23.78	554.92	TOW	10/08/88
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	26.22	552.48	TOW	11/08/88
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	24.22	554.48	TOW	12/12/88
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	22.44	556.26	TOW	01/09/89
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	22.32	556.38	TOW	01/10/89
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	23.39	555.31	TOW	02/09/89
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	23.03	555.67	TOW	02/10/89
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	20.17	558.53	TOW	03/10/89
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	20.10	558.60	TOW	03/11/89
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	25.88	552.82	TOW	04/15/89
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	19.56	559.14	TOW	05/13/89
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	16.24	562.46	TOW	06/15/89

* 1 = PRODUCTION AREA 2 = WASTE STOR. AREA 3 = ON-SITE 4 = OFF-SITE RI/FS 5 = OFF-SITE PRIVATE 6 = OFF-SITE

WATER ELEVATION REPORT FOR 01/01/88 - 11/01/89
REPORT DATE : 04/11/90

RI/FS WELL NUMBER	NORTH COORDINATE	EAST COORDINATE	TOP OF WELL (MSL)	TOP OF CASING (MSL)	GROUND LEVEL (MSL)	CONCRETE LEVEL (MSL)	READING	WATER ELEV. (MSL)	REF. POINT	DATE READ	TYPE OF WELL(*)
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	15.78	562.92	TOW	07/14/89	3
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	16.71	561.99	TOW	08/15/89	3
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	16.91	561.79	TOW	08/17/89	3
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	17.54	561.16	TOW	09/11/89	3
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	23.62	555.08	TOW	10/09/89	3
1029	480826.11	1378398.38	578.70	579.06	577.3	577.38	17.66	561.04	TOW	10/11/89	3
1032	480515.31	1378296.81	570.75	571.25	569.3		10.46	560.29	TOW	01/09/88	3
1032	480515.31	1378296.81	570.75	571.25	569.3		9.31	561.44	TOW	02/10/88	3
1032	480515.31	1378296.81	570.75	571.25	569.3		9.38	561.37	TOW	02/11/88	3
1032	480515.31	1378296.81	570.75	571.25	569.3		8.32	562.43	TOW	03/09/88	3
1032	480515.31	1378296.81	570.75	571.25	569.3		8.76	561.99	TOW	04/11/88	3
1032	480515.31	1378296.81	570.75	571.25	569.3		10.53	560.22	TOW	05/10/88	3
1032	480515.31	1378296.81	570.75	571.25	569.3		11.24	559.51	TOW	06/08/88	3
1032	480515.31	1378296.81	570.75	571.25	569.3		11.46	559.29	TOW	07/08/88	3
1032	480515.31	1378296.81	570.75	571.25	569.3		11.15	559.60	TOW	08/06/88	3
1032	480515.31	1378296.81	570.75	571.25	569.3		11.06	559.69	TOW	09/09/88	3
1032	480515.31	1378296.81	570.75	571.25	569.3		11.52	559.23	TOW	10/09/88	3
1032	480515.31	1378296.81	570.75	571.25	569.3		10.62	560.13	TOW	11/08/88	3
1032	480515.31	1378296.81	570.75	571.25	569.3		11.42	559.33	TOW	12/12/88	3
1032	480515.31	1378296.81	570.75	571.25	569.3		8.89	561.86	TOW	01/09/89	3
1032	480515.31	1378296.81	570.75	571.25	569.3		10.22	560.53	TOW	02/09/89	3
1032	480515.31	1378296.81	570.75	571.25	569.3		7.77	562.98	TOW	03/10/89	3
1032	480515.31	1378296.81	570.75	571.25	569.3		8.91	561.84	TOW	04/15/89	3
1032	480515.31	1378296.81	570.75	571.25	569.3		9.33	561.42	TOW	05/13/89	3
1032	480515.31	1378296.81	570.75	571.25	569.3		10.60	560.15	TOW	06/15/89	3
1032	480515.31	1378296.81	570.75	571.25	569.3		11.52	559.23	TOW	07/14/89	3
1032	480515.31	1378296.81	570.75	571.25	569.3		11.55	559.20	TOW	08/15/89	3
1032	480515.31	1378296.81	570.75	571.25	569.3		11.49	559.26	TOW	09/11/89	3
1032	480515.31	1378296.81	570.75	571.25	569.3		13.10	557.65	TOW	10/11/89	3
1033	480412.89	1378675.14	578.97	579.49	577.0		7.21	571.76	TOW	05/10/88	2
1033	480412.89	1378675.14	578.97	579.49	577.0		8.68	570.29	TOW	06/08/88	2
1033	480412.89	1378675.14	578.97	579.49	577.0		9.97	569.00	TOW	07/09/88	2
1033	480412.89	1378675.14	578.97	579.49	577.0		10.57	568.40	TOW	08/07/88	2
1033	480412.89	1378675.14	578.97	579.49	577.0		10.99	567.98	TOW	09/09/88	2
1033	480412.89	1378675.14	578.97	579.49	577.0		11.25	567.72	TOW	10/08/88	2
1033	480412.89	1378675.14	578.97	579.49	577.0		10.69	568.28	TOW	11/09/88	2
1033	480412.89	1378675.14	578.97	579.49	577.0		8.88	570.09	TOW	12/13/88	2
1033	480412.89	1378675.14	578.97	579.49	577.0		3.02	575.95	TOW	01/10/89	2
1033	480412.89	1378675.14	578.97	579.49	577.0		4.94	574.03	TOW	02/10/89	2
1033	480412.89	1378675.14	578.97	579.49	577.0		2.22	576.75	TOW	03/11/89	2
1033	480412.89	1378675.14	578.97	579.49	577.0		4.12	574.85	TOW	04/15/89	2
1033	480412.89	1378675.14	578.97	579.49	577.0		3.66	575.31	TOW	05/14/89	2
1033	480412.89	1378675.14	578.97	579.49	577.0		3.00	575.97	TOW	06/14/89	2
1033	480412.89	1378675.14	578.97	579.49	577.0		N/A	N/A	N/A	07/14/89	2
1033	480412.89	1378675.14	578.97	579.49	577.0		8.90	570.07	TOW	08/16/89	2
1033	480412.89	1378675.14	578.97	579.49	577.0		8.23	570.74	TOW	09/12/89	2

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WATER ELEVATION REPORT FOR 01/01/88 - 11/01/89
REPORT DATE : 04/11/90

RI/FS WELL NUMBER	NORTH COORDINATE	EAST COORDINATE	TOP OF WELL (MSL)	TOP OF CASING (MSL)	GROUND LEVEL (MSL)	CONCRETE LEVEL (MSL)	READING	WATER ELEV. (MSL)	REF. POINT	DATE READ
1033	480412.89	1378675.14	578.97	579.49	577.0		10.43	568.54	TOW	10/11/89
1034	480240.85	1378410.28	571.29	571.74	569.2		3.10	568.19	TOW	04/11/88
1034	480240.85	1378410.28	571.29	571.74	569.2		5.35	565.94	TOW	05/10/88
1034	480240.85	1378410.28	571.29	571.74	569.2		7.26	564.03	TOW	06/08/88
1034	480240.85	1378410.28	571.29	571.74	569.2		N/A	N/A	N/A	06/08/88
1034	480240.85	1378410.28	571.29	571.74	569.2		8.95	562.34	TOW	07/08/88
1034	480240.85	1378410.28	571.29	571.74	569.2		9.80	561.49	TOW	08/06/88
1034	480240.85	1378410.28	571.29	571.74	569.2		10.46	560.83	TOW	09/09/88
1034	480240.85	1378410.28	571.29	571.74	569.2		10.50	560.79	TOW	09/09/88
1034	480240.85	1378410.28	571.29	571.74	569.2		10.86	560.43	TOW	10/09/88
1034	480240.85	1378410.28	571.29	571.74	569.2		12.49	558.80	TOW	11/08/88
1034	480240.85	1378410.28	571.29	571.74	569.2		7.02	564.27	TOW	12/12/88
1034	480240.85	1378410.28	571.29	571.74	569.2		3.47	567.82	TOW	01/09/89
1034	480240.85	1378410.28	571.29	571.74	569.2		4.03	567.26	TOW	02/09/89
1034	480240.85	1378410.28	571.29	571.74	569.2		2.09	569.20	TOW	03/10/89
1034	480240.85	1378410.28	571.29	571.74	569.2		3.07	568.22	TOW	04/15/89
1034	480240.85	1378410.28	571.29	571.74	569.2		2.60	568.69	TOW	05/13/89
1034	480240.85	1378410.28	571.29	571.74	569.2		2.90	568.39	TOW	06/15/89
1034	480240.85	1378410.28	571.29	571.74	569.2		5.16	566.13	TOW	07/14/89
1034	480240.85	1378410.28	571.29	571.74	569.2		6.54	564.75	TOW	08/15/89
1034	480240.85	1378410.28	571.29	571.74	569.2		5.13	566.16	TOW	09/11/89
1034	480240.85	1378410.28	571.29	571.74	569.2		7.77	563.52	TOW	10/11/89
1072	481025.93	1378476.33	577.72	578.18	575.9		N/A	N/A	N/A	04/11/88
1072	481025.93	1378476.33	577.72	578.18	575.9		N/A	N/A	N/A	05/10/88
1072	481025.93	1378476.33	577.72	578.18	575.9		N/A	N/A	N/A	06/08/88
1072	481025.93	1378476.33	577.72	578.18	575.9		N/A	N/A	N/A	07/09/88
1072	481025.93	1378476.33	577.72	578.18	575.9		N/A	N/A	N/A	08/07/88
1072	481025.93	1378476.33	577.72	578.18	575.9		N/A	N/A	N/A	09/09/88
1072	481025.93	1378476.33	577.72	578.18	575.9		N/A	N/A	N/A	10/08/88
1072	481025.93	1378476.33	577.72	578.18	575.9		N/A	N/A	N/A	11/09/88
1072	481025.93	1378476.33	577.72	578.18	575.9		N/A	N/A	N/A	12/13/88
1072	481025.93	1378476.33	577.72	578.18	575.9		N/A	N/A	N/A	01/10/89
1072	481025.93	1378476.33	577.72	578.18	575.9		N/A	N/A	N/A	02/10/89
1072	481025.93	1378476.33	577.72	578.18	575.9		N/A	N/A	N/A	03/11/89
1072	481025.93	1378476.33	577.72	578.18	575.9		N/A	N/A	N/A	04/15/89
1072	481025.93	1378476.33	577.72	578.18	575.9		N/A	N/A	N/A	05/14/89
1072	481025.93	1378476.33	577.72	578.18	575.9		N/A	N/A	N/A	06/14/89
1072	481025.93	1378476.33	577.72	578.18	575.9		N/A	N/A	N/A	07/14/89
1072	481025.93	1378476.33	577.72	578.18	575.9		N/A	N/A	N/A	08/16/89
1072	481025.93	1378476.33	577.72	578.18	575.9		N/A	N/A	N/A	09/12/89
1072	481025.93	1378476.33	577.72	578.18	575.9		N/A	N/A	N/A	10/11/89
2008	480661.42	1378918.03	578.87	579.37		577.40	57.05	521.82	TOW	04/11/88
2008	480661.42	1378918.03	578.87	579.37		577.40	56.89	521.98	TOW	05/10/88
2008	480661.42	1378918.03	578.87	579.37		577.40	57.40	521.47	TOW	06/08/88
2008	480661.42	1378918.03	578.87	579.37		577.40	58.23	520.64	TOW	07/09/88
2008	480661.42	1378918.03	578.87	579.37		577.40	58.85	520.02	TOW	08/07/88

* 1 = PRODUCTION AREA 2 = WASTE STOR. AREA 3 = ON-SITE 4 = OFF-SITE RI/FS 5 = OFF-SITE PRIVATE 6 = OFF-SITE S.

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WATER ELEVATION REPORT FOR 01/01/88 - 11/01/89
REPORT DATE : 04/11/90

RI/FS WELL NUMBER	NORTH COORDINATE	EAST COORDINATE	TOP OF WELL (MSL)	TOP OF CASING (MSL)	GROUND LEVEL (MSL)	CONCRETE LEVEL (MSL)	READING	WATER ELEV. (MSL)	REF. POINT	DATE READ	TYPE OF WELL(*)
2008	480661.42	1378918.03	578.87	579.37		577.40	59.56	519.31	TOW	09/10/88	2
2008	480661.42	1378918.03	578.87	579.37		577.40	59.88	518.99	TOW	10/08/88	2
2008	480661.42	1378918.03	578.87	579.37		577.40	60.36	518.51	TOW	11/09/88	2
2008	480661.42	1378918.03	578.87	579.37		577.40	60.26	518.61	TOW	12/13/88	2
2008	480661.42	1378918.03	578.87	579.37		577.40	61.50	517.37	TOW	01/10/89	2
2008	480661.42	1378918.03	578.87	579.37		577.40	59.36	519.51	TOW	02/10/89	2
2008	480661.42	1378918.03	578.87	579.37		577.40	58.54	520.33	TOW	03/11/89	2
2008	480661.42	1378918.03	578.87	579.37		577.40	56.79	522.08	TOW	04/15/89	2
2008	480661.42	1378918.03	578.87	579.37		577.40	55.66	523.21	TOW	05/14/89	2
2008	480661.42	1378918.03	578.87	579.37		577.40	54.50	524.37	TOW	06/14/89	2
2008	480661.42	1378918.03	578.87	579.37		577.40	54.79	524.08	TOW	07/14/89	2
2008	480661.42	1378918.03	578.87	579.37		577.40	55.67	523.20	TOW	08/16/89	2
2008	480661.42	1378918.03	578.87	579.37		577.40	56.12	522.75	TOW	09/12/89	2
2008	480661.42	1378918.03	578.87	579.37		577.40	58.26	520.61	TOW	10/11/89	2
2008	480661.42	1378918.03	578.87	579.37		577.40	56.89	521.98	TOW	10/25/89	2
2009	479540.71	1378007.77	557.68	558.05		557.00	36.35	521.33	TOW	01/09/88	3
2009	479540.71	1378007.77	557.68	558.05		557.00	35.22	522.46	TOW	02/10/88	3
2009	479540.71	1378007.77	557.68	558.05		557.00	34.43	523.25	TOW	03/09/88	3
2009	479540.71	1378007.77	557.68	558.05		557.00	33.83	523.85	TOW	04/11/88	3
2009	479540.71	1378007.77	557.68	558.05		557.00	34.15	523.53	TOW	05/10/88	3
2009	479540.71	1378007.77	557.68	558.05		557.00	35.56	522.12	TOW	06/08/88	3
2009	479540.71	1378007.77	557.68	558.05		557.00	36.35	521.33	TOW	07/08/88	3
2009	479540.71	1378007.77	557.68	558.05		557.00	36.85	520.83	TOW	08/06/88	3
2009	479540.71	1378007.77	557.68	558.05		557.00	37.46	520.22	TOW	09/09/88	3
2009	479540.71	1378007.77	557.68	558.05		557.00	37.44	520.24	TOW	09/09/88	3
2009	479540.71	1378007.77	557.68	558.05		557.00	37.94	519.74	TOW	10/09/88	3
2009	479540.71	1378007.77	557.68	558.05		557.00	38.10	519.58	TOW	11/08/88	3
2009	479540.71	1378007.77	557.68	558.05		557.00	38.20	519.48	TOW	12/12/88	3
2009	479540.71	1378007.77	557.68	558.05		557.00	36.83	520.85	TOW	01/09/89	3
2009	479540.71	1378007.77	557.68	558.05		557.00	36.01	521.67	TOW	02/09/89	3
2009	479540.71	1378007.77	557.68	558.05		557.00	35.09	522.59	TOW	03/10/89	3
2009	479540.71	1378007.77	557.68	558.05		557.00	32.94	524.74	TOW	04/16/89	3
2009	479540.71	1378007.77	557.68	558.05		557.00	32.19	525.49	TOW	05/13/89	3
2009	479540.71	1378007.77	557.68	558.05		557.00	31.52	526.16	TOW	06/15/89	3
2009	479540.71	1378007.77	557.68	558.05		557.00	33.00	524.68	TOW	07/13/89	3
2009	479540.71	1378007.77	557.68	558.05		557.00	34.00	523.68	TOW	08/15/89	3
2009	479540.71	1378007.77	557.68	558.05		557.00	34.27	523.41	TOW	09/11/89	3
2009	479540.71	1378007.77	557.68	558.05		557.00	38.84	518.84	TOW	10/11/89	3
2018	479447.70	1378671.57	572.19	573.60		571.50	54.66	518.94	TOC	01/09/88	3
2018	479447.70	1378671.57	572.19	573.60		571.50	52.41	521.19	TOC	02/10/88	3
2018	479447.70	1378671.57	572.19	573.60		571.50	51.59	522.01	TOC	03/09/88	3
2018	479447.70	1378671.57	572.19	573.60		571.50	50.51	523.09	TOC	04/11/88	3
2018	479447.70	1378671.57	572.19	573.60		571.50	51.05	522.55	TOC	05/10/88	3
2018	479447.70	1378671.57	572.19	573.60		571.50	52.01	521.59	TOC	06/08/88	3
2018	479447.70	1378671.57	572.19	573.60		571.50	N/A	N/A	N/A	07/09/88	3
2018	479447.70	1378671.57	572.19	573.60		571.50	N/A	N/A	N/A	08/06/88	3

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WATER ELEVATION REPORT FOR 01/01/88 - 11/01/89
REPORT DATE : 04/11/90

RI/FS WELL NUMBER	NORTH COORDINATE	EAST COORDINATE	TOP OF WELL (MSL)	TOP OF CASING (MSL)	GROUND LEVEL (MSL)	CONCRETE LEVEL (MSL)	READING	WATER ELEV. (MSL)	REF. POINT	DATE READ	T WI
2018	479447.70	1378671.57	572.19	573.60		571.50	53.92	518.27	TOW	09/09/88	
2018	479447.70	1378671.57	572.19	573.60		571.50	N/A	N/A	N/A	10/09/88	
2018	479447.70	1378671.57	572.19	573.60		571.50	54.85	518.75	TOC	11/08/88	
2018	479447.70	1378671.57	572.19	573.60		571.50	54.72	518.88	TOC	11/09/88	
2018	479447.70	1378671.57	572.19	573.60		571.50	54.82	518.78	TOC	12/12/88	
2018	479447.70	1378671.57	572.19	573.60		571.50	54.82	518.78	TOC	12/13/88	
2018	479447.70	1378671.57	572.19	573.60		571.50	54.26	519.34	TOC	01/09/89	
2018	479447.70	1378671.57	572.19	573.60		571.50	53.23	520.37	TOC	02/09/89	
2018	479447.70	1378671.57	572.19	573.60		571.50	52.38	521.22	TOC	03/10/89	
2018	479447.70	1378671.57	572.19	573.60		571.50	50.34	523.26	TOC	04/16/89	
2018	479447.70	1378671.57	572.19	573.60		571.50	49.28	524.32	TOC	05/13/89	
2018	479447.70	1378671.57	572.19	573.60		571.50	48.44	525.16	TOC	06/15/89	
2018	479447.70	1378671.57	572.19	573.60		571.50	49.21	524.39	TOC	07/13/89	
2018	479447.70	1378671.57	572.19	573.60		571.50	50.22	523.38	TOC	08/15/89	
2018	479447.70	1378671.57	572.19	573.60		571.50	50.63	522.97	TOC	09/11/89	
2018	479447.70	1378671.57	572.19	573.60		571.50	52.87	520.73	TOC	10/11/89	
2034	480240.05	1378419.45	571.34	571.90	569.7		48.50	522.84	TOW	04/11/88	
2034	480240.05	1378419.45	571.34	571.90	569.7		48.47	522.87	TOW	05/10/88	
2034	480240.05	1378419.45	571.34	571.90	569.7		49.54	521.80	TOW	06/08/88	
2034	480240.05	1378419.45	571.34	571.90	569.7		50.34	521.00	TOW	07/08/88	
2034	480240.05	1378419.45	571.34	571.90	569.7		50.90	520.44	TOW	08/06/88	
2034	480240.05	1378419.45	571.34	571.90	569.7		51.48	519.86	TOW	09/09/88	
2034	480240.05	1378419.45	571.34	571.90	569.7		51.52	519.82	TOW	09/09/88	
2034	480240.05	1378419.45	571.34	571.90	569.7		51.99	519.35	TOW	10/09/88	
2034	480240.05	1378419.45	571.34	571.90	569.7		52.27	519.07	TOW	11/08/88	
2034	480240.05	1378419.45	571.34	571.90	569.7		52.29	519.05	TOW	12/12/88	
2034	480240.05	1378419.45	571.34	571.90	569.7		51.62	519.72	TOW	01/09/89	
2034	480240.05	1378419.45	571.34	571.90	569.7		50.74	520.60	TOW	02/09/89	
2034	480240.05	1378419.45	571.34	571.90	569.7		49.97	521.37	TOW	03/10/89	
2034	480240.05	1378419.45	571.34	571.90	569.7		47.28	524.06	TOW	04/15/89	
2034	480240.05	1378419.45	571.34	571.90	569.7		46.60	524.74	TOW	05/13/89	
2034	480240.05	1378419.45	571.34	571.90	569.7		45.62	525.72	TOW	06/15/89	
2034	480240.05	1378419.45	571.34	571.90	569.7		46.88	524.46	TOW	07/14/89	
2034	480240.05	1378419.45	571.34	571.90	569.7		47.82	523.52	TOW	08/15/89	
2034	480240.05	1378419.45	571.34	571.90	569.7		48.14	523.20	TOW	09/11/89	
2034	480240.05	1378419.45	571.34	571.90	569.7		50.36	520.98	TOW	10/11/89	
3034	480240.23	1378431.39	571.73	572.17	569.9		49.21	522.52	TOW	04/11/88	
3034	480240.23	1378431.39	571.73	572.17	569.9		48.80	522.93	TOW	05/10/88	
3034	480240.23	1378431.39	571.73	572.17	569.9		49.85	521.88	TOW	06/08/88	
3034	480240.23	1378431.39	571.73	572.17	569.9		50.65	521.08	TOW	07/08/88	
3034	480240.23	1378431.39	571.73	572.17	569.9		51.20	520.53	TOW	08/06/88	
3034	480240.23	1378431.39	571.73	572.17	569.9		51.79	519.94	TOW	09/09/88	
3034	480240.23	1378431.39	571.73	572.17	569.9		51.84	519.89	TOW	09/10/88	
3034	480240.23	1378431.39	571.73	572.17	569.9		52.30	519.43	TOW	10/09/88	
3034	480240.23	1378431.39	571.73	572.17	569.9		52.60	519.13	TOW	11/08/88	
3034	480240.23	1378431.39	571.73	572.17	569.9		52.60	519.13	TOW	12/12/88	

* 1 = PRODUCTION AREA 2 = WASTE STOR. AREA 3 = ON-SITE 4 = OFF-SITE RI/FS 5 = OFF-SITE PRIVATE 6 = OFF-SITE S

WATER ELEVATION REPORT FOR 01/01/88 - 11/01/89
REPORT DATE : 04/11/90

RI/FS WELL NUMBER	NORTH COORDINATE	EAST COORDINATE	TOP OF WELL (MSL)	TOP OF CASING (MSL)	GROUND LEVEL (MSL)	CONCRETE LEVEL (MSL)	READING	WATER ELEV. (MSL)	REF. POINT	DATE READ	TYPE OF WELL(*)
3034	480240.23	1378431.39	571.73	572.17	569.9		51.96	519.77	TOW	01/09/89	3
3034	480240.23	1378431.39	571.73	572.17	569.9		51.08	520.65	TOW	02/09/89	3
3034	480240.23	1378431.39	571.73	572.17	569.9		50.30	521.43	TOW	03/10/89	3
3034	480240.23	1378431.39	571.73	572.17	569.9		47.64	524.09	TOW	04/15/89	3
3034	480240.23	1378431.39	571.73	572.17	569.9		46.95	524.78	TOW	05/13/89	3
3034	480240.23	1378431.39	571.73	572.17	569.9		46.00	525.73	TOW	06/15/89	3
3034	480240.23	1378431.39	571.73	572.17	569.9		47.20	524.53	TOW	07/14/89	3
3034	480240.23	1378431.39	571.73	572.17	569.9		48.14	523.59	TOW	08/15/89	3
3034	480240.23	1378431.39	571.73	572.17	569.9		48.44	523.29	TOW	09/11/89	3
3034	480240.23	1378431.39	571.73	572.17	569.9		50.68	521.05	TOW	10/11/89	3

* 1 = PRODUCTION AREA 2 = WASTE STOR. AREA 3 = ON-SITE 4 = OFF-SITE RI/FS 5 = OFF-SITE PRIVATE 6 = OFF-SITE S.O.W.C

MONITORING WELL CONSTRUCTION DATA

Note: Wells nos. 2018, 3005, 3009, and 3018
were not installed during the RI/FS program.

MONITORING WELL INSTALLATION RECORD

04/11/90

PROJECT NAME: Fernald RI/FS
PROJECT NO. : 602.3.2
BORING NO. : 1008
WELL NUMBER: 1008

FIELD ENG./GEO.: M. GOLDBERG DATE: 03/30/88
CHECKED BY : Not Noted DATE: N/A
N,E COORDINATES: 480660.43, 1378925.8
DATE OF INSTAL.: 03/30/88

BOREHOLE DRILLING

DRILLING METHOD: Cable Tool
DRILLING FLUID(S) USED: (in Feet)
FLUID: WATER FROM: 3 TO: 31
FLUID: N/A FROM: N/ATO: N/A
NOTES/COMMENTS:

TYPE OF BIT: Flat Head Hammer
IS CASING TEMPORARY?: No
CASING TYPE : MONITORING
CASING DIAM.:
CASING SIZE(S) USED: (in Feet)
SIZE: 10 FROM: 0 TO: 31
SIZE: N/A FROM: N/A TO: N/A

WELL DESCRIPTION

TYPE: MONITORING WELL
DIAMETER OF PERFORATED SECTION:
PERFORATION TYPE: Screen
AVG. SIZE OF PERFORATIONS: .010 (In.)
TOTAL PERFORATED AREA: 10 Ft.
NOTES/COMMENTS:

RISER PIPE MATERIAL: Stainless Steel
RISER PIPE DIAMETERS:
O.D.: 4 3/8 In. I.D.: 4 In.
LENGTH OF 1ST PIPE SECTION: 10 Ft.
2ND PIPE SECTION: Not Noted
3RD PIPE SECTION: Not Noted
COMMENTS

RISER JOINING METHOD: THREAD AND COUPLE

PROTECTION SYSTEM

RISER PROTECTIVE PIPE LENGTH: 5 Ft.
PROTECTIVE PIPE O.D.: 10 In.
* LOCKABLE CAP

OTHER PROTECTION (* NOTED BELOW)

ITEM	DISTANCE ABOVE/BELOW GROUND SURFACE	ELEVATION MSL
TOP OF RISER PIPE	2.0 Ft.	579.05
GROUND SURFACE	0.0	N/A
BOTTOM OF PROTECTIVE PIPE	2.5 Ft.	

BOREHOLE FILL MATERIALS	TOP	BOTTOM	TOP	BOTTOM
Grout/Slurry	0	6	N/A	N/A
Bentonite Pellets	6	12	N/A	N/A
Gravel	12	31	N/A	N/A
PERFORATED SECTION	19	29	N/A	N/A
WELL TIP	31		N/A	
BOTTOM OF BOREHOLE	31		N/A	
GWL AFTER INSTALLATION	N/A		N/A	

WAS THE WELL FLUSHED AFTER INSTALLATION? : No
WAS A SENSITIVITY TEST PERFORMED ON THE WELL : No

MONITORING WELL INSTALLATION RECORD
04/11/90

PROJECT NAME: Fernald RI/FS
PROJECT NO. : 602.3.2
BORING NO. : 2009
WELL NUMBER: 2009

FIELD ENG./GEO.: B. DUNNING DATE: 09/08/87
CHECKED BY : D. HOLZMAN DATE: 12/22/87
N,E COORDINATES: 479540.71, 1378007.7
DATE OF INSTAL.: 09/08/87

BOREHOLE DRILLING

DRILLING METHOD: Cable Tool
DRILLING FLUID(S) USED: (in Feet)
FLUID: POTABLE WATERFROM: 0 TO: 10.5
FLUID: N/A FROM: N/ATO: N/A
NOTES/COMMENTS:

TYPE OF BIT: Flat Head Hammer
IS CASING TEMPORARY?: No
CASING TYPE : Stainless Steel
CASING DIAM.: 4 In.
CASING SIZE(S) USED: (in Feet)
SIZE: 12 FROM: SURFACE TO: 53
SIZE: N/A FROM: N/A TO: N/A

WELL DESCRIPTION

TYPE: MONITORING WELL
DIAMETER OF PERFORATED SECTION:
PERFORATION TYPE: Screen
AVG. SIZE OF PERFORATIONS: 0.01 (In.)
TOTAL PERFORATED AREA: 15 Ft.
NOTES/COMMENTS:

RISER PIPE MATERIAL: Stainless Steel
RISER PIPE DIAMETERS:
O.D.: 4 3/8 In. I.D.: 4 In.
LENGTH OF 1ST PIPE SECTION: 5 Ft.
2ND PIPE SECTION: 10 Ft.
3RD PIPE SECTION: Not Noted
COMMENTS

RISER JOINING METHOD: FLUSH JOINT THREADED

PROTECTION SYSTEM

RISER PROTECTIVE PIPE LENGTH: 5 Ft.
PROTECTIVE PIPE O.D.: 10 In.
* LOCKING CAP AND LOCK

OTHER PROTECTION (* NOTED BELOW)

ITEM	DISTANCE ABOVE/BELOW GROUND SURFACE		ELEVATION MSL	
TOP OF RISER PIPE	1.9 Ft.		557.68	
GROUND SURFACE	0.0		N/A	
BOTTOM OF PROTECTIVE PIPE	2.8 Ft.			
BOREHOLE FILL MATERIALS	TOP	BOTTOM	TOP	BOTTOM
Grout/Slurry	-1	-21	N/A	N/A
Bentonite Pellets	-21	-26	N/A	N/A
Sand	-26	-54.5	N/A	N/A
PERFORATED SECTION	-28	-43.5	N/A	N/A
WELL TIP	46.0		N/A	
BOTTOM OF BOREHOLE	54.5		N/A	
GWL AFTER INSTALLATION	-33.6		N/A	

WAS THE WELL FLUSHED AFTER INSTALLATION? : No
WAS A SENSITIVITY TEST PERFORMED ON THE WELL : No

MONITORING WELL INSTALLATION RECORD
04/11/90

PROJECT NAME: Fernald RI/FS
PROJECT NO. : 602.3.2
BORING NO. : 2018
WELL NUMBER: 2018

FIELD ENG./GEO.:
CHECKED BY : Not Noted
N,E COORDINATES: 479447.70, 1378671.5
DATE OF INSTAL.:

DATE:
DATE: N/A

BOREHOLE DRILLING

DRILLING METHOD: Not Noted
DRILLING FLUID(S) USED: NONE NOTED
NOTES COMMENTS:

TYPE OF BIT: N/A
IS CASING TEMPORARY?: N/A
CASING TYPE : Not Noted
CASING DIAM.:
CASING SIZE(S) USED: (Units N/A)
SIZE: FROM: N/A TO: N/A
SIZE: N/A FROM: N/A TO: N/A

WELL DESCRIPTION

TYPE: MONITORING WELL
DIAMETER OF PERFORATED SECTION:
PERFORATION TYPE: N/A
AVG. SIZE OF PERFORATIONS: (N/A)
TOTAL PERFORATED AREA:
NOTES/COMMENTS:

RISER PIPE MATERIAL: N/A
RISER PIPE DIAMETERS:
O.D.: I.D.:
LENGTH OF 1ST PIPE SECTION:
2ND PIPE SECTION: Not Noted
3RD PIPE SECTION: Not Noted
COMMENTS

RISER JOINING METHOD: Not Noted

PROTECTION SYSTEM

RISER PROTECTIVE PIPE LENGTH:
PROTECTIVE PIPE O.D.:

OTHER PROTECTION (* NONE NOTED)

ITEM	DISTANCE ABOVE/BELOW GROUND SURFACE		ELEVATION MSL	
TOP OF RISER PIPE	N/A		572.19	
GROUND SURFACE	0.0		N/A	
BOTTOM OF PROTECTIVE PIPE	N/A			
BOREHOLE FILL MATERIALS	TOP	BOTTOM	TOP	BOTTOM
	N/A	N/A	N/A	N/A
PERFORATED SECTION	N/A	N/A	N/A	N/A
WELL TIP	N/A		N/A	
BOTTOM OF BOREHOLE	N/A		N/A	
GWL AFTER INSTALLATION	N/A		N/A	

WAS THE WELL FLUSHED AFTER INSTALLATION? : N/A
WAS A SENSITIVITY TEST PERFORMED ON THE WELL : N/A

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MONITORING WELL INSTALLATION RECORD
04/11/90

PROJECT NAME: Fernald RI/FS FIELD ENG./GEO.: B. DUNNING DATE: 09/11/87
PROJECT NO. : 602.3.2 CHECKED BY : D. HOLZMAN DATE: 12/12/87
BORING NO. : 1009 N,E COORDINATES: 479546.00, 1378000.7
WELL NUMBER: 1009 DATE OF INSTAL.: 09/11/87

BOREHOLE DRILLING

DRILLING METHOD: Cable Tool
DRILLING FLUID(S) USED: (Units N/A)
FLUID: POTABLE WATERFROM: 0 TO: 10
FLUID: N/A FROM: N/ATO: N/A
NOTES/COMMENTS:

TYPE OF BIT: Flat Head Hammer
IS CASING TEMPORARY?: Yes
CASING TYPE : Stainless Steel
CASING DIAM.: 4 In.
CASING SIZE(S) USED: (in Feet)
SIZE: 10 FROM: SURFACE TO: 10.5
SIZE: N/A FROM: N/A TO: N/A

WELL DESCRIPTION

TYPE: MONITORING WELL
DIAMETER OF PERFORATED SECTION:
PERFORATION TYPE: Screen
AVG. SIZE OF PERFORATIONS: 0.01 (In.)
TOTAL PERFORATED AREA: 5 Ft.
NOTES/COMMENTS:

RISER PIPE MATERIAL: Stainless Steel
RISER PIPE DIAMETERS:
O.D.: 4 3/8 In. I.D.: 4 In.
LENGTH OF 1ST PIPE SECTION: 5 Ft.
2ND PIPE SECTION: Not Noted
3RD PIPE SECTION: Not Noted
COMMENTS

RISER JOINING METHOD: FLUSH JOINT THREADED

PROTECTION SYSTEM

RISER PROTECTIVE PIPE LENGTH: 5 Ft.
PROTECTIVE PIPE O.D.: 10 In.
• LOCKING CAP AND LOCK

OTHER PROTECTION (* NOTED BELOW)

ITEM	DISTANCE ABOVE/BELOW GROUND SURFACE		ELEVATION MSL	
TOP OF RISER PIPE	2 Ft.		558.20	
GROUND SURFACE	0.0		N/A	
BOTTOM OF PROTECTIVE PIPE	-2.8 Ft.			
BOREHOLE FILL MATERIALS	TOP	BOTTOM	TOP	BOTTOM
Bentonite Pellets	-.5	-1.5	N/A	N/A
Sand	1.5	11.3	N/A	N/A
PERFORATED SECTION	3.0	8.0	N/A	N/A
WELL TIP	10.5		N/A	
BOTTOM OF BOREHOLE	11.3		N/A	
GWL AFTER INSTALLATION	N/A		N/A	

WAS THE WELL FLUSHED AFTER INSTALLATION? : No
WAS A SENSITIVITY TEST PERFORMED ON THE WELL : No
REMARKS : N/A MEANS NOT APPLICABLE. WHITE OUT CORRECTIONS WERE MADE BY B. DUNNING AT THE TIME THIS WELL WAS COMPLETED.

MONITORING WELL INSTALLATION RECORD
04/11/90

PROJECT NAME: Fernald RI/FS
PROJECT NO. : 602.3.2
BORING NO. : 1018
WELL NUMBER: 1018

FIELD ENG./GEO.: LOWELL WILLE
CHECKED BY : Not Noted
N,E COORDINATES: 479450.19, 1378661.6
DATE OF INSTAL.: 10/19/87

DATE: 10/19/87
DATE: N/A

BOREHOLE DRILLING

DRILLING METHOD: Cable Tool
DRILLING FLUID(S) USED: (in Feet)
FLUID: WATER FROM: 0 TO: 33
FLUID: N/A FROM: N/ATO: N/A
NOTES/COMMENTS:

TYPE OF BIT: Flat Head Hammer
IS CASING TEMPORARY?: Yes
CASING TYPE : MONITORING WELL
CASING DIAM.: 4 In.
CASING SIZE(S) USED: (in Feet)
SIZE: 10 FROM: 0 TO: 33 1/2
SIZE: N/A FROM: N/A TO: N/A

WELL DESCRIPTION

TYPE: MONITORING WELL
DIAMETER OF PERFORATED SECTION:
PERFORATION TYPE: Screen
AVG. SIZE OF PERFORATIONS: 0.010 (In.)
TOTAL PERFORATED AREA: 10 Ft.
NOTES/COMMENTS:

RISER PIPE MATERIAL: Stainless Steel
RISER PIPE DIAMETERS:
O.D.: 4 3/8 In. I.D.: 4 In.
LENGTH OF 1ST PIPE SECTION: 10 Ft.
2ND PIPE SECTION: Not Noted
3RD PIPE SECTION: Not Noted
COMMENTS

RISER JOINING METHOD: FLUSH JOINT THREAD

PROTECTION SYSTEM

RISER PROTECTIVE PIPE LENGTH: 5 Ft.
PROTECTIVE PIPE O.D.: 10 In.
* LOCKABLE TOP AND LOCK

OTHER PROTECTION (* NOTED BELOW)

ITEM	DISTANCE ABOVE/BELOW GROUND SURFACE	ELEVATION MSL
TOP OF RISER PIPE	2.0 Ft.	572.79
GROUND SURFACE	0.0	N/A
BOTTOM OF PROTECTIVE PIPE	2 1/2 Ft.	

BOREHOLE FILL MATERIALS	TOP	BOTTOM	TOP	BOTTOM
Bentonite Pellets	0	4	N/A	N/A
Sand	4	20	N/A	N/A
Bentonite Pellets	20	25	N/A	N/A
Grout/Slurry	25	30	N/A	N/A
Bentonite Pellets	30	33.5	N/A	N/A
PERFORATED SECTION	6	16	N/A	N/A

WELL TIP	18.4	N/A
BOTTOM OF BOREHOLE	33.5	N/A
GWL AFTER INSTALLATION	DRY	N/A

WAS THE WELL FLUSHED AFTER INSTALLATION? : No
WAS A SENSITIVITY TEST PERFORMED ON THE WELL : No
REMARKS : DRY WELL, BENTONITE PELLETS 32 1/2 - 30, VOLCLAY GROUT 30 - 25, BENTONITE PELLETS 25 - 20, SAND 20 - 4, BENTONITE PELLETS 4 - 0. THIS FORM DID NOT REPRESENT THE INSTALLED MONITORING WELL, THEREFORE, IT WAS MODIFIED WITH WHITE OUT BY L. WILLIE.

MONITORING WELL INSTALLATION RECORD
04/11/90

PROJECT NAME: Fernald RI/FS
PROJECT NO. : 602.3.2
BORING NO. : 1029
WELL NUMBER: 1029

FIELD ENG./GEO.: D. OAKLEY DATE: 10/28/87
CHECKED BY : Not Noted DATE: N/A
N,E COORDINATES: 480826.11, 1378398.3
DATE OF INSTAL.: 10/28/87

BOREHOLE DRILLING

DRILLING METHOD: Cable Tool
DRILLING FLUID(S) USED: (in Feet)
FLUID: WATER FROM: 2 TO: 34
FLUID: N/A FROM: N/ATO: N/A
NOTES/COMMENTS:

TYPE OF BIT: Flat Head Hammer
IS CASING TEMPORARY?: No
CASING TYPE : MONITORING
CASING DIAM.: 4 In.
CASING SIZE(S) USED: (Units N/A)
SIZE: 10 FROM: 0 TO: 30
SIZE: N/A FROM: N/A TO: N/A

WELL DESCRIPTION

TYPE: MONITORING WELL
DIAMETER OF PERFORATED SECTION:
PERFORATION TYPE: Screen
AVG. SIZE OF PERFORATIONS: .010 (In.)
TOTAL PERFORATED AREA: 10 Ft.
NOTES/COMMENTS:

RISER PIPE MATERIAL: Stainless Steel
RISER PIPE DIAMETERS:
O.D.: 4 3/8 In. I.D.: 4 In.
LENGTH OF 1ST PIPE SECTION: 10 Ft.
2ND PIPE SECTION: Not Noted
3RD PIPE SECTION: Not Noted
COMMENTS

RISER JOINING METHOD: THREAD AND COUPLE

PROTECTION SYSTEM

RISER PROTECTIVE PIPE LENGTH: 5.0 Ft.
PROTECTIVE PIPE O.D.: 10 In.
* LOCKABLE CAP AND LOCK

OTHER PROTECTION (* NOTED BELOW)

ITEM	DISTANCE ABOVE/BELOW GROUND SURFACE	ELEVATION MSL
TOP OF RISER PIPE	2.0 Ft.	578.70
GROUND SURFACE	0.0	577.3
BOTTOM OF PROTECTIVE PIPE	2.5 Ft.	

BOREHOLE FILL MATERIALS	TOP	BOTTOM	TOP	BOTTOM
Grout/Slurry	0.0	11.0	N/A	N/A
Bentonite Pellets	11.0	16.2	N/A	N/A
Sand	16.2	31.0	N/A	N/A
Bentonite Pellets	31.00	33.00	N/A	N/A
Sand	33.00	36.00	N/A	N/A
PERFORATED SECTION	18.4	28.4	N/A	N/A
WELL TIP	31.00		N/A	
BOTTOM OF BOREHOLE	36.0		N/A	
GWL AFTER INSTALLATION	N/A		N/A	

WAS THE WELL FLUSHED AFTER INSTALLATION? : No
WAS A SENSITIVITY TEST PERFORMED ON THE WELL : No
REMARKS : THIS FORM DID NOT REPRESENT THE INSTALLED MONITORING WELL, THEREFORE, IT HAS BEEN MODIFIED WITH WHITE OUT BY D. OAKLEY.

MONITORING WELL INSTALLATION RECORD
04/11/90

PROJECT NAME: Fernald RI/FS
PROJECT NO. : 602.3.2
BORING NO. : 1032
WELL NUMBER: 1032

FIELD ENG./GEO.: D. OAKLEY
CHECKED BY : Not Noted
N,E COORDINATES: 480515.31, 1378296.8
DATE OF INSTAL.: 10/31/87

DATE: 10/31/87
DATE: N/A

BOREHOLE DRILLING

DRILLING METHOD: Cable Tool
DRILLING FLUID(S) USED: (in Feet)
FLUID: WATER FROM: 2 TO: 24
FLUID: N/A FROM: N/ATO: N/A
NOTES/COMMENTS:

TYPE OF BIT: Flat Head Hammer
IS CASING TEMPORARY?: No
CASING TYPE : MONITORING
CASING DIAM.: 4 In.
CASING SIZE(S) USED: (in Feet)
SIZE: 10 FROM: 0 TO: 20
SIZE: N/A FROM: N/A TO: N/A

WELL DESCRIPTION

TYPE: MONITORING WELL
DIAMETER OF PERFORATED SECTION:
PERFORATION TYPE: Screen
AVG. SIZE OF PERFORATIONS: .010 (In.)
TOTAL PERFORATED AREA: 2.0 Ft.
NOTES/COMMENTS:

RISER PIPE MATERIAL: Stainless Steel
RISER PIPE DIAMETERS:
O.D.: 4 3/8 In. I.D.: 4 In.
LENGTH OF 1ST PIPE SECTION: 10 Ft.
2ND PIPE SECTION: 2 Ft.
3RD PIPE SECTION: Not Noted
COMMENTS

RISER JOINING METHOD: THREAD AND COUPLE

PROTECTION SYSTEM

RISER PROTECTIVE PIPE LENGTH: 5 Ft.
PROTECTIVE PIPE O.D.: 10 In.
* LOCKABLE CAP

OTHER PROTECTION (* NOTED BELOW)

ITEM	DISTANCE ABOVE/BELOW GROUND SURFACE		ELEVATION MSL	
TOP OF RISER PIPE	2.0 Ft.		570.75	
GROUND SURFACE	0.0		569.3	
BOTTOM OF PROTECTIVE PIPE	2.5 Ft.			
BOREHOLE FILL MATERIALS	TOP	BOTTOM	TOP	BOTTOM
Bentonite Pellets	0.5	5.5	N/A	N/A
Sand	5.5	17.0	N/A	N/A
Bentonite Pellets	17.0	24.0	N/A	N/A
PERFORATED SECTION	7.5	9.5	N/A	N/A
WELL TIP	12.4		N/A	
BOTTOM OF BOREHOLE	24.0		N/A	
GWL AFTER INSTALLATION	N/A		N/A	

WAS THE WELL FLUSHED AFTER INSTALLATION? : No
WAS A SENSITIVITY TEST PERFORMED ON THE WELL : No

MONITORING WELL INSTALLATION RECORD

04/11/90

PROJECT NAME: Fernald RI/FS
PROJECT NO. : 602.3.2
BORING NO. : 1033
WELL NUMBER: 1033

FIELD ENG./GEO.: M. GOLDBERG DATE: 04/10/88
CHECKED BY : Not Noted DATE: N/A
N,E COORDINATES: 480412.89, 1378675.1
DATE OF INSTAL.: 04/10/88

BOREHOLE DRILLING

DRILLING METHOD: Cable Tool
DRILLING FLUID(S) USED: (in Feet)
FLUID: WATER FROM: 3 TO: 21
FLUID: N/A FROM: N/ATO: N/A
NOTES/COMMENTS:

TYPE OF BIT: Flat Head Hammer
IS CASING TEMPORARY?: No
CASING TYPE : MONITORING
CASING DIAM.: 4 In.
CASING SIZE(S) USED: (in Feet)
SIZE: 10 FROM: 3 TO: 21
SIZE: N/A FROM: N/A TO: N/A

WELL DESCRIPTION

TYPE: MONITORING WELL
DIAMETER OF PERFORATED SECTION:
PERFORATION TYPE: Screen
AVG. SIZE OF PERFORATIONS: .010 (In.)
TOTAL PERFORATED AREA: 10 Ft.
NOTES/COMMENTS:

RISER PIPE MATERIAL: Stainless Steel
RISER PIPE DIAMETERS:
O.D.: 4 3/8 In. I.D.: 4 In.
LENGTH OF 1ST PIPE SECTION: 10 Ft.
2ND PIPE SECTION: Not Noted
3RD PIPE SECTION: Not Noted
COMMENTS

RISER JOINING METHOD: THREAD AND COUPLE

PROTECTION SYSTEM

RISER PROTECTIVE PIPE LENGTH: 5 Ft.
PROTECTIVE PIPE O.D.: 10 In.
* LOCKABLE CAP

OTHER PROTECTION (* NOTED BELOW)

ITEM	DISTANCE ABOVE/BELOW GROUND SURFACE	ELEVATION MSL
TOP OF RISER PIPE	2.0 Ft.	578.97
GROUND SURFACE	0.0	577.0
BOTTOM OF PROTECTIVE PIPE	2.5 Ft.	

BOREHOLE FILL MATERIALS	TOP	BOTTOM	TOP	BOTTOM
Bentonite Pellets	0	5	N/A	N/A
Gravel	5	21	N/A	N/A
PERFORATED SECTION	9	19	N/A	N/A
WELL TIP	21		N/A	
BOTTOM OF BOREHOLE	21		N/A	
GWL AFTER INSTALLATION	N/A		N/A	

WAS THE WELL FLUSHED AFTER INSTALLATION? : No
WAS A SENSITIVITY TEST PERFORMED ON THE WELL : No

MONITORING WELL INSTALLATION RECORD
04/11/90

PROJECT NAME: Fernald RI/FS
PROJECT NO. : 602.3.2
BORING NO. : 1034
WELL NUMBER: 1034

FIELD ENG./GEO.: W. MONTGOMERY DATE: 04/06/88
CHECKED BY : Not Noted DATE: N/A
N,E COORDINATES: 480240.85, 1378410.2
DATE OF INSTAL.: 04/07/88

BOREHOLE DRILLING

DRILLING METHOD: Cable Tool
DRILLING FLUID(S) USED: (in Feet)
FLUID: WATER FROM: 0 TO: 20
FLUID: N/A FROM: N/ATO: N/A
NOTES/COMMENTS:

TYPE OF BIT: Flat Head Hammer
IS CASING TEMPORARY?: N/A
CASING TYPE : MONITORING WELL
CASING DIAM.: 4 In.
CASING SIZE(S) USED: (Units N/A)
SIZE: FROM: N/A TO: N/A
SIZE: N/A FROM: N/A TO: N/A

WELL DESCRIPTION

TYPE: MONITORING WELL
DIAMETER OF PERFORATED SECTION:
PERFORATION TYPE: Screen
AVG. SIZE OF PERFORATIONS: 0.010 (In.)
TOTAL PERFORATED AREA: 10. Ft.
NOTES/COMMENTS:

RISER PIPE MATERIAL: Stainless Steel
RISER PIPE DIAMETERS:
O.D.: 4 3/8 In. I.D.: 4 In.
LENGTH OF 1ST PIPE SECTION: 2 Ft.
2ND PIPE SECTION: 10 Ft.
3RD PIPE SECTION: Not Noted
COMMENTS

RISER JOINING METHOD: THREADED COUPLE

PROTECTION SYSTEM

RISER PROTECTIVE PIPE LENGTH: 5 Ft.
PROTECTIVE PIPE O.D.: 10 3 In.
* LOCKING CAP W/MASTER LOCK

OTHER PROTECTION (* NOTED BELOW)

ITEM	DISTANCE ABOVE/BELOW GROUND SURFACE		ELEVATION MSL	
TOP OF RISER PIPE	N/A		571.29	
GROUND SURFACE	0.0		569.2	
BOTTOM OF PROTECTIVE PIPE	2.5 Ft.			
BOREHOLE FILL MATERIALS	TOP	BOTTOM	TOP	BOTTOM
Bentonite Pellets	0.0	5.0	N/A	N/A
Sand	5.0	20.0	N/A	N/A
PERFORATED SECTION	8.0	18.0	N/A	N/A
WELL TIP	20.0		N/A	
BOTTOM OF BOREHOLE	20.0		N/A	
GWL AFTER INSTALLATION	N/A		N/A	

WAS THE WELL FLUSHED AFTER INSTALLATION? : No
WAS A SENSITIVITY TEST PERFORMED ON THE WELL : No

MONITORING WELL INSTALLATION RECORD
04/11/90

PROJECT NAME: Fernald RI/FS
PROJECT NO. : 602.3.2
BORING NO. : 1072
WELL NUMBER: 1072

FIELD ENG./GEO.: M. GOLDBERG DATE: 03/15/88
CHECKED BY : Not Noted DATE: N/A
N,E COORDINATES: 481025.93, 1378476.3
DATE OF INSTAL.: 03/15/88

BOREHOLE DRILLING

DRILLING METHOD: Cable Tool
DRILLING FLUID(S) USED: (in Feet)
FLUID: WATER FROM: 3 TO: 50
FLUID: N/A FROM: N/ATO: N/A
NOTES/COMMENTS:

TYPE OF BIT: Flat Head Hammer
IS CASING TEMPORARY?: No
CASING TYPE : MONITORING
CASING DIAM.: 4 In. ID
CASING SIZE(S) USED: (in Feet)
SIZE: 10 FROM: 3 TO: 50
SIZE: N/A FROM: N/A TO: N/A

WELL DESCRIPTION

TYPE: MONITORING WELL
DIAMETER OF PERFORATED SECTION:
PERFORATION TYPE: Screen
AVG. SIZE OF PERFORATIONS: .010 (In.)
TOTAL PERFORATED AREA: 10 Ft.
NOTES/COMMENTS:

RISER PIPE MATERIAL: Stainless Steel
RISER PIPE DIAMETERS:
O.D.: 4 3/8 In. I.D.: 4 In.
LENGTH OF 1ST PIPE SECTION: 10 Ft.
2ND PIPE SECTION: Not Noted
3RD PIPE SECTION: Not Noted
COMMENTS

RISER JOINING METHOD: THREAD AND COUPLE

PROTECTION SYSTEM

RISER PROTECTIVE PIPE LENGTH: 5 Ft.
PROTECTIVE PIPE O.D.: 10 In.
* LOCKABLE CAP

OTHER PROTECTION (* NOTED BELOW)

ITEM	DISTANCE ABOVE/BELOW GROUND SURFACE		ELEVATION MSL	
TOP OF RISER PIPE	2.0 Ft.		577.72	
GROUND SURFACE	0.0		575.9	
BOTTOM OF PROTECTIVE PIPE	2.5 Ft.			
BOREHOLE FILL MATERIALS	TOP	BOTTOM	TOP	BOTTOM
Grout/Slurry	0	10	N/A	N/A
Bentonite Pellets	10	14	N/A	N/A
Gravel	14	31	N/A	N/A
PERFORATED SECTION	19	29	N/A	N/A
WELL TIP	31		N/A	
BOTTOM OF BOREHOLE	31		N/A	
GWL AFTER INSTALLATION	N/A		N/A	

WAS THE WELL FLUSHED AFTER INSTALLATION? : No
WAS A SENSITIVITY TEST PERFORMED ON THE WELL : No
REMARKS : WELL 172 WAS OVERDRILLED TO 50 FT. TO DETERMINE LITHOLOGY. A VOLCLAY PLUG WAS SET FROM 50 FT. TO 36 FT. WITH A 5 FT. BENTONITE PLUG FROM 36 FT. TO 31 FT. TO SEAL TILL/SAND CONTACT AT 33 FT.

MONITORING WELL INSTALLATION RECORD
04/11/90

PROJECT NAME: Fernald RI/FS
PROJECT NO. : 602.3.2
BORING NO. : 2008
WELL NUMBER: 2008

FIELD ENG./GEO.: M. GOLDBERG DATE: 03/28/88
CHECKED BY : Not Noted DATE: N/A
N,E COORDINATES: 480661.42, 1378918.0
DATE OF INSTAL.: 03/28/88

BOREHOLE DRILLING

DRILLING METHOD: Cable Tool
DRILLING FLUID(S) USED: (in Feet)
FLUID: WATER FROM: 0 TO: 73
FLUID: N/A FROM: N/ATO: N/A
NOTES/COMMENTS:

TYPE OF BIT: Flat Head Hammer
IS CASING TEMPORARY?: No
CASING TYPE : MONITORING
CASING DIAM.: 4 In.
CASING SIZE(S) USED: (in Feet)
SIZE: 10 FROM: 0 TO: 73
SIZE: N/A FROM: N/A TO: N/A

WELL DESCRIPTION

TYPE: MONITORING WELL
DIAMETER OF PERFORATED SECTION:
PERFORATION TYPE: Screen
AVG. SIZE OF PERFORATIONS: .010 (In.)
TOTAL PERFORATED AREA: 10 Ft.
NOTES/COMMENTS:

RISER PIPE MATERIAL: Stainless Steel
RISER PIPE DIAMETERS:
O.D.: 4 3/8 In. I.D.: 4 In.
LENGTH OF 1ST PIPE SECTION: 10 Ft.
2ND PIPE SECTION: Not Noted
3RD PIPE SECTION: Not Noted
COMMENTS

RISER JOINING METHOD: THREAD AND COUPLE

PROTECTION SYSTEM

RISER PROTECTIVE PIPE LENGTH: 5 Ft.
PROTECTIVE PIPE O.D.: 10 In.
* LOCKABLE CAP

OTHER PROTECTION (* NOTED BELOW)

ITEM	DISTANCE ABOVE/BELOW GROUND SURFACE	ELEVATION MSL
TOP OF RISER PIPE	2.0	578.87
GROUND SURFACE	0.0	N/A
BOTTOM OF PROTECTIVE PIPE	2.5 Ft.	

BOREHOLE FILL MATERIALS	TOP	BOTTOM	TOP	BOTTOM
Grout/Slurry	0	46	N/A	N/A
Bentonite Pellets	46	50	N/A	N/A
Gravel	50	72.8	N/A	N/A
PERFORATED SECTION	55.8	70.8	N/A	N/A

WELL TIP	72.8	N/A
BOTTOM OF BOREHOLE	72.8	N/A
GWL AFTER INSTALLATION	57.53	N/A

WAS THE WELL FLUSHED AFTER INSTALLATION? : No
WAS A SENSITIVITY TEST PERFORMED ON THE WELL : No

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MONITORING WELL INSTALLATION RECORD
04/11/90

PROJECT NAME: Fernald RI/FS
PROJECT NO. : 602.3.2
BORING NO. : 2034
WELL NUMBER: 2034

FIELD ENG./GEO.: F. MARKERT/L. WILLE DATE: 04/05/88
CHECKED BY : Not Noted DATE: N/A
N,E COORDINATES: 480240.05, 1378419.4
DATE OF INSTAL.: 04/05/88

BOREHOLE DRILLING

DRILLING METHOD: Cable Tool
DRILLING FLUID(S) USED: (in Feet)
FLUID: WATER FROM: 0 TO: 65
FLUID: N/A FROM: N/ATO: N/A
NOTES/COMMENTS:

TYPE OF BIT: DRIVE SHOE
IS CASING TEMPORARY?: No
CASING TYPE : MONITORING WELL
CASING DIAM.: 4 In.
CASING SIZE(S) USED: (in Feet)
SIZE: 10 FROM: 0 TO: 65
SIZE: N/A FROM: N/A TO: N/A

WELL DESCRIPTION

TYPE: MONITORING WELL
DIAMETER OF PERFORATED SECTION:
PERFORATION TYPE: Screen
AVG. SIZE OF PERFORATIONS: 0.010 (In.)
TOTAL PERFORATED AREA: 15 Ft.
NOTES/COMMENTS:

RISER PIPE MATERIAL: Stainless Steel
RISER PIPE DIAMETERS:
O.D.: 4 3/8 In. I.D.: 4 In.
LENGTH OF 1ST PIPE SECTION: 10 Ft.
2ND PIPE SECTION: Not Noted
3RD PIPE SECTION: Not Noted
COMMENTS

RISER JOINING METHOD: SCREW

PROTECTION SYSTEM

RISER PROTECTIVE PIPE LENGTH: 5 Ft.
PROTECTIVE PIPE O.D.: 10 3 In.
* NONE

OTHER PROTECTION (* NOTED BELOW)

ITEM	DISTANCE ABOVE/BELOW GROUND SURFACE		ELEVATION MSL	
TOP OF RISER PIPE	2 1/2 Ft.		571.34	
GROUND SURFACE	0.0		569.7	
BOTTOM OF PROTECTIVE PIPE	2 1/2 Ft.			
BOREHOLE FILL MATERIALS	TOP	BOTTOM	TOP	BOTTOM
Grout/Slurry	0	34	N/A	N/A
Bentonite Pellets	34	40 1/2	N/A	N/A
Sand	40 1/2	65	N/A	N/A
PERFORATED SECTION	45	60	N/A	N/A
WELL TIP	62.5		N/A	
BOTTOM OF BOREHOLE	65		N/A	
GWL AFTER INSTALLATION	49.0		N/A	

WAS THE WELL FLUSHED AFTER INSTALLATION? : No
WAS A SENSITIVITY TEST PERFORMED ON THE WELL : No

..PBC

MONITORING WELL INSTALLATION RECORD

04/11/90

PROJECT NAME: Fernald RI/FS FIELD ENG./GEO.: F. MARKERT DATE: 03/30/88
PROJECT NO. : 602.3.2 CHECKED BY : Not Noted DATE: N/A
BORING NO. : 3034 N,E COORDINATES: 480240.23, 1378431.3
WELL NUMBER: 3034 DATE OF INSTAL.: 03/29/88

BOREHOLE DRILLING

DRILLING METHOD: Cable Tool
DRILLING FLUID(S) USED: (in Feet)
FLUID: WATER FROM: 0 TO: 60
FLUID: N/A FROM: N/ATO: N/A
NOTES/COMMENTS:

TYPE OF BIT: Flat Head Hammer
IS CASING TEMPORARY?: No
CASING TYPE : MONITORING WELL
CASING DIAM.: 4 In.
CASING SIZE(S) USED: (in Feet)
SIZE: 10 FROM: 0 TO: 140
SIZE: N/A FROM: N/A TO: N/A

WELL DESCRIPTION

TYPE: MONITORING WELL
DIAMETER OF PERFORATED SECTION:
PERFORATION TYPE: Screen
AVG. SIZE OF PERFORATIONS: 0.010 (In.)
TOTAL PERFORATED AREA: 10 Ft.
NOTES/COMMENTS:

RISER PIPE MATERIAL: Stainless Steel
RISER PIPE DIAMETERS:
O.D.: 4 3/8 In. I.D.: 4 In.
LENGTH OF 1ST PIPE SECTION: 10 Ft.
2ND PIPE SECTION: 2 Ft.
3RD PIPE SECTION: Not Noted
COMMENTS

RISER JOINING METHOD: SCREW FLUSH JOINT THREADS

PROTECTION SYSTEM

RISER PROTECTIVE PIPE LENGTH: 5 Ft.
PROTECTIVE PIPE O.D.: 10 3 In.
* LOCKING CAP WITH LOCK

OTHER PROTECTION (* NOTED BELOW)

ITEM	DISTANCE ABOVE/BELOW GROUND SURFACE	ELEVATION MSL
TOP OF RISER PIPE	2.0 Ft.	571.73
GROUND SURFACE	0.0	569.9
BOTTOM OF PROTECTIVE PIPE	2.7 Ft.	

BOREHOLE FILL MATERIALS	TOP	BOTTOM	TOP	BOTTOM
Grout/Slurry	0.0	95.0	N/A	N/A
Gravel	95.0	112.5	N/A	N/A
PERFORATED SECTION	100.0	110.0	N/A	N/A

WELL TIP	112.0	N/A
BOTTOM OF BOREHOLE	140.0	N/A
GWL AFTER INSTALLATION	50.14	N/A

WAS THE WELL FLUSHED AFTER INSTALLATION? : No
WAS A SENSITIVITY TEST PERFORMED ON THE WELL : No
REMARKS : BOTTOM OF BOREHOLE BACK FILLED TO 112.5 FT. BENTONITE: 112.5 TO 114.0 FT., GROUT/SLURRY: 114.0 TO 140.0 FT.

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GROUNDWATER ANALYTICAL RESULTS

GROUNDWATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per liter (pCi/L).
Data presented by well id, sample number, and sample date
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETER	1008 03215 05-20-1988	1008 03418 08-09-1988	1008 03725 11-20-1988	1008 03925 02-05-1989
Cesium 137	< 20.0	< 20.0	< 20.0	< 20.0
Neptunium 237	< 1.0	< 1.0	< 1.0	< 1.0
Plutonium 238	< 1.0	< 1.0	< 1.0	< 1.0
Plutonium 239/240	< 1.0	< 1.0	< 1.0	< 1.0
Radium 226	< 1.0	1.0 ± 0.4	< 1.0	< 1.0
Radium 228	< 3.0	< 3.0	< 3.0	< 3.0
Ruthenium 106	< 150.0	< 150.0	< 150.0	< 150.0
Strontium 90	< 5.0	< 5.0	< 5.0	< 5.0
Technetium 99	< 30.0	< 30.0	< 30.0	< 30.0
Thorium 228	< 1.0	1.4 ± 0.5	< 1.0	< 1.0
Thorium 230	< 1.0	1.3 ± 0.5	< 1.0	< 1.0
Thorium 232	< 1.0	1.3 ± 0.5	< 1.0	< 1.0
Total Thorium **	NA	12.0 ± 4.0	< 4.0	< 3.0
Uranium 234	2.7 ± 0.4	4.5 ± 0.7	< 1.0	1.2 ± 0.4
Uranium 235/236	< 1.0	< 1.0	< 1.0	< 1.0
Uranium 238	3.6 ± 0.5	5.6 ± 0.9	2.4 ± 0.7	1.9 ± 0.5
Total Uranium **	14.0 ± 3.0	13.0 ± 2.0	6.0 ± 1.0	6.0 ± 1.0

* Data validation in progress.

** Results reported in ug/L

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GROUNDWATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per liter (pCi/L).
Data presented by well id, sample number, and sample date
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETER		1018 03138 04-14-1988			1018 03382 07-27-1988			1018 03666 11-02-1988			1018 03858 01-22-1989		
Cesium 137		< 20.0			< 20.0			< 20.0			< 20.0		
Neptunium 237		< 1.0			< 1.0			< 1.0			< 1.0		
Plutonium 238		< 1.0			< 1.0			< 1.0			< 1.0		
Plutonium 239/240		< 1.0			< 1.0			< 1.0			< 1.0		
Radium 226		< 1.0			< 1.0			< 1.0			< 1.0		
Radium 228		< 3.0			< 3.0			< 3.0			< 3.0		
Ruthenium 106		< 150.0			< 150.0			< 150.0			< 150.0		
Strontium 90		< 5.0			< 5.0			< 5.0			< 5.0		
Technetium 99		< 30.0			< 30.0			< 30.0			< 30.0		
Thorium 228		< 1.0			< 1.0			< 1.0			< 1.0		
Thorium 230		< 1.0			< 1.0			< 1.0			< 1.0		
Thorium 232		< 1.0			< 1.0			< 1.0			< 1.0		
Total Thorium	**	NA			< 5.0			< 2.0			< 3.0		
Uranium 234		1.8	±	0.5	2.8	±	0.7	1.8	±	0.4	1.3	±	0.3
Uranium 235/236		< 1.0			< 1.0			< 1.0			< 1.0		
Uranium 238		1.3	±	0.5	1.8	±	0.5	1.4	±	0.4	1.0	±	0.3
Total Uranium	**	5.0	±	1.0	4.0	±	1.0	3.0	±	1.0	4.0	±	1.0

* Data validation in progress.

** Results reported in ug/L

GROUNDWATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per liter (pCi/L).
Data presented by well id, sample number, and sample date
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETER		1029 03076 04-05-1988			1029 03354 07-20-1988			1029 03634 10-23-1988			1029 03852 01-22-1989		
Cesium 137		< 20.0			< 20.0			< 20.0			< 20.0		
Neptunium 237		< 1.0			< 1.0			< 1.0			< 1.0		
Plutonium 238		< 1.0			< 1.0			< 1.0			< 1.0		
Plutonium 239/240		< 1.0			< 1.0			< 1.0			< 1.0		
Radium 226		< 1.0			< 1.0			< 1.0			< 1.0		
Radium 228		< 3.0			< 3.0			< 3.0			< 3.1		
Ruthenium 106		< 150.0			< 150.0			< 150.0			< 150.0		
Strontium 90		< 5.0			< 5.0			< 5.0			< 5.0		
Technetium 99		< 30.0			< 30.0			< 30.0			< 30.0		
Thorium 228		< 1.0			< 1.0			< 1.0			< 1.0		
Thorium 230		< 1.0			< 1.0			< 1.0			< 1.0		
Thorium 232		< 1.0			< 1.0			< 1.0			< 1.0		
Total Thorium	**	NA			< 2.0			< 3.0			< 4.0		
Uranium 234		1.7	±	0.6	1.4	±	0.3	1.2	±	0.3	1.7	±	0.5
Uranium 235/236		< 1.0			< 1.0			< 1.0			< 1.0		
Uranium 238		1.4	±	0.5	< 1.0			< 1.0			< 1.0		
Total Uranium	**	3.0	±	1.0	3.0	±	1.0	2.0	±	1.0	3.0	±	1.0

* Data validation in progress.

** Results reported in ug/L

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GROUNDWATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per liter (pCi/L).
Data presented by well id, sample number, and sample date
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETER	1032 03133 04-27-1988	1032 03355 07-20-1988	1032 03635 10-23-1988	1032 03851 01-22-1989
Cesium 137	< 20.0	< 20.0	< 20.0	< 20.0
Neptunium 237	< 1.0	< 1.0	< 1.0	< 1.0
Plutonium 238	< 1.0	< 1.0	< 1.0	< 1.0
Plutonium 239/240	< 1.0	< 1.0	< 1.0	< 1.0
Radium 226	< 1.0	< 1.0	< 1.0	< 1.0
Radium 228	< 3.0	< 3.0	4.8 ± 1.8	< 3.1
Ruthenium 106	< 150.0	< 150.0	< 150.0	< 150.0
Strontium 90	< 5.0	6.0 ± 1.3	< 5.0	< 5.0
Technetium 99	< 30.0	< 30.0	< 30.0	< 30.0
Thorium 228	< 1.0	< 1.0	< 1.0	< 1.0
Thorium 230	1.6 ± 0.6	< 1.0	< 1.0	< 1.0
Thorium 232	< 1.0	< 1.0	< 1.0	< 1.0
Total Thorium **	NA	< 5.0	< 5.0	< 4.0
Uranium 234	84.9 ± 13.9	61.3 ± 8.7	82.4 ± 11.0	76.1 ± 9.6
Uranium 235/236	4.6 ± 1.4	3.9 ± 0.8	3.3 ± 0.8	3.2 ± 0.7
Uranium 238	96.8 ± 15.7	70.5 ± 9.9	92.4 ± 12.0	88.8 ± 11.1
Total Uranium **	256.0 ± 41.0	196.0 ± 41.0	230.0 ± 44.0	276.0 ± 47.0

* Data validation in progress.

** Results reported in ug/L

GROUNDWATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per liter (pCi/L).
Data presented by well id, sample number, and sample date
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETER	1033 03220 05-22-1988	1033 03567 08-24-1988	1033 03773 11-20-1988	1033 03961 03-10-1989
Cesium 137	< 20.0	< 20.0	< 20.0	< 20.0
Neptunium 237	< 1.0	< 1.0	< 1.0	< 1.0
Plutonium 238	< 1.0	< 1.0	< 1.0	< 1.0
Plutonium 239/240	< 1.0	< 1.0	< 1.0	< 1.0
Radium 226	< 1.0	< 1.0	< 1.0	< 1.0
Radium 228	< 3.0	< 3.0	< 3.0	< 3.0
Ruthenium 106	< 150.0	< 150.0	< 150.0	< 150.0
Strontium 90	< 5.0	< 5.0	< 5.0	< 5.0
Technetium 99	< 30.0	< 30.0	< 30.0	< 30.0
Thorium 228	< 1.0	< 1.0	< 1.0	< 1.0
Thorium 230	1.4 ± 0.4	< 1.0	< 1.0	< 1.0
Thorium 232	< 1.0	< 1.0	< 1.0	< 1.0
Total Thorium **	NA	3.0 ± 2.0	< 2.0	< 2.0
Uranium 234	3.7 ± 0.6	3.3 ± 0.6	4.9 ± 0.8	7.1 ± 1.1
Uranium 235/236	< 1.0	< 1.0	< 1.0	< 1.0
Uranium 238	3.5 ± 0.6	3.0 ± 0.6	5.0 ± 0.8	8.2 ± 1.2
Total Uranium **	11.0 ± 1.0	9.0 ± 1.0	15.0 ± 3.0	23.0 ± 4.0

* Data validation in progress.

** Results reported in ug/L

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GROUNDWATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per liter (pCi/L).
Data presented by well id, sample number, and sample date
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETER		1034 03122 04-25-1988			1034 03356 07-20-1988			1034 03636 10-23-1988			1034 03850 01-22-1989		
Cesium 137		< 20.0			< 20.0			< 20.0			< 20.0		
Neptunium 237		< 1.0			< 1.0			< 1.0			< 1.0		
Plutonium 238		< 1.0			< 1.0			< 1.0			< 1.0		
Plutonium 239/240		< 1.0			< 1.0			< 1.0			< 1.0		
Radium 226		< 1.0			< 1.0			< 1.0			< 1.0		
Radium 228		< 3.0			< 3.0			< 3.0			< 3.2		
Ruthenium 106		< 150.0			< 150.0			< 150.0			< 150.0		
Strontium 90		< 5.0			< 5.0			< 5.0			< 5.0		
Technetium 99		< 30.0			< 30.0			< 30.0			< 30.0		
Thorium 228		< 1.0			< 1.0			< 1.0			< 1.0		
Thorium 230		< 1.0			2.4	±	0.6	< 1.0			< 1.0		
Thorium 232		< 1.0			< 1.0			< 1.0			< 1.0		
Total Thorium	**	NA			< 4.0			< 2.0			< 3.0		
Uranium 234		1.3	±	0.5	2.6	±	0.5	2.9	±	0.4	1.2	±	0.3
Uranium 235/236		< 1.0			< 1.0			< 1.0			< 1.0		
Uranium 238		1.1	±	0.5	1.8	±	0.4	3.4	±	0.6	1.1	±	0.3
Total Uranium	**	4.0	±	1.0	10.0	±	2.0	7.0	±	1.0	3.0	±	1.0

* Data validation in progress.

** Results reported in ug/L

GROUNDWATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per liter (pCi/L).
Data presented by well id, sample number, and sample date
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETER	2008 03193 05-17-1988	DUPLICATE 2008 03194 05-17-1988	2008 03417 08-09-1988	2008 03349 11-20-1988	DUPLICATE 2008 03724 11-20-1988
Cesium 137	< 20.0	< 20.0	< 20.0	< 20.0	< 20.0
Neptunium 237	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Plutonium 238	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Plutonium 239/240	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Radium 226	< 1.0	1.3 ± 0.4	< 1.0	< 1.0	< 1.0
Radium 228	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0
Ruthenium 106	< 150.0	< 150.0	< 150.0	< 150.0	< 150.0
Strontium 90	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Technetium 99	< 30.0	< 30.0	< 30.0	< 30.0	< 30.0
Thorium 228	1.0 ± 0.5	< 1.0	< 1.0	< 1.0	< 1.0
Thorium 230	1.9 ± 0.7	1.0 ± 0.4	< 1.0	< 1.0	< 1.0
Thorium 232	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Total Thorium **	NA	NA	< 2.0	< 3.0	< 12.0
Uranium 234	4.1 ± 0.7	4.8 ± 0.7	6.5 ± 0.9	5.8 ± 1.0	6.3 ± 1.0
Uranium 235/236	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Uranium 238	4.9 ± 0.7	5.1 ± 0.7	6.8 ± 1.0	7.8 ± 1.2	6.0 ± 1.0
Total Uranium **	22.0 ± 5.0	20.0 ± 6.0	16.0 ± 3.0	25.0 ± 4.0	18.0 ± 3.0

* Data validation in progress.

** Results reported in ug/L

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GROUNDWATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per liter (pCi/L).
Data presented by well id, sample number, and sample date
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETER		2008 03923 02-23-1989		
Cesium 137		< 20.0		
Neptunium 237		< 1.0		
Plutonium 238		< 1.0		
Plutonium 239/240		< 1.0		
Radium 226		< 1.0		
Radium 228		< 3.0		
Ruthenium 106		< 150.0		
Strontium 90		< 5.0		
Technetium 99		< 30.0		
Thorium 228		< 1.0		
Thorium 230		< 1.0		
Thorium 232		< 1.0		
Total Thorium	**	< 3.0		
Uranium 234		6.1	±	1.0
Uranium 235/236		< 1.0		
Uranium 238		6.0	±	1.0
Total Uranium	**	5.0	±	1.0

* Data validation in progress.

** Results reported in ug/L

GROUNDWATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per liter (pCi/L).
Data presented by well id, sample number, and sample date
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETER		2009 03067 03-29-1988			2009 03383 07-27-1988			2009 03667 11-07-1988			2009 03866 01-31-1989		
Cesium 137		< 20.0			< 20.0			< 20.0			< 20.0		
Neptunium 237		< 1.0			< 1.0			< 1.0			< 1.0		
Plutonium 238		< 1.0			< 1.0			< 1.0			< 1.0		
Plutonium 239/240		< 1.0			< 1.0			< 1.0			< 1.0		
Radium 226		< 1.0			< 1.0			< 1.0			< 1.0		
Radium 228		< 3.0			< 3.0			< 3.0			< 3.0		
Ruthenium 106		< 150.0			< 150.0			< 150.0			< 150.0		
Strontium 90		< 5.0			< 5.0			< 5.0			< 5.0		
Technetium 99		< 30.0			< 30.0			< 30.0			< 30.0		
Thorium 228		< 1.0			1.1	±	0.4	< 1.0			< 1.0		
Thorium 230		< 1.0			< 1.0			< 1.0			< 1.0		
Thorium 232		< 1.0			< 1.0			< 1.0			< 1.0		
Total Thorium	**	NA			< 4.0			< 3.0			< 3.0		
Uranium 234		5.6	±	1.3	4.7	±	0.8	4.6	±	0.8	5.1	±	0.8
Uranium 235/236		< 1.0			< 1.0			< 1.0			< 1.0		
Uranium 238		6.9	±	1.4	7.0	±	1.1	7.1	±	1.1	8.1	±	1.1
Total Uranium	**	22.0	±	4.0	19.0	±	3.0	24.0	±	4.0	27.0	±	5.0

* Data validation in progress.

** Results reported in ug/L

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GROUNDWATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per liter (pCi/L).
Data presented by well id, sample number, and sample date
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETER		2018 03069 03-29-1988	2018 03381 07-27-1988	2018 03665 11-07-1988	2018 03864 01-23-1989
Cesium 137		< 20.0	< 20.0	< 20.0	< 20.0
Neptunium 237		< 1.0	< 1.0	< 1.0	< 1.0
Plutonium 238		< 1.0	< 1.0	< 1.0	< 1.0
Plutonium 239/240		< 1.0	< 1.0	< 1.0	< 1.0
Radium 226		< 1.0	< 1.0	< 1.0	< 1.0
Radium 228		< 3.0	< 3.0	4.3 ± 1.6	< 3.2
Ruthenium 106		< 150.0	< 150.0	< 150.0	< 150.0
Strontium 90		< 5.0	< 5.0	< 5.0	< 5.0
Technetium 99		< 30.0	< 30.0	< 30.0	< 30.0
Thorium 228		< 1.0	< 1.0	< 1.0	< 1.0
Thorium 230		< 1.0	1.2 ± 0.5	< 1.0	< 1.0
Thorium 232		< 1.0	< 1.0	< 1.0	< 1.0
Total Thorium	**	NA	< 4.0	< 6.0	< 9.0
Uranium 234		< 1.0	< 1.0	< 1.0	< 1.0
Uranium 235/236		< 1.0	< 1.0	< 1.0	< 1.0
Uranium 238		< 1.0	< 1.0	1.2 ± 0.3	< 1.0
Total Uranium	**	2.0 ± 1.0	< 1.0	3.0 ± 1.0	4.0 ± 1.0

* Data validation in progress.

** Results reported in ug/L

GROUNDWATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per liter (pCi/L).
Data presented by well id, sample number, and sample date
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETER	2034 03223 05-23-1988	DUPLICATE 2034 03224 05-23-1988	2034 03367 07-24-1988	2034 03646 10-24-1988	2034 03835 01-19-1989
Cesium 137	< 20.0	< 20.0	< 20.0	< 20.0	< 20.0
Neptunium 237	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Plutonium 238	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Plutonium 239/240	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Radium 226	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Radium 228	< 3.0	< 3.0	< 3.0	< 3.0	< 3.0
Ruthenium 106	< 150.0	< 150.0	< 150.0	< 150.0	< 150.0
Strontium 90	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Technetium 99	< 30.0	< 30.0	< 30.0	< 30.0	< 30.0
Thorium 228	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Thorium 230	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Thorium 232	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Total Thorium **	NA	NA	< 3.0	< 3.0	< 3.0
Uranium 234	4.5 ± 0.6	5.2 ± 0.8	9.1 ± 1.3	8.0 ± 1.2	5.4 ± 0.8
Uranium 235/236	< 1.0	< 1.0	1.1 ± 0.3	< 1.0	< 1.0
Uranium 238	5.5 ± 0.8	5.7 ± 0.8	9.3 ± 1.3	8.3 ± 1.2	6.7 ± 1.0
Total Uranium **	15.0 ± 3.0	15.0 ± 2.0	24.0 ± 4.0	24.0 ± 5.0	19.0 ± 3.0

* Data validation in progress.

** Results reported in ug/L

GROUNDWATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per liter (pCi/L).
Data presented by well id, sample number, and sample date
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETER	3005 03199 05-18-1988	3005 03513 08-19-1988	DUPLICATE 3005 03514 08-19-1988	3005 03464 12-02-1988	DUPLICATE 3005 03758 12-02-1988
Cesium 137	< 20.0	< 20.0	< 20.0	< 20.0	< 20.0
Neptunium 237	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Plutonium 238	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Plutonium 239/240	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Radium 226	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Radium 228	4.0 ± 1.4	< 3.0	< 3.0	< 3.0	< 3.0
Ruthenium 106	< 150.0	< 150.0	< 150.0	< 150.0	< 150.0
Strontium 90	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Technetium 99	< 30.0	< 30.0	< 30.0	< 30.0	< 30.0
Thorium 228	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Thorium 230	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Thorium 232	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Total Thorium **	NA	< 2.0	3.0 ± 2.0	< 5.0	< 3.0
Uranium 234	1.2 ± 0.3	1.5 ± 0.4	1.2 ± 0.3	1.5 ± 0.5	1.5 ± 0.4
Uranium 235/236	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Uranium 238	2.2 ± 0.4	1.5 ± 0.4	1.3 ± 0.4	1.2 ± 0.4	1.5 ± 0.4
Total Uranium **	10.0 ± 2.0	3.0 ± 1.0	3.0 ± 1.0	4.0 ± 1.0	3.0 ± 1.0

* Data validation in progress.

** Results reported in ug/L

GROUNDWATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per liter (pCi/L).
Data presented by well id, sample number, and sample date
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETER		3005 03956 03-13-1989		
Cesium 137		< 20.0		
Neptunium 237		< 1.0		
Plutonium 238		< 1.0		
Plutonium 239/240		< 1.0		
Radium 226		< 1.0		
Radium 228		< 3.0		
Ruthenium 106		< 150.0		
Strontium 90		< 5.0		
Technetium 99		< 30.0		
Thorium 228		< 1.0		
Thorium 230		< 1.0		
Thorium 232		< 1.0		
Total Thorium	**	< 6.0		
Uranium 234		1.2	±	0.3
Uranium 235/236		< 1.0		
Uranium 238		1.0	±	0.3
Total Uranium	**	3.0	±	1.0

* Data validation in progress.

** Results reported in ug/L

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GROUNDWATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per liter (pCi/L).
Data presented by well id, sample number, and sample date
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETER	3009 03068 03-29-1988	3009 03439 08-05-1988	3009 03699 11-08-1988	3009 03865 01-31-1989
Cesium 137	< 20.0	< 20.0	< 20.0	< 20.0
Neptunium 237	< 1.0	< 1.0	< 1.0	< 1.0
Plutonium 238	< 1.0	< 1.0	< 1.0	< 1.0
Plutonium 239/240	< 1.0	< 1.0	< 1.0	< 1.0
Radium 226	< 1.0	< 1.0	< 1.0	< 1.0
Radium 228	< 3.2	< 3.0	< 3.0	< 3.0
Ruthenium 106	< 150.0	< 150.0	< 150.0	< 150.0
Strontium 90	< 5.0	< 5.0	< 5.0	< 5.0
Technetium 99	< 30.0	< 30.0	< 30.0	44.5 ± 21.5
Thorium 228	< 1.0	< 1.0	< 1.0	< 1.0
Thorium 230	< 1.0	< 1.0	< 1.0	< 1.0
Thorium 232	< 1.0	< 1.0	< 1.0	< 1.0
Total Thorium **	NA	3.0 ± 2.0	< 3.0	< 2.0
Uranium 234	1.3 ± 0.6	1.6 ± 0.4	1.2 ± 0.3	1.4 ± 0.4
Uranium 235/236	< 1.0	< 1.0	< 1.0	< 1.0
Uranium 238	2.3 ± 0.8	1.6 ± 0.4	< 1.0	1.5 ± 0.4
Total Uranium **	4.0 ± 1.0	2.0 ± 1.0	2.0 ± 1.0	3.0 ± 1.0

* Data validation in progress.

** Results reported in ug/L

GROUNDWATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per liter (pCi/L).
Data presented by well id, sample number, and sample date
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETER	3018 03072 03-30-1988	3018 03380 07-27-1988	3018 03330 11-07-1988	DUPLICATE 3018 03664 11-07-1988	3018 03863 01-23-1989
Cesium 137	< 20.0	< 20.0	< 20.0	< 20.0	< 20.0
Neptunium 237	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Plutonium 238	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Plutonium 239/240	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Radium 226	< 1.0	< 1.0	1.6 ± 0.6	< 1.0	< 1.0
Radium 228	< 3.0	< 3.0	< 3.0	3.8 ± 1.5	< 3.0
Ruthenium 106	< 150.0	< 150.0	< 150.0	< 150.0	< 150.0
Strontium 90	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Technetium 99	< 30.0	< 30.0	< 30.0	< 30.0	< 30.0
Thorium 228	< 1.0	< 1.0	< 1.0	< 1.0	< 2.1
Thorium 230	< 1.0	< 1.0	< 1.0	< 1.0	< 2.1
Thorium 232	< 1.0	< 1.0	< 1.0	< 1.0	< 2.1
Total Thorium **	NA	< 4.0	< 3.0	< 3.0	< 19.0
Uranium 234	< 1.0	3.7 ± 0.8	1.1 ± 0.3	< 1.0	< 1.0
Uranium 235/236	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Uranium 238	< 1.0	1.3 ± 0.4	< 1.0	< 1.0	< 1.0
Total Uranium **	2.0 ± 1.0	2.0 ± 1.0	1.0 ± 1.0	1.0 ± 1.0	2.0 ± 1.0

* Data validation in progress.

** Results reported in ug/L

GROUNDWATER RADIOLOGICAL RESULTS
RI/FS DATA*

Results in picoCuries per liter (pCi/L).
Data presented by well id, sample number, and sample date
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

RADIOLOGICAL PARAMETER		3034 03116 04-24-1988			3034 03366 07-24-1988			3034 03645 10-24-1988	3034 03836 01-19-1989
Cesium 137		< 20.0			< 20.0			< 20.0	< 20.0
Neptunium 237		< 1.0			< 1.0			< 1.0	< 1.0
Plutonium 238		< 1.0			< 1.0			< 1.0	< 1.0
Plutonium 239/240		< 1.0			< 1.0			< 1.0	< 1.0
Radium 226		< 1.0			< 1.0			< 1.0	< 1.0
Radium 228		< 3.0			< 3.0			< 3.0	< 3.0
Ruthenium 106		< 150.0			< 150.0			< 150.0	< 150.0
Strontium 90		< 5.0			< 5.0			< 5.0	< 5.0
Technetium 99		36.4	±	12.4	< 30.0			< 30.0	< 30.0
Thorium 228		< 1.0			< 1.0			< 1.0	< 1.0
Thorium 230		< 1.0			< 1.0			< 1.0	< 1.0
Thorium 232		< 1.0			< 1.0			< 1.0	< 1.0
Total Thorium	**	NA			< 3.0			< 2.0	< 5.0
Uranium 234		1.3	±	0.6	< 1.0			< 1.0	< 1.0
Uranium 235/236		< 1.0			< 1.0			< 1.0	< 1.0
Uranium 238		1.3	±	0.6	< 1.0			< 1.0	< 1.0
Total Uranium	**	3.0	±	1.0	1.0	±	1.0	< 1.0	< 1.0

* Data validation in progress.

** Results reported in ug/L

DATA QUALIFIERS

EXPLANATION FOR DATA QUALIFIERS SHOWN ON THE FOLLOWING GENERAL CHEMICAL RESULTS

On the data tables that follow, an individual analytical result may include one or more data qualifiers. The list below presents all possible qualifiers and can be used as a reference when looking at the data. The qualifiers are standard Contract Laboratory Program (CLP) data qualifiers.

One note of caution; two types of chemical results tables are presented in this appendix: general chemical results and hazardous substance list results. There are two separate lists of data qualifiers for these separate tables and, although some of the symbols are the same for each, they may have different definitions.

Concentration Qualifiers

B = Reported value was obtained from a reading that was less than the Contract Laboratory Program (CLP) Contract Required Detection Limit (CRQL), but greater than or equal to the Instrument Detection Limit (IDL).

Quality Qualifiers

E = The reported value is estimated because of the presence of interference.

M = Duplicate injection precision not met.

N = Spiked sample recovery not within controls limits.

S = The reported value was determined by the Method of Standard Additions.

W = Post-digestion spike for Furnace AA analysis is out of control limits (85-115%), while sample absorbance is less than 50% of spike absorbance.

G = Native analyte > 4 times spike added; therefore acceptance criteria do not apply.

X = Detection limit is higher than normal due to sample matrix interferences.

* = Duplicate analysis not within control limits.

+ = Correlation coefficient for the MSA is less than 0.955.

EXPLANATION FOR DATA QUALIFIERS SHOWN ON THE FOLLOWING HAZARDOUS SUBSTANCE LIST RESULTS

On the data tables that follow, an individual analytical result may include one or more data qualifiers. The list below presents all possible qualifiers and can be used as a reference when looking at the data. The qualifiers are standard Contract Laboratory Program (CLP) data qualifiers.

One note of caution; two types of chemical results tables are presented in this appendix: general chemical results and hazardous substance list results. There are two separate lists of data qualifiers for these separate tables and, although some of the symbols are the same for each, they may have different definitions.

J = Indicates an estimated value. This flag is used when the mass spectral data indicate the presence of a compound that meets the identification criteria, but the result is less than the sample quantitation limit but greater than zero.

C = This flag applies to pesticide results where the identification has been confirmed by GC/MS.

B = This flag is used when the analyte is found in the associated blank as well as in the sample. It indicates possible/probable blank contamination and warns the data user to take appropriate action.

E = This flag identifies compounds whose concentrations exceed the calibration range of the GC/MS instrument for that specific analysis. This flag will <u>not</u> apply to pesticides/PCBs analyzed by GC/EC methods.

D = This flag identifies all compounds identified in an analysis at a secondary dilution factor.

F = Estimated value due to a confirmed compound which is off-scale in both columns.

X = A flag that FORMASTER III CLP software automatically inserts to indicate that the data was entered manually.

Z = No estimated value reported, or an elevated CRQL reported because matrix effects interfere with or obscure the compound on one or both columns. In either situation, the compound does not confirm as a positive identification.

* = Values outside of contract laboratory-required QC limits.

GROUNDWATER GENERAL CHEMICAL DATA

RI/FS DATA*
Results in parts per million (ppm).
Data presented by well id, sample number, and depth and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	1008 03215 05-20-1988	1008 03418 08-09-1988	1008 03725 11-20-1988	1008 03925 02-05-1989
GENERAL CHEMISTRY				
Ammonia	< 0.1000	< 0.3000	0.2600	< 0.1000
Chloride	3.9000	8.0000	0.5000	8.0000
Fluoride	0.9000	1.2000	0.8800	0.7800
Hydrogen ion	NA	NA	NA	NA
Nitrates	0.1000	0.2300	< 0.1000	NA
Phenols	0.0100	< 0.0500	< 0.0100	< 0.0100
Phosporus (black, white, r	NA	NA	NA	NA
Phosphate as P	NA	NA	NA	NA
Sulfate	17.0000	28.0000	150.0000	52.4000
Total Kjeldahl Nitrogen	NA	< 15.0000	0.6000	0.1970
Total Organic Carbon	NA	NA	NA	NA
Total Organic Halides	NA	NA	< 0.0500	< 0.0500
Total Organic Nitrogen	0.3000	< 15.0000	0.3400	0.1970
METALS				
Aluminum	NA	NA	NA	NA
Antimony	NA	NA	NA	NA
Arsenic	< 0.2000	< 0.0100	< 0.0020	0.0030
Barium	0.3180	0.3000	0.3340	0.3730
Beryllium	NA	NA	NA	NA
Cadmium	0.0160	< 0.0050	0.0040	0.0080
Calcium	83.5000	89.0000	84.5000	89.8000
Chromium	< 0.0200	< 0.0100	< 0.0200	0.0260
Cobalt	NA	NA	NA	NA
Copper	< 0.0100	< 0.0300	< 0.0100	0.0150
Cyanides (soluble salts an	NA	NA	NA	NA
Hexavalent Chromium	NA	NA	NA	NA
Iron	0.0600	< 0.1000	0.4130	0.0430
Lead	< 0.0500	< 0.0050	0.0080	< 0.0020
Magnesium	35.8000	37.0000	35.8000	40.0000
Manganese	0.2780	0.2500	0.2610	0.1960
Mercury	< 0.0002	< 0.0003	< 0.0002	0.0025
Molybdenum	0.0200	< 0.0500	0.0430	< 0.0200
Nickel	< 0.0200	< 0.0400	< 0.0200	< 0.0200
Potassium	1.0200	< 5.0000	1.0100	0.9810
Selenium	< 0.2000	< 0.0050	< 0.0020	< 0.0020
Silicon	NA	NA	NA	NA
Silver	< 0.0100	< 0.0100	< 0.0005	< 0.0005
Sodium	8.9600	12.0000	9.5800	9.3700
Thallium	NA	NA	NA	NA
Vanadium	NA	NA	NA	NA
Zinc	NA	NA	NA	NA

*Data validation in progress

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GROUNDWATER GENERAL CHEMICAL DATA

RI/FS DATA*
Results in parts per million (ppm).
Data presented by well id, sample number, and depth and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	1018 03138 04-14-1988	1018 03382 07-27-1988	1018 03666 11-02-1988	1018 03858 01-22-1989
GENERAL CHEMISTRY				
Ammonia	< 0.1000	< 0.1000	< 0.1000	< 0.1000
Chloride	0.5000	2.4000	2.3000	2.2000
Fluoride	0.3600	1.0000	< 0.5000	0.3000
Hydrogen ion	NA	NA	NA	NA
Nitrates	< 0.1000	< 0.1000	0.1500	NA
Phenols	0.0400	< 0.0500	< 0.0100	< 0.0100
Phosporus (black, white, r	NA	NA	NA	NA
Phosphate as P	NA	NA	NA	NA
Sulfate	11.0000	48.0000	114.0000	55.0000
Total Kjeldahl Nitrogen	NA	NA	0.1300	< 0.1000
Total Organic Carbon	NA	NA	NA	NA
Total Organic Halides	NA	NA	< 0.0500	0.0210
Total Organic Nitrogen	0.2000	< 0.1000	0.1300	< 0.1000
METALS				
Aluminum	NA	NA	NA	NA
Antimony	NA	NA	NA	NA
Arsenic	< 0.2000	< 0.0100	< 0.0020	< 0.0020
Barium	0.0350	< 0.2000	0.0400	0.0400
Beryllium	NA	NA	NA	NA
Cadmium	< 0.0050	< 0.0050	< 0.0020	0.0050
Calcium	78.3000	76.0000	74.1000	81.2000
Chromium	< 0.0200	< 0.0100	< 0.0200	0.0190
Cobalt	NA	NA	NA	NA
Copper	< 0.0100	< 0.0250	< 0.0100	< 0.0100
Cyanides (soluble salts an	NA	NA	NA	NA
Hexavalent Chromium	NA	NA	NA	NA
Iron	0.0050	< 0.1000	0.0400	0.0670
Lead	< 0.0500	< 0.2000	0.0050	< 0.0020
Magnesium	27.5000	28.0000	25.9000	29.1000
Manganese	0.0930	0.0900	0.1000	0.0200
Mercury	< 0.0002	0.0009	< 0.0002	< 0.0002
Molybdenum	< 0.0200	< 0.0500	< 0.0200	< 0.0200
Nickel	< 0.0200	< 0.0400	< 0.0200	< 0.0200
Potassium	0.6700	< 5.0000	0.5770	0.6390
Selenium	< 0.2000	< 0.0050	< 0.0020	< 0.0020
Silicon	NA	NA	NA	NA
Silver	< 0.0100	< 0.0100	< 0.0100	< 0.0005
Sodium	3.8200	6.0000	3.9000	4.2000
Thallium	NA	NA	NA	NA
Vanadium	NA	NA	NA	NA
Zinc	NA	NA	NA	NA

*Data validation in progress

GROUNDWATER GENERAL CHEMICAL DATA

RI/FS DATA*

Results in parts per million (ppm).
Data presented by well id, sample number, and depth and sample date.
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CHEMICAL PARAMETERS	1029 03076 04-05-1988	1029 03354 07-20-1988	1029 03634 10-23-1988	1029 03852 01-22-1989
GENERAL CHEMISTRY				
Ammonia	0.1000	< 0.1000	< 0.1000	< 0.1000
Chloride	7.1000	1.5000	12.5000	2.0000
Fluoride	1.5000	1.1000	1.1000	1.3000
Hydrogen ion	NA	NA	NA	NA
Nitrates	< 5.0000	0.1730	< 0.1000	NA
Phenols	< 0.0100	< 0.0100	0.0300	< 0.0100
Phosporus (black, white, r	NA	NA	NA	NA
Phosphate as P	0.1000	NA	NA	NA
Sulfate	210.0000	124.0000	81.0000	140.0000
Total Kjeldahl Nitrogen	NA	NA	< 0.1000	0.1000
Total Organic Carbon	NA	NA	NA	NA
Total Organic Halides	NA	NA	< 0.0500	< 0.0100
Total Organic Nitrogen	0.8000	0.0240	< 0.1000	0.1000
METALS				
Aluminum	0.0410 B	NA	NA	NA
Antimony	< 0.0300	NA	NA	NA
Arsenic	< 0.0030 W	< 0.2000	< 0.0020	< 0.0020
Barium	0.1820 B	0.1590	0.1630	0.1500
Beryllium	< 0.0010	NA	NA	NA
Cadmium	< 0.0050	< 0.0020	< 0.0020	0.0080
Calcium	96.8000	95.2000	101.0000	95.8000
Chromium	< 0.0100	< 0.0200	< 0.0200	0.0220
Cobalt	< 0.0200	NA	NA	NA
Copper	0.0240 B	< 0.0100	< 0.0100	0.0140
Cyanides (soluble salts an	< 0.0200	NA	NA	NA
Hexavalent Chromium	NA	NA	NA	NA
Iron	0.0430 B	< 0.0050	0.1030	0.0400
Lead	< 0.0300 E	< 0.0500	0.0150	< 0.0020
Magnesium	43.9000	43.9000	44.4000	43.2000
Manganese	0.0560	0.0700	0.1260	0.0520
Mercury	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Molybdenum	0.0200	0.0300	< 0.0200	< 0.0200
Nickel	< 0.0200	< 0.0200	< 0.0200	0.0250
Potassium	1.1900 B	1.6500	3.6000	1.9400
Selenium	< 0.0040 W	< 0.2000	< 0.0020	0.0040
Silicon	NA	NA	NA	NA
Silver	< 0.0050	< 0.0100	< 0.0005	< 0.0005
Sodium	62.8000	31.9000	27.6000	32.2000
Thallium	< 0.0040 W	NA	NA	NA
Vanadium	< 0.0100	NA	NA	NA
Zinc	0.0420	NA	NA	NA

Data validation in progress

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GROUNDWATER GENERAL CHEMICAL DATA

RI/FS DATA*
Results in parts per million (ppm).
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CHEMICAL PARAMETERS	1032 03133 04-27-1988	1032 03851 01-22-1989
GENERAL CHEMISTRY		
Ammonia	< 0.1000	< 0.1000
Chloride	616.0000	310.0000
Fluoride	0.2800	0.2000
Hydrogen ion	NA	NA
Nitrates	0.1400	NA
Phenols	0.0200	< 0.0100
Phosporus (black, white, r	NA	NA
Phosphate as P	NA	NA
Sulfate	375.0000	280.0000
Total Kjeldahl Nitrogen	NA	0.2000
Total Organic Carbon	NA	NA
Total Organic Halides	NA	0.0240
Total Organic Nitrogen	0.1000	0.2000
METALS		
Aluminum	NA	NA
Antimony	NA	NA
Arsenic	< 0.2000	< 0.0020
Barium	0.0830	0.0760
Beryllium	NA	NA
Cadmium	< 0.0050	0.0080
Calcium	233.0000	215.0000
Chromium	< 0.0200	0.0380
Cobalt	NA	NA
Copper	< 0.0100	0.0190
Cyanides (soluble salts an	NA	NA
Hexavalent Chromium	NA	NA
Iron	< 0.0500	0.0850
Lead	< 0.0500	< 0.0020
Magnesium	68.2000	51.6000
Manganese	0.0130	0.0130
Mercury	< 0.0002	< 0.0002
Molybdenum	< 0.0200	< 0.0200
Nickel	< 0.0200	0.0240
Potassium	1.3000	1.4300
Selenium	< 0.2000	0.0160
Silicon	NA	NA
Silver	0.0300	< 0.0005
Sodium	282.0000	189.0000
Thallium	NA	NA
Vanadium	NA	NA
Zinc	NA	NA

*Data validation in progress

GROUNDWATER GENERAL CHEMICAL DATA

RI/FS DATA*
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CHEMICAL PARAMETERS	1033 03220 05-22-1988	1033 03567 08-24-1988	1033 03773 11-20-1988	1033 03961 03-10-1989
GENERAL CHEMISTRY				
Ammonia	< 0.5000	< 0.1000	< 0.1000	0.2000
Chloride	11.0000	29.5000	1.2500	9.2000
Fluoride	0.6300	0.6600	0.4800	0.4000
Hydrogen ion	NA	NA	NA	NA
Nitrates	0.1000	< 0.1000	0.1480	NA
Phenols	0.0200	0.0200	< 0.0100	< 0.0050
Phosporus (black, white, r	NA	NA	NA	NA
Phosphate as P	NA	NA	NA	NA
Sulfate	109.0000	75.0000	116.0000	97.0000
Total Kjeldahl Nitrogen	NA	NA	0.4900	0.3000
Total Organic Carbon	NA	NA	NA	NA
Total Organic Halides	NA	< 0.0500	< 0.0500	< 0.0500
Total Organic Nitrogen	< 0.5000	0.4000	0.4900	0.1000
METALS				
Aluminum	NA	NA	NA	NA
Antimony	NA	NA	NA	NA
Arsenic	< 0.0020	< 0.0020	< 0.0020	< 0.0030
Barium	0.0750	0.0930	0.0660	0.0570
Beryllium	NA	NA	NA	NA
Cadmium	< 0.0020	< 0.0020	< 0.0020	< 0.0050
Calcium	110.0000	120.0000	89.3000	100.0000
Chromium	< 0.0200	< 0.0200	< 0.0200	0.0300
Cobalt	NA	NA	NA	NA
Copper	0.0120	< 0.0100	< 0.0100	0.0100
Cyanides (soluble salts an	NA	NA	NA	NA
Hexavalent Chromium	NA	NA	NA	NA
Iron	0.0180	0.0070	0.1130	0.9400
Lead	< 0.0020	0.0020	< 0.0020	0.0020
Magnesium	43.8000	58.8000	35.3000	37.0000
Manganese	0.0510	0.2100	0.0280	0.0260
Mercury	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Molybdenum	0.0330	< 0.0200	< 0.0200	0.0100
Nickel	< 0.0200	0.0210	< 0.0200	< 0.0300
Potassium	0.5270	1.9000	7.6300	0.7500
Selenium	< 0.0020	< 0.0020	< 0.0020	< 0.0020
Silicon	NA	NA	NA	NA
Silver	< 0.0100	< 0.0100	< 0.0005	< 0.0100
Sodium	11.5000	11.4000	14.6000	24.0000
Thallium	NA	NA	NA	NA
Vanadium	NA	NA	NA	NA
Zinc	NA	NA	NA	NA

*Data validation in progress

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GROUNDWATER GENERAL CHEMICAL DATA

RI/FS DATA*
Results in parts per million (ppm).
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CHEMICAL PARAMETERS	1034 03122 04-25-1988	1034 03850 01-22-1989
GENERAL CHEMISTRY		
Ammonia	< 0.1000	< 0.1000
Chloride	4.6000	6.8000
Fluoride	0.4000	0.4000
Hydrogen ion	NA	NA
Nitrates	1.4000	NA
Phenols	0.0100	< 0.0100
Phosporus (black, white, r	NA	NA
Phosphate as P	NA	NA
Sulfate	197.0000	210.0000
Total Kjeldahl Nitrogen	NA	0.1000
Total Organic Carbon	NA	NA
Total Organic Halides	NA	0.0160
Total Organic Nitrogen	< 0.1000	0.1000
METALS		
Aluminum	NA	NA
Antimony	NA	NA
Arsenic	< 0.2000	< 0.0020
Barium	0.0380	0.0440
Beryllium	NA	NA
Cadmium	< 0.0050	0.0100
Calcium	118.0000	128.0000
Chromium	< 0.0200	0.0280
Cobalt	NA	NA
Copper	< 0.0100	0.0150
Cyanides (soluble salts an	NA	NA
Hexavalent Chromium	NA	NA
Iron	< 0.0050	0.0730
Lead	< 0.0500	< 0.0020
Magnesium	53.1000	57.3000
Manganese	0.1110	0.0090
Mercury	0.0004	< 0.0002
Molybdenum	< 0.0200	< 0.0200
Nickel	< 0.0200	0.0260
Potassium	1.5600	< 0.1000
Selenium	< 0.2000	0.0040
Silicon	NA	NA
Silver	< 0.0100	< 0.0005
Sodium	34.9000	45.5000
Thallium	NA	NA
Vanadium	NA	NA
Zinc	NA	NA

Data validation in progress

GROUNDWATER GENERAL CHEMICAL DATA

RI/FS DATA*

Results in parts per million (ppm).
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CHEMICAL PARAMETERS	2008 03193 05-17-1988	DUPLICATE 2008 03194 05-17-1988	2008 03417 08-09-1988	2008 03349 11-20-1988	DUPLICATE 2008 03724 11-20-1988
GENERAL CHEMISTRY					
Ammonia	0.0900	0.1100	< 0.3000	< 0.1000	< 0.1000
Chloride	31.0000	29.0000	32.0000	< 20.0000	31.3000
Fluoride	0.3000	0.3000	1.3000	0.2800	0.2700
Hydrogen ion	NA	NA	NA	NA	NA
Nitrates	0.5800	0.5800	2.3000	5.3900	4.6600
Phenols	0.0130	0.0160	< 0.0500	< 0.0100	< 0.0100
Phosporus (black, white, r	NA	NA	NA	NA	NA
Phosphate as P	0.0200	0.0200	NA	NA	NA
Sulfate	59.0000	57.0000	62.0000	68.3000	73.9000
Total Kjeldahl Nitrogen	0.0006	0.0003	< 15.0000	0.3800	0.2800
Total Organic Carbon	NA	NA	NA	NA	NA
Total Organic Halides	NA	NA	NA	< 0.0500	< 0.0500
Total Organic Nitrogen	NA	NA	< 15.0000	0.3800	0.2800
METALS					
Aluminum	0.2280	< 0.1000	NA	NA	NA
Antimony	< 0.0500	< 0.0500	NA	NA	NA
Arsenic	< 0.0050	< 0.0050	< 0.0100	< 0.0020	< 0.0020
Barium	0.0417 B	0.0401 B	< 0.2000	0.0410	0.0410
Beryllium	< 0.0050	< 0.0050	NA	NA	NA
Cadmium	< 0.0050	< 0.0050	< 0.0050	< 0.0020	< 0.0020
Calcium	96.3000	85.3000	92.0000	85.2000	83.4000
Chromium	< 0.0100	< 0.0100	< 0.0100	< 0.0200	< 0.0200
Cobalt	< 0.0100	< 0.0100	NA	NA	NA
Copper	< 0.0100	< 0.0100	< 0.0300	< 0.0100	< 0.0100
Cyanides (soluble salts an	< 0.0100	< 0.0100	NA	NA	NA
Hexavalent Chromium	< 0.0200	< 0.0200	NA	NA	NA
Iron	1.1200	0.1350	< 0.1000	0.0070	< 0.0050
Lead	< 0.0050	< 0.0050	< 0.0050	< 0.0020	0.0040
Magnesium	27.3000	23.8000	24.0000	21.9000	21.4000
Manganese	0.1050	0.0414	< 0.0200	0.0030	0.0020
Mercury	< 0.0002	< 0.0002	< 0.0003	< 0.0002	< 0.0002
Molybdenum	0.0400	< 0.0100	< 0.0500	< 0.0200	< 0.0200
Nickel	0.0300	< 0.0300	< 0.0400	< 0.0200	< 0.0200
Potassium	3.3900 B	3.1200 B	< 5.0000	2.5600	2.6000
Selenium	< 0.0050	< 0.0050	< 0.0050	< 0.0020	< 0.0020
Silicon	NA	NA	NA	NA	NA
Silver	< 0.0100	< 0.0100	< 0.0100	< 0.0005	< 0.0005
Sodium	17.2000	15.5000	16.0000	15.2000	14.1000
Thallium	< 0.0050	< 0.0050	NA	NA	NA
Vanadium	< 0.0100	< 0.0100	NA	NA	NA
Zinc	0.0317	0.0162 B	NA	NA	NA

*Data validation in progress

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GROUNDWATER GENERAL CHEMICAL DATA

RI/FS DATA*
Results in parts per million (ppm).
Data presented by well id, sample number, and depth and sample date.
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CHEMICAL PARAMETERS		2008 03923 02-23-1989
GENERAL CHEMISTRY		
Ammonia		0.2000
Chloride		28.0000
Fluoride		0.3000
Hydrogen ion		NA
Nitrates		NA
Phenols	<	0.0050
Phosporus (black, white, r		NA
Phosphate as P		NA
Sulfate		63.0000
Total Kjeldahl Nitrogen		0.3000
Total Organic Carbon		NA
Total Organic Halides	<	0.0100
Total Organic Nitrogen		0.1000
METALS		
Aluminum		NA
Antimony		NA
Arsenic		NA
Barium		NA
Beryllium		NA
Cadmium		NA
Calcium		NA
Chromium		NA
Cobalt		NA
Copper		NA
Cyanides (soluble salts an		NA
Hexavalent Chromium		NA
Iron		NA
Lead		NA
Magnesium		NA
Manganese		NA
Mercury		NA
Molybdenum		NA
Nickel		NA
Potassium		NA
Selenium		NA
Silicon		NA
Silver		NA
Sodium		NA
Thallium		NA
Vanadium		NA
Zinc		NA

*Data validation in progress

GROUNDWATER GENERAL CHEMICAL DATA

RI/FS DATA*
Results in parts per million (ppm).
Data presented by well id, sample number, and depth and sample date.
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CHEMICAL PARAMETERS	2009 03067 03-29-1988	2009 03383 07-27-1988	2009 03667 11-07-1988	2009 03866 01-31-1989
GENERAL CHEMISTRY				
Ammonia	< 0.1000	< 0.1000	< 0.1000	< 0.1000
Chloride	24.0000	23.0000	25.9000	24.0000
Fluoride	< 0.5000	0.8100	0.1500	0.1000
Hydrogen ion	7.4900	NA	NA	NA
Nitrates	< 5.0000	3.9000	0.0900	NA
Phenols	< 0.0100	< 0.0500	< 0.0100	0.0200
Phosporus (black, white, r	NA	NA	NA	NA
Phosphate as P	0.3000	NA	NA	NA
Sulfate	53.0000	60.0000	131.0000	55.6000
Total Kjeldahl Nitrogen	NA	NA	0.3000	0.5680
Total Organic Carbon	NA	NA	NA	NA
Total Organic Halides	NA	NA	< 0.0500	< 0.0100
Total Organic Nitrogen	0.2000	< 0.1000	0.3000	0.5680
METALS				
Aluminum	NA	NA	NA	NA
Antimony	NA	NA	NA	NA
Arsenic	< 0.0300	< 0.0100	< 0.0020	< 0.0020
Barium	0.0450	< 0.2000	0.0300	0.0390
Beryllium	NA	NA	NA	NA
Cadmium	< 0.0050	< 0.0050	< 0.0020	< 0.0020
Calcium	80.7000	80.0000	75.0000	85.1000
Chromium	< 0.0100	< 0.0100	< 0.0200	0.0250
Cobalt	NA	NA	NA	NA
Copper	< 0.0100	< 0.0250	< 0.0100	0.0170
Cyanides (soluble salts an	NA	NA	NA	NA
Hexavalent Chromium	< 0.0200	NA	NA	NA
Iron	0.0900	< 0.1000	0.0400	0.0800
Lead	< 0.0300	< 0.2000	0.0040	< 0.0020
Magnesium	22.3000	21.0000	18.4000	21.7000
Manganese	0.0140	< 0.0150	0.0020	0.0090
Mercury	< 0.0010	0.0008	< 0.0002	0.0058
Molybdenum	< 0.0100	< 0.0500	< 0.0200	< 0.0200
Nickel	< 0.0200	< 0.0400	< 0.0200	< 0.0200
Potassium	3.0000	< 5.0000	2.0700	2.4200
Selenium	< 0.0100	< 0.0050	< 0.0020	0.0040
Silicon	NA	NA	NA	NA
Silver	< 0.0050	< 0.0100	< 0.0100	< 0.0005
Sodium	12.3000	11.0000	11.1000	12.5000
Thallium	NA	NA	NA	NA
Vanadium	NA	NA	NA	NA
Zinc	NA	NA	NA	NA

*Data validation in progress

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GROUNDWATER GENERAL CHEMICAL DATA

RI/FS DATA*
Results in parts per million (ppm).
Data presented by well id, sample number, and depth and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	2018 03069 03-29-1988	2018 03381 07-27-1988	2018 03665 11-07-1988	2018 03864 01-23-1989
GENERAL CHEMISTRY				
Ammonia	< 0.1000	< 0.1000	< 0.1000	0.1210
Chloride	6.4000	7.9000	7.2000	3.0000
Fluoride	0.1400	1.0000	0.1800	0.1200
Hydrogen ion	NA	NA	NA	NA
Nitrates	0.1000	2.1000	0.3440	NA
Phenols	< 0.0100	< 0.0500	< 0.0100	0.2200
Phosporus (black, white, r	NA	NA	NA	NA
Phosphate as P	NA	NA	NA	NA
Sulfate	4.0000	46.0000	102.0000	79.7000
Total Kjeldahl Nitrogen	NA	NA	0.4500	0.7450
Total Organic Carbon	NA	NA	NA	NA
Total Organic Halides	NA	NA	< 0.0500	0.0100
Total Organic Nitrogen	< 0.1000	< 0.1000	0.4500	0.6240
METALS				
Aluminum	NA	NA	NA	NA
Antimony	NA	NA	NA	NA
Arsenic	< 0.2000	< 0.0100	< 0.0020	< 0.0020
Barium	< 0.0500	< 0.2000	0.0300	0.0490
Beryllium	NA	NA	NA	NA
Cadmium	< 0.0050	< 0.0050	0.0200	0.0060
Calcium	91.7000	100.0000	93.8000	108.0000
Chromium	< 0.0200	< 0.0100	< 0.0200	0.0240
Cobalt	NA	NA	NA	NA
Copper	< 0.0100	< 0.0250	< 0.0100	0.0120
Cyanides (soluble salts an	NA	NA	NA	NA
Hexavalent Chromium	0.0200	NA	NA	NA
Iron	0.1000	< 0.1000	< 0.0050	0.1260
Lead	< 0.0500	< 0.2000	0.0150	< 0.0020
Magnesium	23.0800	26.0000	24.2000	27.9000
Manganese	< 0.0200	< 0.0150	0.0070	0.0120
Mercury	< 0.0002	0.0009	< 0.0002	0.0004
Molybdenum	< 0.0200	< 0.0500	< 0.0200	< 0.0200
Nickel	< 0.0200	< 0.0400	< 0.0200	< 0.0200
Potassium	1.1800	< 5.0000	1.5400	1.2200
Selenium	< 0.2000	0.0050	< 0.0020	< 0.0020
Silicon	NA	NA	NA	NA
Silver	< 0.0200	< 0.0100	< 0.0100	< 0.0005
Sodium	5.9000	6.0000	5.6000	5.3400
Thallium	NA	NA	NA	NA
Vanadium	NA	NA	NA	NA
Zinc	NA	NA	NA	NA

*Data validation in progress

GROUNDWATER GENERAL CHEMICAL DATA

RI/FS DATA*
Results in parts per million (ppm).
Data presented by well id, sample number, and depth and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	2034 03223 05-23-1988	DUPLICATE 2034 03224 05-23-1988	2034 03367 07-24-1988	2034 03646 10-24-1988	2034 03835 01-19-1989
GENERAL CHEMISTRY					
Ammonia	< 0.5000	< 0.5000	< 0.0200	< 0.1000	< 0.1000
Chloride	24.0000	23.6000	51.0000	30.0000	21.0000
Fluoride	0.1300	0.1100	0.2600	0.3200	0.1600
Hydrogen ion	NA	NA	NA	NA	NA
Nitrates	3.9600	3.2800	2.0200	11.8000	NA
Phenols	< 0.0500	0.0500	< 0.0020	< 0.0100	< 0.0100
Phosporus (black, white, r	NA	NA	NA	NA	NA
Phosphate as P	NA	NA	NA	NA	NA
Sulfate	63.9000	63.9000	62.0000	39.0000	59.5000
Total Kjeldahl Nitrogen	< 0.5000	1.5500	NA	0.2500	0.4730
Total Organic Carbon	NA	NA	NA	NA	NA
Total Organic Halides	NA	NA	NA	< 0.0500	0.0200
Total Organic Nitrogen	< 0.5000	1.5500	< 0.0500	0.2500	0.4730
METALS					
Aluminum	0.0761 B	0.1170 B	NA	NA	NA
Antimony	< 0.0467	< 0.0467	NA	NA	NA
Arsenic	< 0.0019	< 0.0019	< 0.0100	< 0.0020	< 0.0020
Barium	0.0405 B	0.0409 B	< 0.5000	0.0410	0.0430
Beryllium	< 0.0024	< 0.0024	NA	NA	NA
Cadmium	< 0.0007	< 0.0007	< 0.0050	0.0020	0.0040
Calcium	98.7000	98.9000	99.0000	87.7000	88.0000
Chromium	< 0.0017	< 0.0017	< 0.0100	< 0.0200	0.0220
Cobalt	< 0.0052	< 0.0052	NA	NA	NA
Copper	< 0.0067	< 0.0067	< 0.0100	< 0.0100	0.0120
Cyanides (soluble salts an	< 0.0200	< 0.0200	NA	NA	NA
Hexavalent Chromium	NA	NA	NA	NA	NA
Iron	0.2140	0.3190	< 0.1000	0.2610	0.0470
Lead	< 0.0021 WN	< 0.0021 WN	< 0.0050	0.0240	< 0.0020
Magnesium	234.0000	23.4000	25.0000	22.2000	22.4000
Manganese	0.0250	0.0286	< 0.0100	0.0260	0.0060
Mercury	< 0.0003	< 0.0003	< 0.0002	< 0.0002	< 0.0002
Molybdenum	< 0.0333	< 0.0333	< 0.0500	< 0.0200	< 0.0200
Nickel	< 0.0123	< 0.0123	< 0.0300	< 0.0200	0.0210
Potassium	2.8300 B	2.7700 B	2.5000	2.5800	2.8400
Selenium	0.0019 BWN	< 0.0018 WN	< 0.0050	< 0.0020	< 0.0020
Silicon	NA	NA	NA	NA	NA
Silver	< 0.0043	< 0.0043	< 0.0100	< 0.0005	< 0.0005
Sodium	12.1000	12.1000	18.0000	12.6000	12.8000
Thallium	< 0.0041 WN	< 0.0041 WN	NA	NA	NA
Vanadium	< 0.0034	< 0.0034	NA	NA	NA
Zinc	0.0119 B	0.0194 B	NA	NA	NA

*Data validation in progress

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GROUNDWATER GENERAL CHEMICAL DATA

RI/FS DATA*
Results in parts per million (ppm).
Data presented by well id, sample number, and depth and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	3005 03199 05-18-1988	3005 03513 08-19-1988	DUPLICATE 3005 03514 08-19-1988	3005 03464 12-02-1988	DUPLICATE 3005 03758 12-02-1988
GENERAL CHEMISTRY					
Ammonia	< 0.1000	< 0.1000	< 0.1000	< 0.1000	< 0.1000
Chloride	333.0000	19.5000	19.5000	32.0000	22.4000
Fluoride	0.3000	0.2500	0.2300	0.2000	0.1850
Hydrogen ion	NA	NA	NA	NA	NA
Nitrates	0.1000	0.1300	0.1500	< 0.1000	< 0.1000
Phenols	< 0.0100	< 0.0100	< 0.0100	< 0.0100	< 0.0100
Phosporus (black, white, r	NA	NA	NA	NA	NA
Phosphate as P	NA	NA	NA	NA	NA
Sulfate	76.0000	50.0000	50.0000	54.4000	50.3000
Total Kjeldahl Nitrogen	NA	NA	NA	< 0.1000	< 0.1000
Total Organic Carbon	NA	NA	NA	NA	NA
Total Organic Halides	NA	< 0.0500	< 0.0500	< 0.0500	< 0.0500
Total Organic Nitrogen	< 0.1000	< 0.1000	< 0.1000	< 0.1000	< 0.1000
METALS					
Aluminum	NA	NA	NA	NA	NA
Antimony	NA	NA	NA	NA	NA
Arsenic	< 0.2000	< 0.0020	< 0.0020	< 0.0020	< 0.0020
Barium	0.0700	0.0600	0.0590	0.0810	0.0610
Beryllium	NA	NA	NA	NA	NA
Cadmium	< 0.0050	< 0.0020	< 0.0020	0.0100	< 0.0020
Calcium	102.0000	96.0000	94.7000	100.0000	102.0000
Chromium	< 0.0200	< 0.0200	< 0.0200	< 0.0200	< 0.0200
Cobalt	NA	NA	NA	NA	NA
Copper	< 0.0100	< 0.0100	< 0.0100	0.0170	< 0.0100
Cyanides (soluble salts an	NA	NA	NA	NA	NA
Hexavalent Chromium	NA	NA	NA	NA	NA
Iron	2.0800	1.8000	1.7000	2.2000	2.0700
Lead	< 0.0500	< 0.0020	< 0.0020	0.0030	< 0.0020
Magnesium	0.5000	25.9000	25.6000	26.2000	25.8000
Manganese	0.5130	0.5200	0.5100	0.5840	0.5720
Mercury	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002
Molybdenum	< 0.0200	< 0.0200	< 0.0200	< 0.0200	< 0.0200
Nickel	< 0.0200	< 0.0200	< 0.0200	< 0.0200	< 0.0200
Potassium	2.9700	2.9000	3.8000	2.6100	2.5900
Selenium	< 0.2000	< 0.0020	< 0.0020	< 0.0020	< 0.0020
Silicon	NA	NA	NA	NA	NA
Silver	< 0.0100	< 0.0100	< 0.0100	< 0.0005	< 0.0005
Sodium	8.6700	8.7000	8.6000	9.1300	9.3100
Thallium	NA	NA	NA	NA	NA
Vanadium	NA	NA	NA	NA	NA
Zinc	NA	NA	NA	NA	NA

*Data validation in progress

GROUNDWATER GENERAL CHEMICAL DATA

RI/FS DATA*
Results in parts per million (ppm).
Data presented by well id, sample number, and depth and sample date.
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CHEMICAL PARAMETERS		3005 03956 03-13-1989
GENERAL CHEMISTRY		
Ammonia		0.2000
Chloride		18.0000
Fluoride		0.2000
Hydrogen ion		NA
Nitrates		NA
Phenols		0.0080
Phosporus (black, white, r		NA
Phosphate as P		NA
Sulfate		66.0000
Total Kjeldahl Nitrogen		0.3000
Total Organic Carbon		NA
Total Organic Halides	<	0.0500
Total Organic Nitrogen		0.1000
METALS		
Aluminum		NA
Antimony		NA
Arsenic	<	0.0030
Barium		0.0660
Beryllium		NA
Cadmium	<	0.0050
Calcium		110.0000
Chromium		0.0300
Cobalt		NA
Copper	<	0.0100
Cyanides (soluble salts an		NA
Hexavalent Chromium		NA
Iron		2.7000
Lead	<	0.0020
Magnesium		26.0000
Manganese		0.5100
Mercury	<	0.0002
Molybdenum		0.0100
Nickel	<	0.0300
Potassium		2.6000
Selenium	<	0.0050
Silicon		NA
Silver	<	0.0100
Sodium		9.4000
Thallium		NA
Vanadium		NA
Zinc		NA

*Data validation in progress

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GROUNDWATER GENERAL CHEMICAL DATA

RI/FS DATA*
Results in parts per million (ppm).
Data presented by well id, sample number, and depth and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	3009 03068 03-29-1988	3009 03439 08-05-1988	3009 03699 11-08-1988	3009 03865 01-31-1989
GENERAL CHEMISTRY				
Ammonia	4.1000	< 0.1000	0.1000	0.1130
Chloride	9.9000	20.0000	31.2000	20.0000
Fluoride	< 0.5000	0.2400	< 0.1000	0.1100
Hydrogen ion	7.5800	NA	NA	NA
Nitrates	< 5.0000	1.8000	0.1160	NA
Phenols	0.0100	0.0400	< 0.0100	0.0200
Phosporus (black, white, r	NA	NA	NA	NA
Phosphate as P	0.2000	NA	NA	NA
Sulfate	8.0000	49.8000	126.0000	53.8000
Total Kjeldahl Nitrogen	NA	NA	0.3200	0.2750
Total Organic Carbon	NA	NA	NA	NA
Total Organic Halides	NA	NA	< 0.0500	0.0160
Total Organic Nitrogen	1.2000	< 0.1000	0.2200	0.1620
METALS				
Aluminum	NA	NA	NA	NA
Antimony	NA	NA	NA	NA
Arsenic	< 0.0300	< 0.0100	< 0.0020	< 0.0020
Barium	0.0160	< 0.2000	0.0400	0.0500
Beryllium	NA	NA	NA	NA
Cadmium	< 0.0050	< 0.0050	0.0020	0.0020
Calcium	34.4000	81.0000	73.8000	84.4000
Chromium	< 0.0100	< 0.0100	< 0.0200	0.0290
Cobalt	NA	NA	NA	NA
Copper	0.0900	< 0.0300	< 0.0100	0.0180
Cyanides (soluble salts an	NA	NA	NA	NA
Hexavalent Chromium	< 0.0200	NA	NA	NA
Iron	19.2000	0.2000	0.3000	0.2760
Lead	< 0.0300	< 0.0050	< 0.0020	< 0.0020
Magnesium	10.2000	23.0000	20.4000	23.6000
Manganese	0.4700	0.0800	0.0700	0.0770
Mercury	< 0.0010	< 0.0002	< 0.0002	< 0.0002
Molybdenum	< 0.0100	< 0.0500	< 0.0200	< 0.0200
Nickel	< 0.0200	< 0.0400	< 0.0200	< 0.0200
Potassium	6.0000	< 5.0000	1.9200	2.3400
Selenium	< 0.0100	< 0.0050	< 0.0020	< 0.0020
Silicon	NA	NA	NA	NA
Silver	< 0.0050	< 0.0100	< 0.0100	< 0.0005
Sodium	5.4000	12.0000	10.5000	11.7000
Thallium	NA	NA	NA	NA
Vanadium	NA	NA	NA	NA
Zinc	NA	NA	NA	NA

*Data validation in progress

GROUNDWATER GENERAL CHEMICAL DATA

RI/FS DATA*
Results in parts per million (ppm).
Data presented by well id, sample number, and depth and sample date.
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CHEMICAL PARAMETERS	3018 03072 03-30-1988	3018 03380 07-27-1988	3018 03330 11-07-1988	DUPLICATE 3018 03664 11-07-1988	3018 03863 01-23-1989
GENERAL CHEMISTRY					
Ammonia	< 0.1000	< 0.1000	< 0.1000	< 0.1000	< 0.1000
Chloride	13.0000	13.0000	16.7000	16.5000	12.0000
Fluoride	0.5000	0.9800	0.2100	0.2100	0.1700
Hydrogen ion	7.4800	NA	NA	NA	NA
Nitrates	< 5.0000	< 0.1000	0.0120	0.0130	NA
Phenols	< 0.0100	< 0.0500	< 0.0100	< 0.0100	0.0300
Phosporus (black, white, r	NA	NA	NA	NA	NA
Phosphate as P	0.3300	NA	NA	NA	NA
Sulfate	73.0000	76.0000	7.9800	139.0000	64.7000
Total Kjeldahl Nitrogen	NA	NA	< 0.1000	< 0.1000	0.2050
Total Organic Carbon	NA	NA	NA	NA	NA
Total Organic Halides	NA	NA	< 0.0500	< 0.0500	0.0170
Total Organic Nitrogen	< 0.1000	< 0.1000	< 0.1000	< 0.1000	0.2050
METALS					
Aluminum	NA	NA	NA	NA	NA
Antimony	NA	NA	NA	NA	NA
Arsenic	< 0.0300	< 0.0100	< 0.0020	< 0.0020	< 0.0020
Barium	0.0620	< 0.2000	0.0700	0.0600	0.0610
Beryllium	NA	NA	NA	NA	NA
Cadmium	< 0.0050	< 0.0050	0.0060	< 0.0020	0.0050
Calcium	77.2000	82.0000	74.8000	76.8000	83.8000
Chromium	< 0.0100	< 0.0100	< 0.0200	< 0.0200	0.0200
Cobalt	NA	NA	NA	NA	NA
Copper	< 0.0100	< 0.0250	0.0100	< 0.0100	0.0100
Cyanides (soluble salts an	NA	NA	NA	NA	NA
Hexavalent Chromium	< 0.0200	NA	NA	NA	NA
Iron	0.2900	< 0.1000	0.0200	0.0600	0.0430
Lead	< 0.0300	< 0.2000	0.0090	0.0030	< 0.0020
Magnesium	29.4000	32.0000	27.0000	27.5000	30.6000
Manganese	0.0140	< 0.0150	0.0200	0.0080	0.0060
Mercury	< 0.0010	0.0009	< 0.0002	< 0.0002	0.0004
Molybdenum	< 0.0100	< 0.0500	< 0.0200	< 0.0200	< 0.0200
Nickel	< 0.0200	< 0.0400	< 0.0200	< 0.0200	< 0.0200
Potassium	< 1.0000	< 5.0000	0.8000	0.7470	0.4790
Selenium	< 0.0100	< 0.0050	< 0.0020	< 0.0020	< 0.0020
Silicon	NA	NA	NA	NA	NA
Silver	< 0.0050	< 0.0100	< 0.0100	< 0.0100	< 0.0005
Sodium	7.0000	9.0000	7.9000	8.2000	7.8200
Thallium	NA	NA	NA	NA	NA
Vanadium	NA	NA	NA	NA	NA
Zinc	NA	NA	NA	NA	NA

*Data validation in progress

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GROUNDWATER GENERAL CHEMICAL DATA

RI/FS DATA*
Results in parts per million (ppm).
Data presented by well id, sample number, and depth and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	3034 03116 04-24-1988	3034 03366 07-24-1988	3034 03645 10-24-1988	3034 03836 01-19-1989
GENERAL CHEMISTRY				
Ammonia	0.1000	0.0400	< 0.1000	< 0.1000
Chloride	23.9000	35.0000	21.0000	19.0000
Fluoride	0.4300	0.2000	0.2300	0.1200
Hydrogen ion	NA	NA	NA	NA
Nitrates	1.1000	2.1100	9.9800	NA
Phenols	< 0.0100	0.0090	0.0100	0.0960
Phosporus (black, white, r	NA	NA	NA	NA
Phosphate as P	NA	NA	NA	NA
Sulfate	70.0000	70.0000	27.0000	50.7000
Total Kjeldahl Nitrogen	NA	NA	0.1000	0.2910
Total Organic Carbon	NA	NA	NA	NA
Total Organic Halides	NA	NA	< 0.0500	0.0100
Total Organic Nitrogen	0.3000	< 0.0500	0.1000	0.2910
METALS				
Aluminum	NA	NA	NA	NA
Antimony	NA	NA	NA	NA
Arsenic	< 0.2000	< 0.0100	< 0.0020	< 0.0020
Barium	0.0060	< 0.5000	0.0390	0.0450
Beryllium	NA	NA	NA	NA
Cadmium	< 0.0050	0.0320	< 0.0020	0.0040
Calcium	74.4000	92.0000	83.9000	90.1000
Chromium	< 0.0200	< 0.0100	< 0.0200	0.0230
Cobalt	NA	NA	NA	NA
Copper	< 0.0100	< 0.0100	< 0.0100	0.0110
Cyanides (soluble salts an	NA	NA	NA	NA
Hexavalent Chromium	NA	NA	NA	NA
Iron	< 0.0050	< 0.1000	< 0.0050	0.0710
Lead	< 0.0500	< 0.0050	0.0130	< 0.0020
Magnesium	23.7000	24.0000	21.8000	23.5000
Manganese	0.0410	0.0400	0.0290	0.0360
Mercury	0.0008	< 0.0002	< 0.0002	< 0.0002
Molybdenum	< 0.0200	< 0.0500	< 0.0200	< 0.0200
Nickel	< 0.0200	< 0.0300	< 0.0200	0.0340
Potassium	3.2000	2.4000	2.2000	2.5300
Selenium	< 0.2000	< 0.0050	< 0.0020	< 0.0020
Silicon	NA	NA	NA	NA
Silver	0.0240	< 0.0100	< 0.0005	< 0.0005
Sodium	29.6000	16.0000	10.6000	11.3000
Thallium	NA	NA	NA	NA
Vanadium	NA	NA	NA	NA
Zinc	NA	NA	NA	NA

*Data validation in progress

GROUNDWATER
HAZARDOUS SUBSTANCE LIST RESULTS
RI/FS DATA*

Results in parts per million (ppm).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	1029 03076 04-05-1988	1029 04061 03-31-1989	2008 03193 05-17-1988	2008 03194 05-17-1988
ORGANOPHOSPOROUS PESTICIDES				
Azinphos-methyl \ Guthion	NA	< 0.0005	< 0.0050	< 0.0050
Demeton \ Systox	NA	< 0.0004	< 0.0010	< 0.0010
Diazinon \ Spectracide	NA	< 0.0002	< 0.0005	< 0.0005
Disulfoton	NA	< 0.0002	< 0.0005	< 0.0005
Ethion \ Bladan	NA	< 0.0002	< 0.0002	< 0.0002
Malathion \ Sumitox	NA	< 0.0002	< 0.0010	< 0.0010
Methyl parathion \ Parathion	NA	< 0.0002	NA	NA
Methyl parathion \ Parathion	NA	NA	< 0.0010	NA
Methyl parathion \ Parathion	NA	NA	NA	< 0.0010
Parathion \ Parathion, ethyl	NA	< 0.0002	< 0.0005	< 0.0005
PESTICIDES				
4,4'-DDD	< 0.0001	NA	< 0.0001	< 0.0001
4,4'-DDE	< 0.0001	NA	< 0.0001	< 0.0001
4,4'-DDT	< 0.0001	NA	< 0.0001	< 0.0001
Aldrin	< 0.0000	NA	< 0.0000	< 0.0000
Dieldrin	< 0.0001	NA	< 0.0001	< 0.0001
Endosulfan sulfate	< 0.0001	NA	< 0.0001	< 0.0001
Endosulfan-I	< 0.0000	NA	< 0.0000	< 0.0000
Endosulfan-II	< 0.0001	NA	< 0.0001	< 0.0001
Endrin	< 0.0001	NA	< 0.0001	< 0.0001
Endrin ketone	< 0.0001	NA	< 0.0001	< 0.0001
Heptachlor	< 0.0000	NA	< 0.0000	< 0.0000
Heptachlor epoxide	< 0.0000	NA	< 0.0000	< 0.0000
Lindane \ gamma-BHC \ Hexach	< 0.0000	NA	NA	NA
Lindane \ gamma-BHC \ Hexach	NA	NA	< 0.0000	NA
Lindane \ gamma-BHC \ Hexach	NA	NA	NA	< 0.0000
Methoxychlor	< 0.0005	NA	< 0.0005	< 0.0005
PCB-1016	< 0.0005	NA	< 0.0005	< 0.0005
PCB-1221	< 0.0005	NA	< 0.0005	< 0.0005
PCB-1232	< 0.0005	NA	< 0.0005	< 0.0005
PCB-1242	< 0.0005	NA	< 0.0005	< 0.0005
PCB-1248	< 0.0005	NA	< 0.0005	< 0.0005
PCB-1254	< 0.0010	NA	< 0.0010	< 0.0010
PCB-1260	< 0.0010	NA	< 0.0010	< 0.0010
Toxaphene	< 0.0010	NA	< 0.0010	< 0.0010
alpha-BHC	< 0.0000	NA	< 0.0000	< 0.0000
alpha-Chlordane	< 0.0005	NA	< 0.0005	< 0.0005

*Data validation in progress

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GROUNDWATER
HAZARDOUS SUBSTANCE LIST RESULTS
RI/FS DATA*

Results in parts per million (ppm).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	1029 03076 04-05-1988	1029 04061 03-31-1989	2008 03193 05-17-1988	2008 03194 05-17-1988
beta-BHC	< 0.0000	NA	< 0.0000	< 0.0000
delta-BHC	< 0.0000	NA	< 0.0000	< 0.0000
gamma-Chlordane	< 0.0005	NA	< 0.0005	< 0.0005
SEMI-VOLATILE ORGANICS				
1,2,4-Trichlorobenzene	< 0.0100	NA	< 0.0100	< 0.0100
1,2-Dichlorobenzene	< 0.0100	NA	< 0.0100	< 0.0100
1,3-Dichlorobenzene	< 0.0100	NA	< 0.0100	< 0.0100
1,4-Dichlorobenzene	< 0.0100	NA	< 0.0100	< 0.0100
2,4,5-Trichlorophenol	< 0.0500	NA	< 0.0500	< 0.0500
2,4,6-Trichlorophenol	< 0.0100	NA	< 0.0100	< 0.0100
2,4-Dichlorophenol	< 0.0100	NA	< 0.0100	< 0.0100
2,4-Dimethylphenol	< 0.0100	NA	< 0.0100	< 0.0100
2,4-Dinitrophenol	< 0.0500	NA	< 0.0500	< 0.0500
2,4-Dinitrotoluene	< 0.0100	NA	< 0.0100	< 0.0100
2,6-Dinitrotoluene	< 0.0100	NA	< 0.0100	< 0.0100
2-Chloronaphthalene	< 0.0100	NA	< 0.0100	< 0.0100
2-Chlorophenol	< 0.0100	NA	< 0.0100	< 0.0100
2-Methylnaphthalene	< 0.0100	NA	< 0.0100	< 0.0100
2-Nitroaniline	< 0.0500	NA	< 0.0500	< 0.0500
2-Nitrophenol	< 0.0100	NA	< 0.0100	< 0.0100
3,3'-Dichlorobenzidine	< 0.0200	NA	< 0.0200	< 0.0200
3-Nitroaniline	< 0.0500	NA	< 0.0500	< 0.0500
4-Bromophenyl phenyl ether	< 0.0100	NA	< 0.0100	< 0.0100
4-Chloro-3-methylphenol	< 0.0100	NA	< 0.0100	< 0.0100
4-Chlorophenylphenyl ether	< 0.0100	NA	< 0.0100	< 0.0100
4-Nitrophenol	< 0.0500	NA	< 0.0500	< 0.0500
Acenaphthene	< 0.0100	NA	< 0.0100	< 0.0100
Acenaphthylene	< 0.0100	NA	< 0.0100	< 0.0100
Anthracene	< 0.0100	NA	< 0.0100	< 0.0100
Benzenamine, 4-chloro-	< 0.0100	NA	< 0.0100	< 0.0100
Benzo(a)anthracene	< 0.0100	NA	< 0.0100	< 0.0100
Benzo(a)pyrene	< 0.0100	NA	< 0.0100	< 0.0100
Benzo(b)fluoranthene	< 0.0100	NA	< 0.0100	< 0.0100
Benzo(ghi)perylene	< 0.0100	NA	< 0.0100	< 0.0100
Benzo(k)fluoranthene	< 0.0100	NA	< 0.0100	< 0.0100
Benzoic acid	< 0.0500	NA	< 0.0500	< 0.0500
Benzyl alcohol	< 0.0100	NA	< 0.0100	< 0.0100
Butyl benzyl phthalate	< 0.0100	NA	< 0.0100	< 0.0100
Chrysene	< 0.0100	NA	< 0.0100	< 0.0100
Di-n-butyl phthalate \ dibut	< 0.0100	NA	NA	NA
Di-n-octyl phthalate	< 0.0100	NA	< 0.0100	< 0.0100

*Data validation in progress

GROUNDWATER
HAZARDOUS SUBSTANCE LIST RESULTS
RI/FS DATA*

Results in parts per million (ppm).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	1029 03076 04-05-1988	1029 04061 03-31-1989	2008 03193 05-17-1988	2008 03194 05-17-1988
Di-n-propylnitrosamine	< 0.0100	NA	< 0.0100	< 0.0100
Dibenzo(a,h)anthracene	< 0.0100	NA	< 0.0100	< 0.0100
Dibenzofuran	< 0.0100	NA	< 0.0100	< 0.0100
Diethyl phthalate	< 0.0100	NA	< 0.0100	< 0.0100
Dimethyl phthalate	< 0.0100	NA	< 0.0100	< 0.0100
Di-n-butyl phthalate \ dibut	NA	NA	0.0040 JB	NA
Di-n-butyl phthalate \ dibut	NA	NA	NA	0.0080 JB
Fluoranthene	< 0.0100	NA	< 0.0100	< 0.0100
Fluorene	< 0.0100	NA	< 0.0100	< 0.0100
Hexachlorobenzene	< 0.0100	NA	< 0.0100	< 0.0100
Hexachlorobutadiene	< 0.0100	NA	< 0.0100	< 0.0100
Hexachlorocyclopentadiene \	< 0.0100	NA	NA	NA
Hexachloroethane	< 0.0100	NA	< 0.0100	< 0.0100
Hexachlorocyclopentadiene \	NA	NA	< 0.0100	NA
Hexachlorocyclopentadiene \	NA	NA	NA	< 0.0100
Indeno(1,2,3-cd)pyrene	< 0.0100	NA	< 0.0100	< 0.0100
Isophorone	< 0.0100	NA	< 0.0100	< 0.0100
N-Nitrosodiphenylamine	< 0.0100	NA	< 0.0100	< 0.0100
Naphthalene	< 0.0100	NA	< 0.0100	< 0.0100
Nitrobenzene	< 0.0100	NA	< 0.0100	< 0.0100
Pentachlorophenol	< 0.0500	NA	< 0.0500	< 0.0500
Phenanthrene	< 0.0100	NA	< 0.0100	< 0.0100
Phenol	< 0.0100	NA	< 0.0100	0.0020 J
Phenol, 2-methyl-4,6-dinitro	< 0.0500	NA	NA	NA
Pyrene	< 0.0100	NA	< 0.0100	< 0.0100
Phenol, 2-methyl-4,6-dinitro	NA	NA	< 0.0500	NA
Phenol, 2-methyl-4,6-dinitro	NA	NA	NA	< 0.0500
bis(2-Chloroethoxy)methane	< 0.0100	NA	< 0.0100	< 0.0100
bis(2-Chloroethyl) ether	< 0.0100	NA	< 0.0100	< 0.0100
bis(2-Chloroisopropyl) ether	< 0.0100	NA	< 0.0100	< 0.0100
bis(2-Ethylhexyl) phthalate	< 0.0100	NA	0.0500 B	0.0410 B
o-Cresol	< 0.0100	NA	< 0.0100	< 0.0100
p-Cresol	< 0.0100	NA	< 0.0100	< 0.0100
p-Nitroaniline	< 0.0500	NA	< 0.0500	< 0.0500
VOLATILE ORGANICS				
1,1,1-Trichloroethane	< 0.0050	NA	< 0.0050	NA
1,1,2,2-Tetrachloroethane	< 0.0050	NA	< 0.0050	NA
1,1,2-Trichloroethane	< 0.0050	NA	< 0.0050	NA
1,1-Dichloroethane	< 0.0050	NA	< 0.0050	NA
1,1-Dichloroethene	< 0.0050	NA	< 0.0050	NA
1,2-Dichloroethane	< 0.0050	NA	< 0.0050	NA

*Data validation in progress

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GROUNDWATER
HAZARDOUS SUBSTANCE LIST RESULTS
RI/FS DATA*

Results in parts per million (ppm).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	1029 03076 04-05-1988	1029 04061 03-31-1989	2008 03193 05-17-1988	2008 03194 05-17-1988
1,2-Dichloroethylene	< 0.0050	NA	< 0.0050	NA
1,2-Dichloropropane	< 0.0050	NA	< 0.0050	NA
2-Butanone	< 0.0100	NA	< 0.0100	NA
2-Hexanone	< 0.0100	NA	< 0.0100	NA
2-Propanone	< 0.0100	NA	< 0.0100	NA
4-Methyl-2-pentanone	< 0.0100	NA	< 0.0100	NA
Benzene	< 0.0050	NA	< 0.0050	NA
Bromodichloromethane	< 0.0050	NA	< 0.0050	NA
Bromomethane	< 0.0100	NA	< 0.0100	NA
Carbon disulfide	< 0.0050	NA	< 0.0050	NA
Chlorobenzene	< 0.0050	NA	< 0.0050	NA
Chloroethane	< 0.0100	NA	< 0.0100	NA
Chloroform	< 0.0050	NA	< 0.0050	NA
Chloromethane	< 0.0100	NA	< 0.0100	NA
Dibromochloromethane	< 0.0050	NA	< 0.0050	NA
Ethylbenzene	< 0.0050	NA	< 0.0050	NA
Methylene chloride	< 0.0050	NA	0.0060 B	NA
Styrene	< 0.0050	NA	< 0.0050	NA
Tetrachlorethene	< 0.0050	NA	< 0.0050	NA
Tetrachloromethane	< 0.0050	NA	< 0.0050	NA
Toluene	< 0.0050	NA	< 0.0050	NA
Total xylenes	< 0.0050	NA	< 0.0050	NA
Tribromomethane	< 0.0050	NA	< 0.0050	NA
Trichloroethene	< 0.0050	NA	< 0.0050	NA
Vinyl acetate	< 0.0100	NA	< 0.0100	NA
Vinyl chloride	< 0.0100	NA	< 0.0100	NA
cis-1,3-Dichloropropene	< 0.0050	NA	< 0.0050	NA
trans-1,3-Dichloropropene	< 0.0050	NA	< 0.0050	NA

*Data validation in progress

GROUNDWATER
HAZARDOUS SUBSTANCE LIST RESULTS
RI/FS DATA*

Results in parts per million (ppm).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS	2034 03223 05-23-1988	2034 03224 05-23-1988
ORGANOPHOSPOROUS PESTICIDES		
Azinphos-methyl \ Guthion	< 0.0050	< 0.0050
Demeton \ Systox	< 0.0010	< 0.0010
Diazinon \ Spectracide	< 0.0005	< 0.0005
Disulfoton	< 0.0005	< 0.0005
Ethion \ Bladan	< 0.0005	< 0.0005
Malathion \ Sumitox	< 0.0010	< 0.0010
Methyl parathion \ Parathion	< 0.0010	NA
Methyl parathion \ Parathion	NA	< 0.0010
Parathion \ Parathion, ethyl	< 0.0005	< 0.0005
PESTICIDES		
4,4'-DDD	< 0.0001	< 0.0001
4,4'-DDE	< 0.0001	< 0.0001
4,4'-DDT	< 0.0001	< 0.0001
Aldrin	< 0.0000	< 0.0000
Dieldrin	< 0.0000	< 0.0000
Endosulfan sulfate	< 0.0001	< 0.0001
Endosulfan-I	< 0.0000	< 0.0000
Endosulfan-II	< 0.0001	< 0.0001
Endrin	< 0.0000	< 0.0000
Endrin ketone	< 0.0001	< 0.0001
Heptachlor	< 0.0000	< 0.0000
Heptachlor epoxide	< 0.0000	< 0.0000
Lindane \ gamma-BHC \ Hexach	< 0.0000	NA
Lindane \ gamma-BHC \ Hexach	NA	< 0.0000
Methoxychlor	< 0.0005	< 0.0005
PCB-1016	< 0.0005	< 0.0005
PCB-1221	< 0.0005	< 0.0005
PCB-1232	< 0.0005	< 0.0005
PCB-1242	< 0.0005	< 0.0005
PCB-1248	< 0.0005	< 0.0005
PCB-1254	< 0.0010	< 0.0010
PCB-1260	< 0.0010	< 0.0010
Toxaphene	< 0.0010	< 0.0010
alpha-BHC	< 0.0000	< 0.0000
alpha-Chlordane	< 0.0005	< 0.0005
beta-BHC	< 0.0000	< 0.0000
delta-BHC	< 0.0000	< 0.0000

*Data validation in progress

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GROUNDWATER
HAZARDOUS SUBSTANCE LIST RESULTS
RI/FS DATA*

Results in parts per million (ppm).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS		2034 03223 05-23-1988		2034 03224 05-23-1988
gamma-Chlordane	<	0.0005	<	0.0005
SEMI-VOLATILE ORGANICS				
1,2,4-Trichlorobenzene	<	0.0100	<	0.0100
1,2-Dichlorobenzene	<	0.0100	<	0.0100
1,3-Dichlorobenzene	<	0.0100	<	0.0100
1,4-Dichlorobenzene	<	0.0100	<	0.0100
2,4,5-Trichlorophenol	<	0.0500	<	0.0500
2,4,6-Trichlorophenol	<	0.0100	<	0.0100
2,4-Dichlorophenol	<	0.0100	<	0.0100
2,4-Dimethylphenol	<	0.0100	<	0.0100
2,4-Dinitrophenol	<	0.0500	<	0.0500
2,4-Dinitrotoluene	<	0.0100	<	0.0100
2,6-Dinitrotoluene	<	0.0100	<	0.0100
2-Chloronaphthalene	<	0.0100	<	0.0100
2-Chlorophenol	<	0.0100	<	0.0100
2-Methylnaphthalene	<	0.0100	<	0.0100
2-Nitroaniline	<	0.0500	<	0.0500
2-Nitrophenol	<	0.0100	<	0.0100
3,3'-Dichlorobenzidine	<	0.0200	<	0.0200
3-Nitroaniline	<	0.0500	<	0.0500
4-Bromophenyl phenyl ether	<	0.0100	<	0.0100
4-Chloro-3-methylphenol	<	0.0100	<	0.0100
4-Chlorophenylphenyl ether	<	0.0100	<	0.0100
4-Nitrophenol	<	0.0500	<	0.0500
Acenaphthene	<	0.0100	<	0.0100
Acenaphthylene	<	0.0100	<	0.0100
Anthracene	<	0.0100	<	0.0100
Benzenamine, 4-chloro-	<	0.0100	<	0.0100
Benzo(a)anthracene	<	0.0100	<	0.0100
Benzo(a)pyrene	<	0.0100	<	0.0100
Benzo(b)fluoranthene	<	0.0100	<	0.0100
Benzo(ghi)perylene	<	0.0100	<	0.0100
Benzo(k)fluoranthene	<	0.0100	<	0.0100
Benzoic acid	<	0.0500	<	0.0500
Benzyl alcohol	<	0.0100	<	0.0100
Butyl benzyl phthalate		0.0010 J		0.0010 J
Chrysene	<	0.0100	<	0.0100
Di-n-butyl phthalate \ dibut		0.0060 BJ		NA
Di-n-octyl phthalate	<	0.0100	<	0.0100
Di-n-propylnitrosamine	<	0.0100	<	0.0100
Dibenzo(a,h)anthracene	<	0.0100	<	0.0100

*Data validation in progress

GROUNDWATER
HAZARDOUS SUBSTANCE LIST RESULTS
R1/FS DATA*

Results in parts per million (ppm).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS		2034 03223 05-23-1988		2034 03224 05-23-1988
Dibenzofuran	<	0.0100	<	0.0100
Diethyl phthalate	<	0.0100	<	0.0100
Dimethyl phthalate	<	0.0100	<	0.0100
Di-n-butyl phthalate \ dibut		NA		0.0060 BJ
Fluoranthene	<	0.0100	<	0.0100
Fluorene	<	0.0100	<	0.0100
Hexachlorobenzene	<	0.0100	<	0.0100
Hexachlorobutadiene	<	0.0100	<	0.0100
Hexachlorocyclopentadiene \	<	0.0100		NA
Hexachloroethane	<	0.0100	<	0.0100
Hexachlorocyclopentadiene \		NA	<	0.0100
Indeno(1,2,3-cd)pyrene	<	0.0100	<	0.0100
Isophorone	<	0.0100	<	0.0100
N-Nitrosodiphenylamine	<	0.0500	<	0.0500
Naphthalene	<	0.0100	<	0.0100
Nitrobenzene	<	0.0100	<	0.0100
Pentachlorophenol	<	0.0500	<	0.0500
Phenanthrene	<	0.0100	<	0.0100
Phenol	<	0.0100	<	0.0100
Phenol, 2-methyl-4,6-dinitro	<	0.0500		NA
Pyrene	<	0.0100	<	0.0100
Phenol, 2-methyl-4,6-dinitro		NA	<	0.0500
bis(2-Chloroethoxy)methane	<	0.0100	<	0.0100
bis(2-Chloroethyl) ether	<	0.0100	<	0.0100
bis(2-Chloroisopropyl) ether	<	0.0100	<	0.0100
bis(2-Ethylhexyl) phthalate	<	0.0100	<	0.0100
o-Cresol	<	0.0100	<	0.0100
p-Cresol	<	0.0100	<	0.0100
p-Nitroaniline	<	0.0500	<	0.0500
VOLATILE ORGANICS				
1,1,1-Trichloroethane	<	0.0050	<	0.0050
1,1,2,2-Tetrachloroethane	<	0.0050	<	0.0050
1,1,2-Trichloroethane	<	0.0050	<	0.0050
1,1-Dichloroethane	<	0.0050	<	0.0050
1,1-Dichloroethene	<	0.0050	<	0.0050
1,2-Dichloroethane	<	0.0050	<	0.0050
1,2-Dichloroethylene	<	0.0050	<	0.0050
1,2-Dichloropropane	<	0.0050	<	0.0050
2-Butanone	<	0.0100	<	0.0100
2-Hexanone	<	0.0100	<	0.0100
2-Propanone		0.0060 BJ		0.0020 BJ

*Data validation in progress

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GROUNDWATER
HAZARDOUS SUBSTANCE LIST RESULTS
RI/FS DATA*

Results in parts per million (ppm).
Data presented by location, sample number, and sample date.
NA indicates not analyzed; a number preceeded by a "less than" symbol indicates that the compound was not present above the detection limit of the analytical instrument.

CHEMICAL PARAMETERS		2034 03223 05-23-1988		2034 03224 05-23-1988
4-Methyl-2-pentanone	<	0.0100	<	0.0100
Benzene	<	0.0050	<	0.0050
Bromodichloromethane	<	0.0050	<	0.0050
Bromomethane	<	0.0100	<	0.0100
Carbon disulfide	<	0.0050	<	0.0050
Chlorobenzene	<	0.0050	<	0.0050
Chloroethane	<	0.0100	<	0.0100
Chloroform	<	0.0050	<	0.0050
Chloromethane	<	0.0100	<	0.0100
Dibromochloromethane	<	0.0050	<	0.0050
Ethylbenzene		0.0020 J	<	0.0050
Methylene chloride		0.0020 BJ		0.0020 BJ
Styrene	<	0.0050	<	0.0050
Tetrachlorethene	<	0.0050	<	0.0050
Tetrachloromethane	<	0.0050	<	0.0050
Toluene	<	0.0050	<	0.0050
Total xylenes		0.0030 J	<	0.0050
Tribromomethane	<	0.0050	<	0.0050
Trichloroethene	<	0.0050	<	0.0050
Vinyl acetate	<	0.0100	<	0.0100
Vinyl chloride	<	0.0100	<	0.0100
cis-1,3-Dichloropropene	<	0.0050	<	0.0050
trans-1,3-Dichloropropene	<	0.0050	<	0.0050

*Data validation in progress

REMEDIAL INVESTIGATION REPORT FOR OPERABLE UNIT 4

APPENDIX E: BASELINE RISK ASSESSMENT

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO

Prepared for

U.S. DEPARTMENT OF ENERGY
OAK RIDGE OPERATIONS OFFICE

Prepared by

ADVANCED SCIENCES, INC.
IT CORPORATION

October 1990
FMPC-0404-5

APPENDIX E

BASELINE RISK ASSESSMENT

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LIST OF ACRONYMS

ADI	acceptable daily intake
AEC	Atomic Energy Commission
AMS	Air Monitoring Station
ASI	Advanced Sciences, Incorporated
ARARs	Applicable or Relevant and Appropriate Requirements
BEIR	Biological Effects of Ionizing Radiation
CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CIS	Characterization Investigation Study
CFR	Code of Federal Regulations
DE	dose equivalent
DOE	U.S. Department of Energy
EDI	estimated daily intake
EIS	Environmental Impact Statement
EP	Extraction Procedure
EPA	U.S. Environmental Protection Agency
FFCA	Federal Facilities Compliance Agreement
FMPC	Feed Materials Production Center
FS	feasibility study
GRI	Gas Research Institute
GI	gastrointestinal
HI	Hazard Index
HSL	Hazardous Substance List
ICRP	International Commission on Radiological Protection
ISP	Interim Stabilization Project
IT	IT Corporation
km	kilometer
LET	linear energy transfer
LOAEL	lowest observed adverse effect level
MSL	mean sea level
NAS	National Academy of Sciences
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NCRP	National Council on Radiation Protection and Measurements

LIST OF ACRONYMS
(Continued)

NLO	National Lead (Company) of Ohio
NOAEL	no observed adverse effect level
O&M	operations and maintenance
ODH	Ohio Department of Health
PCBs	polychlorinated biphenyls
ppm	parts per million
ppt	parts per trillion
RA	Risk Assessment
RfD	reference dose
RGTS	radon gas treatment system
RI	remedial investigation
RI/FS	Remedial Investigation/Feasibility Study
RME	reasonable maximum exposure
SARA	Superfund Amendments and Reauthorization Act
SQL	sample quantitation limit
SSOD	storm sewer outfall ditch
TCLP	Toxicity Characteristic Leaching Procedure
TL	tolerance level
TLD	thermoluminescent dosimeter
USGS	United States Geological Survey
USLE	universal soil loss equation
WL	working level
WLM	working level month
WMCO	Westinghouse Materials Company of Ohio
WM	working month

LIST OF DEFINITIONS

Absorbed Dose - The quantity of energy deposited in matter (usually the human body) by ionizing radiation per unit mass of irradiated matter at the location of interest. The common unit for absorbed dose is the rad.

Action Level - A dose level below a dose limit that indicates a need to take further action to decrease the dose level to ensure that limits are not exceeded.

Baseline Risk Assessment - An assessment of potential risks to public health and the environment from current site conditions and future site conditions in the absence of remediation.

Berm - Earthen embankment surrounding the K-65 waste storage silos.

Chemicals and Radionuclides of Concern - Those site-specific chemicals and radionuclides identified as contributing the greatest portion of the health risk associated with an operable unit.

Committed Effective Dose Equivalent (CEDE) - The sum, over specified tissues, of the products of the committed dose equivalent in a tissue and the weighting factor for the tissue.

Committed Dose Equivalent - The total dose equivalent averaged throughout a tissue in a specified time period after intake of a radionuclide into the body. For this assessment, a 50-year time period after intake is specified.

Dose Equivalent - The quantity used to express the amount of effective absorbed dose caused by ionizing radiation. It is obtained by multiplying the absorbed dose by the quality factor and other modifying factors. The common unit for dose equivalent is the rem.

Dose Limits - Maximum dose rates permitted by regulations. Dose limits do not define a boundary between safe and hazardous conditions, but rather they are conservatively established for regulatory purposes at levels that are not known to induce observable health effects in humans.

Exposure Pathway - A transport route and mechanism for human exposure to materials that have migrated from a source. An exposure pathway consists of a point of exposure in the environment, a receptor, a migration pathway, and a mechanism of entering the body (e.g., inhalation).

Hydraulic Conductivity - Indicates the ease with which water will flow through geologic media, such as soils. It is dependent upon a variety of characteristics and is expressed in terms of distance per unit of time.

K-65 Raffinates - The less soluble residues that remained after extraction of uranyl nitrate during the processing of pitchblende ore. These residues ultimately were transferred to the K-65 silos for storage.

Migration Pathway - Mechanism for the transport of radioactive or hazardous materials through environmental media.

Mixed Waste - Waste materials containing a mixture of hazardous chemicals and radioactive materials.

Pharmacokinetic Model - A mathematical model that describes how a substance moves through the human body.

Pitchblende - A primary mineral-ore source of natural uranium.

Radon Progeny - The series of radionuclides that result from the radiological decay of radon-222.

Reasonable Maximum Exposure (RME) - The highest exposure that is reasonably expected to occur at a site. Quantification of the RME under current and future land-use conditions requires that the risk assessor make operable unit-specific source term and exposure pathway assumptions.

Receptor - A member of human, animal, or plant populations that may be exposed to radioactive or hazardous materials.

Reference Dose (RfD) - An estimate of the daily chemical exposure of humans that is unlikely to result in deleterious effects during a lifetime of exposure, based on the assumption that a threshold exists for certain toxic effects of chemical substances. The RfD is derived from pertinent human or animal toxicity data.

Toxic Waste - Waste that contains chemicals that can cause an increase in the incidence of an adverse health effect in humans as a result of exposure.

Working Level (WL) - Any combination of short-lived radon progeny in 1 liter of air that will result in the ultimate emission of 1.3×10^5 million electron volts (MeV) of alpha particle energy.

Working Level Month (WLM) - Cumulative exposure to radon progeny is expressed in WLMs. One WLM is equal to exposure to a combination of radon progeny equal to one working level times an exposure duration of a 170-hour occupational month.

EXECUTIVE SUMMARY

This document presents the baseline risk assessment for Operable Unit 4 at the Feed Materials Production Center (FMPC), Fernald, Ohio. This risk assessment is mandated under the Consent Agreement under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) signed in Sections 120 and 106(a) signed in 1990 by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA), which implements the Federal Facilities Compliance Agreement (FFCA) signed in 1986. It complies with provisions of both the 1986 Superfund Amendments and Reauthorization Act (SARA) and CERCLA that require the completion of an assessment of risks to public health and the environment during the Remedial Investigation (RI) of a CERCLA site. Operable Unit 4 includes the waste storage silos (two K-65 silos and the metal oxide silo). A fourth silo is also present within the Operable Unit 4 study area; however, this silo has not been used and is not addressed further in this risk assessment. The soils directly beneath the silos and the berm soils surrounding the K-65 silos are also considered within Operable Unit 4 assuming that any contamination originating from the silo wastes could be remedied in the most cost-effective manner as an integral part of the remedial action program for the silos.

Several scenarios were evaluated to determine the human health risks associated with Operable Unit 4: current exposures; future potential exposures assuming institutional controls are in place for 100 years; and future potential exposures assuming no institutional controls after 100 years. Three current human exposure pathways are quantitatively evaluated in this risk assessment:

- Exposure to penetrating radiation emitted from the material in the silos
- Exposure to airborne radon and radon progeny emitted from the K-65 silos
- Exposure to uranium and radium-226 (Ra-226) eroded into stream sediments and ingested by children

Data collected during the RI and the results of other studies suggest that two radiological exposure pathways from Operable Unit 4 currently contribute above-background radiation exposure to the public. These pathways are:

- Exposure to penetrating radiation emitted from the silos
- Exposure to airborne radon and radon progeny emitted from the K-65 silos

Data also suggest surface water runoff to stream sediments could be a current potential pathway of migration for radionuclides or chemicals from Operable Unit 4; however, no data currently exist to directly link contamination measured in sediments with releases from Operable Unit 4.

The above-background calculated radiation dose equivalent associated with direct exposure to penetrating whole body radiation from Operable Unit 4 under current conditions is 2500 mrem over a 70-year lifetime (36 mrem/year) in the vicinity of a hypothetical reasonable maximally exposed individual. The reasonable maximum exposure (RME) is represented by the highest average measured off-site exposure, which is in the vicinity of the FMPC boundary west of Operable Unit 4. This lifetime radiation dose equivalent corresponds to an incremental lifetime fatal cancer risk of 3×10^{-4}.

The above-background calculated exposure to radon progeny from Operable Unit 4 under current conditions is 13 working level months (WLM) over a 70-year lifetime (0.19 WLM/year) in the vicinity of a hypothetical RME individual. The RME for radon exposure is also represented by the highest average measured off-site exposure, which is in the vicinity of the FMPC boundary west of Operable Unit 4. This lifetime radon progeny exposure corresponds to an incremental lifetime fatal lung cancer risk of 5×10^{-3}.

The calculated RME committed effective dose equivalent associated with exposure to uranium and Ra-226 eroded into stream sediments and ingested by children is approximately 8 mrem over a six-year exposure duration. This exposure corresponds to a lifetime fatal cancer risk of 1×10^{-6}. The calculated nonradiological RME exposure to uranium eroded into stream sediments and ingested by children is 0.13 microgram/kilogram/day (µg/kg/day). The nonradiological hazard index ratio (HI) associated with a child exposed to this intake of uranium in stream sediment is 0.043 when the intake is compared to the reference dose (RfD) of 3 µg/kg/day, and 0.17 when the intake is compared to the site-specific action level of 0.75 µg/kg/day. Thus, children could receive a calculated intake of uranium that is 17 percent of the action level based on chemical toxicity. The nonradiological intake estimate and the radiological dose and risk estimate for the sediment ingestion pathway incorporate assumptions that overestimate exposures. For example, an exposure frequency of 365 days per year and an exposure duration of six years are assumed. It is unlikely that a child receptor will actually experience this exposure; therefore, the exposure estimate is considered an overestimate.

Potential future exposures to Operable Unit 4 constituents were evaluated for three pathways:

- Exposure to penetrating radiation, assuming no institutional controls after 100 years
- Exposure to airborne radon, assuming no institutional controls after 100 years
- Exposure to constituents from leakage out of the silos and migration through the groundwater

Future exposures to penetrating radiation and airborne radon, assuming a receptor is exposed in the vicinity of the K-65 fenceline, are approximately 50 times and 7 times, respectively, the current estimated exposures to penetrating radiation and airborne radon.

Potential future exposures via the groundwater were estimated assuming that rain water could leak into the silos and assuming that cracks in the bases of the silos could provide a mechanism for leaking through the bottom. Upperbound estimates of leachate concentrations were used to calculate the concentrations of silo constituents leaking through the bottom. There is no direct evidence that leaking is occurring from the silos at the present time; however, there is insufficient basis for determining that contaminants are, or are not, migrating out of the silos and into subsurface soils and potentially the aquifer.

Potential future exposures via the groundwater at the FMPC property boundary, assuming institutional controls, indicate that the silos could contribute unacceptable concentrations of several chemical toxicants, including beryllium, cadmium, thallium, uranium, radium, lead-210 (Pb-210), actinium-227 (Ac-227), and protactinium-231 (Pa-231). Potential future exposures via the groundwater assuming no institutional controls after 100 years are unacceptable for uranium, radium, Pb-210, Ac-227, Pa-231, and many metals.

A model has been used to assess the potential for migration of radon through the K-65 silo walls and into the berm soil. If this migration pathway is significant, the longer lived radon decay product Pb-210 may accumulate in the berm soils. Model results suggest that significant activity concentrations of Pb-210 may be present in the berm soil, particularly in soil layers close to the silo walls. Supplemental sampling and analysis of the berm soil is planned to determine whether this potential contamination exists.

In summary, this risk assessment has determined that the potential public exposure and corresponding risk from baseline conditions attributable to Operable Unit 4 currently exceeds the

acceptable risk range in 40CFR300. Assuming that a single individual could reasonably be exposed to the current estimated above-background RME from both penetrating radiation and airborne radon, the combined lifetime risk from lifetime exposure to these two pathways is 5×10^{-3}. The uranium chemical exposure action level of 25 percent of the acceptable daily intake is not exceeded under current conditions attributed to Operable Unit 4. Environmental modeling results suggest that if the silos begin to leak in the future, Operable Unit 4 could lead to unacceptable human exposures to both radionuclides and inorganic metals, including lead.

Ecological organisms potentially exposed to contaminants from Operable Unit 4 under both current and future land-use conditions include a variety of terrestrial plants and animals in introduced grasslands and aquatic organisms in Paddys Run. The estimated radiation dose to plant tissue from the maximum predicted uranium concentration in vegetation in the vicinity of Operable Unit 4 is 0.04 rad per year. This is 10,000 times less than the dose reported to reduce the growth of radiosensitive plants. No data are available on radionuclide uptake or exposure by mammals and birds in the vicinity of Operable Unit 4. Radiation exposures causing detectable chronic to acute effects in mammals and birds are several hundred rads.

E.1.0 INTRODUCTION

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requires that actions selected to remedy hazardous waste sites be protective of human health and the environment. Compliance with this objective under the Remedial Investigation/Feasibility Study (RI/FS) is determined by the risk assessment process. The goal of the risk assessment is to provide information upon which a decision-making process based on risk management can progress. The baseline risk assessment, which provides an analysis of the baseline risks and determines the need for remedial action, is an integral part of the decision-making process. This document contains the risk assessment for the waste storage silos (two K-65 and two metal oxide silos) at the Feed Materials Production Center (FMPC) located near Fernald, Ohio.

The FMPC is a contractor-operated federal facility for the production of pure uranium metals for the U.S. Department of Energy (DOE). The FMPC site is located near the unincorporated village of Fernald, Ohio on a 1050-acre (4.2×10^6 m^2) site in a rural area approximately 20 miles (32 km) northwest of downtown Cincinnati, Ohio. Approximately 850 acres (3.4×10^6 m^2) of the FMPC site are in northern Hamilton County and the remaining 200 acres (0.8×10^6 m^2) in southern Butler County. The villages of Ross, New Haven, New Baltimore, and Shandon are also within a few miles of the FMPC (Figure E.1-1). The site is on a relatively level plain approximately 580 feet (177 m) above mean sea level (msl). The Production Area is limited to an approximate 136-acre (5.5×10^5 m^2) tract near the center of the FMPC site.

On March 9, 1985, the U.S. Environmental Protection Agency (EPA) issued a Notice of Noncompliance letter to DOE identifying EPA's major concerns about potential environmental impacts associated with the FMPC's past and present operations. Between April 1985 and July 1986, conferences were held between DOE and EPA representatives to discuss the issues and to identify the steps DOE proposed to take for achieving and maintaining environmental compliance. On July 18, 1986, a Federal Facility Compliance Agreement (FFCA) was jointly signed by DOE and EPA pertaining to environmental impacts associated with the FMPC. The FFCA was entered into pursuant to Executive Order 12088 (42CFR47707) to ensure compliance with existing environmental statutes and implementing regulations. The FFCA is intended to ensure that human health and environmental impacts associated with past and present activities at the FMPC are thoroughly investigated so that appropriate remedial response actions can be formulated, assessed, and implemented.

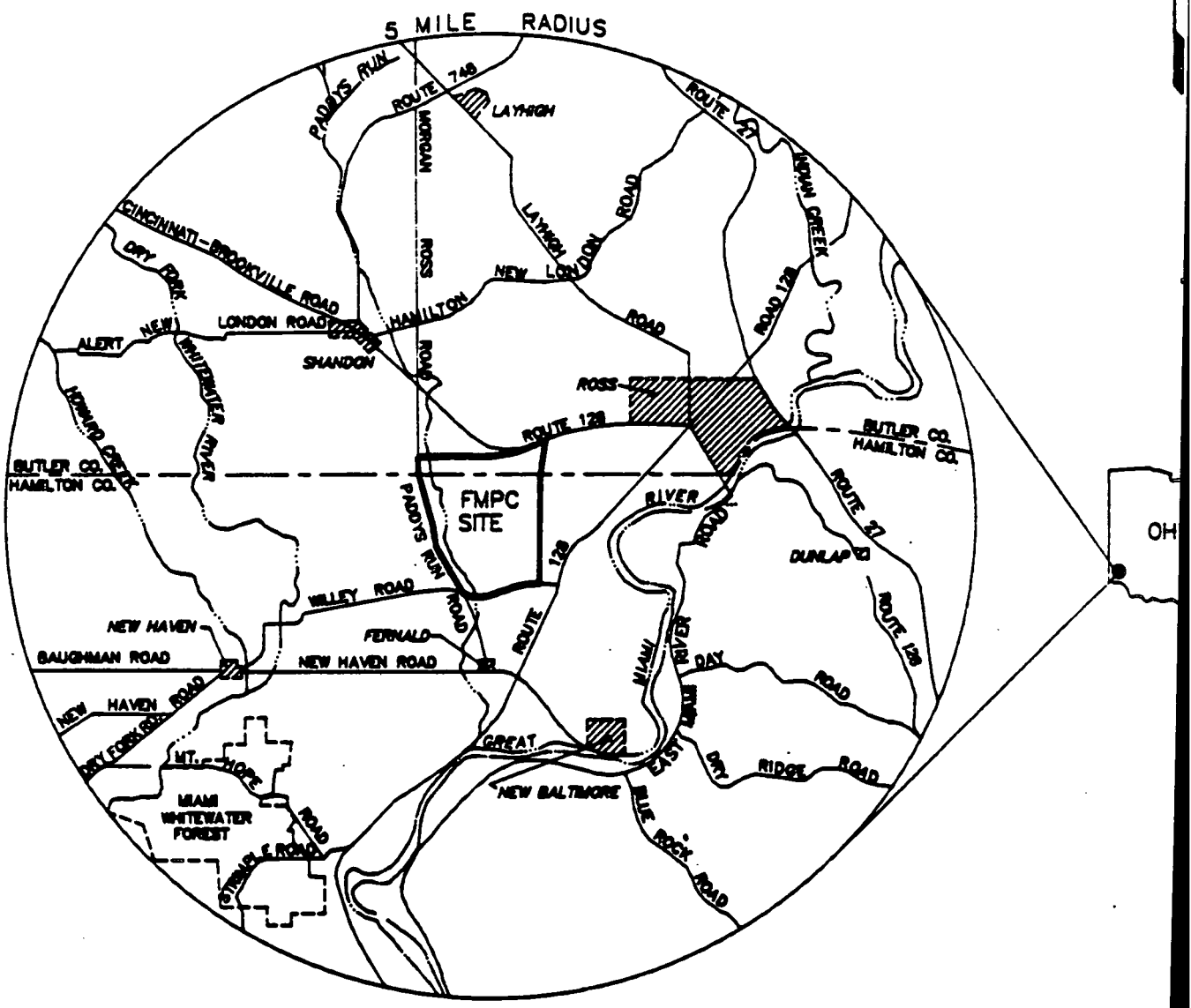

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FIGURE E1-1. FIVE-MILE RADIUS MAP, FEED MATERIALS PRODUCTION CENTER

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In response to the FFCA, the FMPC RI/FS was initiated in 1987 pursuant to CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986. All FMPC RI/FS activities, including the risk assessment(s), are being conducted in conformance with the Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (EPA 1988a). The performance of this baseline risk assessment conforms with current EPA guidance, guidelines, and criteria and with the requirements set forth in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (EPA 1990a).

E.1.1 OVERVIEW

The RI/FS for the FMPC was initially designed to address the entire site and to focus on various environmental media that could be potentially affected by past and present operations at the FMPC. Within the CERCLA framework, 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. In the course of the investigation, it became apparent that for technical and program management purposes, the site should be divided into operable units (Figure E.1-2). The five operable units identified within the FMPC and approved for use in the recently modified Consent Agreement under CERCLA Sections 120 and 106(a) (signed April 9, 1990 and effective June 29, 1990) are:

- Operable Unit 1 - Waste Storage Area
- Operable Unit 2 - Solid Waste Units
- Operable Unit 3 - Production Area and Suspect Areas
- Operable Unit 4 - K-65 Silos and Metal Oxide Silos
- Operable Unit 5 - Environmental Media

The focus of this baseline risk assessment is Operable Unit 4, which encompasses waste storage silos that contain elevated levels of hazardous chemicals and radioactive materials. Because mixed waste is present at the FMPC, the risk assessment addresses both the radiological components and hazardous chemical components of the wastes. This report is a supplement to the Operable Unit 4 RI Report and provides the baseline risk assessment for Operable Unit 4.

The baseline risk assessment has two major objectives. The first is to determine if "no further action" is an acceptable alternative from a public health perspective. The second objective is to provide the baseline conditions for comparing the public health impacts of remedial alternatives that will be identified in the FS. To fulfill these objectives, a systematic evaluation of potential risks to human health was conducted in accordance with the Baseline Risk Assessment Guidance for Superfund --Human Health Evaluation Manual, Part A -- Interim Final (EPA 1989a), and the

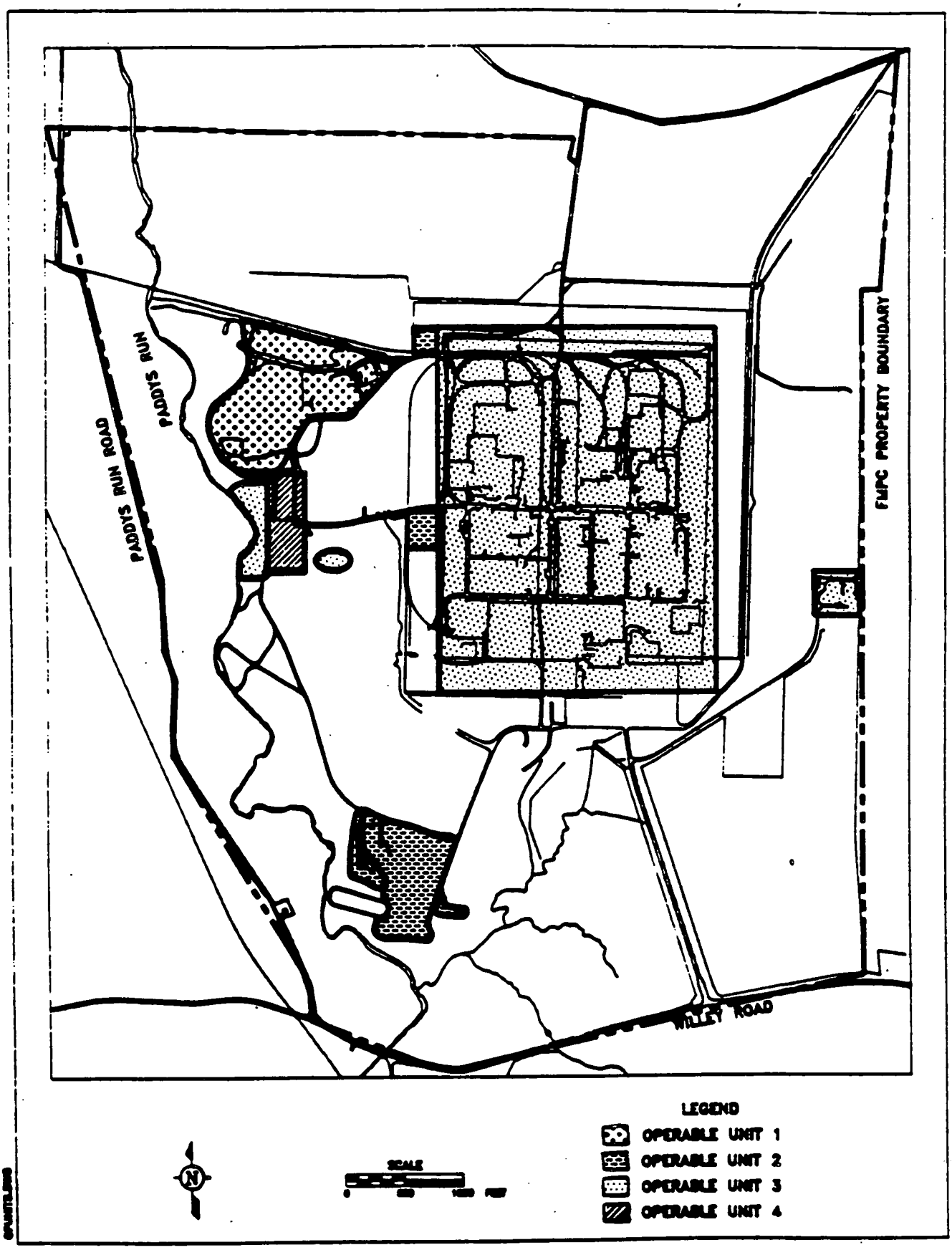

FIGURE E1-2. SOURCE OPERABLE UNITS

Environmental Evaluation Manual (EPA 1989b). The environmental impacts associated with the FMPC will be addressed by a companion program-wide Environmental Impact Statement (EIS); however, appropriate sections of the EIS are adapted to Operable Unit 4 in Section E.6.0 of this report. The evaluation of risks to environmental media from all operable units at the FMPC will be addressed collectively in the baseline risk assessment report for Operable Unit 5, which will address all environmental media that are not addressed by another operable unit.

E.1.2 SITE BACKGROUND

Descriptive information on the FMPC site and Operable Unit 4 is available in the RI Report for Operable Unit 4. This section excerpts from the RI report general background information on the FMPC and the surrounding area. It includes a brief description of the FMPC and its history as well as an overview of the waste areas that make up Operable Unit 4.

E.1.2.1 FMPC General Site Description and History

The Atomic Energy Commission (AEC), predecessor to the DOE, established the FMPC for processing uranium and its compounds from natural uranium ore concentrates for U.S. government needs. This integrated production complex began operations in conformance with AEC Orders in the early 1950s. In 1951, National Lead Company of Ohio (NLO) entered into contract with the AEC as Operations and Maintenance (O&M) Contractor. This contractual relationship lasted with the AEC, and eventually the 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 five-year period.

The Pilot Plant was completed in 1951 and was the first operational facility at the FMPC. Following completion of the Pilot Plant, numerous other processing and support facilities were constructed within that portion of the FMPC known as the Production Area. A variety of chemical and metallurgical processes are utilized at the FMPC for the manufacture of uranium products. These processes are described in detail in the RI reports. The FMPC wastes include:

- Process wastes
- General scrap and refuse
- Contaminated and noncontaminated metal scrap
- Waste oils
- Low-level radioactive waste
- Mixed wastes
- Toxic waste
- Sewage Treatment Plant sludge

- Fly ash
- Stored radium- and thorium-bearing residues

E.1.2.2 Operable Unit 4 - General Description

Operable Unit 4 is located inside a fenced, limited-access area approximately 1300 feet (320 m) west of the main production area fence (Figure E.1-3) and consists of the two K-65 silos (Silos 1 and 2) and the metal oxide silo (Silo 3). A fourth silo (Silo 4) is also present within the Operable Unit 4 study area, but this silo has not been used and is not addressed in the risk assessment. The berm soils surrounding the K-65 silos and the soils directly beneath the silos are also considered within Operable Unit 4 assuming that any contamination originated from the silo wastes and could be remediated in the most cost-effective manner as an integral part of the remedial action program for the silos.

Descriptions of the structural characteristics of the K-65 silos are presented in two reports (Grumski 1987a; Shanks and Vogel 1988). Each of the concrete silos is 80 feet in diameter with an overall height of 36 feet (27-foot-high walls and a 9-foot-high dome). The walls are constructed of eight-inch-thick, posttensioned, reinforced concrete. The domes are constructed of concrete reinforced by wire mesh, and they taper from a thickness of eight inches at the silo walls to a thickness of four inches at their apex. The four-inch concrete floors were constructed over an eight-inch layer of gravel. This gravel layer contains a system of two-inch-diameter slotted piping that drains to a collection sump tank. Below the gravel is a two-inch layer of asphalt and concrete underlain by 17 inches of compacted clay. Silos 1 and 2 are surrounded by an earthen embankment (berm).

Silos 1 and 2 were built in 1951 and 1952, respectively, to store radium-bearing residues from the processing of pitchblende ore mined in what was then known as the Belgian Congo. The radium-bearing residues from aqueous slurries were collected in these silos from 1953 to 1955 (Boback et al. 1987). The radioactive residues in the slurry were allowed to settle, and the free liquid was decanted through a series of valves placed at various levels along the exterior of the silo wall. The decanted liquid was recycled back to the residue slurry process. As the depth of solids approached the level of a given valve, the valve was sealed and the next higher valve was used to decant the liquids. The K-65 silos were filled to approximately four feet below the top of their vertical walls (DOE 1988a). The current combined volume of residues in the K-65 silos is estimated to be 195,000 ft^3 (approximately 8800 metric tons) (ASI/IT 1988; Dettorre et al. 1981, Grumski 1987a).

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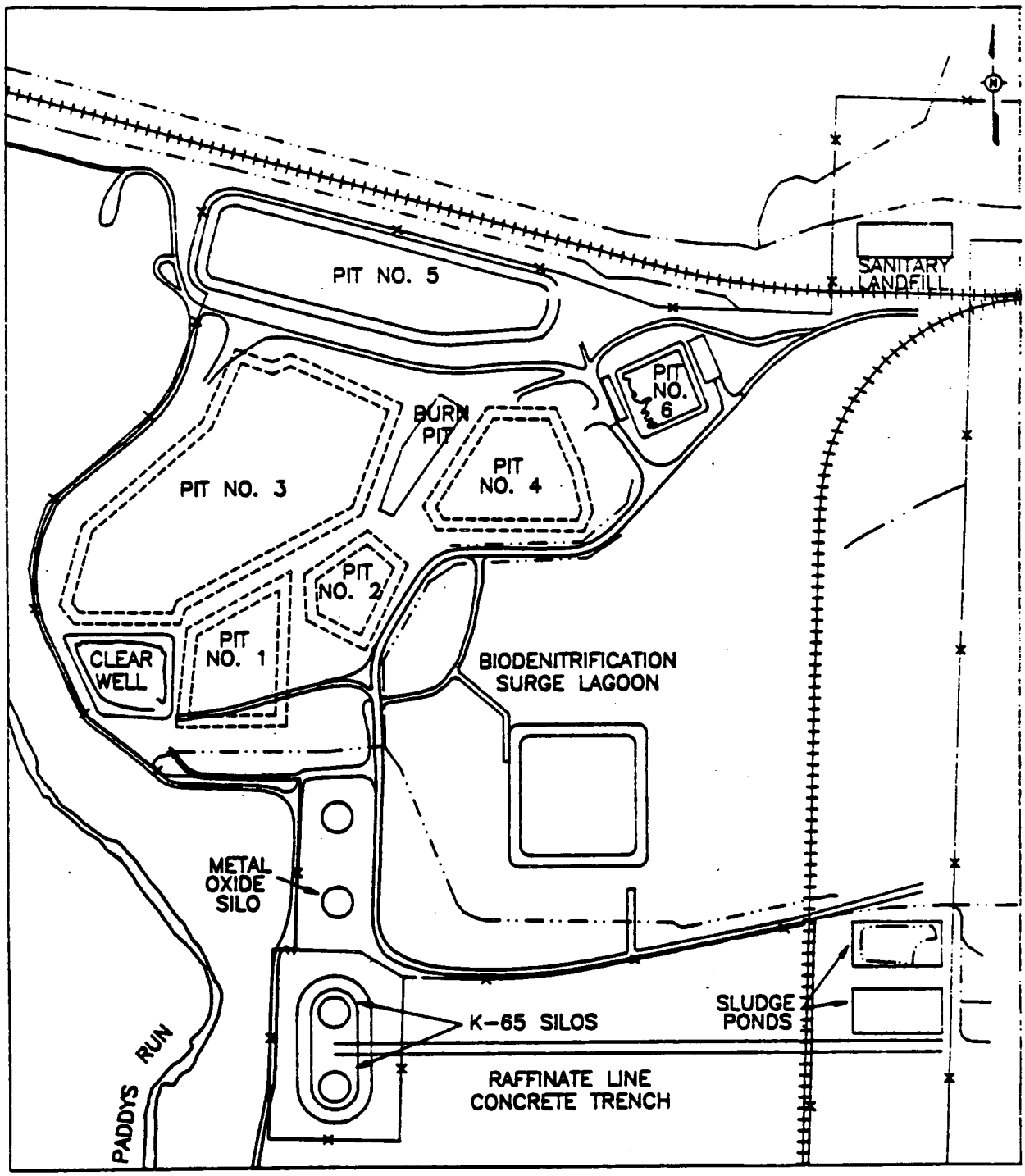

NOTES:

PITS 1, 2 AND 3 ARE COVERED

PIT 4 HAS AN INTERIM CAP

LEGEND:

RAILROAD

DRAINAGEWAYS

FENCELINE

ROADWAY

SCALE

0 175 350 FEET

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FIGURE E1-3. WASTE STORAGE AREA

The residues currently stored in the K-65 silos came from the FMPC, from a plant in St. Louis, Missouri, and from a storage facility in Niagara Falls, New York. Shipments from the latter two facilities totaled 25,000 drums and 6000 drums, respectively (DOE 1988a).

Silos 1 and 2 contain an air space, above the pitchblende residues, where radon gas accumulates. Current estimates of the void volumes above the residues are 38,000 cubic feet (ft^3) in Silo 1 and 48,000 ft^3 in Silo 2 (Grumski and Shanks 1988). The K-65 silos exchange air with the outside environment (Grumski 1987a). The estimated historical rate of exchange of gas from the silos to the outside atmosphere is 1650 ft^3 per day from each silo (IT Corporation 1989). Since the installation of a foam covering over the silos in November 1987, the rate of gas exchange should be significantly reduced because the foam is an effective thermal insulator that should reduce daily temperature variations inside the silo dome. No diffusion of radon occurred through an average foam thickness of 2.2 inches in laboratory tests of the attenuating ability of the foam (Grumski 1987b).

After the FMPC discontinued transfer of pitchblende residue slurries to the K-65 silos, the slurry system piping was removed (Boback et al. 1987). All openings to the K-65 silos were sealed except for one small gooseneck vent pipe on each silo. These two remaining openings were permanently sealed in 1979 (Boback et al. 1987).

In 1953, NLO personnel detected a leak in Silo 1 (Heatherton 1953). NLO correspondence dating from early years of plant operation also suggests that the decant liquor sump buried adjacent to the K-65 silos overflowed on occasion (Karl 1953). The sump captures liquids from the collection system beneath the silos to prevent releases to environmental media. This information suggests that leakage from Silo 1 and from the buried collection system has occurred in the past.

By 1963, the exterior surfaces of the K-65 silos were showing signs of deterioration, necessitating repairs in 1964. At that time, an earthen embankment was built to the top of the vertical walls of Silos 1 and 2 to provide relief from tensile stress that had developed within the walls. This embankment also provides weather protection, a reduction of radon emissions, and increased shielding from penetrating radiation. The embankment originally had a slope of 1.5:1 (horizontal:vertical), which was subsequently modified in 1983 to a slope of 3:1 to reduce erosion (Grumski 1987b; Boback et al. 1987). This embankment is commonly referred to as the silo berm.

In 1985, Camargo Associates began a structural analysis of the K-65 silos (Camargo 1986). Grumski (1987a) has summarized the Camargo recommendations and conclusions, which include but are not limited to the following:

- The base slab and walls were structurally stable at the time of the analysis and should remain stable for approximately 5 to 10 years.
- The contents of the silos and the silo berm must be removed simultaneously rather than separately or failure of the walls or base slab could result.
- The center 20-foot-diameter portion of each dome is structurally unsound for a load greater than the existing static dead load.
- The weight of a structure chosen to cover the center portion of each silo should be as light as possible.

In January 1986, construction and installation of temporary dome covers over the center portions of the K-65 silos were completed (Grumski 1987a). The 30-foot-diameter steel and plywood covers were installed to contain the contents of the silos in the event of a dome center collapse (Grumski 1987a).

In 1987, an interim stabilization project (ISP) was implemented at the K-65 site in response to the FFCA between DOE and EPA (Grumski 1987b). Compliance with the FFCA required that DOE take immediate action to control radioactive emissions from the FMPC. Work performed as part of the ISP included:

- Installation of a radon gas treatment system (RGTS)
- Application of a layer of rigid polyurethane foam insulation to the exterior of the dome surfaces

The RGTS consists of a calcium sulfate bed to remove moisture followed by charcoal beds to adsorb the radon. It is a closed system in which the cleaned air is recirculated back to the silos. The RGTS is designed to be operated on an interim basis, such as when the dome is opened; therefore it does not provide permanent reduction of external radiation exposure levels or radon levels. This system was operated before and during application of the exterior foam layer. Operation of this system immediately before the installation of the polyurethane foam reduced penetrating radiation levels at the exterior surfaces of the K-65 silo domes by 60 to 70 percent without increasing the ambient radon levels outside the silos (Grumski and Shanks 1988).

In November 1987, the exterior surfaces of the domes were covered with a 3-inch layer of polyurethane foam, the dome caps were covered with a 1.5-inch layer of foam, and the entire exterior surface of the domes was waterproofed with an ultraviolet-resistant, urethane-finish coating 0.045 inches thick (Grumski and Shanks 1988).

Silo 3 was constructed in mid-1952 and was designed to receive dry materials only. Waste raffinate slurries from the FMPC refinery operations were dewatered in a raffinate evaporator and spray calcined to produce a dry waste form. This waste was blown under pressure into Silo 3 (DOE 1988a). An estimated volume of 138,000 ft^3 of material is contained in Silo 3 (DOE 1988a). There is no soil embankment around this silo.

E.1.3 SCOPE OF THE RISK ASSESSMENT

The process used in the baseline risk assessment for Operable Unit 4 is shown in Figure E.1-4 (EPA 1989a). The first step in the completion of the baseline risk assessment involves the identification of all radionuclides and hazardous chemicals of potential concern. These constituents were identified by examination of existing site information, including:

- Descriptions of the processes used at the FMPC
- Radionuclides and chemicals known to have been used in these processes
- Present and historical site environmental monitoring data
- Results of special investigations conducted within Operable Unit 4

Throughout this process, existing information was supplemented with data collected through the RI field investigation. The quality of the data to be used in the baseline risk assessment was also evaluated during this initial data analysis. Once chemicals and radionuclides of potential concern were identified, the process was directed toward the exposure assessment that includes both the characterization of an exposure setting and the identification of exposure pathways.

Exposure pathways are identified by describing how humans may be exposed to contaminants originating from Operable Unit 4. Each pathway consists of:

- A source of contamination
- A mechanism for transporting the contaminant through environmental media to a point of exposure
- A potential receptor at the location of exposure
- A mechanism of receptor exposure

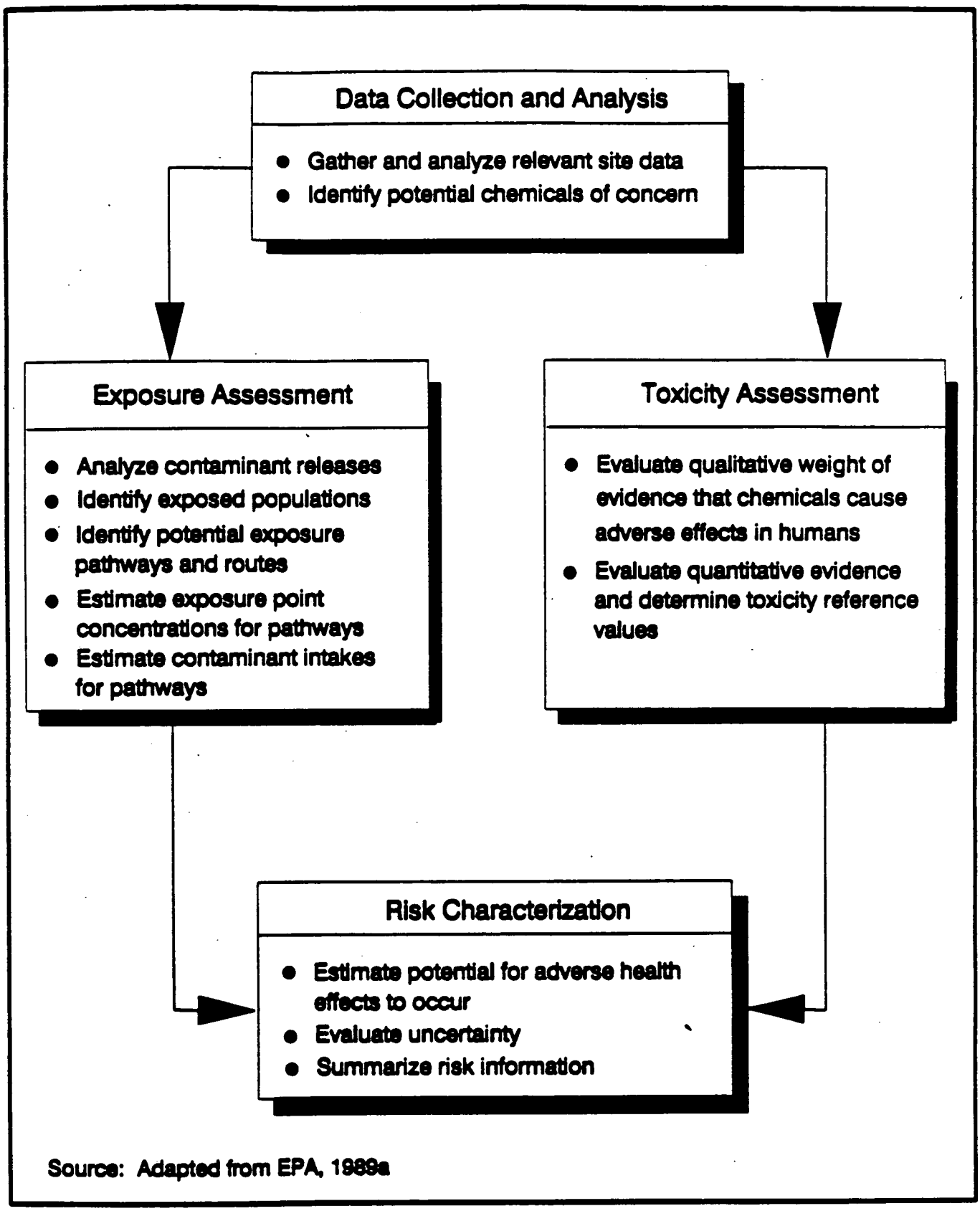

FIGURE E1–4. BASELINE RISK ASSESSMENT PROCESS

The concentrations of contaminants are estimated at potential exposure points for the present and future time intervals. Where possible, direct measurements are used to determine current exposure point concentrations. In other cases, environmental transport models are used to predict current and future receptor exposure concentrations.

Intakes of the constituents of concern are estimated on the basis of the reasonable maximum exposure (RME) scenarios for both present and future land-use conditions. The RME is defined by the EPA (1989a) as "the highest exposure that is reasonably expected to occur at the site." This concept is also set forth in EPA's preamble to the adoption of the NCP (EPA 1990a). In this preamble, the EPA explains that the concept of RME is designed to include all exposure that can be reasonably expected to occur but does not focus on worst-case exposure assumptions. Only potential exposures that are likely to occur are to be included in the assessment of exposures. The EPA further cautions against the use of unrealistic exposure scenarios and assumptions. The RME is the product of factors that are an appropriate mix of values that are conservative because they tend to overestimate risk, but they are within a realistic range of potential exposure. The selection of parameter values is based on a mix of values characteristic of either average individuals or within a 95 percentile distribution for members of the public to yield a reasonable overall assessment of potential exposure to individuals or the general population.

The toxic characteristics of chemicals of concern are then evaluated to identify potential adverse effects on human health. These effects include impacts on the function of body organs and the induction of cancer. When possible, an estimate is made of the relationship between the extent of potential exposure to the contaminant and the probability and/or severity of identified adverse effects.

The characterization of risk follows the exposure and toxicity assessments. In this step, the probability that an individual may develop cancer over a lifetime from potential exposures to site-related chemicals from Operable Unit 4 is estimated from potential intakes and contaminant-specific dose-response relationships. In addition, comparisons are made between estimated potential intakes and the threshold values for noncarcinogenic effects identified in the toxicity assessment.

In accordance with the NCP and CERCLA, remedial actions must be adequate to protect the environment as well as human health. As indicated in Section E.1.1 of this baseline risk assessment report, the environmental impacts associated with the FMPC will be addressed by a

companion program-wide EIS. Appropriate sections of the EIS are adapted to Operable Unit 4 in Section E.6.0.

E.1.4 ORGANIZATION OF THE BASELINE RISK ASSESSMENT REPORT

This risk assessment report provides a baseline (or no-action) risk assessment for Operable Unit 4 and serves as the point of comparison for possible remedial alternatives being considered for Operable Unit 4. In general, this baseline risk assessment follows the "Suggested Outline for a Baseline Risk Assessment Report" set forth in Exhibit 9-1 of the Baseline Risk Assessment Guidance for Superfund -- Human Health Evaluation Manual, Part A -- Interim Final (EPA 1989a). This report is modified to address Operable Unit 4 rather than all hazardous waste units at the FMPC site.

- Section E.1.0 provides an introduction and overview of the FMPC and the waste units covered under Operable Unit 4 of the RI/FS.
- Section E.2.0 describes the evaluation of general site-specific data and the identification of constituents of potential concern.
- Section E.3.0 details the process used in identifying pathways of exposure, selecting the most significant of these pathways, and estimating the exposure point concentrations and exposures.
- Section E.4.0 presents toxicity information for radionuclides and specific chemicals.
- Section E.5.0 characterizes the risks associated with the estimated exposure point concentrations and exposures calculated in Section E.3.0.
- Section E.6.0 summarizes the portions of the FMPC EIS that apply to Operable Unit 4.
- Section E.7.0 summarizes the results of the risk assessment.

Throughout the baseline risk assessment report, there are discussions of uncertainties that exist in the available analytical data, in the modeling assumptions supporting the exposure assessment, and in the toxicity evaluations and radiation dose assessment.

E.2.0 IDENTIFICATION OF CHEMICALS AND RADIONUCLIDES OF POTENTIAL CONCERN

This section of the Operable Unit 4 baseline risk assessment report identifies the chemicals and radionuclides of potential concern for Operable Unit 4. The first section describes general site-specific data collection and evaluation considerations for the risk assessment. The second section presents the site-specific data collected, evaluated, and used in the Operable Unit 4 risk assessment. A summary at the end of the section identifies the chemicals and radionuclides of potential concern in the Operable Unit 4 baseline risk assessment.

E.2.1 GENERAL SITE-SPECIFIC DATA COLLECTION AND EVALUATION CONSIDERATIONS

The following general data collection and evaluation considerations are of importance to the baseline risk assessment:

- Identification of chemical and radiological constituents in the silos
- Quantification of chemical and radiological constituent concentrations in the silos and adjacent environmental media
- Determination of the characteristics of source materials
- Determination of the characteristics of environmental media that may affect the migration of constituents from Operable Unit 4
- Evaluation of collected data.

The first consideration is to identify constituents present in the K-65 silos and the metal oxide silo. This provides a starting point for the development of exposure pathways by identifying potential source terms in the silos.

The second consideration is to quantify constituent concentrations in the silos, the berm soils, the soils directly beneath the silos, and in any other media of concern. Quantification of potential source terms furthers the development of potential exposure pathways and is necessary to quantify the health hazard associated with potential exposure pathways.

The third consideration is to determine the physical characteristics of the source materials of concern. These characteristics are important because they affect the potential for release of constituents into the environment. Characteristics of source materials include chemical forms of

constituents, solubilities of constituents, porosities or permeabilities of the waste materials, and potential water flow rates through the waste materials.

The fourth consideration is to determine the characteristics of environmental media that may potentially become contaminated by releases from the waste storage silos and that may affect the migration of contaminants. This type of information is critical to any exposure pathway modeling to be performed. Characteristics of environmental media include surface and subsurface geological and hydrological properties that affect contaminant retention and transport.

The fifth consideration is to evaluate the available data before it is used in the risk assessment. This is necessary because some of the data collected are not representative or are otherwise unsuitable for use in the risk assessment. For example, data may not be pertinent to the baseline risk assessment process because they do not reflect baseline conditions; data may not meet quality assurance/quality control requirements of the risk assessment; or a set of data may be too qualitative for the purpose of quantitative risk assessment.

E.2.2 DATA COLLECTED AND EVALUATED FOR OPERABLE UNIT 4

Numerous sources of information were examined during the course of the Operable Unit 4 baseline risk assessment. Specific sources that were examined and a description of the type of useful information obtained from each source are tabulated in Table E.2-1. The materials in the silos are not expected to be uniformly mixed forming a homogeneous residue; therefore some samples will have a higher or lower concentration of a particular constituent.

Initially, source term data were evaluated in the following manner:

- Historical data were reviewed.
- RI/FS silo sampling analytical results for radionuclides were checked for consistencies between parent and decay product relationships.
- Potentially misidentified radionuclides were screened.
- Organic analyses were compared to blank sample results and were screened out if the concentration in the sample did not "exceed ten times the maximum amount detected in any blank" for common laboratory contaminants, and "five times" for other chemicals (EPA 1989a).
- Average concentrations were determined for all radionuclides and chemicals from RI/FS analytical results.

TABLE E.2-1

SOURCES OF INFORMATION EXAMINED IN THE OPERABLE UNIT 4 BASELINE RISK ASSESSMENT

Source of Information	Type of Information Obtained
WMCO 1988a, 1989a	Concentrations of contaminants in environmental samples
Boback et al. 1987	Source term estimates for silo residues
Dames and Moore 1985	Groundwater modeling parameters and characteristics
Site Remedial Investigation	Concentrations of contaminants in environmental samples and silo residues
Dettorre et al. 1981	Uranium processing and purification information
Grumski 1987a	Engineering information on silos, ISP information, silo residues source term estimates
Grumski 1987b	Engineering information on silos, ISP information
Grumski and Shanks 1988	Engineering information on silos, ISP information
Heatherton 1953	Qualitative indication of silo leakage
Weston 1987	Concentrations of contaminants in environmental samples
ODH 1988	Radon concentration data
Karl 1953	Qualitative indication of silo leakage
Litz 1974	Source term information for K-65 residues
Camargo 1986	Silo engineering information and source term characteristics
Gill 1988	Analyses of K-65 residues

The results of these evaluations are listed in Tables E.2-1 through E.2-7.

Radiological contaminants identified in the waste storage silos are listed in Tables E.2-2 and E.2-3. Isotopes of uranium, radium-226 (Ra-226), thorium-230 (Th-230), and decay products of Ra-226 are of particular concern as a consequence of their radiological properties and the large activities present. Elemental uranium is also considered a chemical hazard because of its chemical toxicity.

Nonradioactive inorganic constituents are also present in the waste storage silo residues. Tables E.2-4 and E.2-5 present elemental, nonradiological constituents of Silos 1 and 2. Approximately 40 percent (by weight) of the waste in Silos 1 and 2 is accounted for by silicates (SiO_2). Other elements contributing at least 1 percent to the total mass of waste material include calcium, iron, magnesium, and lead.

Polychlorinated biphenyls (PCBs) were detected in low concentrations in Silos 1 and 2 with the maximum value being 4 ppm. Several volatile organic compounds were also detected during the 1989 sampling. These are listed in Table E.2-6. The table indicates that with the exception of three organics, most were found in the blank samples. For example, of a total of 10 blank samples, 2-butanone was detected in all 10. Methylene chloride and acetone were detected in nine and seven, respectively. The EPA has stated that a detected concentration of common laboratory contaminants should not be considered a positive hit if it is less than 10 times the highest detected blank concentration for common laboratory contaminants and less than five times the blank concentration for other constituents (EPA 1989a).

The three volatile organic compounds not found in the blank samples are also suspect because they were detected infrequently and the waste residues are thought to be fairly homogeneous. Chloromethane was detected in a single Silo 3 sample; 4-methyl 2-pentanone, a common laboratory contaminant, was detected in two Silo 1 and two Silo 2 samples, and trichloroethane was detected in a single Silo 2 sample.

Constituents in Silo 3 are residues from waste raffinate slurries that were dewatered in an evaporator, spray calcined, and pneumatically transferred to the silos (DOE 1988b). The waste is in a dry, powder-like form. Principal nonradiological constituents of Silo 3 include aluminum, calcium, iron, magnesium, sodium, phosphate, and sulfate. Many of the chemicals in the silo residues are physiologically essential elements and naturally occurring ions.

TABLE E.2-2

ESTIMATED QUANTITIES OF RADIONUCLIDES IN SILOS 1, 2, AND 3

Radiological Constituent	Quantity or Concentration	Reference
	Silos 1 and 2	
Total uranium	11,200 kg (0.71% U-235)	Grumski 1987a
	1400 ppm to 1800 ppm	Gill 1988
Radium	1672 g[a] to 3164 g[b]	Grumski 1987a Litz 1974
Ra-226	0.13 ppm to 0.21 ppm	Gill 1988
Ra-228	0.18 ppt to 0.22 ppt	Gill 1988
Total thorium	301 ppm to 322 ppm	Gill 1988
Th-228	0.77 ppt to 0.85 ppt	Gill 1988
Th-230	1.5 ppm to 2.1 ppm	Gill 1988
	Silo 3	
Uranium	18,000 kg	DOE 1988a
Radium	15.2 g[a]	DOE 1988a

[a]Assumes all radium in K-65 residues is radium-226 with a specific activity of 0.988 Ci/g.

[b]Assumes the total mass of K-65 residues is 8.79×10^6 kg.

TABLE E.2-3

MEASURED QUANTITIES OF RADIONUCLIDES IN SILOS 1, 2, AND 3[a]

Radiological Constituent	Average Concentration[d]	Standard Deviation
Silos 1 and 2	(pCi/g)	(pCi/g)
U-234	772.6	313.0
U-235/236	55.5	13.1
U-238	704.2	291.4
Total Uranium	2111.3 (µg/g)	873.9 (µg/g)
Ra-224	524.5[b]	-
Ra-226	112627.0	53761.0
Ra-228	808.5[b]	-
Th-228	524.5	113.5
Th-230	28928.2	10828.4
Th-232	808.5	42.5
Pb-210	122252.0	89383.7
Ac-227	326.3[c]	-
Pa-231	314.0[c]	-
Silo 3		
U-234	1486.3	417.0
U-235/236	99.4	36.3
U-238	1502.0	459.6
Total Uranium	2999.0 (µ/g)	1242.5 (µg/g)
Ra-224	299.8	133.7
Ra-226	2891.8	1525.6
Ra-228	355.4	146.7
Th-228	825.0	275.5
Th-230	51678.3	15039.2
Th-232	793.0	273.8
Pb-210	2556.9	1448.3
Ac-227	584.4	272.7
Pa-231	562.3	197.0

[a] Analytical results obtained from the supplemental sampling and analysis of the waste storage silos. Average concentration calculated as the arithmetic mean of detected concentrations reported in laboratory analytical results. Standard deviations calculated for the set of detected concentrations reported in laboratory analytical results.

[b] These values are assumed to be equal to the concentration of their most immediate parent radionuclide for which there are analytical results.

[c] These values were calculated by multiplying the corresponding analytical results reported for silo 3 by the ratio of the parent radionuclide activity concentration in Silos 1 and 2 versus Silo 3.

[d] All data, with the exception of values marked by footnotes b and c, reflect positive analytical measurements. The concentrations of constituents reported in this table consistently exceeded detection limits.

TABLE E.2-4

ESTIMATED QUANTITIES OF NONRADIOLOGICAL CONSTITUENTS IN SILOS 1, 2, AND 3[a]

Chemical Constituent	Silos 1 and 2 (metric ton)	Silos 1 and 2 (ppm[b])	Silo 3 (metric ton)
Ag	0.176	18	<0.07
Al	77.0		98.67
As	<2.64		c
Au	0.44	<40 - 78	<0.14
B	1.32		0.70
Ba	6.16	45,300 - 50,000	0.70
Ca	342.0		144.48
Cd	<0.008	c	c
Cl	0.19	c	c
Co	15.4	1500 - 2000	8.81
Cr	1.06		1.76
Cu	4.4	400 - 800	8.81
F	0.33		c
Fe	105.6	13,000 - 18,000	225.52
La	7.83		c
Mg	110		229.52
Mn	1.76		17.27
Mo	1.76		2.11
Na	61.6		133.9
Ni	19.8	2000 - 3700	22.9
Pb	448.8	48,000 - 94,900	8.81
PO_4	c		683.62
Sb	c		<0.53
SiO_2	3587.0		461.62
Sn	0.7		1.41
SO_4	c		692.08
Ti	6.16		2.11
V	1.85		3.52
Zn	<0.060		c
Zr	1.76		c

[a]Source: DOE 1988b.

[b]Source: Dettorre et al. 1981.

[c]Data not reported.

TABLE E.2-5

MEASURED QUANTITIES OF NONRADIOLOGICAL CONSTITUENTS IN SILOS 1, 2, AND 3[a]

Chemical Constituent Silos 1 and 2	Average Concentration (mg/kg)	Standard Deviation (mg/kg)
Aluminum	1018.7	685.2
Arsenic	316.4	548.2
Barium	3634.1	2802.1
Beryllium	2.0	1.4
Cadmium	5.6	4.7
Calcium	45158.2	85234.8
Chromium	43.6	44.6
Cobalt	704.1	600.3
Copper	411.1	475.7
Iron	20440.0	20379.6
Lead	27094.9	28327.9
Magnesium	3933.5	2349.2
Manganese	164.3	122.0
Mercury	0.8	0.6
Nickel	922.5	683.0
Potassium	208.6	128.8
Selenium	104.0	32.9
Silver	10.2	6.1
Sodium	2461.1	3788.4
Thallium	0.6	0.4
Vanadium	124.3	56.6
Zinc	43.1	39.7
Cyanide	2.0	1.3

TABLE E.2-5
(continued)

Chemical Constituent Silo 3	Average Concentration (mg/kg)	Standard Deviation (mg/kg)
Aluminum	17227.3	3733.1
Arsenic	1952.9	1568.0
Barium	216.6	76.3
Beryllium	24.2	9.0
Cadmium	59.8	50.2
Calcium	29372.7	6238.1
Chromium	288.1	134.7
Cobalt	2104.0	832.5
Copper	2546.4	1542.7
Iron	37800.0	15837.2
Lead	1727.8	967.1
Magnesium	58581.8	14676.8
Manganese	4380.0	1433.9
Mercury	0.4	0.2
Nickel	2974.5	1418.4
Potassium	7258.2	6069.2
Selenium	173.5	76.0
Silver	15.9	4.6
Sodium	36100.0	8543.3
Thallium	19.0	21.8
Vanadium	1819.7	1214.0
Zinc	450.0	127.2

[a]Analytical results obtained from the supplemental sampling and analysis of the waste storage silos.

TABLE E.2-6

MEASURED QUANTITIES OF ORGANIC CONSTITUENTS IN SILOS 1, 2, AND 3

Organic Compound	Highest Blank (µg/kg)	Average Concentration (µg/kg) Silo 1	Silo 2	Silo 3
Acetone	4800	2190	1450	5860
2-Butanone	11000	11550	10900	13340
Chloroform	720	715	825	694
Chloromethane	ND	ND	ND	140[e]
Methylene Chloride	3000	2140	3314	1680
4-Methyl 2-Pentanone	ND	1175[b]	1785	ND
Styrene	810	350	200	ND
Trichloroethane	ND	ND	120[c]	ND
Toluene	160	230	191	3398
Total Xylenes	720	ND	165	ND
Aroclor - 1248[d]	ND	3520	2303	ND
Aroclor - 1254	ND	4786	ND	ND
Aroclor - 1260	ND	ND	340[e]	ND

ND = Not detected.

[a] Detected in one of five samples.

[b] Detected in two of six samples.

[c] Detected in one of seven samples.

[d] Aroclor is a tradename for a polychlorinated biphenyl (PCB). The number (1248 and 1254) defines the relative level of chlorination of the compound. The higher this numerical designation the higher the level of chlorination of the compound and the higher the toxicity and potential carcinogenicity of the compound.

[e] Detected in one of six samples.

TABLE E.2-7

EXTRACTION PROCEDURE TOXICITY RESULTS FOR OPERABLE UNIT 4 SILOS (mg/L)

Parameter	Range	Average	Allowable Leachate Concentration[b]
Silo 1[a]			
Arsenic	0.23 - 0.48	0.36	5.0
Barium	0.08 - 14.5	4.4	100.0
Cadmium	0.01 - 1.0	0.03	1.0
Chromium	0.02 - 0.96	0.33	5.0
Lead	0.16 - 904	561.0	5.0
Selenium	0.22 - 1	0.54	1.0
Silver	0.04 - 0.12	0.09	5.0
Mercury	ND[c]		0.2
Silo 2[d]			
Arsenic	0.16 - 0.59	0.39	5.0
Barium	0.1 - 2.6	1.1	100.0
Cadmium	0.02 - 0.28	0.1	1.0
Chromium	0.16 - 1.02	0.57	5.0
Lead	0.16 - 714	322.0	5.0
Selenium	0.24 - 1.6	0.7	1.0
Silver	0.05 - 0.21	0.13	5.0
Mercury	ND		0.2
Silo 3[e]			
Arsenic	0.02 - 41.5	11.6	5.0
Barium	0.02 - 1.6	0.07	100.0
Cadmium	0.12 - 6.3	0.93	1.0
Chromium	0.34 - 11.9	4.8	5.0
Lead	0.05 - 1.01	0.36	5.0
Selenium	1.2 - 11.7	2.8	1.0
Silver	0.032		5.0
Mercury	ND		0.2

[a]Based on six samples and one duplicate sample.
[b]Source: EPA 1990b, "Identification and Listing of Hazardous Waste," 40CFR261, May 1, 1990, Washington, D.C.
[c]ND = Not detected.
[d]Based on six samples.
[e]Based on seventeen samples.

Extraction Procedure (EP) Toxicity tests were performed to determine the leachability of the nonradiological constituents of the silos. Results indicate that some of the silo material is very soluble, including lead in the K-65 silos and arsenic and selenium in the metal oxide silo. Table E.2-7 summarizes the results of the EP Toxicity analyses. Note that in some instances average leachate concentrations exceed the former standards used to determine the presence of characteristic hazardous wastes. New standards under 40CFR261 are based on the Toxicity Characteristic Leaching Procedure (TCLP). Proposed sampling for the silo residues includes TCLP analyses.

Environmental sampling data were evaluated in the following manner:

- The frequency of detection was determined for each constituent detected at least once in each medium.
- The range of sample quantitation limits (SQL) was reviewed. For the groundwater data evaluation, an acceptable SQL was determined because some SQLs were too high for the results to be useful in the analyses. These acceptable SQLs are listed in the summary table footnotes.
- The range of detected concentrations was evaluated.
- Detected concentrations were compared to background concentrations.

The result of these evaluations are presented in Tables E.2-8 through E.2-13.

The area proximal to Operable Unit 4 has been monitored for direct exposure to penetrating radiation (gamma radiation). These measurements are collected at periodic intervals using thermoluminescent dosimeters (TLDs) placed at fixed air monitoring stations along the FMPC site boundary to provide a composite annual measurement (Figure E.2-1). The monitoring stations employ TLDs to measure the annual external exposure rate from penetrating radiation. A summary of measured penetrating radiation data from WMCO's environmental monitoring program is included in Table E.2-8. The summary external exposure rate data presented in Table E.2-8 correspond to measurement locations AMS-1 through AMS-7 (Figure E.2-1). The background external exposure rate data presented in Table E.2-8 correspond to measurement locations BKGD-1 and BKGD-2 (Figure E.2-1). Examination of the WMCO external exposure rate data reveals that radiation fields at the waste silos and along the western FMPC boundary fenceline due west of the silos are consistent with the assumption that the silos are the primary source of above-background external exposure rates in the vicinity of Operable Unit 4. Thus, it is assumed in the risk assessment that the silos are the source of above-background external exposure rates used to quantitate risk. The receptor exposure level used to quantitate risk is established in Section E.3.0.

TABLE E.2-8

SUMMARY OF PENETRATING RADIATION FIELDS AND AIRBORNE RADON CONCENTRATIONS MEASURED IN THE VICINITY OF OPERABLE UNIT 4[a]

Radiation Dose or Radionuclide	Frequency of Detection	Range of Detected Values[b]	Range of Background Levels[c]
Penetrating radiation[d]	28/28	6.50 - 23.53 µrem/hr	7.12 - 15.72 µrem/hr
Radon-222[e]	64/64	0.20 - 3.40 pCi/L	0.30 - 1.60 pCi/L

[a]Data from the WMCO environmental monitoring program for 1988.

[b]Pentrating radiation data obtained from locations AMS-1 through AMS-7. Radon data obtained from locations FMPC-A through FMPC-P. Data represent quarterly results.

[c]Background penetrating radiation data and airborne radon concentration data obtained from locations BKGD-1 and BKGD-2 (Figure E.2-1). Data represent quarterly results.

[d]Penetrating radiation is defined as energetic electromagnetic emissions from radionuclides.

[e]Analytical results from type "M" detectors only.

TABLE E.2-9

SUMMARY OF CHEMICALS AND RADIONUCLIDES SAMPLED IN SURFACE SOILS IN THE VICINITY OF OPERABLE UNIT 4

Chemical or Radionuclide	Frequency of Detection	Range of Sample Quantitation Limits[a]	Range of Detected Concentration[b]	Background Concentrations
Ra-226	31/38	0.3 - 0.5 pCi/g	0.5 - 35.8 pCi/g	1.5 pCi/g[c]
U-238	28/38	3.3 - 19.4 pCi/g	2.4 - 37.4 pCi/g	1.4 pCi/g[c]
U-234	7/38	d	2.4 - 11.0 pCi/g	1.4 pCi/g[e]
U-235	0/38	0.4 - 0.6 pCi/g	None	0.06 pCi/g[f]
Th-232	8/38	0.3 - 6.5 pCi/g	0.6 - 1.7 pCi/g	1.0 pCi/g[c]
Th-230	4/38	d	2.2 - 295 pCi/g	1.4 pCi/g[e]

[a]Sample quantitation limit is the lowest level of a contaminant that the laboratory can accurately and reducibly quantitate in a sample. Because a specific sample may require adjustment in preparation or analytical method, the value for individual constituents may vary.

[b]Analytical results obtained from the FMPC RI/FS Surface Soil Characterization program and the FMPC Characterization Investigation Study (Weston 1987). Analyses were performed by either gamma-ray spectrometry or radiochemical separation followed by specific spectrometric techniques appropriate for the radionuclides of interest. RI/FS data correspond to locations 5650, 5647, 5644, 5884, 5887; CIS data correspond to locations 194 to 209, 318 to 325, 566 to 569.

[c]Myrick et al. 1983.

[d]Data not available.

[e]Assuming secular equilibrium for U-238, U-234, and Th-230 under natural background conditions.

[f]Assuming natural isotopic ratios of U-235 to U-238.

TABLE E.2-10

SUMMARY OF CHEMICALS AND RADIONUCLIDES SAMPLED IN SLANT BORINGS BENEATH THE K-65 SILOS[a]

Chemical or Radionuclide	Frequency of Detection	Range of Sample Quantitation Limits	Range of Detected Concentration	Background Concentrations
Natural (total) uranium	8/8	b	0.77 - 9.66 pCi/g	2.9 pCi/g[c]
Ra-226	8/8	b	0.68 - 1.2 pCi/g	1.5 pCi/g[c]

[a]Source: Vogel 1989.
[b]Data not available.
[c]Assumed to be the same as for surface soils.

TABLE E.2-11

SUMMARY OF CHEMICALS AND RADIONUCLIDES SAMPLED IN GROUNDWATER IN THE VICINITY OF OPERABLE UNIT 4

Chemical or Radionuclide	Frequency of Detection[a]	Range of Sample Quantitation Limits[b]	Range of Detected Concentration[c]	Background Concentrations[d]
1000-Series Wells				
Ra-226	1/24	1 pCi/L	1 pCi/L	<1 pCi/L
Ra-228	1/24	3 pCi/L	4.8 pCi/L	3.2 (5.1) pCi/L
Sr-90	1/24	5 pCi/L	6.0 pCi/L	<5 pCi/L
Th-230	2/24	1 pCi/L	1.4 - 2.4 pCi/L	<1 pCi/L
Th-total	1/18	2 - 9 µg/L	3 µg/L	<30 µg/L
U-total	24/24	1 µg/L	2 - 276 µg/L	1.2 (2.3) µg/L
Arsenic	1/11	0.0017 - 0.2 mg/L	0.003 µg/L	0.002 (0.004) mg/L
Barium	19/19	0.002 - 0.2 mg/L	0.035 -37 mg/L	0.062 (0.11) mg/L
Cadmium	7/13	0.0007 - 0.005 mg/L	0.004 - 0.016 mg/L	0.003 (0.011) mg/L
Chromium	6/20	0.0017 - 0.002 mg/L	0.019 - 0.038 mg/L	0.021 (0.032) mg/L
Copper	7/19	0.002 - 0.2 mg/L	0.01 - 0.024 mg/L	0.016 (0.048) mg/L
Lead	6/13	0.002 - 0.2 mg/L	0.002 - 0.015 mg/L	0.003 (0.008) mg/L
Manganese	20/20	0.01 - 0.02 mg/L	0.009 - 0.28 mg/L	0.044 (0.158) mg/L
Mercury	3/19	0.0002 - 0.001 mg/L	0.0009 - 0.026 mg/L	0.00022 (0.00037) mg/L
Nickel	3/18	0.012 - 0.04 mg/L	0.021 - 0.025 mg/L	0.02 (0.03) mg/L
Silver	1/20	0.0005 - 0.01 mg/L	0.03 mg/L	0.016 (0.055) mg/L
Zinc	1/1	None given	0.042 mg/L	NA
PCBs	0/1	0.001 - 0.0005 mg/L	ND	NA

TABLE E.2-11
(continued)

Chemical or Radionuclide	Frequency of Detection[a]	Range of Sample Quantitation Limits[b]	Range of Detected Concentration[c]	Background Concentrations[d]
2000-Series Wells				
Ra-226	1/16	1 pCi/L	1.6 pCi/L	1.11 (1.89) pCi/L
Th-228	2/16	1 pCi/L	1-1.1 pCi/L	<1 pCi/L
Th-230	2/16	1 pCi/L	1.2 - 1.9 pCi/L	<1 pCi/L
U-total	15/16	1 µg/L	2-27 µg/L	1 (1) µg/L
Barium	10/11	0.002 - 0.2 mg/L	0.03 - 0.049 mg/L	0.63 (0.89) mg/L
Cadmium	4/8	0.0007 - 0.005 mg/L	0.002 - 0.02 mg/L	<0.005 mg/L
Chromium	3/15	0.0017 -0.002 mg/L	0.022 - 0.025 mg/L	0.02 (0.028) mg/L
Copper	3/12	0.002 - 0.2 mg/L	0.012 - 0.017 mg/L	<0.01 mg/L
Lead	4/8	0.002 - 0.2 mg/L	0.004 - 0.024 mg/L	0.005 (0.022)
Manganese	12/15	0.01 - 0.02 mg/L	0.002 - 0.105 mg/L	0.046 (0.134) mg/L
Mercury	4/13	0.0002 - 0.001 mg/L	0.0004 - 0.0058 mg/L	0.00027 (0.00076 mg/L)
Nickel	2/12	0.012 - 0.04 mg/L	0.021 - 0.03 mg/L	<0.02 mg/L
Zinc	2/2	None given	0.012 - 0.032 mg/L	NA
PCBs	0/2	0.005 - 0.001 mg/L	ND	ND
Di-n-butylphthialate	2/2	None given	0.004JB-0.006JB mg/L[e]	ND
Benzyl-butylphthalate	1/2	0.01 mg/L	0.001J[e] mg/L	ND
Ethyl benzene	1/2	0.005 mg/L	0.002J[e] mg/L	ND
Methylene Chloride	2/2	None given	0.002JB - 0.006 mg/L[e]	ND
Bis (2 Ethylhexyl) phthalate	1/2	0.01 mg/L	0.05 B mg/L[e]	ND
2-propanone (acetone)	1/2	0.01 mg/L	0.006BJ mg/L	ND
3000-Series Wells				
Tc-99	2/12	1 pCi/L	36.4 - 44.5 pCi/L	<30 pCi/L
Ra-228	1/12		3.8 pCi/L	<3 pCi/L
Th-total	1/9		1 µg/L	<30 µg/L
U-total	10/12	1 µg/L	1-4 µg/L	1.1 (1.6) µg/L
Barium	9/9		0.006-0.062 mg/L	0.63 (0.89) mg/L
Cadmium	5/7	0.0007 - 0.005 mg/L	0.002 - 0.032 mg/L	0.005 (0.006) mg/L
Chromium	3/12		0.02 - 0.029 mg/L	0.021 (0.028) mg/L
Copper	4/11		0.01 -0.09 mg/L	<0.01 mg/L
Lead	2/6	0.002 -0.2 mg/L	0.003 - 0.013 mg/L	0.006 (0.022) mg/L
Manganese	11/12	0.01 - 0.02 mg/L	0.006 - 0.47 mg/L	0.047 (0.134) mg/L
Mercury	1/10		0.0008 mg/L	0.00026 (0.00076) mg/L
Nickel	1/9	0.012 - 0.04 mg/L	0.034 mg/L	<0.02 mg/L
Silver	1/11		0.024 mg/L	0.01 (0.01) mg/L

TABLE E.2-11
(continued)

[a]Frequency of detection is the number of times a chemical was positively detected in a sample over the number of samples analyzed. The number of samples considered for the metals changes for each metal due to the following data analysis consideration: Several metal analyses were unable to achieve an acceptable sample quantitation limit, often due to matrix interference. For each metal, an acceptable SQL was determined and any analyses that did not achieve that SQL were not considered in the sample population. Acceptable SQLs are: Arsenic-0.002; Barium-0.05; Cadmium-0.002; Chromium-0.02; Copper-0.01; Lead-0.002; Manganese-0.05; Mercury-0.0002; Nickel-0.02; Silver 0.01.

[b]Range of sample quantitation limits devotes the instrument detection limits achieved throughout all analyses of the environmental medium of interst. Because a specific sample may require adjustment in preparation of analytical procedures, values for individual constituents may vary. Note that sample quantitation limits are sometimes noted for chemicals detected in 100 percent of the samples. In these cases, it was predetermined that samples with high SQLs could not be included in the sample population (see footnote a). These high SQLs are reported in the table even though they were not included in the data evaluation.

[c]Range of detected concentrations were determined from review of positive detections from the following Operable Unit 4 wells: 1000 series-1029, 1032, 1008, 1033, 1034, 1009, 1018; 2000 series-2008, 2034, 2009, 2018,; 3000 series -3034, 3009, 3018.

[d]Background concentrations are determined by analysis of background wells north of Operable Unit 4. These wells include: 1000 series - 1024, 1059, 1060, 1065; 2000 series - 2056, 2050, 2105, 2066; 3000 series - same as 2000 series plus 3063, 3099, 3100. For each series wells, an average and upper 95% tolerance limit (TL) was determined, as suggested by EPA (1989e). Downgradient concentrations detected above the TL indicate potential contamination.

[e]J = below instrument quantitation limit; B = compound found in associated blank; ND = not detected; NA = not analyzed.

TABLE E.2-12

SUMMARY OF CHEMICALS AND RADIONUCLIDES SAMPLED IN SURFACE WATER IN THE VICINITY OF OPERABLE UNIT 4

Chemical or Radionuclide	Frequency of Detection	Range of Sample Quantitation Limits	Range of Detected Concentration[a]	Background Concentrations
Natural (total) uranium	6/6	1 µg/L	5 - 2219 µg/L	1.4 pCi/L[c] (2.1 µg/L)
U-234	6/6	1.0 pCi/L	1.3 - 85.6 pCi/L	1.0 pCi/L
U-235/236	2/6	1.0 pCi/L	6.0 - 6.7 pCi/L	0.2 pCi/L
U-238	6/6	1.0 pCi/L	2.0 - 196 pCi/L	1.0 pCi/L
Ra-226	0/6	1.0 pCi/L	None	1.0 pCi/L
Tc-99	1/6	30 pCi/L	36.9 pCi/L	b

[a]Data obtained from RI/FS sample locations ASIT-10, 23, 24, 25, 26; WMCO sample location W-10.

[b]Data not available.

[c]WMCO 1989a.

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TABLE E.2-13

SUMMARY OF CHEMICALS AND RADIONUCLIDES SAMPLED IN SEDIMENT FROM PADDYS RUN

Chemical or Radionuclide	Frequency of Detection	Range of Sample Quantitation Limits	Range of Detected Concentration[a]	Background Concentrations
Natural uranium	6/7	1.0 µg/g	1.0 - 30.3 µg/g	2.9 pCi/g[b]
Ra-226	7/7	c	0.4 - 1.0 pCi/g	1.5 pCi/g[b]

[a]Sediment samples collected at same locations as surface water samples.
[b]Assumed to be the same as for surface soil.
[c]Data not available.

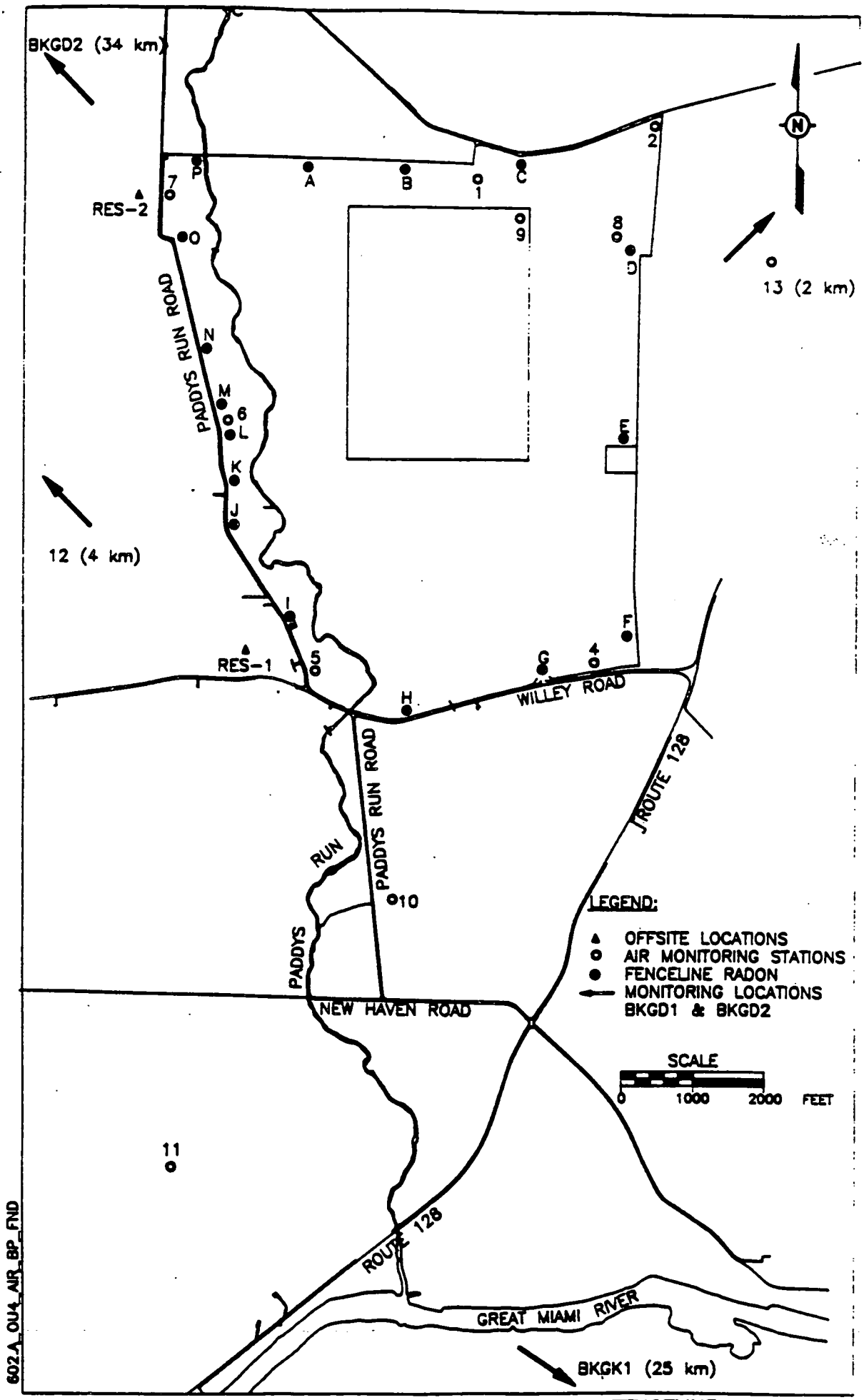

FIGURE E2-1. AIR MONITORING STATIONS AND FENCELINE RADON MONITORING LOCATIONS

External exposure rate data along the northern, eastern, and southern FMPC boundary fencelines indicate that public exposure rates proximal to those fencelines are at background levels. Exposure rate data along the western FMPC fenceline due west of Operable Unit 4 are slightly elevated above background. The exposure rates along the K-65 silo fenceline are an order of magnitude higher than all the boundary fenceline exposure rates.

Airborne radon concentrations at various locations on and off the FMPC site are measured throughout each year as part of the FMPC environmental monitoring program. Locations of radon monitors used in the FMPC environmental monitoring program are shown in Figure E.2-1. Monitoring locations employ commercially available alpha-track radon detectors. These devices are exposed to the ambient air and, after processing, indicate the radon concentrations at each location. A summary of measured airborne radon concentration data collected since completion of the foaming project is included in Table E.2-8. The summary airborne radon concentration data presented in Table E.2-8 correspond to measurement locations FMPC-A through FMPC-P (Figure E.2-1). The background data in Table E.2-8 correspond to measurement locations BKGD-1 and BKGD-2 (Figure E.2-1). Examination of the WMCO radon concentration data reveals that concentrations at the K-65 silos and along the western FMPC boundary fenceline due west of the silos are consistent with the assumption that the K-65 silos are the primary source of above-background airborne radon concentrations in the vicinity of Operable Unit 4. In addition, the K-65 silos are a unique source of large quantities of Ra-226 activity at the FMPC. Thus, it is assumed in the risk assessment that the K-65 silos are the source of above-background airborne radon concentration used to quantitate risk. The receptor exposure level used to quantitate risk is established in Section E.3.0. Radon concentrations along the FMPC boundary fenceline follow the trend of the external exposure rate data. Radon concentrations along the K-65 fenceline are several times higher than boundary fenceline concentrations.

The Ohio Department of Health (ODH) performed independent indoor and outdoor radon concentration measurements in the vicinity of the FMPC (ODH 1988). The ODH established 16 outdoor radon monitoring stations around the FMPC, including 12 locations along the FMPC site boundary (samples) and 4 locations distant from the FMPC (controls). In its report, the ODH concluded that analyses of the detectors located at the site boundary closest to the K-65 silos and at background locations did not reveal consistent significant differences in measured radon concentrations (ODH 1988). The ODH study also concluded that environmental concentrations of radon and radon progeny at the FMPC boundary are sufficiently low so that they often cannot be distinguished from variations in natural background concentrations, and measured concentrations did

not appear to correlate with distance or prevailing wind direction from the K-65 silos (ODH 1 The data collected in the ODH study are not utilized in the quantitative risk assessment becau data were collected prior to the completion of the K-65 ISP and are not representative of the current exposure conditions.

Surface soil samples collected in the area proximal to Operable Unit 4 have been analyzed fo radionuclides. To date, no Hazardous Substance List (HSL) analyses have been performed on samples from areas surrounding the silos. Locations of RI surface soil samples are shown in E.2-2. Radiological characterization of surface soils surrounding the Operable Unit 4 silos re elevated levels of uranium in the vicinity of the silos (Table E.2-9). Table E.2-9 presents me concentrations of uranium in surface soils as high as 37.4 picocuries/gram (pCi/g) of U-238 a 11.0 pCi/g of U-234 within the vicinity of Operable Unit 4. For comparison purposes, backg concentrations of U-238 in Ohio surface soils average 1.4 pCi/g (Myrick et al. 1983). In nat soils, a similar background activity concentration of U-234 may be expected. Details of RI s pling and analysis procedures are presented in the RI/FS project plans (IT Corporation 1988).

Radiological assessment of surface soils surrounding the Operable Unit 4 silos also reveals el concentrations of Ra-226 (Table E.2-9). The highest concentration of Ra-226 in surface soil pCi/g. For comparison purposes, background concentrations of Ra-226 in Ohio surface soils average 1.5 pCi/g (Myrick et al. 1983).

In addition, soil samples were collected in 1983 from two diagonal slant boreholes drilled be the silo berms. Radiological analyses of these samples reveal elevated concentrations of uran soil (Table E.2-10) (Vogel 1989). Analytical results provide some evidence of a decrease in uranium concentration with depth. The concentrations of Ra-226 are below background for s (1.5 pCi/g). A similar sampling program that will include analyses for radionuclides, HSL inorganics, volatiles, semivolatiles, pesticides, PCBs, and EP Toxicity metals has been request (Harmer 1989). The new subsurface soil results should provide a more extensive characteriz contaminants beneath the silos than the slant boring effort conducted during 1983. The new could provide an indication of whether the uranium and Ra-226 detected during the 1983 sam effort resulted from a historical spill or from a continuous leak from the silos. If the silos a leaking, a concentration gradient as a function of depth would be expected. A historical spill area would be likely to result in a mobile plume of contamination rather than a continuous concentration gradient.

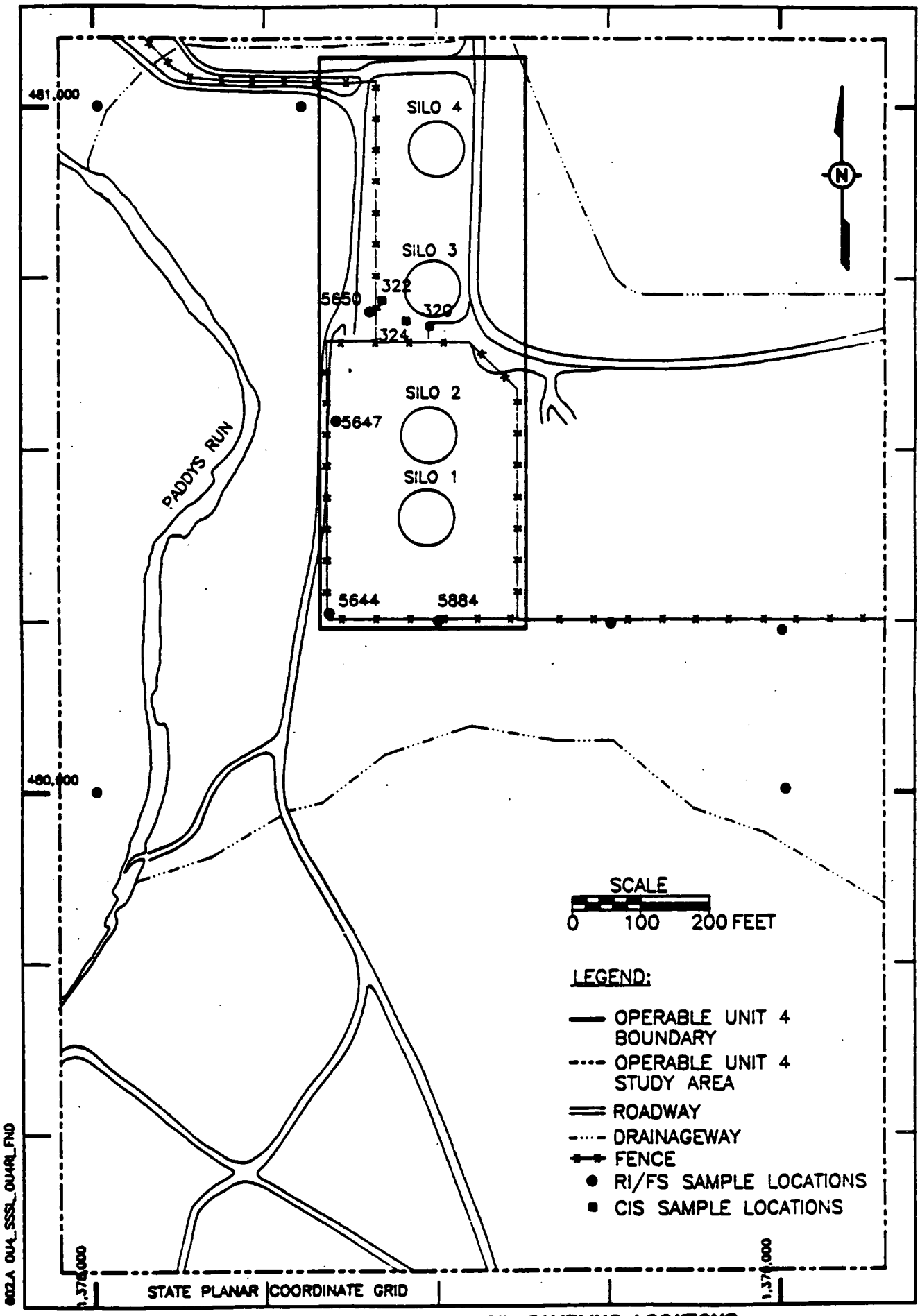

FIGURE E2-2. SURFACE SOIL SAMPLING LOCATIONS

The deposition of progeny of the radon that escapes from the K-65 silos was evaluated to estimate the accumulation of the longer half-life progeny, such as lead-210 (Pb-210), in surface soils and the use of these soils for agriculture. This evaluation indicates that the accumulation of these progeny will not be discernible from the natural variation in background concentrations.

An additional potential transport pathway identified during the risk assessment concerns radon diffusion through the K-65 silo walls and into the silo berms. This pathway is considered a potential release mechanism. Diffusion through the domes is reported to release approximately 60 curies of radon per year (Grumski 1987a; Borak 1985). If radon diffuses laterally through the silo walls into the berm soil, it decays to nongaseous progeny that deposit in the soil. Two of these progeny, Pb-210 and polonium-210 (Po-210), have sufficiently long half-lives to accumulate in the berm soil. The radiological characterization of the K-65 silo berm soils has not yet been performed; therefore, the extent of accumulation of radiological contaminants in berm soil cannot be fully assessed. However, calculations using RAECOM, a Nuclear Regulatory Commission computer code for assessing radon releases from uranium mill tailings, indicate a potential for sufficient activity concentrations of Pb-210 to warrant concern during remedial action and in the future should the Pb-210 become available in soils used for agriculture. The method and assumptions used in the assessment of potential Pb-210 activity concentrations in the berm soil and the calculation results are presented in Attachment E.I.

Simplified modeling of the migration of radon into the berm soil suggests that radon may be diffusing through the K-65 silo walls into the berm soils. Preliminary estimates suggest that up to 1.2×10^5 pCi/g (approximately 1.6×10^{-3} µg/g) Pb-210 may be present in the silo berms as a result of radon diffusion through the silo walls. The background concentration for elemental lead in southwest Ohio is approximately 15 µg/g (USGS 1984). This suggests that the total mass of lead contributed to the environment via this pathway may not be a significant increase above background; however, the elevated Pb-210 activity would be of potential concern if the calculated concentrations are present. An explanation of the method used to estimate the potential concentration of Pb-210 in the berm soil is presented in Attachment E.I. These estimates demonstrate that accumulation of Pb-210 in the bern soil could be sufficient to warrant control of berm materials during remediation and could be of concern in the future should uncontrolled access to the berm soil be permitted.

Data on Pb-210 and Po-210 activity concentrations in the concrete walls of the K-65 silo at the Niagara Falls Storage Site indicate that the activity concentrations of these radionuclides at a depth

of eight inches in the wall is reduced by a factor of approximately 500 relative to the concentrations at the surface. The modeled activity concentrations have led to a request for berm soil sampling to determine whether significant berm soil contamination by these radionuclides exists. If soil samples collected from the berms around the K-65 silos reveal elevated concentrations of Pb-210 or Po-210 activity, the contamination must be considered in the evaluation of remedial alternatives. It is believed that if present, the lead in the soils is likely to be deep in the berm soils and not available for erosion in surface water runoff.

Groundwater in the area proximal to and downgradient from Operable Unit 4 has been sampled for radionuclides and chemicals as part of the RI/FS (Figure E.2-3). Elevated concentrations of uranium have been measured in water from all wells in the vicinity of Operable Unit 4. Well 1032 to the west of the K-65 silos (Figure E.2-3) revealed a maximum total uranium concentration of 276 micrograms/liter (µg/L) (184 pCi/L) (Table E.2-11). Total uranium in 2000-series background wells is below the analytical lower limit of detection of 1 µg/L. The background total uranium concentration for groundwater flowing from the north is approximately 1 µg/L. The source of the uranium in Well 1032 has not been confirmed. Well 1032 is located in a buried rubble pile that has been designated a suspect area to be addressed in Operable Unit 3. Therefore, the contaminated perched water in Well 1032 is not addressed in the Operable Unit 4 risk assessment. The maximum concentration of total uranium in 2000-series wells is an order of magnitude less than the maximum concentration in Well 1032. The concentration of total uranium in 3000-series wells is comparable to background concentrations. If the source of the measured uranium in these wells had been Operable Unit 4, one would also expect to detect Ra-226 in above-background concentrations because Ra-226 is a unique indicator of waste material from Operable Unit 4 (and the K-65 silos in particular). No wells in the vicinity of Operable Unit 4 reveal concentrations of Ra-226 above 1 pCi/L (Table E.2-11). However, the absence of Ra-226 in groundwater samples collected does not preclude the possibility that uranium, in a more soluble form than radium, could have been or could be released from the silos.

Table E.2-11 also presents results of analyses for metals in groundwater samples. One well in the glacial overburden, Well 1008, exhibited concentrations slightly above-background for barium and manganese. No other overburden wells exhibited above-background concentrations for metals. Well 1008 may be influenced by the waste pits. Average metal concentrations for each Operable Unit 4 2000-series well were below background well 95 percent tolerance levels. Selected groundwater samples were also analyzed for semivolatile organics, volatile organics, pesticides and PCBs. No organics or PCBs were found in concentrations above quantitation limits.

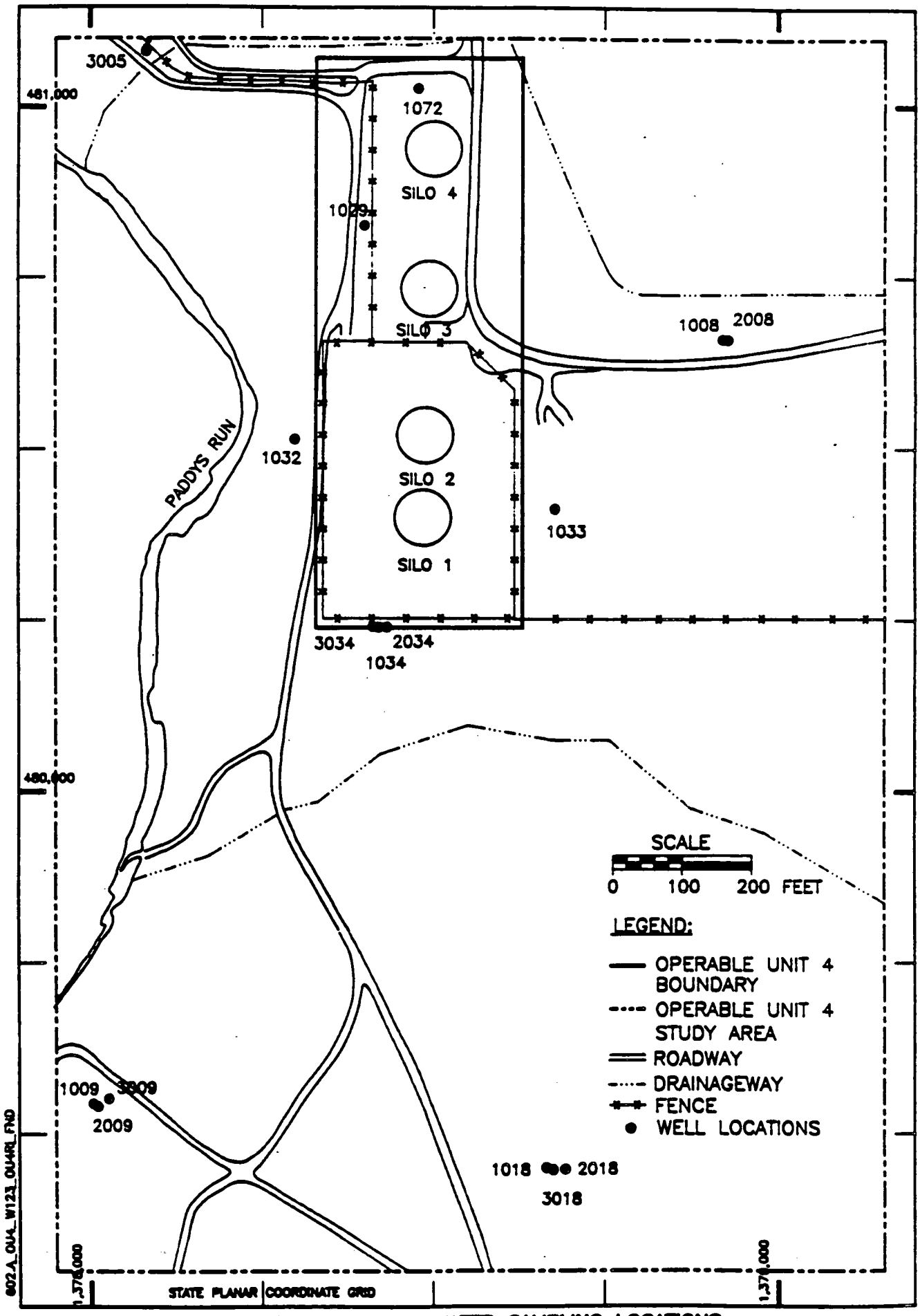

FIGURE E2-3. GROUNDWATER SAMPLING LOCATIONS

Surface water in the vicinity of Operable Unit 4 has been sampled as part of the WMCO annual environmental monitoring program and the RI/FS. Surface water sampling locations are shown in Figure E.2-4. Measured concentrations of chemicals and radionuclides in surface water are presented in Table E.2-12. Above-background concentrations of uranium have been found at sampling location W-10 in Paddys Run downstream from the silos but upstream from the confluence of Paddys Run and the storm sewer outfall ditch (SSOD). The maximum measured total uranium concentration is 2219 µg/L (1480 pCi/L) from a sample collected at location ASIT-10 (Table E.2-12). The average background total uranium concentration in surface water in the vicinity of the FMPC is approximately 2.1 µg/L (1.4 pCi/L) (WMCO 1989a). This average background was derived by averaging data from three sampling locations along the Great Miami River upstream of the FMPC.

Analyses of sediment samples from Paddys Run collected as part of the WMCO environmental monitoring program and the RI/FS provide a description of the radiological concentrations in stream sediments. Figure E.2-4 presents sediment sample locations of RI/FS data. At each sediment sample location, a sample was collected from the eastern and western sides of the stream bed and from the middle of the stream bed. Concentrations of chemicals and radionuclides measured in RI/FS sediment samples are presented in Table E.2-13. The maximum total uranium concentration in the sediment samples collected is 30.3 micrograms/gram (µg/g).

Sediment sampling conducted as part of the WMCO environmental monitoring program is summarized in environmental monitoring reports (WMCO 1988; WMCO 1989a). Sediment samples were collected every 100 meters in Paddys Run upstream of the confluence with the SSOD, every 200 meters in Paddys Run between the SSOD and the Great Miami River, and every 100 meters in the SSOD. Three samples were collected from each location, at each bank, and at the center of the stream bed. Samples were analyzed for isotopes of uranium, thorium, radium, plutonium, and Tc-99. Analytical results are summarized in the WMCO environmental monitoring reports (WMCO 1988; WMCO 1989a). In 1987 and 1988, above-background concentrations of uranium, thorium, and radium were detected in sediment samples form the SSOD. Concentrations of uranium, thorium, and radium detected in sediment samples from Paddys Run were determined to be background (WMCO 1988; WMCO 1989a).

The source of above-background concentrations of uranium in surface water and sediment in Paddys Run is not confirmed, but it is noteworthy that drainage ditches from the Waste Storage Area enter Paddys Run in this general area. Concentrations of total uranium detected in surface water samples

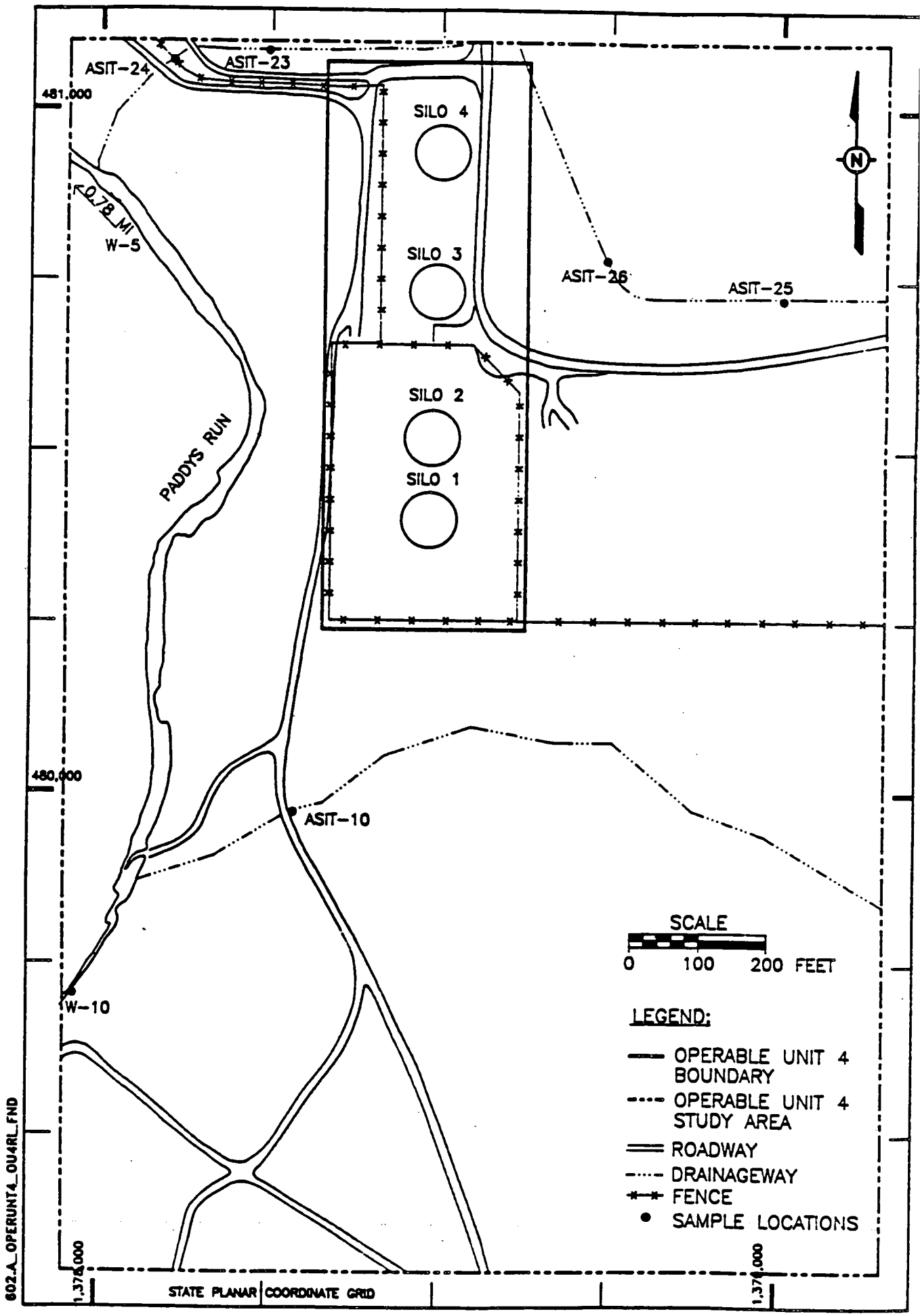

FIGURE E2-4. SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS

collected from the waste pit area average approximately 3400 µg/L. Concentrations of Ra-226 in surface water samples from Paddys Run did not exceed background concentrations at any location.

E.2.3 UNCERTAINTIES, LIMITATIONS, AND GAPS IN DATA

EPA risk assessment guidance emphasizes the importance of identifying the variables and assumptions that contribute the greatest uncertainty to the risk assessment rather than collecting sufficient data to conduct a highly quantitative uncertainty analysis (EPA 1989a). Therefore, discussions of uncertainty in this section address sources of uncertainty only in a qualitative manner.

The data used in the Operable Unit 4 quantitative risk assessment incorporate uncertainty from radiation exposure rate data and airborne radon concentration data because of the natural variations in these quantities in the environment. Stations monitoring external radiation exposure and airborne radon concentrations are located at points in the environment on site and off site. Few of the external radiation exposure rate measurements and airborne radon concentrations at the FMPC fenceline exceed background levels by more than a factor of two. This makes it difficult to differentiate between natural variations in background levels and levels of radon and external radiation exposure attributable to Operable Unit 4 in the vicinity of the FMPC boundary fenceline.

This uncertainty has a major impact on the level of risk determined by the baseline risk assessment for Operable Unit 4. To ensure the risk assessment represents an RME that would result in remedial actions that are protective of human health and the environment, it is necessary to assume that the difference between the highest annual average measured radiation and radon levels at the location of a potential receptor and the regional background is attributable to Operable Unit 4. In fact, a study by the ODH (ODH 1988) reported that all measured off-site radon concentrations are indistinguishable from natural background. Likewise, Operable Unit 4 may contribute very little or nothing to the penetrating radiation exposure of any member of the public. The difference between the highest off-site measurement of radiation exposure and the average background levels measured in the region are within normal temporal and spatial variability of the natural background or may result from statistical artifacts in measurements and calculational data.

Uncertainty also exists in the data used to conduct the quantitative risk assessment as a result of systematic biases. Examples include biased selection of sampling locations, numbers of samples collected, media sampled, and types of analyses performed on samples.

Analytical data for environmental media immediately adjacent to the silos are limited. Surface soil analytical data in the vicinity of the K-65 silos are very limited, including only four RI/FS sample locations (Figure E.2-2). The K-65 silo berms have not been sampled and the soils directly beneath the K-65 silos have not been sampled as part of the RI/FS field investigation. The effect of these current gaps in data applicable to Operable Unit 4 is that two important questions cannot be definitely answered:

- Are above-background concentrations of radionuclides and chemicals in surface soils, subsurface soils, groundwater, and surface water within and adjacent to Operable Unit 4 attributable to releases from Operable Unit 4?
- If so, to what extent are these conditions attributable to Operable Unit 4 rather than other source terms?

Sampling and analyses are planned for the berm soil and the soil beneath the waste storage silos to determine whether the silos could be releasing contaminants to berm soil, subsurface soil, and groundwater and to measure the concentrations of Pb-210 that may have accumulated from radon decay in the berm soil. Until the results of these analyses are available, the quantitative exposure assessment relies on best estimates of source terms and transport parameters.

E.2.4 SUMMARY OF RADIONUCLIDES AND CHEMICALS OF POTENTIAL CONCERN

Based on available measurement data concerning the constituents of the Operable Unit 4 waste storage silos, measurement data from environmental monitoring, and information concerning uranium purification processes at the FMPC, the current site-related radionuclides of concern for Operable Unit 4 are listed in Table E2-14. Although environmental sample analytical data do not demonstrate that Th-230 has been released from the silos, available analytical data are inadequate to confirm that leakage of Th-230 has not occurred. Therefore, it is assumed that Th-230 could leach from the silos and migrate to groundwater. Pb-210 is included because significant quantities of radon may have diffused through the silo walls into the berm soil and deposited radon decay products including Pb-210 within the berm soil. Berm soil sampling is planned to determine the extent of Pb-210 accumulation in the K-65 berms. Elemental uranium is the only current site-related potential chemical of concern.

The site-related radionuclides of potential future concern for Operable Unit 4 are listed in Table E2-15. The additional radionuclides and chemicals are included in this list because they are present inside the silos, but no data exist to indicate that they have been released from the silos. These radionuclides and chemicals may potentially be released in the future.

TABLE E.2-14
CURRENT CHEMICALS OF CONCERN FOR OPERABLE UNIT 4 BY MEDIA

Medium	Chemical of Concern
Air	Direct penetrating radiation Radon Radon progeny
Soil	Uranium Radium Radon progeny
Sediment/Surface Water	Uranium Radium Radon progeny
Groundwater[a]	Uranium

[a]Current chemicals of concern in the groundwater are being addressed in Operable Unit 5.

TABLE E.2-15

FUTURE CHEMICALS OF CONCERN FOR OPERABLE UNIT 4 FOR ALL MEDIA

Direct penetrating radiation	Chromium
Radon	Copper
Thorium	Lead
Actinium	Manganese
Protactinium	Mercury
Lead (radioactive)	Nickel
Arsenic	Selenium
Barium	Thallium
Beryllium	Vanadium
Cadmium	Zinc

The K-65 waste storage silos are a relatively unique source of large quantities of Ra-226 activity at the FMPC. In contrast, uranium contamination at the FMPC most likely originates from many areas of the site. Measured above-background quantities of Ra-226 in environmental media in the vicinity of Operable Unit 4 could indicate releases from the K-65 silos or contamination from past practices associated with silo filling. However, the relative absence of Ra-226 contamination in environmental samples does not entirely preclude the possible release of uranium from the K-65 silos because radium in the silos in its insoluble radium sulfate form would be expected to be less mobile than uranium in its soluble uranyl carbonate or phosphate form (Dettorre et al. 1981). Under such circumstances and assuming that materials are being released from the silos, uranium could be released at a faster rate than radium. The planned sampling and analyses of the soils directly beneath the silos are expected to resolve the issue as to whether Operable Unit 4 presents any significant current exposure pathways other than direct radiation exposure and exposure to airborne radon from the K-65 silos.

E.3.0 EXPOSURE ASSESSMENT

This section presents the estimation of contact, or exposure, between human and environmental receptors and radionuclides and chemicals from Operable Unit 4. The general procedure for conducting an exposure assessment is (EPA 1989a):

- Characterization of exposure setting
- Identification of exposure pathways
- Quantification of exposures

This section covers each step of the exposure assessment.

E.3.1 CHARACTERIZATION OF EXPOSURE SETTING

E.3.1.1 Physical Setting

Operable Unit 4 is located west of the FMPC production area in the Waste Storage Area. To the north of Operable Unit 4 lies the waste pit area, which historically has contributed relatively large quantities of uranium to the environment (WMCO 1989b). Directly west of the silos is a creek, Paddys Run, which flows south before feeding into the Great Miami River. Paddys Run is dry at times throughout the year. West of the creek lies the FMPC boundary, which is marked by a fence. The land between Paddys Run and the western FMPC boundary is leased to local dairy farmers for grazing cattle. This area is hydrologically upgradient of the silos. An on-property wooded area is located south of Operable Unit 4.

The average annual rainfall for the area is 39 inches (99.2 centimeters) (IT Corporation 1989). Prevailing winds at the site are from the south-southwest at approximately 10 miles (16 kilometers) per hour (U.S. Department of Commerce 1985).

A review of aerial photographs taken from 1950 through 1988 reveals that the course of Paddys Run has changed, flowing closer to the silos over time. Historically, the east bank of the creek has experienced significant soil erosion (Grumski 1987b; Boback et al. 1987). The silos are situated at an elevation approximately 15 to 20 feet above Paddys Run. The east bank of Paddys Run is covered with thick vegetation. Areas of water seepage have been noted from the east bank of Paddys Run below the silos. Surface waters generally run off the Operable Unit 4 area to the west and southwest toward Paddys Run. The estimated flow rate into Paddys Run is 1.2×10^7 gallons/year from the Waste Storage Area (WMCO 1987).

A grass-covered soil berm surrounds the K-65 silos; however, no berm surrounds the metal oxide silo. The original berm eroded and has been regraded to reduce the erosion. The current slope of the berm soils is 3:1 (horizontal:vertical). The bulk density of the soils is approximately 1.7 grams/cubic centimeter (g/cm^3). A fence surrounds the K-65 silos at the bottom of the berm.

Review of RI/FS well boring logs, water elevation surveys, and geologic cross sections (Dames and Moore 1985) reveals that there are at least four layers of diverse soil types beneath the silos. Beginning at the ground surface these four layers are:

- Seven and one-half feet of dry, weathered till composed of dense brown silt and clay
- Five feet of moist, dense silty clay, fine sand, and traces of gravel
- Twelve feet of dry, dense dark-grey clay with traces of silt and unweathered till
- Twenty-three and one-half feet of dry, dense, tan to brown, fine sand

The water table is at a depth of approximately 48 feet below ground surface and flows generally east with a southeastern branch. However, water from Paddys Run may also enter the aquifer downstream of the silos, near the confluence of Paddys Run and the FMPC SSOD, and flows south from that point.

A general description of ecological habitats on the FMPC is provided in Section 3.0 of the RI report for Operable Unit 4. A complete description of the ecology of the FMPC can be found in Facemire et al. (1990). Two habitat types described by Facemire et al. (1990) may be affected by contamination from Operable Unit 4, introduced grasslands in the operable unit itself, and riparian woodlands along Paddys Run.

E.3.1.2 Potentially Exposed Populations

Current and potential future populations surrounding the FMPC must be identified in order to determine potential receptors to FMPC releases. Two land-use scenarios must be evaluated for the baseline risk assessment: current land use and future potential land use. This section describes the assumptions used to define these scenarios and the potentially exposed populations associated with each.

E.3.1.2.1 Current Land Use

Under current land-use conditions at the site, DOE maintains security control measures to prevent members of the public from accessing the land. These controls include fences and security personnel. It is assumed for the purpose of this risk assessment that these controls will remain in

place for 100 years. Under this scenario, populations of concern begin at the FMPC property boundary for Operable Unit 4 because it is completely located within the FMPC boundaries.

Population centers in the area surrounding the FMPC include the town of Fernald, 1.7 miles (2.8 kilometers) directly south of the plant site with an estimated population of 30; and New Baltimore, 2.7 miles (4.4 kilometers) southeast of the plant with an estimated population of 200 (SAIC 1987). The villages of Ross, New Haven, and Shandon are also located near the FMPC. Within a 50-mile (80-kilometer) radius of the plant, there is a population of approximately 2,577,000 in Hamilton and Butler counties (SAIC 1987). Surrounding lands support several residences, small industries, and farms. Several industries are located south of the FMPC. These include Rutgers-Nease Chemical Company, Albright and Wilson Chemical Co., and Delta Steel. The Knollman Dairy is located at the southeast corner of the property. Population density in the immediate area is low, with approximately 160 persons within a 1-mile radius of the plant boundary (SAIC 1987). Cincinnati, the largest metropolitan area, is approximately 20 miles (32 kilometers) southeast.

For the purpose of this risk assessment, it is assumed that land use adjacent to the FMPC will not change appreciably in the next 100 years. Aside from the introduction of the FMPC in the early 1950s, local land use has always been primarily agrarian. The assumption that land use in the area will remain unchanged is supported by studies performed to evaluate future potential economic growth and development of the area (OKI 1989; CDM 1989). These population and economic forecasts, prepared for the Hamilton County Metropolitan Sewer District (CDM 1989) and the Ohio, Kentucky, Indiana (OKI) Regional Council of Governments (OKI 1989), conservatively estimate a population growth of less than 1 percent for Hamilton County by the year 2010. More detailed population trends in the area immediately adjacent to the site show population decreases of up to 25 percent (OKI 1989). The area will continue to exhibit low-density residential levels and is not expected to be officially classified as "residential." Northwest Hamilton County has the potential to grow economically by a factor of 7.78 percent because 24.7 percent of the land is considered "potentially" developable as residential and 1.1 percent as industrial (CDM 1989).

Potential current contact with constituents from Operable Unit 4 may occur via radionuclide and chemical migration from the FMPC. Potentially exposed populations outside the FMPC boundary include persons living near the western FMPC boundary. An additional potentially exposed population includes persons who live downstream along Paddys Run and have contact with sediments in Paddys Run. It is assumed that only children will be exposed to incidental ingestion of creek sediments while playing on the stream bed because adults generally do not play in streams.

Groundwater south and east of the FMPC could be impacted by potential future releases from Operable Unit 4 within the next 100 years. ODH (ODH 1988) received requests to sample 264 private wells in the vicinity of the FMPC; however, not all of these wells are downgradient from Operable Unit 4. Wells for three industries are located directly south of the site; however, the groundwater is not used in commercial products without treatment. In 1988, a single groundwater well was drilled for irrigation purposes southeast of the plant site.

E.3.1.2.2 Future Land Use

Because security control measures are assumed to be lost at the end of 100 years, "reasonable" judgement must be made about the level of control the government will maintain over all or portions of the FMPC property. For the purpose of the future land-use scenario for Operable Unit 4, it is assumed that the DOE will not be legally able to walk away from the silos without taking measures to control direct contact with the wastes in lieu of CERCLA remediation. These DOE measures may include barriers or monolith-type markers that warn against human intrusion.

Bases on this assumption and limited projections that future land use surrounding the property will remain agrarian, it is assumed that the future land user may farm immediately adjacent to the silos without being able to directly contact the wastes themselves. These assumptions were developed to meet the requirements of DOE regulations and the spirit of the NCP to investigate a "reasonable maximum" future exposure situation.

The FMPC lies in the Oak-Hickory Forest Section of the Eastern Deciduous Forest, as described by Bailey (1978). Ecological communities at the FMPC consist of grazed and ungrazed pastures, two pine plantations, deciduous woodlands, riparian woodlands, and a reclaimed fly ash pile area.

Organisms potentially exposed to Operable Unit 4 contaminants include a variety of terrestrial plants and animals in the introduced grasslands and aquatic organisms in Paddys Run. Plants in the introduced grasslands include timothy (Phleum pratense), red top (Agrostis sp.), Kentucky bluegrass (Poa pratensis), teasel (Dipsacus sylvestris), ragweed (Ambrosia sp.), moth mullein (Verbascum blatteria), and wild parsnip (Pastinaca sativa). The dominant tree species in the riparian woodland along Paddys Run are cottonwood (Populus deltoides), hackberry (Celtis occidentalis), and box elder (Acer negundo). Dominant understory species include trumpet creeper (Campsis radicans) and hackberry saplings. The most common herb is garlic mustard (Allaria officinalis). Aquatic vascular plants, e.g., cattails (Typha sp.) and sedges (Carex sp.), as well as algae, also occur along Paddys Run.

A variety of small mammals occur in the introduced grasslands and the deciduous forest immediately to the south of Operable Unit 4. Species include the fox squirrel (Sciurus niger), eastern cottontail (Sylvilagus floridanus), white-footed mouse (Peromyscus leucopus), short-tailed shrew (Blarina brevicauda), meadow vole (Microtus pennsylvanicus), meadow jumping mouse (Zapus hudsonicus), eastern chipmunk (Tamias striatus), and several species of bats. White-tailed deer (Odocoileus virginianus) also occur on the FMPC in the pine plantations on the southwest and northeast portions of the FMPC.

Common bird species in and adjacent to Operable Unit 4 include the barn swallow (Hirundo rustica), red-winged blackbird (Agelaius phoeniceus), American robin (Turdus migratorius), eastern meadowlark (Stumella magna), blue jay (Cyanocitta cristata), northern cardinal (Cardinalis cardinalis), mourning dove (Zenaida macroura), and European starling (Sturnus vulgaris). The most abundant species in the introduced grasslands are the barn swallow, red-winged blackbird, and eastern meadowlark. The most abundant species in the riparian woodland are the blue jay, American robin, and northern cardinal.

Aquatic organisms found in Paddys Run include benthic macroinvertebrates and fish. The most common macroinvertebrates in Paddys Run are the nonbiting midges (Chironomidae), riffle beetle (Stenelmis sp.), mayfly (Caenis sp.), and stonefly (Allocapnia sp.). Also common are isopods (Lirceus fontinalis), caddisflies (Cheumatopsyche sp. and Hydropsyche sp.), oligochaetes, and blackflies (Simulium sp.). The most abundant fish are the bluntnose minnow (Pimephales notatus), creek chub (Semotilus atromaculatus), and stoneroller minnow (Campostoma anomalum).

No federally-listed threatened or endangered species have been observed at the FMPC or in its immediate vicinity. Suitable habitat for one species of mammal listed as federally endangered, the Indiana bat, occurs along Paddys Run. However, the Indiana bat was not found on property.

E.3.2 IDENTIFICATION OF EXPOSURE PATHWAYS

A wide range of environmental media and potential exposure pathways were considered in the Operable Unit 4 Baseline Risk Assessment. These pathways include three major exposure categories:

- Direct exposure
- Inhalation
- Ingestion

The pathways within each of these categories that were considered include:

Direct exposure

- Gamma radiation emitted by the contents of the K-65 silos
- Radiation from contaminants deposited on surface soils and sediments
- Contact with surface water while swimming
- Dermal contact with hazardous chemicals

Inhalation

- Airborne particulates and aerosols
- Radon progeny
- Resuspended contaminated dusts and soils
- Release of contaminated materials from water used in residences
- Volatilization of chemicals from soils

Ingestion

- Drinking contaminated water
- Consumption of food contaminated by the use of contaminated water for irrigating crops, irrigating feed for livestock, and watering livestock
- Consumption of contaminated soil and sediment (child only)
- Consumption of contaminated surface water
- Consumption of food contaminated by uptake of contaminants from soil
- Consumption of food contaminated by livestock ingesting contaminated soil

Four fundamental conditions must be met for any exposure pathway to exist. Each pathway must have:

- A source of contamination
- A mechanism for transporting the contaminant through an environmental medium to a point of exposure
- A potential receptor at the location of the exposure
- A route of exposure

Potential exposure pathways considered in this risk assessment are summarized in Table E.3-1. Five pathways potentially satisfied all of these conditions. One, surface water contamination in Paddys Run, was discarded after screening calculations indicated that contributions to surface water contamination from Operable Unit 4 soils are very low and would not contribute to an RME scenario. The four remaining pathways are discussed below. These include:

- Direct exposure to gamma radiation from emissions of gamma rays from the contents of the K-65 silos

- Inhalation of radon gas emitted from the K-65 silos and dispersed through the air

TABLE E.3-1
POTENTIAL EXPOSURE PATHWAYS FROM OPERABLE UNIT 4

Exposed Population	Pathway	Probability of Exposure/ Inclusion in Risk Assessment	Reason for Inclusion or Exclusion
Current Land Use[a]			
Nearby residents	Direct radiation	High/Yes	Current and future exposure may exist
Nearby residents	Airborne radon	High/Yes	Current and future exposures may exist
Children	Ingestion of creek sediments eroded from soils surrounding Operable Unit 4	Low/Yes	Operable Unit 4 could be contributing to elevated levels of uranium and radium in creek sediments, under current and future land use.
Residents outside FMPC Fenceline	Ingestion of contaminated groundwater	Low/Yes	Current conditions in groundwater south of site are addressed in detail in the RI and RA for Operable Unit 5. Future potential exposures via this pathway from Operable Unit 4 are addressed quantitatively.
	Ingestion of contaminated vegetables	Low/Yes	
	Ingestion of contaminated meat	Low/Yes	
	Ingestion of contaminated milk	Low/Yes	
	Expsure to accumulations of long-lived radon progeny in surface soils	Low/No	Screening calculations demonstrate very low potential for accumulation of above-background concentrations.

TABLE E.3-1
(continued)

Exposed Population	Pathway	Probability of Exposure/Inclusion in Risk Assessment	Reason for Inclusion or Exclusion
Residents outside FMPC fenceline	Inhalation of resuspended soils	Low/No	Low probability of significant resuspension from Operable Unit 4
	Inhalation of volatiles from soil	Low/No	No volatiles in soils of Operable Unit 4
	Ingestion of contaminated surface water	Low/No	Modeled contribution to surface water contamination is low
Future Land Use[a]			
Resident adjacent to Operable Unit 4	Direct Radiation	High/Yes	Current and future exposure may exist
Resident adjacent to Operable Unit 4	Airborne Radon	High/Yes	Current and future exposure may exist
Children adjacent to Operble Unit 4	Ingestion of creek sediment eroded from soils in Operable Unit 4	Low/Yes	Operable Unit 4 could be contributing to elevated levels of uranium and radium in creek sediment under current and future land use.
Residents adjacent to Operable Unit 4	Ingestion of contaminated groundwater	Low/Yes	Potential future exposures are evaluated quantitatively.
	Ingestion of contaminated vegetables	Low/Yes	
	Ingestion of contaminated meat	Low/Yes	

TABLE E.3-1
(continued)

Exposed Population	Pathway	Probability of Exposure/Inclusion in Risk Assessment	Reason for Inclusion or Exclusion
	Ingestion of contaminated milk	Low/Yes	
	Ingestion of food contaminated by uptake from soil	Low/No	Low contaminant concentrations in soil in Operable Unit 4
	Ingestion of livestock contaminated by uptake of soil	Low/No	Low contaminant concentrations in soil in Operable Unit 4
	Dermal contact with contaminants in soil	Low/No	Low contaminant concentrations in soil; low skin absorption rates for contaminants of concern

[a]Current land use assumes institutional controls are in place for 100 years. Future land use assumes security control measures are not in place after 100 years.

- Ingestion of contaminated soils that have eroded into Paddys Run from the soils surrounding the silos
- Ingestion of contaminated groundwater and agricultural products contaminated by groundwater

Ingestion of groundwater containing contaminants that may migrate from Operable Unit 4 in the future is considered as a potential future pathway. The nonradiological constituents of the silos are not volatile; thus, it is not likely that any residues will partition into the air.

The potential for accumulation of radon progeny (Pb-210) contamination on the ground in areas where cows graze has been investigated. Air dispersion modeling, using very conservative assumptions for transport of radon from the K-65 silos, indicates that the accumulation of Pb-210 on the ground surface would not reach background levels. The resultant doses from all potential ingestion pathways are insignificant compared to natural background. Therefore, the exposure pathway involving cows grazing near Operable Unit 4 was not presented quantitatively. Analytical data for milk from cows that graze in the area west of Operable Unit 4 are not available. Analytical data for milk from cows that graze in other areas of the site are available from the WMCO environmental monitoring program, but these data do not include analyses for radon progeny.

E.3.2.1 Direct Radiation

Penetrating radiation propagates in the form of electromagnetic waves; therefore, no transport media are involved. The contents of the K-65 silos are the primary source of penetrating radiation from Operable Unit 4. The silos contain large quantities of Ra-226 activity from the processing and purification of uranium ores. The Ra-226 decays to Rn-222, which decays to a series of radon progeny. Several of the radon progeny emit penetrating radiations that contribute significantly to the intensity of penetrating radiation fields from the silos. The energy of penetrating radiation is reduced through scattering processes as it travels from the source and interacts with materials (including air) in its path. The intensity of penetrating radiation decreases with increasing distance from the source. As a result, direct exposure to penetrating radiation exceeding background levels is confined to areas a short distance from Operable Unit 4. Except for a small area immediately adjacent to the western property boundary of the FMPC near the K-65 silos, all measured penetrating radiation exposure rates outside the property boundary are equal to or below the mean regional background radiation exposure rate. This is a small area, therefore, only a small segment of the general public is potentially subject to any above-background exposure to penetrating radiation from Operable Unit 4. External radiation exposure rates are determined from TLD

measurements taken at the FMPC boundary, at off-site monitoring locations, and at monitoring locations around the K-65 silos.

E.3.2.2 Airborne Radon

Radioactive decay of Ra-226 in the K-65 residues produces Rn-222. Because Ra-226 has a very long radioactive half-life (1600 years), the rate of generation of radon inside the K-65 silos is nearly constant. Radon accumulates in the airspace inside the K-65 silos between the surface of the residues and the silo domes. Radon in this airspace either decays to its progeny or escapes from the K-65 silos. The emission of radon from the K-65 silos is affected by several parameters including:

- The short half-life of radon (3.82 days)
- Local meteorological conditions establishing pressure gradients between the outside air and the silo airspaces
- The porosity of the residues, the silo domes, and the silo walls

Exposure concentrations of radon are determined from airborne concentration measurements taken at the FMPC boundary, at off-site air monitoring locations, and at monitoring locations surrounding the K-65 silos.

E.3.2.3 Erosion of Soils

Above-background concentrations of uranium and Ra-226 have been detected in surface soil samples in the vicinity of Operable Unit 4. The source of the uranium and radium is uncertain; it could be from leakage from the silos, from deposition of airborne emissions from other areas of the FMPC, from historical spills and leaks in the K-65 area, from other areas at the site such as the waste pits, or combinations of the above. Because established institutional controls at the FMPC boundary and around Operable Unit 4 prevent unintentional access to the operable unit, potential receptors are not expected to be directly exposed to soils in or immediately surrounding Operable Unit 4. However, the potential exists for constituents from Operable Unit 4 surface soils to migrate to Paddys Run, especially in the event of heavy rainfall.

The universal soil loss equation (USLE) (Williams 1975; EPA 1988b) has been used to estimate the amount of soils eroding annually from the silo area. Additional equations have been used to estimate the amount of material that will erode from the silo berm into the surface water of Paddys Run and the amount that will remain in the sediments along Paddys Run (Haith 1980; Mills et al. 1982). These equations are based on the ability of the material to partition between soil and water. Application of these models is difficult without results of berm soil samples. Calculations have

been performed using the average measured uranium and radium concentrations in surface soil samples from the RI field investigation and three samples taken at the base of the berms during the Characterization Investigation Study (CIS) (Weston 1987). The model assumes that constituents in the upper one centimeter of soil are available for erosion. Results of the modeling are presented in Table E.3-2. A complete explanation of the model and modeling parameters is provided in Attachment E.II. Modeling results compare well with analytical results of sediment samples collected along the banks of Paddys Run directly downgradient of Operable Unit 4.

E.3.2.4 Groundwater

The presence of above-background concentrations of uranium in groundwater and surface water within the FMPC boundaries has been confirmed by environmental sampling. Limited groundwater and surface water sample data are available for the immediate vicinity of Operable Unit 4. Water found in Silo 2 during recent core sampling of K-65 silo residues suggests that leaking through the bottom of the K-65 silos could occur; however, neither the K-65 silos nor the other areas of Operable Unit 4 have been established as the source of uranium contamination in environmental media within or outside the immediate area of Operable Unit 4. Significant above-background concentrations of Ra-226 have not been detected in groundwater samples in the vicinity of Operable Unit 4.

Potential exposure to contamination currently in the regional aquifer is being considered under Operable Unit 5. Consequently, evaluation of the groundwater pathway under Operable Unit 4 will be confined to the potential for Operable Unit 4 to contribute to future groundwater contamination.

This is performed by projecting the concentration of the contaminants of concern from the silos to a hypothetical receptor, using a combination of analytical modeling for the transport of contaminants in the vadose zone and numeric modeling for transport within the Great Miami Aquifer.

Two future potential land-use scenarios are considered: Scenario 1 assumes that institutional controls will be active at the FMPC for the next 100 years and that the hypothetical receptor would be located on the FMPC boundary. Under Scenario 2, institutional controls will be lost and the hypothetical receptor would be located directly at the waste unit after 100 years.

E.3.2.5 Potential Exposure of Environmental Receptors

Environmental receptors may potentially be exposed to constituents from Operable Unit 4 under both current and future land-use conditions. These potential receptors include various types of

TABLE E.3-2

ESTIMATED CONTAMINANT RUNOFF FROM OPERABLE UNIT 4 BERM SOILS USING THE UNIVERSAL SOIL LOSS EQUATION[a]

Constituent	Average Concentration in soils (pCi/g)/(µg/g)	Modeled Concentration migrating to sediments (pCi/g)/(µg/g)
Total Uranium	9.8[b]/ 15	9.6/ 14
Ra-226	10[c]/ 1.1×10^{-5}	10.7/ 1.1×10^{-5}

[a]See Attachment E.II for complete modeling results.

[b]Average of four RI samples taken at the base of the berm soils (5650, 5644, 5647, 5884), and three CIS samples (320, 322, 324) taken at the northern base of the berm surrounding Silo 2.

[c]Average of 1 RI sample taken at the base of the berm (5884) and three CIS samples (320, 322, 324) taken at the northern base of the berm surrounding Silo 2.

plants, animals, and aquatic organisms. Exposure of environmental receptors to constituents from Operable Unit 4 depends on the degree to which environmental media are contaminated, the degree to which environmental receptors are exposed to contaminated media, and the portion of contamination attributable to Operable Unit 4.

Data concerning contaminant levels in environmental media and biological samples are presented in Section E.6.0. These data are used to quantify potential effects of constituents from Operable Unit 4 on environmental receptors. Quantitative results are presented in Section E.6.3 of Section E.6.0.

E.3.2.6 Potential Future Exposures From Silo Failure Scenarios

Airborne release of radon and other constituents of the K-65 silos is possible in the event of a failure of the K-65 silo domes. This release scenario is suggested because a study of the structural condition of the K-65 silos indicates that although the silos were structurally stable at the time of the study, they may be expected to remain stable only for approximately 5 to 10 years (Camargo 1986).

The Consent Agreement between DOE and EPA contains a provision for conducting a removal action for the K-65 silos. The removal action is being conducted by Bechtel National Incorporated, and a baseline risk assessment is being conducted by the University of Cincinnati to support the removal action.

The University of Cincinnati risk assessment (Eckart et al. 1990) evaluates the human health risks associated with estimated exposures from three airborne release scenarios (Acute Case A1, Acute Case A2, and the Chronic Radon Case). Acute Case A1 involves silo dome failure due to a severe weather event, Acute Case A2 involves silo dome failure due to prolonged structural deterioration, and the Chronic Radon Case involves continued release of radon without acute dome failure.

E.3.3 QUANTIFICATION OF EXPOSURE

Measured values from environmental sampling are used to estimate receptor exposures for the quantification of direct exposure to penetrating radiation and exposure to airborne radon from Operable Unit 4. Modeled results are used to estimate potential exposure to Operable Unit 4 constituents in sediments and groundwater.

An RME is identified for each potential current or future exposure to constituents from Operable Unit 4. The RME is defined as the highest exposure that is reasonably expected to occur at the

site (EPA 1989a). In addition, an Operable Unit 4 RME is identified to account for an individual that may be subject to one or more identified exposure pathways.

E.3.3.1 Exposure to Human Receptors - Current Land Use

E.3.3.1.1 Direct Radiation

Environmental measurements of radiation dose equivalent at monitoring stations along the FMPC boundary are used to quantify direct exposure to penetrating radiation from Operable Unit 4 under current conditions. Examination of the radiation dose equivalent rate data collected as part of the WMCO environmental monitoring program for 1988 reveals only slight differences between annual average results along the western FMPC fenceline, along Paddys Run Road, and at two distant background locations. Thus, it is reasonable to use annual average data from the western FMPC boundary fenceline as a representation of the potential receptor radiation exposure rate in the vicinity. For exposure to direct radiation, the RME individual (located in the vicinity of the FMPC boundary west of the silos) is assumed to be exposed to an average above-background dose equivalent rate of 5.4 µrem/hr. This annual average above-background dose equivalent rate is associated with air monitoring station (AMS) No. 6 west of the silos. Data from this location are used because AMS-6 exhibits the highest annual average exposure rate at or outside the FMPC fenceline. Nevertheless, the magnitude of the above-background exposure rate at AMS-6 is less than the annual average background exposure rate of 9.9 µrem/hr from two locations distant from the FMPC. The RME individual is assumed to spend 24 hours/day in the vicinity for 365 days/year. This time is divided into:

- Waking hours spent outdoors
- Waking hours spent indoors
- Sleeping hours spent indoors

A shielding factor is applied to the time spent indoors to account for the reduction in dose equivalent rate provided by typical dwellings. The following expression is used to calculate the dose equivalent rate for each of the three daily time periods:

$$DE = (DE_{gross} - DE_{bkg})(CF)(FI)(EF)(MF)(SF)$$

where

DE = annual dose equivalent (mrem/yr)

DE_{gross} = gross RME dose equivalent rate (µrem/hr)

DE_{bkg} = background dose equivalent rate (µrem/hr)

CF = conversion factor (mrem/µrem)

FI = time spent as waking hours (hr/day); time spent as sleeping hours (hr/day)

EF = exposure frequency (days/yr)

MF= modifying factor for waking hours spent outdoors; modifying factor for waking hours spent indoors; modifying factor for sleeping hours spent indoors (unitless)

SF = shielding factor for dose rate reduction indoors (unitless).

The dose equivalent rates for each of the three daily time periods are summed to obtain a total annual RME dose equivalent rate from penetrating radiation exposure from Operable Unit 4 of 36 mrem/year. The total annual RME dose equivalent rate is converted to total RME lifetime dose equivalent by multiplying by 70 years, resulting in a dose of 2500 mrem over a lifetime. The parameter values used to calculate these results are defined in Table E.3-3. Potential exposure estimate results for the penetrating radiation pathway are presented in Table E.3-4.

E.3.3.1.2 Airborne Radon

Environmental measurements of airborne radon concentrations collected at air monitoring stations along the FMPC boundary are used to quantify exposure to airborne radon and radon progeny from Operable Unit 4 under current conditions. Examination of the airborne radon concentration data collected as part of the WMCO environmental monitoring program for 1988 reveals slight differences between annual average airborne radon concentrations along the western FMPC fenceline, the remainder of the FMPC fenceline, at residences along Paddys Run Road, and at distant background locations. Thus, it is reasonable to use annual average data from the western FMPC boundary fenceline as a representation of the potential receptor exposure concentration in the vicinity. For exposure to airborne radon and radon progeny, the RME individual is assumed to be exposed to an average above-background airborne radon concentration of 0.75 pCi/L. This annual average above-background airborne radon concentration is associated with radon monitoring location FMPC-L west of the silos. Data from this location are used because location FMPC-L exhibits the highest annual average radon concentration at or outside the FMPC fenceline. Nevertheless, the magnitude of the above-background radon concentration at location FMPC-L is approximately equal to the annual average background radon concentration of 0.90 pCi/L from two locations distant from the FMPC. The RME individual is assumed to spend 24 hours/day in the vicinity for 365 days/year. The time is divided into:

- Waking hours spent outdoors
- Waking hours spent indoors
- Sleeping hours spent indoors

TABLE E.3-3

PARAMETERS USED TO DESCRIBE EXPOSURE TO SITE-RELATED CHEMICALS AND RADIONUCLIDES OF POTENTIAL CONCERN

Exposure Pathway	Measured Quantity of Constituent in Medium	Exposure Assumptions		Source
Current Land Use[a]				
Direct Radiation	Highest average value measured along western fenceline	DE_{bkg}	= 9.9 µrem/hr	WMCO data
		DE_{gross}	= 15.3 µrem/hr	WMCO data
		CF	= 10^3 µrem/mrem	
		FI	= 16 hr/day awake	Assumption
			= 8 hr/day asleep	Assumption
		EF	= 365 days/year	EPA 1989a
		MF	= 0.75 awake outdoors	NCRP 1984a
			= 0.25 awake indoor	Assumption
			= 1.0 asleep indoor	Assumption
		SF	= 0.5	NRC 1977
Airborne Radon	Highest average value measured along western fenceline	pCi/L_{bkg}	= 0.90 pCi/L	WMCO data
		pCi/L_{gross}	= 1.65 pCi/L	WMCO data
		CF	= 10^{-2} WL/pCi/L	Assumption
		DF	= 0.6 outdoor daughter equilibrium;	UNSCEAR 1982
			= 0.5 indoor daughter equilibrium	UNSCEAR 1977, 1982
		EF	= 50 WM/yr	NCRP 1984b
		FI	= 0.67, awake	Assumption
			= 0.33, asleep	Assumption
		MF	= 0.75, awake, outdoor	NCRP 1984a
			= 0.25 awake, indoor	
			= 1.0 asleep, indoor	

TABLE 3-3
(Continued)

Exposure Pathway	Measured Quantity of Constituent in Medium	Exposure Assumptions		Source
Sediment Ingestion				
Radiological	Average value modeled in Paddys Run upstream of storm sewer outfall ditch	C_s	= Table 3-2	
		DCF	= radionuclide specific	NRPB 1987
		IR	= 0.2 g/day	EPA 1989a
		EF	= 365 days/yr	EPA 1989a
		FI	= 1	Site-specific
Chemical	Average value modeled in Paddys Run upstream of storm sewer outfall ditch	C_s	= Table 3-2	
		IR	= 0.2 g/day	EPA 1989a
		CF	= 1E-6 kg/mg	
		FI	= 1	Site-specific
		EF	= 365 days/yr	EPA 1989a
		ED	= 6 years	EPA 1989a
		BW	= 16 kg	EPA 1989a
		AT	= ED x 365 days/yr	EPA 1989a
Groundwater Ingestion				
Radiological	Modeled concentration at FMPC fence	C_w	= Table III-1/III-2	
		DCF	= radionuclide specific	EPA 1988c
		IR	= 2 l/day	EPA 1989a
		FI	= 1	site-specific
Chemical	Modeled concentration at FMPC fence	C_w	= Table III-1/III-2	
		IR	= 2 l/day	EPA 1989a
		EF	= 365 days/yr	EPA 1989a
		ED	= 70 yrs	EPA 1989a
		BW	= 70 kg	EPA 1989a
		AT	= 25550 days	EPA 1989a
		FI	= 1	site-specific

TABLE 3-3
(Continued)

Exposure Pathway	Measured Quantity of Constituent in Medium	Exposure Assumptions		Source
Food Ingestion[b]				
Radiological	Calculated using groundwater at FMPC boundary	C_F	= calc. conc. in food	
		DCF	= radionuclide specific	EPA 1988c
		IR	= Food ingestion, g/day	EPA 1989d
		EF	= 365 days/yr	EPA 1989a
		FI	= 1	site-specific
Chemical	Calculated using groundwater at FMPC boundary	C_F	= calc. conc. in food	
		IR	= food ingestion, g/day	EPA 1989d
		EF	= 365 days/yr	EPA 1989a
		ED	= 70 yrs	EPA 1989a
		BW	= 70 kg	EPA 1989a
		AT	= 25,550 days	EPA 1989a
		FI	= 1	site-specific

TABLE 3-3
(Continued)

Exposure Pathway	Measured Quantity of Constituent in Medium	Exposure Assumptions	Source
Future Land Use[a]			
Direct Radiation	Average value along K-65 fence	DE_{bkg} = 9.9 µrem/hr DE_{gross} = 290/µrem/hr C	WMCO data WMCO data
Airborne Radon	Average value along K-65 fence	pCi/L_{bkg} = 0.90 pCi/L $pCi/_{gross}$ = 6.14 pCi/L C	WMCO data WMCO data
Sediment Ingestion	(same as current land use)	(same as current land use)	

TABLE 3-3
(Continued)

Exposure Pathway	Measured Quantity of Constituent in Medium	Exposure Assumptions	Source
Groundwater Ingestion			
Radiological	Leachate concentration from silos	C_L = Table III-3/III-4 C	
Chemical	Leachate concentration from silos	C_L = Table III-3/III-4 C	
Food Ingestion			
Radiological	Calculated using groundwater at the waste unit	(Same as current land use)	
Chemical	Calculated using groundwater at the waste unit	(Same as current land use)	

[a]Current land use assumes institutional controls are in place for 100 years. Future land use assumes institutional controls are not in place after 100 years.

[b]Food ingestion includes ingestion of vegetables, meat, and milk potentially contaminated by irrigation of crops and animal feed and watering of animals with contaminated groundwater.

[c]Remaining exposure pathways assumptions are the same as for the analogous pathways under current land-use conditons.

TABLE E.3-4

POTENTIAL HUMAN EXPOSURE ESTIMATES FROM PENETRATING RADIATION, AIRBORNE RADON, AND SEDIMENT INGESTION

Exposure Pathway	Constituent	Receptor Exposure Level	RME Dose/Intake
Current Land Use[a]			
Direct radiation	Gamma radiation	5.4 µrem/hr above background	36 mrem/yr
Inhalation of airborne radon progeny	Radon and radon progeny	0.75 pCi/L above background	0.19 WLM/yr
Ingestion of creek sediments			
Radiological	Uranium Radium Sum	9.6 pCi/g 10.7 pCi/g	1.2 mrem/6 yrs 7.2 mrem/6 yrs 8.4 mrem/6 yrs
Chemical	Uranium	10 µg/g	0.13 µg/kg/day
Future Land Use[a]			
Direct radiation	Gamma radiation	280 µrem/hr above background	1800 mrem/yr
Inhalation of airborne radon progeny	Radon and radon progeny	5.24 pCi/L above background	1.44 WLM/yr
Ingestion of creek sediments[b]			

[a] Current land use assumes institutional controls are in place for 100 years. Future land use assumes institutional controls are not in place after 100 years.

[b] Sediment ingestion results under future land use are the same as under current land use.

No shielding factor is applied to the time spent indoors. It is assumed that the outdoor above-background airborne radon concentration attributed to releases from Operable Unit 4 is also present indoors (NRC 1980). The following expression is used to calculate the radon exposures during each of the three daily time periods:

$$WLM = (pCi/L_{gross} - pCi/L_{bkg})(CF)(DF)(EF)(FI)(MF)$$

where

WLM = cumulative working level month radon progeny exposure (WLM/yr)

pCi/L_{gross} = gross RME radon concentration (pCi/L)

pCi/L_{bkg} = background radon concentration (pCi/L)

CF = conversion factor (WL/pCi/L)

DF = radon daughter equilibrium factor outdoors, indoors (unitless)

EF = exposure frequency (WM/year)

FI = fraction of time spent as waking time; fraction spent as sleeping time (unitless)

MF= modifying factor for waking time spent outdoors; for waking time spent indoors, and for sleeping time spent indoors (unitless).

This equation is used to determine the airborne radon progeny exposure for each of the daily time periods. These three exposures are then summed to obtain a total annual RME radon progeny exposure from Operable Unit 4 of 0.19 WLM/year. The parameter values used to calculate exposure results are presented in Table E.3-3.

The total annual RME exposure is converted to total lifetime RME radon progeny exposure by multiplying by 70 years, resulting in a lifetime exposure of 13 WLM. The parameter values used to calculate these results are defined in Table E.3-3. Potential exposure estimate results for the airborne radon pathway are presented in Table E.3-4.

E.3.3.1.3 Sediment Ingestion

Calculations of both radiation dose and chemical intake were performed for the hypothetical scenario of children ingesting sediments in Paddys Run. For purposes of this risk assessment, it is assumed that the RME concentration in the sediment is the average concentration of total uranium and the average concentration of Ra-226 modeled using the USLE. Modeled sediment concentrations are used instead of concentrations measured in sediment because the modeled results are based on measured surface soil concentrations from the silo area. The concentrations measured in sediment from Paddys Run are likely to be partially attributable to erosion from areas other than Operable Unit 4. The modeled concentration of uranium in sediment is 6.9 pCi/g (approximately

10 µg/g assuming naturally occurring isotopic percent abundance) and the calculated concentration of Ra-226 in sediment is 11 pCi/g (1.1×10^{-5} µg/g). This is the concentration of uranium and radium from Operable Unit 4 that could exist in the vicinity of Operable Unit 4 in Paddys Run. This concentration assumes that a child could play in the creek immediately downstream of Operable Unit 4. Because sediments deposit along the banks of the creek and the creek is often dry, sediments are frequently exposed.

For the calculation of radiological dose, it was assumed that a child consumes 0.2 grams of sediment/day, 365 days/year. This is conservative because it is likely that, during the winter months, exposure to creek sediments would not occur. Approximately one-half of the total uranium activity (3.5 pCi/g) is contributed by U-234 and one-half (3.5 pCi/g) by U-238, assuming the uranium isotopes are present in their natural percent abundance. The equation for describing the 50-year committed effective dose equivalent (CEDE) for ingestion of uranium or radium is:

$$CEDE = (Cs)(DCF)(IR)(EF)(ED)$$

where

CEDE = 50-year committed effective dose equivalent (mrem)
Cs = concentration of contaminant in sediment (pCi/g)
DCF = dose conversion factor (mrem CEDE/pCi)
IR = sediment ingestion rate (g/day)
EF = exposure frequency (days/year)
ED = exposure duration years).

Using a U-234 sediment concentration of 3.5 pCi/g with a dose conversion factor of 4.1×10^{-4} mrem/pCi (NRPB 1987) and a U-238 concentration of 3.5 pCi/g with a dose conversion factor of 3.7×10^{-4} mrem/pCi (NRPB 1987), the resultant CEDE for total uranium is 0.2 mrem per year of ingestion. Using a Ra-226 soil concentration of 11 pCi/g with a dose conversion factor of 1.5×10^{-3} mrem/pCi (NRPB 1987), the resultant CEDE from ingestion of Ra-226 is 1.2 mrem per year of ingestion. It is conservatively assumed that children ingest sediment for six years, resulting in a total radiological dose of 8.4 mrem for ingestion of contaminated sediments. Table E.3-3 presents a summary of the parameters used for the sediment ingestion pathway.

For the calculation of chemical intake the model describing intake is (EPA 1989a):

$$Isi = (Cs)(IR)(CF)(FI)(EF)(ED)/(BW)(AT)$$

where

Isi = Intake from sediment ingestion (mg/kg/day)
Cs = concentration in the sediment (mg/kg)
IR = sediment ingestion rate (mg/day)
CF = conversion factor (10^{-6} kg/mg)
FI = fraction of ingested soils from contaminated source (unitless)
EF = exposure frequency (days/yr)
ED = exposure duration (yrs)
BW = body weight (kg)
AT = averaging time (equal to ED x EF) (days).

The resultant chemical intake from ingestion of uranium from Paddys Run sediment is 0.13 µg/kg/day. Potential exposure estimate results for the sediment ingestion pathway are presented in Table E.3-4. The parameter values used to calculate exposure results are presented in Table E.3-3.

E.3.3.1.4 Ingestion of Groundwater

The evaluation of exposure to groundwater under the current land-use scenario is described in Attachment E.III, and is briefly described here. It is assumed that contamination of the groundwater may occur via leakage of contaminated liquid via the sump drain for Silos 1 and 2 and directly through the floor for Silo 3. The concentrations of constituents in the leachate flowing from the silos were determined using EP Toxicity results and geochemical modeling. The flow of leachate from the silos to the receptor involves flow through both unsaturated (vadose zone) and saturated zones (regional aquifer; perched zones). Estimates of movement were performed using a no-retardation assumption and using a best estimate of retardation based on available information. However, as discussed in Section E.3.4, this may be extremely conservative and may result in calculated radiological exposures and chemical intakes that exaggerate the potential impact of this exposure pathway. These two approaches produce two estimates of the concentration at the receptor location.

The major worst-case assumptions used in the modeling include:

- Precipitation enters the silos to act as the leaching fluid. At this time there is no indication that this is happening at the site.
- Modeled leachate concentrations are limited only by the solubility of the identified metal species.
- Leachate concentrations from EP Toxicity data are based on acidic analytical conditions that may be unrealistic.
- The leachate concentrations are considered to be constant over time throughout the source depletion period.

The concentrations of contaminants at the hypothetical receptor beyond the FMPC fenceline for the current land-use scenario are listed in Attachment E.III, Tables E.III-1 and E.III-2. Four intake scenarios are considered for exposure to contaminants in groundwater:

- Direct ingestion of groundwater
- Ingestion of vegetables irrigated with contaminated groundwater
- Ingestion of beef from cows raised on contaminated groundwater and feed
- Ingestion of milk from cows raised on contaminated groundwater and feed

For each contaminant the radiological doses and chemical intakes are summed across the groundwater exposure pathways.

Intake via drinking contaminated groundwater is estimated using the following equation:

$$I_{DW} = (C_w)(IR)(EF)(ED)(FI)/(BW)(AT)$$

where

I_{DW} = Intake from groundwater ingestion (mg/kg/day)

C_w = concentration in groundwater (mg/L)

IR = ingestion rate (L/day)

EF = exposure frequency (days/yr)

ED = exposure duration (yrs)

BW= body weight (kg)

AT = averaging time (equal to ED x EF) (days).

FI = Fraction of ingested water from contaminated source (unitless).

Radiation dose received via drinking contaminated groundwater is estimated using the following equation:

$$CEDE = (C_w)(DCF)(IR)(EF)(ED)$$

where

CEDE = 50-year committed effective dose equivalent (mrem)
C_w = concentration in groundwater (pCi/L)
IR = ingestion rate (L/day)
DCF = dose conversion factor (mrem CEDE/pCi)
EF = exposure frequency (days/year)
ED = exposure duration (years).

Intake and radiation dose for the food ingestion pathway (contaminated vegetables, meat, milk) are estimated using the same equations used for the groundwater ingestion pathway, substituting the concentration in food for the concentration in groundwater. Equations used to determine concentrations in vegetables, meat, and milk are presented in Attachment E.IV. The parameter values used to calculate exposure results are presented in Table E.3-3.

The calculated lifetime radiological doses and chemical intakes for the future groundwater exposure pathways under current land-use conditions are presented in Tables E.3-5 and E.3-6. The radiological results indicate that human receptors at the FMPC boundary using contaminated groundwater for drinking water, irrigating vegetables and animal feed, and watering animals could be exposed to a lifetime radiation dose from Ra-226 from Silos 1 and 2 as high as 50 rem. All of the radiation doses presented assume that the silos are leaking, that precipitation enters the silos to act as a leaching fluid, and that the contaminant source is depleted with time. In lieu of site-specific data, it was assumed that the silos contain very soluble forms of uranium (phosphate) and radium and that the only factor limiting the concentration of uranium and radium in the leachate is the solubility of the species. These are potentially extreme upperbound estimates.

The chemical results indicate that after 100 years, a receptor at the property boundary could be exposed to high concentrations of several metals. The assumed soluble uranium in Silo 3 appears to be of greatest concern.

TABLE E.3-5

RADIOLOGICAL DOSES AND CHEMICAL INTAKES FROM GROUNDWATER PATHWAYS AT THE FMPC BOUNDARY AT 100 YEARS SILOS 1 AND 2

Radiological Doses (lifetime mrem)

Constituent	Best Estimate
U-234	2.4×10^{-3}
U-235	1.6×10^{-4}
U-238	1.9×10^{-3}
Th-228	1.6×10^{-9}
Th-230	1.2×10^{-7}
Th-232	1.7×10^{-8}
Ra-226	5.0×10^{4}
Ra-228	3.0×10^{1}
Pb-210	1.5×10^{3}
Ac-227	5.0×10^{7}
Pa-231	3.6×10^{7}

Chemical Intake (mg/kg/day)

Arsenic	7.0×10^{-6}
Barium	9.2×10^{-8}
Beryllium	7.9×10^{-3}
Cadmium	2.3×10^{-2}
Chromium	8.6×10^{-8}
Copper	2.1×10^{-7}
Lead	5.1×10^{-4}
Manganese	9.1×10^{-5}
Nickel	7.9×10^{-3}
Selenium	2.4×10^{-5}
Thallium	3.4×10^{-3}
Vanadium	8.7×10^{-8}
Zinc	1.9×10^{-3}
Uranium	8.9×10^{-9}

TABLE E.3-6

RADIOLOGICAL DOSES AND CHEMICAL INTAKES FROM GROUNDWATER PATHWAYS AT THE FMPC BOUNDARY AT 100 YEARS SILO 3

Radiological Doses (lifetime mrem)

Constituent	Best Estimate
U-234	1.8×10^{4}
U-235	1.1×10^{3}
U-238	1.6×10^{4}
Th-228	2.6×10^{-9}
Th-230	2.3×10^{-7}
Th-232	1.7×10^{-8}
Ra-226	5.6×10^{4}
Ra-228	5.9×10^{3}
Pb-210	1.4×10^{2}
Ac-227	3.4×10^{5}
Pa-231	2.4×10^{5}

Chemical Intake (mg/kg/day)

Arsenic	3.7×10^{-5}
Barium	1.0×10^{-5}
Beryllium	3.3×10^{-4}
Cadmium	9.6×10^{-4}
Chromium	1.6×10^{-4}
Copper	1.8×10^{-8}
Lead	6.0×10^{-6}
Nickel	3.0×10^{-5}
Selenium	1.8×10^{-4}
Thallium	1.1×10^{-3}
Vanadium	6.8×10^{-5}
Zinc	2.0×10^{-6}
Uranium	7.5×10^{-2}

E.3.3.2 Exposure To Human Receptors - Future Land Use

E.3.3.2.1 Direct Radiation

Environmental measurements of radiation dose equivalent rate at monitoring stations along the K-65 fenceline are used to quantify direct exposure to penetrating radiation from Operable Unit 4 under potential future conditions. Beyond 100 years, the assumption that security prohibit access to areas inside the FMPC boundary fenceline is replaced with the assumption that receptors may potentially be exposed at locations closer to Operable Unit 4. It is assumed under potential future conditions that receptors are exposed in the vicinity of the K-65 fenceline. Thus, it is reasonable to use annual average radiation exposure rates at the K-65 fenceline as a representation of the potential future receptor exposure rate in the vicinity. The average above-background exposure rate along the K-65 boundary is approximately 280 µrem/hr.

Using this value and the same exposure pathway assumptions used under current land-use conditions, the above-background RME increases by a factor of approximately 50 to 1800 mrem/yr. Potential exposure estimate results for the penetrating radiation pathway are presented in Table E.3-4.

E.3.3.2.2 Airborne Radon

Using the same rationale to quantify exposure to airborne radon under potential future land-use conditions that is used for potential future exposure to direct radiation, it is assumed that receptors may be exposed to an annual average above-background airborne radon concentration of 5.24 pCi/L in the vicinity of the K-65 fenceline. Using this value and the same exposure pathway assumptions used under current conditions, the above-background RME increases by a factor of approximately 7 to 1.44 WLM/year. Potential exposure estimate results for the airborne radon pathway are presented in Table E.3-4.

E.3.3.2.3 Sediment Ingestion

The sediment ingestion exposure pathway under future land-use conditions in the same pathway quantified under current land-use conditions because the exposure under current land use was an overestimate that assumed a modeled sediment concentration in Paddys Run within the FMPC boundary in the vicinity of Operable Unit 4. Because the dose associated with exposure to contaminated sediment in Paddys Run proximal to Operable Unit 4 is a worst-case overestimate and the estimated exposure is nominal, it is not necessary to refine the exposure to account for receptor locations under different land-use conditions.

E.3.3.2.4 Ingestion of Groundwater

The evaluation of exposure to contaminated groundwater under future-land use conditions involves the same assumptions and equations used for current land-use evaluations. However, under future land use it is assumed that the receptor is exposed to groundwater leachate concentrations leaching directly from the silos rather than concentrations modeled at the FMPC boundary.

The concentrations of contaminants in leachate from Operable Unit 4 for the future land-use scenario are listed in Attachment E.III, Tables E.III-3 and E.III-4. The intake pathways evaluated for current land use are also evaluated for future land use. The same equations and assumptions are used, substituting the leachate contaminant concentrations for the modeled groundwater contaminant concentrations used under current land-use. The parameter values used to calculate exposure results are presented in Table E.3-3.

The calculated lifetime radiological doses and chemical intakes for the future groundwater exposure pathways under future land-use conditions are presented in Tables E.3-7 and E.3-8. The radiological results indicate that human receptors at the waste unit who are using groundwater for drinking water, irrigating vegetables and animal feed, and watering animals, could be exposed to a lifetime radiation dose from Ra-226 from Silos 1 and 2 as high as 3700 rem. All of the radiation doses presented assume that the silos are leaking, that precipitation enters the silos to act as a leaching fluid, and that the contaminant source is depleted with time. In lieu of site-specific data, it was assumed that the silos contain very soluble forms of uranium (phosphate) and radium, and that the only factor limiting the concentration of uranium and radium in the leachate is the solubility of the species. These are potentially extreme upperbound estimates.

The chemical results indicate that after 500 years, a receptor at the property boundary could be exposed to high concentrations of several metals. The soluble uranium in Silo 3 appears to be of greatest concern.

E.3.3.2.5 Summary of Exposure and Intake

Tables E.3-4 through E.3-8 present the estimated radiological doses and chemical intakes for each potential pathway quantified under Operable Unit 4. The penetrating radiation, airborne radon, and sediment ingestion pathways are considered potential exposure pathways under both current and future land-use conditions (Table E.3-4). The modeled groundwater exposure pathways are considered potential pathways for future exposures under both current and future land-use conditions

(Tables E.3-5 through E.3-8). It has been determined that the Operable Unit 4 site RME individual may potentially be exposed to both direct radiation and airborne radon throughout a lifetime. The combined health effect for the RME individual from these two pathways is addressed in the risk characterization in Section E.5.0.

E.3.4 UNCERTAINTIES

A major source of uncertainty associated with modeling transport of constituents from Operable Unit 4 arises from predicting migration through environmental media. Data that are needed but were unavailable to model migration of constituents include:

- Characterization of the chemical species of the constituents in Operable Unit 4 to determine solubility and soil sorption properties
- Determination of the extent of potential leakage from Operable Unit 4 waste storage silos
- Characterization of radioactive and chemical materials in the berm soils and the soil beneath the operable unit

Several uncertainties are associated with receptor exposure estimates. The use of environmental measurement data to estimate receptor exposure concentrations to contaminants, assuming Operable Unit 4 as the single source term, tends to overestimate the dose and risk associated with that particular operable unit because contaminants could originate from various areas of the FMPC. However, above-background concentrations of Ra-226 in groundwater or subsurface soils would be likely to have originated from the K-65 silos, in particular, because the K-65 residues are a unique source of large quantities of Ra-226 activity at the FMPC site. However, above-background concentrations of uranium may be attributed to releases from a variety of sources.

It is uncertain if the silos are currently leaking hazardous constituents to the subsoils beneath, or not. If they are, it is important that such a scenario be evaluated to determine the potential consequences. Unfortunately, the data required to accurately estimate exposure via this pathway are very limited, and may not provide a realistic assessment of potential radiological exposures or chemical intakes. Therefore, it was necessary to perform scoping calculations with available data to determine the maximum hypothetical radiological exposures and chemical intakes. The exposures presented in this section are based on such an assessment and may exaggerate the potential for radiological exposures and chemical intakes; nevertheless, they provide some important insights. For example, these calculations demonstrate that leakage of hazardous constituents from the silos to the aquifer may be an overriding consideration for any remedial action; therefore, it is very

TABLE E.3-7

RADIOLOGICAL DOSES AND CHEMICAL INTAKES FROM GROUNDWATER PATHWAYS AT THE WASTE UNIT AT 500 YEARS SILOS 1 AND 2

Radiological Doses (lifetime mrem)

Constituent	Conservative Estimate
U-234	1.7×10^{-1}
U-235	1.2×10^{-2}
U-238	1.4×10^{-1}
Th-228	1.2×10^{-7}
Th-230	9.6×10^{-6}
Th-232	1.3×10^{-6}
Ra-226	3.7×10^{6}
Ra-228	2.2×10^{4}
Pb-210	1.1×10^{6}
Ac-227	1.2×10^{7}
Pa-231	8.5×10^{6}

Chemical Intake (mg/kg/day)

Arsenic	5.2×10^{-4}
Barium	7.0×10^{-6}
Beryllium	1.9×10^{-3}
Cadmium	5.6×10^{-3}
Chromium	6.0×10^{-6}
Copper	8.2×10^{-4}
Lead	3.7×10^{-2}
Manganese	5.0×10^{-3}
Nickel	5.8×10^{-1}
Selenium	1.9×10^{-3}
Thallium	7.9×10^{-4}
Vanadium	6.0×10^{-6}
Zinc	6.9×10^{-2}
Uranium	6.5×10^{-7}

TABLE E.3-8

RADIOLOGICAL DOSES AND CHEMICAL INTAKES FROM GROUNDWATER PATHWAYS AT THE WASTE UNIT AT 500 YEARS SILO 3

Radiological Doses (lifetime mrem)

Constituent	Conservative Estimate
U-234	6.5×10^{5}
U-235	4.2×10^{4}
U-238	5.9×10^{5}
Th-228	9.6×10^{-8}
Th-230	8.5×10^{-6}
Th-232	6.4×10^{-7}
Ra-226	2.1×10^{6}
Ra-228	2.1×10^{5}
Pb-210	5.3×10^{3}
Ac-227	1.2×10^{7}
Pa-231	9.0×10^{6}

Chemical Intake (mg/kg/day)

Arsenic	1.3×10^{-3}
Barium	3.7×10^{-4}
Beryllium	1.3×10^{-2}
Cadmium	3.5×10^{-2}
Chromium	5.7×10^{-3}
Copper	1.0×10^{-6}
Lead	2.6×10^{-4}
Nickel	1.2×10^{-3}
Selenium	6.6×10^{-3}
Thallium	1.5×10^{-2}
Vanadium	3.5×10^{-3}
Zinc	5.7×10^{-5}
Uranium	2.8×10^{0}

important to understand the chemical and physical characteristics of the residue constituents and their migration through subsurface soils in better detail than is currently available. These calculations were used to identify the factors that are the primary contributors to the calculated exposures and require refinement in order to develop a more reasonable assessment. It is likely, considering the silo contents are residues from extensive chemical extraction processes, that they are in a highly insoluble form and would be relatively immobile. However, it cannot be concluded form current information and data that the residue constituents will not at some time be available in soluble forms and migrate to the aquifer. In the absence of data, or other information, to the contrary, it is prudent to assume soluble species. Depending on the species solubility and mobility used in calculating migration from the silos to the aquifer, two extreme cases are possible: i.e. no potential exposure, or extremely high radiological exposure and chemical intakes. It is evident from this assessment which radionuclides and chemicals are major contributors to the potential radiological exposure and chemical intakes. Using this information, effort is now in progress to refine the input data to calculational models to approximate more closely an RME. It is also important to understand that even calculations using the more pessimistic assumptions demonstrate that migration to the aquifer is very slow and there is no imminent danger to the public via this exposure pathway.

Receptors for this risk assessment are RME individuals. These scenarios assume that an individual is exposed continuously 24 hours/day, 365 days/year. The receptors for the sediment ingestion pathway are assumed to ingest sediment for 365 days/year. These scenarios err on the side of health protectiveness with regard to the period of exposure assumed. Uncertainties are always inherent in defining potential land-use conditions 100 years in the future. Assumptions used in this risk assessment attempt to lead to evaluation of "reasonable maximum" future exposure.

E.3.5 SUMMARY OF EXPOSURE ASSESSMENT

Three exposure pathways from Operable Unit 4 to human receptors have been identified as potential exposure pathways under both current and future land-use conditions. A fourth pathway, involving the use of contaminated groundwater, is evaluated as a potential future pathway of concern under both current and future land-use conditions. Exposure pathways involving the use of contaminated groundwater assume that the silos eventually leak. The risks associated with exposures from all pathways are addressed quantitatively in the risk characterization presented in Section E.5.0.

E.4.0 TOXICITY ASSESSMENT

Potential health hazards reviewed in this section include direct exposure to penetrating radiation, exposure to airborne radon gas, and constituents of Operable Unit 4 with emphasis on uranium and radium. Direct exposure to penetrating radiation and exposure to airborne radon are considered potential health hazards in the Operable Unit 4 risk assessment because above-background levels of these constituents have been measured at the site boundary. Exposure to penetrating radiation or airborne radon gas poses a radiocarcinogenic health hazard.

Oral intakes of uranium and radium are evaluated for the sediment ingestion pathway. Silo constituents that may reach a potential receptor in groundwater are briefly discussed.

E.4.1 NONCARCINOGENIC EFFECTS

E.4.1.1 Uranium

The chemical toxicity of uranium is the only noncarcinogenic health effect from current exposure pathways from Operable Unit 4 chemicals of concern. The primary chemically-induced health effect of uranium is nephritis, or kidney damage. Symptoms of this include albuminuria (elevated protein in the urine) and glycosuria (elevated sugar in the urine). Pharmacokinetic and pharmacodynamic studies on the toxicity of uranium and the development of a threshold effect dose limit are summarized below.

E.4.1.1.1 Pharmacokinetics

In general, uranium compounds are not easily absorbed across the human gastrointestinal tract. Soluble uranium compounds demonstrate the best absorption, but in a study where patients drank a solution of uranyl nitrate hexahydrate, a water soluble compound, only 0.5 to 5 percent of the dose was found to be absorbed (Hursh et al. 1969). Most recently, uranium metabolic models have estimated absorption from the gastrointestinal (GI) tract to the blood to be 0.6 percent (Wrenn et al. 1987). Although human data for dermal exposure are minimal, water-insoluble uranium compounds are not absorbed in significant amounts across the skin and are not believed to pose a risk to humans via this exposure route (Yuile 1973).

Once absorbed into the bloodstream, uranium compounds are metabolically converted to uranyl ions. The uranyl ion acts as a ligand in the systemic circulation, binding to the plasma proteins and bicarbonate. Although this uranyl-bicarbonate complex is stable at the pH of the plasma, the pH of

510

urine favors dissociation of the complex. This leaves the uranyl ion free to bind to the tissues in the proximal tubule wall, resulting in cellular necrosis (Leggett 1989).

In addition to being the only soft tissue that stores uranium in any appreciable amount, the kidney is the main organ of excretion (Hursh and Spoor 1973). Approximately 70 percent of a dose of uranium has been estimated to be excreted by the kidney within 24 hours of intake (Berlin and Rudell 1979). Uranium not excreted is stored in both the kidney and the bone. Binding to the bone is thought to be caused by the affinity of uranium for the phosphate groups in the bone structure.

E.4.1.1.2 Human Studies

Human data on exposure to uranium compounds were collected from 1940 to 1960 from acute studies on terminal and volunteer patients. Single injections of 70 to 100 µg/kg of uranium nitrate to terminally ill patients resulted in proteinuria and increased levels of catalase in the urine (Berlin and Rudell 1979; Luessenhop et al. 1958). In another study, patients were given uranyl nitrate injections ranging from 6.3 to 71 µg/kg. One of the early signs of renal damage, the appearance of the enzyme catalase in the urine, occurred in patients receiving 55 or 71 µg/kg (Hursh and Spoor 1973; Leggett 1989).

E.4.1.1.3 Animal Studies

Laboratory animals demonstrate a great deal of variation in their responses to acute intravenous toxicity studies with rabbits and guinea pigs appearing to be the most sensitive. The acute intravenous toxicity of soluble uranium compounds like uranyl nitrate is very high: the approximate dose at which 50 percent of the test organisms did not survive (LD_{50}) for rabbits is 0.1 mg/kg; for guinea pigs, 0.3 mg/kg; for rats, 1 mg/kg; and for mice, 10 to 20 mg/kg (Stokinger 1982).

In chronic animal experiments, sublethal threshold doses of uranium have been demonstrated (Leggett 1989). Although the exact mechanism of tolerance is not known, it is believed that regenerated kidney tissue is associated with tolerance. When uranium exposure ceases, the regenerated epithelium will be transformed into normal renal tubular tissue (Yuile 1973).

An extensive chronic feeding study was performed on rabbits, rats, and dogs for periods of 30 days, 1 year, and 2 years (Maynard and Hodge 1949). These animals received uranium doses of 2.8, 14, and 71 mg/kg/day in the diet. Rabbits were maintained for 30 days, dogs for 1 year, and

rats for 1 and 2 years. For all species, water soluble compounds were more toxic than insoluble compounds, and lowest observed adverse effect levels (LOAELs) were established for all compounds and each species (Maynard and Hodge 1949). In all cases, the LOAEL could be established within the first 30 days (EPA 1989c). Of the three species, rabbits appeared to be the most sensitive with renal damage exhibited at all administered dose levels. The renal damage was judged to be only moderate at the lower doses, but moderately severe at the highest dose. Based on this, the lowest uranium dose of 2.8 mg/kg/day was established as the LOAEL by EPA (EPA 1989c).

E.4.1.1.4 Regulatory Guidance

The EPA (1989c) has recently established a reference dose (RfD) for uranium of 3 µg/kg/day. In lieu of a no observed adverse effect level (NOAEL), the RfD is based on the LOAEL of 2.8 mg/kg/day from the Maynard and Hodge (1949) bioassay and an uncertainty factor of 1000. The uncertainty factor accounts for intraspecies and interspecies variability in toxicological response and for the use of the LOAEL. No factor was included to account for the short duration of the exposure (30 days) because it has been shown that chronic nephrotoxic effects can be adequately characterized with experiments of acute/subacute duration (EPA 1989c).

A pharmacokinetic model has also been used to determine the acceptable threshold dose for uranium levels in the kidney, which are then used to calculate an acceptable uranium intake. The National Council on Radiation Protection and Measurements (NCRP) (Wrenn et al. 1985) proposed a single compartment model with long-term retention in the kidney. The International Commission on Radiological Protection (ICRP) (1979) developed a two-compartment model that also assumes long-term retention in the kidney (e.g. a 1500-day metabolic half-life). The NCRP model is considered more appropriate for the evaluation of chronic ingestion of uranium at low levels found in the environment because the ICRP model was developed for application to inhalation of insoluble forms by radiation workers (Kocher 1989) and the fraction transferred to the kidney is so small (Kathren et al. 1989). The NCRP model is:

$$\frac{A_{\infty}}{Im} = \frac{f_1}{m(\ln 2)} f_2 T_1$$

where

A_{∞} = amount of U in the kidney at equilibrium
m = kidney mass (310 g)
f_1 = fractional GI absorption from GI tract to blood (0.014)

f_2 = fractional transfer from blood to kidney (0.11)
T_1 = half time in kidney (15 days)
I = daily intake (µg/day).

then

$$\frac{C_\infty}{I} = \frac{A_\infty}{Im}$$

where

C_∞ = concentration of uranium in µg/g kidney per µg/day intake, or the amount of ingested uranium that deposited in the kidney at equilibrium.

An acceptable daily intake (I_L) can then be calculated by:

$$I_L = \frac{(C_L/S)}{(A_\infty/m)}$$

where

C_L = threshold concentration in the kidney (1 µg/g)
S = safety factor (50).

The threshold concentration of 1 µg/g suggested by the NCRP is lower than the generally acceptable concentration of 3 µg/g kidney (Spoor and Hursh 1973). This is based on dog data that suggest 0.6 µg/g kidney may be below the threshold for man (Wrenn et al. 1985). The safety factor of 50 is higher than recently suggested by Kocher (1989).

Based on this model, the I_L for uranium is 186 µg/day. In terms of intake by a 70-kilogram adult, this corresponds to an acceptable intake of 2.7 µg/kg/day, or approximately 3 µg/kg/day, which agrees with 3 µg/kg/day RfD determined using animal data.

E.4.1.2 Other Chemical Toxicants

Although uranium is the only constituent from Operable Unit 4 that is currently and consistently present above background in the environment, toxicity information on additional silo constituents is presented in order to evaluate potential future exposures. Table E.4-1 summarizes toxicity information for those silo constituents estimated to have the potential to migrate from the silos, through the glacial overburden, and into the groundwater aquifer in the future.

TABLE E.4-1

ORAL TOXICITY VALUES FOR POTENTIAL NONCARCINOGENIC EFFECTS

Chemical	Chronic RfD[a] (mg/kg/day)	RfD Source	Critical Effect	Uncertainty Factor
Arsenic	1.0×10^{-3}	HEAST[b]	Keratosis	1
Barium	5.0×10^{-2}	IRIS[c]	Fetotoxicity, high blood pressure	100
Beryllium	5.0×10^{-3}	IRIS	d	100
Cadmium	1.0×10^{-3} (food) 5.0×10^{-4} (water)	IRIS IRIS	Renal damage Renal damage	10 10
Chromium VI	5.0×10^{-3}	IRIS	Liver toxicity	500
Copper	3.7×10^{-2}	DWHA = 1.3 mg/L, HEAST[e]	Local GI irritation	NG[f]
Lead	6.9×10^{-4}	Marcus 1986	Renal damage, anemia	5
Manganese	2.0×10^{-1}	IRIS	Central nervous system	100
Selenium	3.0×10^{-3}	IRIS	Dermatitis, hair loss	15
Thallium	7.0×10^{-5}	IRIS	Hair loss	3000
Uranium	3.0×10^{-3}	IRIS	Nephrotoxicity	1000
Vanadium	7.0×10^{-3}	HEAST	NG	100
Zinc	2.0×10^{-1}	IRIS	Anemia	10

[a] Reference dose signifying acceptable daily intake

[b] Health Effects Assessment Summary Tables (EPA 1989f)

[c] Integrated Risk Information System (EPA 1989c)

[d] Not toxic at highest dose tested (EPA 1989f)

[e] DWHA = Drinking Water Health Advisory

[f] NG = Not given

E.4.2 CARCINOGENIC EFFECTS

This section presents a compilation of radiocarcinogenic risk coefficients for use in radiological risk assessments for Operable Unit 4. These risk coefficients have been obtained from three radiation protection publications (NCRP 1987; NAS 1988; ICRP 1987). Radiocarcinogenic risk coefficients are generally expressed as a function of exposure to radiation or exposure to quantities of radionuclides; therefore, they may be multiplied by either the estimated radiation dose received or the estimated exposure to radioactive material.

E.4.2.1 Radiocarcinogenic Risk from Exposure to Penetrating Radiation and Ingested Radioactive Material

Assessment of the lifetime radiocarcinogenic risk of fatal cancer from exposure to radiation is performed using a somatic whole body risk coefficient of 125×10^{-6} rem^{-1} published by the NCRP (1987). The NCRP presents a tabulation of risk coefficients associated with various body tissues (Table E.4-2). The sum of the tissue-specific risk coefficients equals the NCRP's total whole body risk coefficient of 165×10^{-6} rem^{-1}. The total whole body risk coefficient of 165×10^{-6} rem^{-1} includes the somatic whole body risk of 125×10^{-6} rem^{-1} and the genetic risk of 40×10^{-6} rem^{-1}. The somatic whole body risk is used in the risk characterization in Section E.5.0 to quantify the risk of fatal cancers in individuals exposed to ionizing radiation. The genetic risk of 40×10^{-6} rem^{-1} addresses the genetic risks to offspring from exposure of the parents' gonads to radiation. The risk of fatal cancer is used as the basis for assessing radiation-related human health risks (EPA 1989a).

All of these risk coefficients quantify risk as deaths per unit dose equivalent received (rem^{-1}). The risk coefficients presented by the NCRP are consistent with the recommendations of the ICRP in Publication 26 (ICRP 1977). The EPA recently adopted a risk coefficient of 4×10^{-4} rem^{-1} for low linear energy transfer (LET) radiation in place of the 1.25×10^{-4} rem^{-1} used in this risk assessment. The EPA risk factor is approximately three times higher; therefore, the estimated risks would be proportionately higher if the EPA risk coefficient is used.

The somatic whole body risk coefficient may be used whether the dose equivalents received are delivered by external penetrating whole body radiation exposure or by radiation exposure of specific tissues from internally deposited radionuclides provided that the tissue dose equivalents are expressed as risk-weighted dose equivalents. Risk-weighted tissue dose equivalents are tissue dose equivalents that have been multiplied by the appropriate tissue risk-weighting factor (Table E.4-2).

TABLE E.4-2

RISK COEFFICIENTS AND RECOMMENDED WEIGHTING FACTORS FOR POTENTIAL RADIOCARCINOGENIC EFFECTS

Tissue	Risk Coefficient	Weighting Factor
Breast	25×10^{-6} rem^{-1}	0.15
Red Bone Marrow	20×10^{-6} rem^{-1}	0.12
Lung	20×10^{-6} rem^{-1}	0.12
Thyroid	5×10^{-6} rem^{-1}	0.03
Bone Surfaces	5×10^{-6} rem^{-1}	0.03
Remainder[a]	50×10^{-6} rem^{-1}	0.30
Somatic (whole body)[b]	125×10^{-6} rem^{-1}	0.75
Gonads	40×10^{-6} rem^{-1}	0.25
Total (whole body)[b]	165×10^{-6} rem^{-1}	1.00

[a]A weighting factor of 0.06 is assigned to each of the five remainder tissues receiving the highest dose equivalents under the particular exposure conditions of concern. Dose equivalents to any other tissues beyond the five remainder tissues are neglected.

[b]The somatic whole body risk alone is 125×10^{-6} rem^{-1}. The genetic risk alone is 40×10^{-6} rem^{-1}.

Source: NCRP 1987

E.4.2.2 Radiocarcinogenic Risk from Exposure to Radon-222 Progeny

Assessment of the radiocarcinogenic risk from exposure to airborne radon and its short-lived progeny is performed using risk coefficients published by the Biological Effects of Ionizing Radiation (BEIR) IV Committee (NAS 1988) and the ICRP (ICRP 1987), and adopted by the EPA for use in risk assessments (EPA 1989f). The BEIR IV and ICRP risk coefficients are selected by the EPA (EPA 1989f) because they represent the most recent comprehensive examinations of estimated health risks associated with exposure to radon and radon progeny. The risk estimation approach employed by the BEIR IV Committee and the ICRP involves the evaluation of epidemiological data concerning underground miners. The BEIR IV Committee and the ICRP developed relative risk models based on estimated radon progeny exposures of the miners and the incidence of lung cancer mortality in the miners. The EPA selected an average of the risk coefficients obtained using the BEIR IV and ICRP models, consistent with the recommendation of the EPA's Radiation Advisory Committee (EPA 1989f).

A fatal lung cancer risk coefficient for radon progeny exposure has been adopted by the EPA for use in assessing risk (EPA 1989f). The risk coefficient selected by EPA for assessing the risk from exposure to radon progeny is 360 excess lung cancer deaths per million persons per WLM due to lifetime exposure to radon progeny (360×10^{-6}/WLM).

E.4.3 UNCERTAINTIES RELATED TO TOXICITY INFORMATION

Toxicity information used in the human health assessment incorporates considerable uncertainty. This is because toxicity information is often based upon modeled projections that are based on empirical studies of animals or humans exposed to radiological or hazardous agents under circumstances that differ from the circumstances of exposure in a site-specific human health assessment. Four principal sources of uncertainty that are incorporated into the human health assessment for both chemical and radiological toxicity are:

- The use of dose-response relationships (models) based on exposures at high doses to predict low dose effects
- The use of dose-response relationships based on acute exposures to predict effects from chronic exposures
- The use of dose-response relationships based on laboratory animal studies to predict effects on humans
- The use of dose-response relationships based on human study populations that may be significantly different from the populations of concern in the site-specific human health assessment

The radiological risk coefficients and the chemical toxicity RfDs presented incorporate conservative assumptions that are considered to overestimate risk. This conservatism is built into the risk estimates because of the uncertainties that are associated with risk estimation.

The whole body risk coefficient selected by the NCRP incorporates a conservative assumption for radiation protection purposes. This assumption is that the dose-response relationship used to estimate risk is linear without threshold throughout the range of dose equivalent and dose equivalent rates of importance in routine radiation protection (NCRP 1987).

The risk coefficients associated with exposure to radon progeny range from 140×10^{-6} to 720×10^{-6}/WLM. The magnitude of this range is a factor of approximately five. This risk range is presented to reflect an estimate of the uncertainty associated with the relative risk coefficient (EPA 1989f). More detailed treatments of the uncertainties associated with the radiological fatal cancer risk factors are presented in the referenced documents (NCRP 1987; NAS 1988; ICRP 1987).

The oral RfD for uranium (EPA 1989c) is based on a published LOAEL of 2.8 mg/kg/day (Maynard and Hodge 1949) and an uncertainty factor of 1000. The uncertainty factor is included to compensate for intraspecies and interspecies variability in toxicological response.

E.5.0 RISK CHARACTERIZATION

This section provides a characterization of the potential health effects associated with the intake of chemicals and exposure to radionuclides that have migrated, or have the potential to migrate, from Operable Unit 4. Section E.3.0 presented potential exposures and estimates of intake associated with these exposures. Section E.4.0 presented the radiological cancer risk factors and RfDs for chemical intake that will be used to characterize the potential health effects associated with identified exposures. In accordance with methods described by EPA (1989a), a health protective approach that is likely to overestimate rather than underestimate risk is used. A quantitative evaluation of the lifetime risk associated with exposure under current land-use conditions, assuming a 70-year lifetime, is presented. An evaluation of the lifetime risk associated with potential future exposure under both current and future land-use conditions is also presented. The exposure estimates for future land-use conditions calculated in Section E.3.0 assume that future conditions allow receptor exposures inside the FMPC boundary close to the K-65 fenceline.

E.5.1 CURRENT LAND-USE CONDITIONS

This section addresses the concerns associated with identified current exposures. Current and potential future land-use assumptions used to quantity exposures are described in Section E.3.0.

E.5.1.1 Carcinogenic Effects

Radiocarcinogenic risks from exposure to radiation and radionuclides are calculated using estimated radiation dose equivalents expressed as roentgen equivalent man (rem), or cumulative exposure to radionuclides, and the appropriate risk coefficients presented in Section E.4.0 of this report. Table E.4-2 presents risk coefficients as a function of risk-weighted dose equivalent received (rem^{-1}). Section E.4.0 also presents a risk coefficient as a function of cumulative exposure to radon progeny (WLM^{-1}).

Radiocarcinogenic risks are characterized under current land-use conditions for the following exposure pathways:

- Exposure to penetrating radiation
- Exposure to airborne radon and short-lived progeny
- Exposure to uranium and Ra-226 in stream sediments from Paddys Run via ingestion
- Exposure to contaminated groundwater and food raised with groundwater

Table E.3-4 presents the estimated RME exposures to penetrating radiation, radiation from internally deposited radionuclides from sediment ingestion, and radon progeny. Tables E.3-5 and E.3-6

present the estimated RME exposures to contaminated groundwater and food. The method for calculating the risk contributed by each of the exposure pathways is expressed by:

$$R_L = (E_L)\ (RC)$$

where

R_L = lifetime risk of fatal cancer from lifetime exposure to the pathway of interest
E_L = lifetime exposure from the pathway of interest
RC = lifetime risk coefficient per unit exposure from the pathway of interest.

E.5.1.1.1 Penetrating Radiation

The incremental RME exposure to penetrating radiation from the silos was estimated in the exposure assessment to be 36 mrem/year, or 2500 mrem over a 70-year lifetime. The lifetime somatic risk per rem to the whole body presented in the toxicity assessment is 125×10^{-6} rem^{-1}. Thus, the incremental lifetime risk of fatal cancer from lifetime RME exposure to penetrating radiation from the silos is 3×10^{-4} for an individual exposed under potential current conditions.

E.5.1.1.2 Airborne Radon

The incremental RME exposure to airborne radon and its short-lived progeny from the silos was estimated in the exposure assessment to be 0.19 WLM/year or 13 WLM over a 70-year lifetime.

The lifetime risk per WLM presented in the toxicity assessment is 360×10^{-6} WLM^{-1}. Thus, the incremental lifetime risk of fatal lung cancer from lifetime RME exposure to airborne radon and radon progeny from the silos is 5×10^{-3} for an individual potentially exposed under current conditions.

E.5.1.1.3 Ingestion of Uranium and Radium-226 in Sediments

The incremental RME exposure to uranium in ingested sediments from Paddys Run was estimated in the exposure assessment to be 1.2 mrem over a six-year period (Table E.3-4). Because this dose equivalent is a CEDE, it is already risk-weighted and is simply converted from mrem to rem and multiplied by the lifetime risk coefficient per rem. The lifetime risk per rem presented in the toxicity assessment is 125×10^{-6} rem^{-1}. Thus, the incremental lifetime risk of fatal cancer from the six-year exposure to uranium in ingested sediment from Paddys Run is 2×10^{-7}.

The incremental RME exposure to Ra-226 in ingested sediments from Paddys Run was estimated in the exposure assessment to be 7.2 mrem over a six-year period (Table E.3-4). This exposure is

used in the same manner as the uranium exposure because it is also a CEDE. The incremental lifetime risk of fatal cancer from the six-year exposure to Ra-226 in ingested sediment from Paddys Run is 9×10^{-7}. These uranium and Ra-226 ingestion exposures and risks represent the maximum potential exposures and risks unique to a member of the most sensitive population under this baseline risk assessment.

E.5.1.1.4 Groundwater Pathways

The estimated lifetime radiation dose to human receptors at the FMPC boundary fenceline under current land-use conditions using contaminated groundwater could exceed 1000 rem using modeling and exposure assumptions that greatly overestimate radiation doses. The corresponding estimated radiological fatal cancer risk exceeds 1.0. However, as discussed in Section E.3.4, the modeling results may be extremely conservative and may result in calculated radiological exposures and chemical intakes that exaggerate the potential impact of this exposure pathway.

E.5.1.1.5 Summation of Carcinogenic Risks

The lifetime risks from lifetime exposure to penetrating radiation and airborne radon are summed because it is reasonable to assume that the RME individual may be exposed to the RME exposure from both penetrating radiation and airborne radon released from the silos. This results in an incremental lifetime risk of 5×10^{-3}.

The risks from exposure to uranium and Ra-226 in sediments are not summed with the risks from penetrating radiation and airborne radon because the sediment ingestion pathway is considered a unique exposure pathway for children. However, the risks contributed by the uranium and the Ra-226 in the sediment can reasonably be summed. This results in an incremental lifetime risk of 1×10^{-6}. Addition of the sediment ingestion risk (1×10^{-6}) to the airborne radon risk (5×10^{-3}) does not change the total risk. Although it is possible that the child receptor for the sediment ingestion pathway may simultaneously be a receptor for the airborne radon and penetrating radiation exposure pathways, combining the three exposures is questionable because the description of the receptor for the sediment ingestion pathway is different from the description of the receptor for the airborne radon and penetrating radiation pathways.

E.5.1.2 Noncarcinogenic Effects

The potential health consequence of the noncarcinogenic effects of chemicals is evaluated by comparing estimated intakes (Section E.3.0) with the RfD, which represents an estimate of the level

of intake that would not result in adverse health effects (i.e., a "threshold" effect). The parameter of interest is the hazard index (HI) defined as:

$$HI = I/RfD$$

where

HI = hazard index (unitless)
I = intake (µg/kg/day)
RfD = reference dose (µg/kg/day)

This approach is different from the probabilistic approach used to evaluate carcinogens. Note that an HI of 0.01 does not imply a 1 in 100 chance of adverse effect, but indicates that the estimated intake is 100 times less than the RfD.

An identified potential exposure to elemental uranium from Operable Unit 4 is from ingestion of creek sediments by children. Table E.3-4 presents the estimated uranium intake of 0.13 µg/kg/day from ingestion of sediments contaminated by erosion of soil from Operable Unit 4 to Paddys Run. The chronic RfD is appropriate for use in this situation because the chronic effect of uranium toxicity, nephrotoxicity, is the same effect that would be of concern during the six-year exposure. The estimated HI for this pathway is 0.043. This is below the specific operable unit action level goal of one-fourth of the allowable intake, which corresponds to an HI of 0.25.

Assuming leakage from the silos in the future, potential exposure to a variety of chemical constituents from Operable Unit 4 is possible via consumption of contaminated groundwater and food raised with contaminated groundwater. Table E.5-1 indicates that if the silos begin leaking, the potential exists for receptors at the FMPC boundary to be exposed to unacceptable concentrations of several toxicants, assuming worst-case leaching conditions. Beryllium, cadmium, thallium, and uranium all may have HI values greater than 1.0. Lead and nickel are the remaining chemicals and have HI values above 0.25 (the operable unit HI action level).

E.5.2 FUTURE LAND-USE CONDITIONS

This section addresses the risks associated with potential future exposures estimated in Section E.3.0. Future land-use assumptions are described in Section E.3.0. Potential exposures under future land use were estimated for the direct penetrating radiation pathway and the airborne radon exposure pathway. These two pathways, particularly the radon pathway, present the most significant potential receptor exposures. The modeled sediment ingestion pathway is of nominal

TABLE E.5-1

NONCARCINOGENIC EFFECTS ASSOCIATED WITH FUTURE RELEASES FROM OPERABLE UNIT 4 - 100-YEAR SCENARIO

Constituents	Intake[a] (mg/kg/day)	RfD (mg/kg/day)	Hazard Index
Arsenic	4.4×10^{-5}	0.001	0.044
Barium	9.9×10^{-6}	0.05	0.0014
Beryllium	8.3×10^{-3}	0.005	1.7
Cadmium	2.4×10^{-2}	0.00005	49.2
Chromium	1.6×10^{-4}	0.005	0.031
Copper	2.4×10^{-7}	0.037	0.0000048
Lead	5.1×10^{-4}	0.00069	0.75
Manganese	9.1×10^{-5}	0.2	0.00014
Nickel	8.0×10^{-3}	0.02	0.42
Selenium	2.1×10^{-4}	0.003	0.07
Thallium	4.5×10^{-3}	0.00007	52.5
Vanadium	6.9×10^{-5}	0.007	0.014
Zinc	2.0×10^{-3}	0.2	0.0048
Uranium	7.5×10^{-2}	0.003	25.2

[a]Combined intake from drinking water, meat ingestion, vegetable ingestion, and milk ingestion from Silos 1, 2, and 3.

concern under current land use; therefore, it is not addressed under future land use. Exposure to contaminated groundwater is considered a potential exposure pathway under both current and future land-use conditions. No evidence exists to confirm the existence of a groundwater exposure pathway from Operable Unit 4; however, the risk associated with potential exposure to contaminated groundwater is being considered (assuming the silos begin to leak in the future). Additional RI data are to be collected in the form of slant borings beneath the silos to determine if leakage from the silos may be occurring. Evidence of leakage from the silos into soil directly beneath the silos would indicate potential for contamination of groundwater by releases from Operable Unit 4.

E.5.2.1 Carcinogenic Effects

In Section E.3.0 the estimated exposure to direct penetrating radiation under potential future land-use conditions is approximately 50 times the estimated exposure under current land-use conditions. Thus, the estimated risk becomes 50 times the estimated risk under potential current land-use conditions, or 2×10^{-2}.

The estimated exposures to airborne radon under potential future land-use conditions is approximately seven times the estimated exposure under potential current land-use conditions. Thus, the estimated risk becomes seven times the estimated risk under potential current land-use conditions or 3×10^{-2}. The combined above-background lifetime risk from lifetime exposure to the penetrating radiation and airborne radon pathways under potential future land-use conditions is 5×10^{-2}.

The estimated lifetime radiation dose to human receptors at the waste unit under future land-use conditions using contaminated groundwater could exceed 1000 rem using modeling and exposure assumptions that greatly overestimate radiation doses. The corresponding estimated radiological fatal cancer risk exceeds 1.0. However, as discussed in Section E.3.4, the modeling results may be extremely conservative and may result in calculated radiological exposures and chemical intakes that exaggerate the potential impact of this exposure pathway.

E.5.2.2 Noncarcinogenic Effects

Results in Table E.5-2 indicate that if current security control measures are lost after 100 years under future land-use conditions, the silos could pose potential health risks to receptors within the FMPC boundary close to the silos. The results presented in Table E.5-2 incorporate many worst-case assumptions including:

TABLE E.5-2

NONCARCINOGENIC EFFECTS ASSOCIATED WITH FUTURE RELEASES FROM OPERABLE UNIT 4 - 500-YEAR SCENARIO

Constituents	Intake[a] (mg/kg/day)	RfD (mg/kg/day)	Hazard Index
Arsenic	0.0018	0.001	1.8
Barium	0.00037	0.05	0.0071
Beryllium	0.015	0.005	3.1
Cadmium	0.041	0.00005	82.0
Chromium	0.0057	0.005	1.1
Copper	0.00082	0.037	0.00046
Lead	0.037	0.00069	54.3
Manganese	0.005	0.2	0.01
Nickel	0.58	0.02	29.6
Selenium	0.0085	0.003	2.8
Thallium	0.016	0.00007	224.1
Vanadium	0.0035	0.007	0.52
Zinc	0.069	0.2	0.35
Uranium	2.78	0.003	927.5

[a]Combined intake from drinking water, meat ingestion, vegetable ingestion, and milk ingestion from Silos 1, 2, and 3.

- The receptor is located immediately beside Operable Unit 4 and is exposed to leachate concentrations prior to any dilution.
- The silos begin leaking at approximately 100 years because leakage prior to that time would deplete the source resulting in lower leachate concentrations.
- The leachate concentrations are based on EP Toxicity results, which are performed using acidic leaching solutions, or on the solubility of the modeled metal species.

E.5.3 UNCERTAINTIES

The risk characterization integrates environmental sampling, fate and transport analysis, exposure analysis, and toxicological data. Uncertainties associated with each step of the risk assessment process affect the results of the risk characterization. The uncertainties associated with analysis of the environmental sampling data, fate and transport results, exposure estimates, and toxicological data have been qualitatively presented in previous sections. This risk characterization strives to minimize the probability that uncertainties may result in an underestimation of the actual health hazards associated with the operable unit. Thus, each step of the process has incorporated bias intended to overestimate the potential hazards being addressed.

E.6.0 ENVIRONMENTAL ASSESSMENT

In addition to documenting the assessment of risks to human health, the baseline risk assessment addresses effects on the environment. Because the relationship of the FMPC with environmental media and the local ecology cannot be isolated to a particular operable unit, the environmental impacts associated with the FMPC will be addressed by a companion program-wide EIS. The reader is referred to the EIS for a comprehensive presentation of the environmental impacts. Nevertheless, for completeness of the baseline risk assessment for Operable Unit 4, this chapter will summarize those actions of the EIS that apply to Operable Unit 4.

E.6.1 SUMMARY OF RADIONUCLIDES AND CHEMICALS OF POTENTIAL CONCERN

The source of above-background concentrations of uranium in surface water and sediment in Paddys Run is not confirmed, but it is noteworthy that drainage ditches from the Waste Storage Area enter Paddys Run in this general area. Concentrations of total uranium detected in surface water samples collected from the waste pit area average approximately 3400 µg/L. Concentrations of Ra-226 in surface water samples from Paddys Run did not exceed background concentrations at any location.

Data on radionuclide uptake by biota within the boundaries of Operable Unit 4 are not available. One site sampled for radionuclide uptake by macroinvertebrates and fish, PR-3, is on Paddys Run adjacent to Operable Unit 4 (ASI/IT 1990). A crayfish sample from PR-3 contained 5.1 pCi/g total uranium. Radionuclides were not detected in fish collected from this site. Radionuclides present in biota at Site PR-3 cannot be reliably attributed to contamination from Operable Unit 4 because contamination in Paddys Run Site PR-3 could have originated upstream from Operable Unit 4 (for example, from runoff from the Waste Storage Area).

Although data are not available on the uptake of radionuclides by biota within the boundaries of Operable Unit 4, potential uptake can be estimated using the range of vegetation:soil uptake ratios suggested by the NCRP (1986) of 0.002 to 0.01.

The maximum concentration of uranium in soil in Operable Unit 4 was 48.4 pCi/g (the sum of 37.4 pCi/g of U-238 and 11.0 pCi/g of U-234). Plants taking up uranium from this soil using the root:soil concentration factor of 0.01 would accumulate 0.01 times 48.4 equals 0.48 pCi/g total uranium.

The highest Ra-226 concentration in soil in Operable Unit 4 is 35.8 pCi/g. The vegetation:soil transfer factor used by the NRC for Ra-226 in forage (NCRP 1986) ranges from 0.0001 to 0.2. Bases et al. (1984) suggests using 0.015. The estimated maximum concentration of Ra-226 in vegetation in Operable Unit 4 is therefore 0.015 times 35.8, or 0.58 pCi/g. Ra-226 contamination of organisms in Paddys Run is therefore unlikely. Po-210, Pb-210, and Th-230, if present in berm soils, could be taken up by plants, but no data are available to test this hypothesis.

E.6.2 ECOLOGICAL CHARACTERIZATION OF OPERABLE UNIT 4

The FMPC lies in the Oak-Hickory Forest Section of the Eastern Deciduous Forest, as described by Bailey (1978). Ecological communities at the FMPC consist of grazed and ungrazed pastures, two pine plantations, deciduous woodlands, riparian woodlands, and a reclaimed fly ash pile area.

Organisms potentially exposed to Operable Unit 4 contaminants include a variety of terrestrial plants and animals in the introduced grasslands and aquatic organisms in Paddys Run. Plants in the introduced grasslands include timothy (Phleum pratense), red top (Agrostis sp.), Kentucky bluegrass (Poa pratensis), teasel (Dipsacus sylvestris), ragweed (Ambrosia sp.), moth mullein (Verbascum blatteria), and wild parsnip (Pastinaca sativa). The dominant tree species in the riparian woodland along Paddys Run are cottonwood (Populus deltoides), hackberry (Celtis occidentalis), and box elder (Acer negundo). Dominant understory species include trumpet creeper (Campsis radicans) and hackberry saplings. The most common herb is garlic mustard (Allaria officinalis). Aquatic vascular plants, e.g., cattails (Typha sp.) and sedges (Carex sp.), as well as algae, also occur along Paddys Run.

A variety of small mammals occur in the introduced grasslands and the deciduous forest immediately to the south of Operable Unit 4. Species include the fox squirrel (Sciurus niger), eastern cottontail (Sylvilagus floridanus), white-footed mouse (Peromyscus leucopus), short-tailed shrew (Blarina brevicauda), meadow vole (Microtus pennsylvanicus), meadow jumping mouse (Zapus hudsonicus), eastern chipmunk (Tamias striatus), and several species of bats. White-tailed deer (Odocoileus virginianus) also occur on the FMPC in the pine plantations on the southwest and northeast portions of the FMPC.

Common bird species in and adjacent to Operable Unit 4 include the barn swallow (Hirundo rustica), red-winged blackbird (Agelaius phoeniceus), American robin (Turdus migratorius), eastern meadowlark (Stumella magna), blue jay (Cyanocitta cristata), northern cardinal (Cardinalis cardinalis), mourning dove (Zenaida macroura), and European starling (Sturnus vulgaris). The most

abundant species in the introduced grasslands are the barn swallow, red-winged blackbird, and eastern meadowlark. The most abundant species in the riparian woodland are the blue jay, American robin, and northern cardinal.

Aquatic organisms found in Paddys Run include benthic macroinvertebrates and fish. The most common macroinvertebrates in Paddys Run are the nonbiting midges (Chironomidae), riffle beetle (Stenelmis sp.), mayfly (Caenis sp.), and stonefly (Allocapnia sp.). Also common are isopods (Lirceus fontinalis), caddisflies (Cheumatopsyche sp. and Hydropsyche sp.), oligochaetes, and blackflies (Simulium sp.). The most abundant fish are the bluntnose minnow (Pimephales notatus), creek chub (Semotilus atromaculatus), and stoneroller minnow (Campostoma anomalum).

No federally-listed threatened or endangered species have been observed at the FMPC or in its immediate vicinity. Suitable habitat for one species of mammal listed as federally endangered, the Indiana bat, occurs along Paddys Run. However, the Indiana bat was not found on property.

E.6.3 EXPOSURE TO ENVIRONMENTAL RECEPTORS

Exposure to environmental receptors is being addressed in detail under the National Environmental Policy Act (NEPA) EIS being performed at the site. This section presents estimates of radiological dose equivalent rates to plants, animals, and aquatic organisms from uranium uptake attributed to Operable Unit 4. These dose equivalent rates are not committed dose equivalents; they represent the dose equivalent delivered to the organism in one year from the estimated uranium concentration (pCi/g) in the tissue. The estimated maximum uptake of uranium by vegetation in Operable Unit 4 of 0.48 pCi/g would produce a radiation dose of approximately 0.04 rad per year, using an average energy per decay for uranium of 4.5 MeV. The corresponding figure for Ra-226, with a maximum uptake of 0.58 pCi/g, is 0.05 rad per year, using an average energy of decay of radium of 4.78 MeV. A total radiation dose to plant tissue of 0.1 rad per year is only 1×10^{-4} the radiation dose reported to reduce the growth of conifers, plants that are particularly sensitive to radiation (Klechkovskii et al. 1973). Herbs have been reported to be unaffected by radiation doses as high as 350 rads per day. Vegetation samples with radionuclide concentrations less than the estimated maximum would have proportionately lower internal radiation exposures. No data are available on radionuclide uptake or exposure by mammals and birds in the vicinity of Operable Unit 4.

The maximum concentration of uranium in surface water in the vicinity of Operable Unit 4 was 1480 pCi/L at ASIT-10 (2219 µg/L). Constant exposure to this concentration of uranium could be toxic to invertebrates and fish in Paddys Run. However, the annual average total uranium

concentration in Paddys Run at Site W-10, adjacent to Operable Unit 4, was only 7 to 39 pCi/L from 1986 to 1988 (WMCO 1989a). Poston et al. (1984) reported that reproduction of the cladoceran Daphnia magna was suppressed at total uranium concentrations of 0.5 to 3.5 mg/L, with toxicity decreasing as alkalinity and hardness of the water increased. Acute toxic effects occurred at higher levels. The 48-hour LC_{50} for D. magna in Columbia River water was 6 mg/L total uranium. Uranium concentrations toxic to fish are higher than those for invertebrates. For example, Parkhurst et al. (1984) reported that development of trout larvae was affected by uranium only at concentrations greater than 9 mg/L. The 48-hour LC_{50} was 59 mg/L total uranium. It is thus unlikely that aquatic organisms in Paddys Run would be exposed to acute toxic concentrations of radionuclides except during brief encounters with contaminated runoff.

Accumulation of radionuclides in tissue is also an unlikely source of radiation exposure of aquatic organisms. The total uranium concentration of 5.1 pCi/g for crayfish collected from Site PR-3 would result in an internal dose of 0.43 rad per year, far below the one rad per day at which any effects on aquatic biota would be detectable (Templeton 1975).

E.7.0 SUMMARY

E.7.1 CHEMICALS OF POTENTIAL CONCERN

Operable Unit 4 was used historically to store by-products of the uranium separation process. Consistent with process information, it was found that the silos contain high levels of uranium, uranium decay products, radon gas, and other inorganic materials found in the initial ores.

Review of environmental sampling data suggests that silo constituents may be released to the environment from the silos. Constituents of concern based on sampling data include:

- High levels of uranium decay products, which emit gamma rays or penetrating radiation
- Ra-226, which produces radon gas that escapes from the silos
- Uranium and Ra-226 detected in surface soils within the silo study area

Th-230 and Pb-210 are also radionuclides of potential concern, although no environmental sample analytical data confirm that Th-230 or Pb-210 has been released from the silos. Th-230 in the silo residues could be of concern for groundwater pathways if the silos begin to leach constituents in the future. Pb-210 could be of concern if significant quantities of radon activity are migrating through the silo walls into the berm soil and depositing radon decay products including Pb-210. Berm soil sampling is planned to determine if Pb-210 is accumulating in the K-65 berms.

Due to the complex nature of the waste problem at the FMPC and the availability of analytical sample data, it is not possible to determine what fractions of the contaminants in surface soil, groundwater, and sediment, if any, are attributable to releases from Operable Unit 4. It is believed that uranium and Ra-226 may be in the surface soils as a result of historical spills and leaks around the silos. Uranium detected in groundwater at above-background levels cannot be definitively attributed to releases from Operable Unit 4 because there is no confirmation of significant silo leakage into the underlying soils. Additional slant boring sampling is required to resolve this issue. The necessary data are to be obtained under the proposed sampling and analysis plan. However, assuming leaking may occur sometime in the future, all constituents of the silos are considered to be of potential concern for future exposures.

E.7.2 EXPOSURE ASSESSMENT

Three potential current exposure pathways from Operable Unit 4 have been identified: direct exposure to penetrating radiation, exposure to airborne radon and radon progeny, and ingestion of constituents eroded from the surface soils into stream sediment. Penetrating radiation presents direct

radiation exposure. Airborne radon is transported by the prevailing winds. Constituents found in the soils in Operable Unit 4 may erode into Paddys Run during periods of rain. Soil transport to exposure areas has been modeled using the USLE.

Human exposure pathways have been identified for each constituent migrating from Operable Unit 4. The RME individual for direct exposure to penetrating radiation is a person living in the vicinity of the western FMPC boundary who receives an incremental dose of approximately 36 mrem/year, or 2500 mrem over a 70-year lifetime. The RME individual for exposure to airborne radon is also a person in the vicinity of the western FMPC boundary who receives an incremental exposure of 13 WLM over a 70-year lifetime. The RME individual for exposure to eroded soils is a child that ingests sediments while playing in Paddys Run. This individual may be exposed to modeled concentrations of 9.6 pCi/g of uranium (14 µg/g) and 10.7 pCi/g of Ra-226 (Table E.3-2). This sediment exposure scenario results in a dose equivalent of approximately 8 mrem over a 6-year exposure period.

Three potential future exposure pathways from Operable Unit 4 have been identified: direct exposure to penetrating radiation, exposure to airborne radon and radon progeny, and exposure to groundwater potentially contaminated by releases from Operable Unit 4. The RME individual for direct exposure to penetrating radiation is allowed access to land in the vicinity of the K-65 fenceline inside the FMPC boundary, assuming that security control measures are not in place in the future after 100 years. This individual potentially receives an estimated incremental dose equivalent of approximately 50 times (1800 mrem/yr) the estimated dose equivalent under potential current conditions. The RME individual for radon exposure is also allowed access to land in the vicinity of the K-65 fenceline. This individual potentially receives an estimated incremental WLM exposure approximately 7 times (1.44 WLM/yr) the estimated exposure under potential current conditions.

The results of groundwater modeling suggest that several silo constituents may reach the FMPC property boundary within 100 years, the time period for assuming current security control measures. Some of these constituents may be at modeled concentrations requiring that contributions from other operable units be considered in establishing remedial action objectives for Operable Unit 4. Assuming current security control measures are lost after 100 years, an "intruder" receptor may be exposed to higher concentrations of silo constituents in groundwater at the waste unit.

Results of the assessment of potential exposures to environmental receptors indicate that radionuclide contamination has been measured in aquatic organisms collected in the vicinity of Operable Unit 4. These results are presented in Section E.3.0. Estimated radiation doses from these levels of contamination are at least one hundred times less than radiation doses estimated to cause detectable effects in the organisms considered.

E.7.3 TOXICITY ASSESSMENT

The two major toxicological hazards associated with Operable Unit 4 are the radiocarcinogenicity of the radionuclides and the chemical toxicity of uranium. The radiocarcinogenic hazard is quantified using established risk coefficients expressed as a function of radiation dose or exposure to radionuclides. A risk coefficient of 125 x 10^{-6} rem^{-1} (NCRP 1987) is used to quantify the lifetime fatal cancer risk from exposure to ambient penetrating radiation fields. This risk coefficient is also used to quantify the lifetime fatal cancer risk from exposure to radiation emitted by internally deposited radionuclides. The EPA recently adopted a risk coefficient of 4 x 10^{-4} rem^{-1} for low LET radiation in place of the 1.25 x 10^{-4} rem^{-1} used in this risk assessment. The EPA risk coefficient is approximately three times higher; therefore, the risks would be proportionately higher if the EPA risk coefficient is used. A risk coefficient of 360 x 10^{-6} WLM^{-1} (EPA 1990d) is used to quantify the lifetime fatal lung cancer risk from exposure to airborne radon and radon progeny.

Uranium is a potent chemical toxicant that acts as a nephrotoxicant. Kidney damage has been seen in rabbits at levels as low as 2.8 mg/kg/day. The RfD for humans based on the rabbit data is 3 µg/kg/day, incorporating an uncertainty factor of 1000. Individual RfDs for silo constituents other than uranium are identified in Section E.4.0.

E.7.4 RISK CHARACTERIZATION

The incremental lifetime risk of fatal cancer from lifetime exposure at the RME level to penetrating radiation from Operable Unit 4 under current conditions is 3 x 10^{-4}. The incremental lifetime risk of fatal lung cancer from lifetime exposure at the RME level to airborne radon released from Operable Unit 4 under current conditions is 5 x 10^{-3}. Each of these risk estimates is based on annual averages of measurements collected at the FMPC boundary, which incorporates the assumption that it is reasonable to use annual average data from the western FMPC boundary as a conservative representation of the potential receptor exposure in the vicinity. Assuming that a single individual could reasonably be exposed to both penetrating radiation and airborne radon, the combined incremental lifetime risk from lifetime exposure to these two exposure pathways is 5 x 10^{-3}.

The incremental lifetime risks of fatal cancer from lifetime exposures to RME levels of penetrating radiation and airborne radon from Operable Unit 4 under potential future conditions are 2×10^{-2} and 3×10^{-2}, respectively. Each of these risk estimates is based on annual averages of measurements collected at the K-65 fenceline, which incorporates the assumption that it is reasonable to use annual average data from the K-65 fenceline as a conservative representation of the potential future receptor exposure in the vicinity. The combined incremental lifetime risk from lifetime exposure to these two exposure pathways under potential future exposure conditions in 5×10^{-2}.

A perspective can be placed on the incremental lifetime risks associated with RME exposures from the penetrating radiation and airborne radon pathways under current conditions by considering the lifetime risks associated with background exposures from these pathways. Using the same calculational approach, the lifetime risks from lifetime exposures to background penetrating radiation and airborne radon levels under current conditions are 6×10^{-4} and 6×10^{-3}, respectively. This indicates that the background risks from these two pathways under current conditions are in the same order of magnitude as their respective incremental risks, which is consistent with the fact that the incremental RME exposures from these pathways are within a factor of approximately two of the background exposure levels.

The estimated risks associated with exposure to background levels of penetrating radiation and airborne radon are documented in Section E.3.0. The risks from background exposures were estimated using the same calculation approach that was used to estimate risks from above-background exposures. This means that the methodology and input values were the same except for the substitution of the background exposure level in place of the above-background exposure level (refer to Table E.3-3 for input values).

Exposure of children to uranium and Ra-226 via ingestion of contaminated sediments eroded from soils in Operable Unit 4 is considered separately because this exposure pathway is considered unique to children, the most sensitive population under the baseline risk assessment. The sediment ingestion pathway is presented in Section E.3.0. Conservative assumptions were chosen to maximize any potential exposure to an infant child and provide an upper limit on the risk to the most sensitive population. The upper limit of risk of fatal cancer from this exposure pathway is 1×10^{-6}.

The calculated risk from the child sediment ingestion exposure pathway is nominal and within the acceptable range specified in 40CFR300. Although it is possible that the child may simultaneously

be a receptor for airborne radon and penetrating radiation exposure pathways, the addition of the sediment risk (1×10^{-6}) to the airborne radon risk (5×10^{-3}) does not change the total risk, nor does it change the decision regarding the need for remediation from a risk assessment perspective. However, combining the three pathways in this case is questionable. The receptor for the sediment ingestion pathway is assumed for a scenario that has a very low probability of occurrence; whereas, the receptor description for the airborne radon and penetrating radiation pathways more closely approximates present potential exposures to the nearest resident. Therefore, the receptor descriptions are different. The sediment ingestion receptor is exposed at a location in Paddys Run adjacent to the silos for an exposure duration of six years, but the receptor is not continuously present at the exposure location as assumed in the case for the adult in the airborne radon and penetrating radiation pathways. The airborne radon and penetrating radiation receptor is exposed off site at a hypothetical residence in the vicinity of the western FMPC boundary fenceline for an exposure duration of 70 years.

The chemical toxicity hazard associated with exposure to the elemental form of uranium in Paddys Run sediment does not appear to be of concern. The value of the HI ratio associated with a child ingesting 0.13 µg/kg/day of uranium in creek sediments is 0.043 using the RfD of 3 µg/kg/day in the denominator, and 0.17 using the site-specific action level of 0.75 µg/kg/day in the denominator. This suggests that children would receive an intake of uranium that is less than 20 percent of the allowable limit even under the conservative exposure scenario assumed.

The potential upperbound radiocarcinogenic fatal cancer risk associated with future groundwater exposure under either current or future land-use conditions exceeds 1.0. The potential chemical toxicity hazard associated with future groundwater exposure under both current and future land-use conditions indicates that a receptor may be exposed to unacceptable levels of several chemical toxicants, including arsenic, beryllium, cadmium, thallium, chromium, lead, nickel, selenium, thallium, and uranium.

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ATTACHMENT E.I

THE POTENTIAL PRESENCE OF LEAD-210, POLONIUM-210, AND STABLE LEAD IN K-65 BERM SOILS

Radium-226 present in K-65 residues decays to radon-222 (referred to herein as radon). Radon is a dense noble gas and is free to diffuse in all directions. However, before radon can escape to the atmosphere, it must migrate through air spaces (pores and cracks) in surrounding materials. The half-life of radon is short, only 3.82 days; therefore, only a fraction of the radon gas inside the K-65 silos can migrate through the residues, walls, and any cracks before decaying. In the case of the K-65 silos, the radon that migrates laterally through the silo walls also passes through the soil in the silo berms prior to emanating into the atmosphere.

As radon decays in transit through the berm soils, radon progeny are deposited in these soils. The radon progeny can react physically and chemically with the soil matrix and will accumulate in the region of deposition. Radon progeny include lead-210 (Pb-210) and polonium-210 (Po-210), which have half-lives of 22.3 years and 138.4 days, respectively. The half-lives of Pb-210 and Po-210 are sufficiently long to allow significant accumulation in the berm soil surrounding the K-65 silos. However, radon progeny will ultimately decay to stable lead-206 (Pb-206).

Radon progeny can pose a health risk if their activity concentrations reach significant levels and if a pathway to human receptors exists. The concentration of Pb-210 in the berm soil is a significant consideration in the Feed Materials Production Center (FMPC) Remedial Investigation/Feasibility Study (RI/FS) if the Pb-210 becomes available in soils used to grow agricultural products. Both direct use of berm soils for agriculture and contamination of agricultural soils irrigated by groundwater containing Pb-210 that has leached from these soils are potential pathways of concern. This appendix presents calculated estimates of potential residual Pb-210 concentrations within the soil berms of the K-65 silos. These estimates demonstrate that accumulation of Pb-210 in the berm soils could be sufficient to warrant control of berm materials during remedial actions under the RI/FS, and could be a concern in the future should uncontrolled access to the berm soils be permitted.

Objective

The objectives are to assess the potential for radon diffusion through the silo walls and berm soil and to estimate the potential Pb-210 activity concentration in the berm soil resulting from radon decay. The computer code RAECOM (NRC 1988) is used to estimate radon fluence rates from the

K-65 silo walls and the silo berms. RAECOM is a computer-based program developed for the U.S. Nuclear Regulatory Commission to estimate radon fluence rates from uranium mill tailing piles. Source geometry restrictions of the RAECOM code require that the silo berms be considered as a series of concentric cylindrical layers of soil surrounding each of the K-65 silos. Each layer of the berm is assumed to be two meters thick for these calculations. The maximum berm thickness is 8 meters for the original berm slope and 18 meters for the current berm slope. These thicknesses are based on the cylindrical approximation of the berms and are equivalent to the maximum thicknesses of the actual conical shape of the berms. Calculation results are approximate because the computer model approximates the conical berm shape with a cylindrical berm shape. Using the differences between fluence rates from adjoining layers, as calculated by RAECOM, and assuming that these differences represent radon retained in silo walls and berm soil layers, the concentration of Pb-210 in the berm soil is estimated. The calculated Pb-210 contamination in the first two meters of berm soil is 1.2×10^5 pCi/g.

Assumptions

1. The fluence rate entering the concrete silo wall from the residue is equal to 6.2×10^4 pCi/m^2-s/silo.

   The rate is obtained from the estimated radon activity per year that is available to emanate from the residue surface into the adjacent silo walls and the estimated surface area of the residues. The available radon activity is approximated by the activity released annually from the silos by free air exchange (IT Corporation 1989a) plus the activity at equilibrium in the silo dome void volumes. The latter is based on measured void volume radon concentrations (Grumski and Shanks 1988).

2. The concrete wall has a porosity of 0.25 and a diffusion coefficient of 3.08×10^{-5} cm^2/s (Culot et al. 1976).

3. The berm soil is mainly a sandy material with a porosity of 0.30, a diffusion coefficient of 5.4×10^{-2} cm^2/s (NRC 1988), and a density of 1.6 g/cm^3.

4. The activity deposited in a berm soil layer (2 meters thick) is estimated from the difference between the fluence rate entering and the fluence rate exiting the layer.

5. The height of the residue has been reported as 20 feet and 22 feet for the south and north silos, respectively. An average of 21 feet (6.4 m) is used as the average berm height.

6. The maximum berm thickness is assumed to represent the total thickness of the concentric cylinders for use in calculations. The thickness of the original 1.5:1 slope berm is 8 meters and the thickness of the current 3:1 slope berm is 18 meters.

7. The original berm has been in place for 25 years. The current berm (3:1) has been in place for five years.

8. The specific activity of Pb-210 is equal to 76.4 Ci/g.

9. The berm surface area through which radon may migrate is approximated by a cylindrical surface area. This surface area is the area of the K-65 residues that is adjacent to the interior surface of the silo walls (approximately 490 m^2 per silo).

   Surface Area of Silo Walls = (2)(3.14)(12.2m)(6.4m) = 490 m^2

Results: Pb-210 Contamination in Berms

Concentrations of Pb-210 in berm soil calculated by RAECOM are:

Layer	Activity Deposition (pCi/m^2-s)	Concentration (pCi Pb-210/g soil)	Concentration * µg Pb-210/g soil)
Concrete 20cm			
Soil 1st 2m	4.7×10^{2}	1.2×10^{5}	1.6×10^{-3}
Soil 2nd 2m	1.3×10^{2}	3.2×10^{4}	4.2×10^{-4}
Soil 3rd 2m	3.9×10^{1}	9.6×10^{3}	1.3×10^{-4}
Soil 4th 2m	1.1×10^{1}	2.7×10^{3}	3.5×10^{-5}
Soil 5th 2m	3.2×10^{0}	7.9×10^{2}	1.0×10^{-5}
Soil 6th 2m	9.2×10^{-1}	2.3×10^{2}	3.0×10^{-6}
Soil 7th 2m	2.6×10^{-1}	6.4×10^{1}	8.4×10^{-7}
Soil 8th 2m	7.4×10^{-2}	1.8×10^{1}	2.4×10^{-7}
Soil 9th 2m	1.5×10^{-2}	3.7×10^{0}	4.8×10^{-8}

*The concentration of Pb-210 in units of µg/g soil is provided to show the equivalent concentration of elemental lead after complete decay of Pb-210 and Po-210.

The lead concentration in a two-meter layer of the original berm soil, per pCi/m^2-s entry fluence rate is:

$$(1\ pCi/m^2\text{-}s)(25\ y)(365\ d/y)(24\ h/d)(3600\ s/h)(1/2m)(m^3/10^6\ cm^3)(cm^3/1.6\ g) = 246\ pCi/g$$

$$(246\ pCi/g)(Ci/10^{12}\ pCi)(g/76.4\ Ci)(10^6\ \mu g/g) = 3.2 \times 10^{-6}\ \mu g/g$$

The lead concentration in a two-meter layer of the added berm soil, per $pCi/m^2/s$ fluence rate, is a factor of five lower because it was exposed for a 5-year period compared to 25 years for soils in the original berm.

These calculated concentrations do not account for radiological decay of Pb-210 as it accumulates in the berm soil. The original 1.5:1 slope berm soil has been in place for 25 years.

Approximately 45 percent of the Pb-210 deposited in the berm soil at the beginning of 25 years would remain at the end of 25 years. Similarly, the current 3:1 slope berm soil has been in place for about five years. Approximately 85 percent of the Pb-210 deposited in this berm soil at the beginning of five years would remain at the end of five years.

There are no known regulatory concentration limits for protection of human health and the environment for Pb-210 or stable lead in soil. However, the U.S. Department of Energy (DOE) does use a Ra-226 soil concentration limit of 5 pCi/g for its Formerly Utilized Sites Remedial Action Program (FUSRAP) program (EPA 1980). Because Pb-210 is a decay product of Ra-226, this limit could be used as a reference concentration until a more appropriate value can be selected. The estimated potential Pb-210 activity concentration in the berm soil is several orders of magnitude above the referenced level of 5 pCi/g. The best way to verify or refute these calculations is with soil sampling. Sampling and analysis of the berm soil is planned to determine whether the preliminary estimates presented in this attachment reveal a significant existing source of contamination.

ATTACHMENT E.II

MIGRATION OF CONTAMINANTS FROM SURFACE SOILS INTO RECEIVING WATER

Objective

Surface soils taken around the berms of the K-65 and metal oxide silos show above-background concentrations of uranium and radium-226 (Ra-226). The potential exists for additional constituents to be present in the berm soils, such as lead-206 (Pb-206) and lead-210 (Pb-210) (Attachment E.I). The potential exists for these constituents to be resuspended and to migrate towards Paddys Run in the event of heavy rainfall. In this event, some of the constituents will sorb to the soils and will deposit in the creek sediments; a portion will dissolve, run off into the water, and flow into the creek surface water. This attachment presents estimates of the potential for migration. It assumes steady-state conditions for all environmental and physical influences.

Methodology

Annual migration of contaminants in surface soils can be estimated with the Universal Soil Loss Equation (USLE) (Williams 1975, EPA 1988b) and with models describing contaminant partitioning between soil and water (EPA 1988b, Haith 1980, Mills et al. 1982).

The first step in the process is to estimate soil loss (Ys) using USLE:

$$Ys = (Ac)(Rr)(K)(LS)(C)(P)(SD)$$

where

- Ys = annual sediment yield (kg)
- Ac = contaminated area (hectares)
- Rr = rainfall and runoff erosion factor
- K = soil erodibility factor (metric ton/unit R)
- LS = slope length and slope steepness factor
- C = cover factor
- P = correction for erosion control practice
- SD = sediment delivery ratio ($D^{-0.22}$)
- D = overland distance between erosion site and receiving water (cm).

The second step is to estimate the portion of contaminant in the eroded soils that will remain in the sediment (Ss) and the portion that will dissolve in the water (Ds):

$$Ss = [1/(1+Oc/(Kd \times B))] \times (Cad \times Ys), \text{ and}$$

$$Ds = [(1/(1+(Kd \times B)/Oc)](Cad \times Ys)$$

where

Oc = available water capacity in the top cm of soil (unitless)
Kd = sorption partition coefficient (cm^3/g)
B = bulk soil density (g/cm^3)
Cad = contaminant in surface soil (mg/kg)
Ys = annual sediment yield (kg).

The total contaminant concentration in the effluent (Ce) for the year is estimated by:

$$Ce = Ds/Vr$$

where

Ce = contaminant in effluent (mg/L)
Ds = dissolved substance in runoff (mg/yr)
Vr = site storm runoff (L/yr)

and

$Vr = 100(Ac)(Qr) \times 1000\ L/m^3$
Ac = contaminated area (hectares)
Qr = depth of runoff (cm)
$Qr = (Rt - 0.2Sw)^2/(Rt + 0.8Sw)$
Rt = annual rainfall (cm)
Sw = water retention factor (cm).

The contaminant concentration in the receiving water body downstream (Cw) is estimated by:

$$Cw = (Ce \times qp)/Qt,$$

where

Ce = contaminant in the effluent (mg/L)

qp = runoff peak flow rate (L/yr)

Qt = receiving water body flow rate (L/yr).

The contaminant concentration in the creek sediments (Cs) is estimated by:

$$Cs = Ss/Ys$$

where

Cs = contaminant in the creek sediment (mg/kg)

Ss = sorbed substance in runoff (mg/yr)

Ys = annual sediment yield (kg/yr).

This approach was used to estimate contaminant runoff from the Operable Unit 4 berm soils and the soils immediately adjacent to the berms.

Assumptions

Site-specific soil parameters were taken from Advanced Sciences, Inc./IT Corporation (ASI/IT) (1989). Remaining assumptions were taken from the Gas Research Institute (GRI) (1988). All assumptions are listed in Tables E.II-1 and E.II-2 along with modeling results.

LE EII-1 CONTAMINANT MOVEMENT TO PADDY'S RUN FROM EROSION OF K-65 BERM - NATURAL URANIUM

eferences: Williams, 1975; Haith, 1980; Mills et al., 1982; EPA, 1988b)

description	units	variable		value	References/ Assumptions
<<---------- Input Parameters -->>					
ontaminated area	hectares	Ac	=	0.485	1.5 acres * 0.8 (portion sloped to creek)/2.47 (conversion to hectares)
oil erodibility factor	mtrc tons/unit R	K	=	0.26	GRI, 1988
lope length * slope steepness factor	-	LS	=	9	GRI, 1988
over factor	-	C	=	0.003	GRI, 1988
rosion control practice factor	-	P	=	1	Assume no erosion control
ainfall and runoff erosion factor	-	Rr	=	200	GRI, 1988
verland distance between erosion site and receiving water	ft	D	=	100	From bottom of berm to Paddy's Run
nnual rainfall	cm/yr	Rt	=	99.2	IT Corporation, 1989
CS runoff curve number	unitless	Cn	=	71	GRI, 1988
vailable water capacity in top cm of soil	unitless	Oc	=	0.6	calculated
orption partition coefficent	g/cm3	Kd	=	33	NCRP, 1984a
ulk soil density	cm3/g	B	=	1.7	Typical value for FMPC site
ontaminant activity	pci	pCi/g	=	9.76	Average U value surrounding silos
pecific activity of radionuclide	sa	ug/pCi	=	1.50E+00	
taminant concentration	mg/kg	Cad	=	1.46E+01	Average value detected at base of berm
addy's Run flow rate	l/yr	Qt	=	4.50E+07	1.19E7 gallons/yr (WMCO, 1987)
torm duration	yr	St	=	1	
<<---------- Intermediates -->>					
ediment delivery ratio	-	Sd	=	0.36	Sd = D^-0.22
nnual sediment yield	kg/yr	Ys	=	247.23	Ys = [(Ac)(Rr)(K)(L)(S)(C)(P)(Sd)]*1000
ater retention factor	cm	Sw	=	-11.32	Sw = (1000/CN) - 10(2.45)
epth of runoff	cm	Qr	=	114.20	Qr = (Rt-0.2Sw)^2/(Rt+0.8Sw)
unoff peak flow rate	l/yr	qp	=	5415184.84	qp = [((((Ac)(2.471)(4047))(Rt*0.01)(Qr)*1000)/(St(Rt-0.2Sw))]**
orbed substance quantity in runoff	mg/yr	Ss	=	3571.42675	Ss = [1/(1+Oc/((Kd)(B)))]*(Cad*Ys)
issolved substance quantity in runoff	mg/yr	Ds	=	38.60558	Ds = [1/(1+((Kd)(B))/Oc)]*(Cad*Ys)
otal substance in runoff	mg/yr	TR	=	3610.03034	TR = Ss + Ds
ite storm runoff per year	l/yr	Vr	=	5538648.25	Vr = 100(Ac)(Qr)*1000 (m3 to liter)
ontaminant concentration in effluent	mg/l	Ce	=	6.97E-06	Ce = Ds/Vr
ontaminant concentration in receiving water body	mg/l	Cw	=	8.39E-07	Cw = ((Ce)(qp)/Qt)
	pCi/l		=	5.59E-04	
ontaminant Concentration in creek sediments directly below Op. Unit 4	mg/kg	Cs	=	1.44E+01	Cs = Ss/Ys
	pCi/g		=	9.63	

· silty clay loam, 4% organic matter
: - See GRI, 1988 exhibit 7-10; L = slope length (80 feet) and S = slope steepness (3:1)
: - canopy of grass (50% - G), 95 - 100% ground cover
** - Note: adjustments for hectares to acres to m2; cm to m; and m3 to liters

TABLE EII-2 CONTAMINANT MOVEMENT TO PADDY'S RUN FROM EROSION OF K-65 BERM - RADIUM-226

(references: Williams, 1975; Haith, 1980; Mills et al., 1982; EPA, 1988b)

description	units	variable		value	References/ Assumptions
<<---------- Input Parameters -->>					
contaminated area	hectares	Ac	=	0.485	1.5 acres * 0.8 (portion sloped to creek)/2.47 (conversion to hectares)
soil erodibility factor	mtrc tons/unit R	K	=	0.26	GRI, 1988
slope length * slope steepness factor	-	LS	=	9	GRI, 1988
cover factor	-	C	=	0.003	GRI, 1988
erosion control practice factor	-	P	=	1	Assume no erosion control
rainfall and runoff erosion factor	-	Rr	=	200	GRI, 1988
overland distance between erosion site and receiving water	ft	D	=	100	From bottom of berm to Paddy's Run
annual rainfall	cm/yr	Rt	=	99.2	IT Corporation, 1989
SCS runoff curve number	unitless	Cn	=	71	GRI, 1988
available water capacity in top cm of soil	unitless	Oc	=	0.6	calculated
sorption partition coefficent	g/cm3	Kd	=	214	NCRP, 1984a
bulk soil density	cm3/g	B	=	1.7	Typical value for FMPC site
contaminant activity	pci	pCi/g	=	10.7	Average Ra-226 value surrounding silos
cific activity of radionuclide	sa	ug/pCi	=	1.01E-06	based on 0.988 Ci/g
ontaminant concentration	mg/kg	Cad	=	1.08E-05	Average value detected at base of berm
Paddy's Run flow rate	l/yr	Qt	=	4.50E+07	1.19E7 gallons/yr (WMCO, 1987)
Storm duration	yr	St	=	1	
<<---------- Intermediates --->>					
sediment delivery ratio	-	Sd	=	0.36	Sd = D^-0.22
annual sediment yield	kg/yr	Ys	=	247.23	Ys = [(Ac)(Rr)(K)(L)(S)(C)(P)(Sd)]*1000
water retention factor	cm	Sw	=	-11.32	Sw = (1000/CN) - 10(2.45)
depth of runoff	cm	Qr	=	114.20	Qr = (Rt-0.2Sw)^2/(Rt+0.8Sw)
runoff peak flow rate	l/yr	qp	=	5415184.84	qp = [((((Ac)(2.471)(4047))(Rt*0.01)(Qr)*1000)/(St(Rt-0.2Sw))]**
sorbed substance quantity in runoff	mg/yr	Ss	=	0.00267	Ss = [1/(1+Oc/((Kd)(B)))]*(Cad*Ys)
dissolved substance quantity in runoff	mg/yr	Ds	=	0.00000	Ds = [1/(1+((Kd)(B))/Oc)]*(Cad*Ys)
total substance in runoff	mg/yr	TR	=	0.00267	TR = Ss + Ds
site storm runoff per year	l/yr	Vr	=	5538648.25	Vr = 100(Ac)(Qr)*1000 (m3 to liter)
Contaminant concentration in effluent	mg/l	Ce	=	7.96E-13	Ce = Ds/Vr
Contaminant concentration in receiving water body downstream	mg/l	Cw	=	9.57E-14	Cw = ((Ce)(qp)/Qt)
	pCi/l		=	9.48E-05	
Contaminant Concentration in creek sediments directly below Op. Unit 4	mg/kg	Cs	=	1.08E-05	Cs = Ss/Ys
	pCi/g		=	10.68	

K - silty clay loam, 4% organic matter
LS - See GRI, 1988 exhibit 7-10; L = slope length (80 feet) and S = slope steepness (3:1)
C - canopy of grass (50% - G), 95 - 100% ground cover
** - Note: adjustments for hectares to acres to m2; cm to m; and m3 to liters

ATTACHMENT E.III

MIGRATION OF CONTAMINANTS FROM WASTE RESIDUES INTO THE GROUNDWATER

E.III.1.0 INTRODUCTION

E.III.1 OBJECTIVE

To complete the baseline risk assessment for Operable Unit 4 at the Feed Materials Production Center (FMPC), it is necessary to evaluate the fate and transport of constituents of concern through the potential groundwater pathway from the waste units to the regional aquifer. The objective of the analysis is to model the extent and magnitude of groundwater contamination under two risk-based scenarios based on guidance from the U.S. Department of Energy (DOE). Scenario 1 assumes that institutional controls are active at the FMPC boundary for the next 100 years and that the hypothetical receptor is located on the FMPC boundary. Under Scenario 2, it is assumed that institutional controls will be lost after 100 years and that the hypothetical receptor exposed to contaminated groundwater is located directly at the waste site 500 years into the future.

The objective is accomplished by projecting the concentration of the contaminants of concern at the hypothetical receptor locations by reviewing hydrogeologic conditions, water quality data, geochemical modeling, and by using a combination of analytical modeling for the transport of contaminants in the vadose zone and numeric modeling for transport within the Great Miami Aquifer.

E.III.1.2 SCOPE OF WORK

The scope of work for the fate and transport assessment is focused on Operable Unit 4, which consists of the K-65 silos and the metal oxide silos. The operation of these silos as waste disposal units is described in the Operable Unit 4 Remedial Investigation (RI) Report. The assessment includes the following tasks:

- An evaluation of the Remedial Investigation/Feasibility Study (RI/FS) boring logs in Operable Unit 4 and along the potential flow pathways
- An assessment of the potential flow pathways' hydrogeologic characteristics
- An evaluation of the existing groundwater quality of the area
- The development of a conceptual vadose zone/groundwater flow model
- The selection of appropriate flow modeling techniques
- Geochemical modeling of leachate concentrations

- The projection of concentrations at the receptor locations under the two selected scenarios

E.III.1.3 SUMMARY OF APPROACH

The need to project concentrations at 100 and 500 years in the future necessitates the use of estimation techniques such as flow and transport modeling. The development of a fate and transport model progresses from the development of a conceptual model based on the depositional history and hydrogeology of a site to the formulation of a mathematical representation of the conceptual model. Groundwater and vadose zone systems are complex and cannot be completely defined. Therefore, some degree of simplification or abstraction is required to represent these systems. This simplification is bound to the conceptual understanding of the contaminant hydrogeology of the site and the basic hydrologic principles. An important aspect of modeling is the understanding of the assumptions and limitations of the analysis. In any application of the results of the fate and transport analysis, the assumptions, limitations, and uncertainties must be kept in mind.

Based on the available data and the work conducted to date, an analytical model was selected for projecting the fate and transport in the vadose zone, and a numeric model was selected for the analysis of the Great Miami Aquifer. Because the primary receptor in both cases is a user of groundwater from the Great Miami Aquifer, the basic need for the vadose zone model is to project a conservative travel time and concentration to the aquifer. The analytical solution combined with geochemical modeling provides a conservative order of magnitude estimate of these concentrations.

Flow paths within the Great Miami Aquifer are more critical as they determine the location of the hypothetical receptor. The numeric model selected has been calibrated for flow within the aquifer and has been extensively used for the assessment of groundwater conditions for the RI/FS process and other investigations at the FMPC. The calibration and verification process for the regional model has been on going since 1988 with input for the model being provided by the RI/FS field program.

Operable Unit 4 was divided into two waste units based on the waste characteristics of the different silos. The K-65 silos were analyzed together because the waste within these silos is similar. The metal oxide tank was evaluated as a separate waste source because the chemistry of these wastes is substantially different.

E.III.1.3.1 Constituents of Concern

The constituents of concern based on risk assessment guidance for the site and the average quantities within the silos from the RI/FS supplemental sampling and analysis are given in Chapter 2.0 of the risk assessment.

E.III.2.0 FATE AND TRANSPORT MODELING

E.III.2.1 INTRODUCTION

The two major routes for groundwater contamination that can be expected at a waste site involve the leaching of solid contaminants and the percolation of liquid contamination to the underlying aquifer. In Operable Unit 4, spills and leaks of contaminated liquids were documented during active operations of the K-65 silos. However, under current conditions the direct discharge of fluids is not likely, and the leaching of the silo solids is the most likely source of contamination. Attenuation and retardation are considered in the flow modeling. Attenuation is the irreversible loss of the contaminant from the plume. Although the mass of the contaminant is not changed, a certain percentage of the total contaminant will be removed from the solution and will no longer be available for transport. Retardation consists of reversible reactions that slow the arrival of a constituent but do not act as a sink for contaminants.

Attenuation is used to model those processes that immobilize contaminants. For Operable Unit 4, 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 the radionuclides. The partitioning coefficient (Kd) is used to derive a retardation factor (Rf), which slows the velocity of the contaminant movement. Although the Kd 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.

E.III.2.1.1 Modeling Approach

To account for the various components of the contaminant hydrogeology, the following steps were taken to develop the analysis of the conceptual flow model.

- The available information on the specific waste unit was reviewed to establish the characteristics of the waste.
- Geochemical modeling was completed to partially account for attenuation by determining the precipitation that would result from the reactions with the vadose zone material.

- Estimates of retardation were completed based on the existing concentrations of constituents in wells immediately downgradient from the waste site compared with the anticipated leachate concentrations.

- Flow modeling was completed to determine the effects of dispersion and retardation on the projected leachate concentration at the receptor under the two scenarios.

E.III.2.2 GEOCHEMICAL ANALYSIS

E.III.2.2.1 Models Used

The geochemical modeling used three models (EQ3NR, EQ6, and PHREEQE) to project leachate concentrations at the base of the silos to the vadose zone. EQ3NR and EQ6 are solubility/ speciation/reaction path geochemical computer programs developed at Lawrence Livermore National Laboratory primarily to solve problems related to nuclear waste disposal. The solubility portions of the code are used to determine the maximum concentration limits for contaminants in groundwater found along the potential flow path. The speciation portion of the code is used to determine the various forms that the contaminants will take in groundwater. The reaction path portion of the code is used to predict the evolution of contaminated groundwater as a function of time as it migrates from one environment to another.

E.III.2.2.2 Approach

The EQ3NR, EQ6, and PHREEQE geochemical models were used to develop solubility-constrained leachate concentrations for the constituents of concern. These concentrations were used as input into the flow model to analyze the fate and transport of the constituents of concern. The conceptual model is based on infiltrating precipitation reacting with the waste solids. These waste solids will be dissolved as the precipitation acquires the characteristics of leachate, which is assumed to be in equilibrium, or steady state, with the solids. The leachate moves downward into the unsaturated zone. As the leachate moves through the vadose zone, it is modified by reactions with the mineralogy of the zone. The reaction will buffer the leachate, and precipitation of solids may reduce the concentrations of the contaminants. It is assumed that the modified leachate reaches a steady state of equilibrium with respect to the vadose zone mineralogy. The modified leachate reaches the regional aquifer and mixes with the groundwater. As mixing occurs, precipitation of solids may reduce the concentration of certain constituents. Again, equilibrium is assumed.

E.III.2.3 LIMITATIONS AND ASSUMPTIONS

To model leachate concentrations and attenuation in the absence of site-specific data it is necessary to make certain simplifying assumptions and to recognize the limitations of the results. These include:

- It was assumed that precipitation could enter the silos to act as the leaching fluid.
- It was assumed that the projected mineralogical phases of the waste represent the actual waste phases.
- The kinetics of dissolution and precipitation were not considered. In the absence of user-supplied kinetic data, EQ6 assumed that reactions that are thermodynamically possible are also kinetically possible.
- It was assumed that the solutions were in contact with the waste solids long enough to acquire the modeled compositions.
- It was assumed that the projected vadose zone mineralogy used for modeling was representative of the vadose zone at the FMPC.
- Modeled concentrations are limited by solubility considerations. In most cases these concentrations are conservative (i.e., highest concentrations) because adsorption, ion-exchange, and coprecipitation were not considered. However, the concentrations determined from the procedure are not intrinsically conservative. Due to kinetic factors, the solid phases may not control concentrations, and more soluble phases may actually control concentrations.

E.III.2.4 LEACHATE CONCENTRATIONS

The leachate concentrations are the result of the geochemical modeling. It should be noted that these concentrations generally are conservative and represent the maximum concentrations that could be expected. Currently, there are no indications that these leachate concentrations are being released from the silos.

E.III.2.5 FLOW MODEL

The models used for the evaluation of flow through the unsaturated zone and the aquifer were ST1D, a one-dimensional analytical solution, and SWIFT III, a finite difference three-dimensional model. ST1D was used for determining fate and transport in the unsaturated zone, and SWIFT III was used for flow in the regional aquifer. The initial source concentration was developed using leachate data, where available, and geochemical modeling results for other constituents of concern. Each layer in the conceptual flow system was analyzed separately with the concentrations from the upper layers acting as the input concentrations to the lower layers.

E.III.2.6 TRANSPORT MODELING ASSUMPTIONS

To complete the analysis, it is necessary to make certain assumptions based on the adequacy of the database and on the type of code used for the analysis. These assumptions included:

- The concentration of the leachate from the silos was based on Extraction Procedure (EP) Toxicity data and geochemical modeling. These techniques assume that equilibrium conditions exist between the waste and the water that causes the leaching and that all of the waste material is in contact with the leaching fluid. This approach is conservative in that it will tend to overestimate the concentration of a given constituent. However, kinetics may limit precipitation and may allow maximum concentrations above the solubility limits. Organic complexes may also form with certain metals that will produce a supersaturated condition for the specific constituent.

- Steady-state infiltration conditions were assumed. Infiltration rates were based on a projected water balance for the site developed using the HELP (Hydrologic Evaluation of Landfill Performance) model.

- The use of partition coefficients (Kd) and the retardation factor (Rf) to describe the reaction term of the transport equation assumes that an equilibrium relationship exists between the solid and solution phase concentrations and that the relationship is linear.

- Flow in the glacial overburden is assumed to be in a uniformly porous medium.

- It was assumed that each layer in the vadose zone was homogeneous and isotropic.

- The analysis assumed steady-state conditions in terms of both flow and contaminant loading.

E.III.3.0 RESULTS AND UNCERTAINTIES

The concentrations of the constituents of concern are presented in Tables E.III-1 and E.III-2 for the 100-year scenario and in Tables E.III-3 and E.III-4 for the 500-year scenario.

E.III.3.1 UNCERTAINTIES

The major uncertainty in the analysis is the projection of attenuation and retardation of constituents. Based on the data available, a conservative approach was used and may overestimate the concentration of the leachate. The estimated retardation factor also assumes a high degree of mobility for the constituents. These factors combined with the previously mentioned assumptions give the results an estimated low (less than one order of magnitude) to medium (one order of magnitude) degree of uncertainty for the overestimation of concentrations.

TABLE E.III-1

CONCENTRATIONS AT THE FMPC BOUNDARY
SCENARIO 1 (100 YEARS)
SILOS 1 AND 2
K-65 SILOS

RADIOLOGICAL CONSTITUENTS (mg/L)

Constituent	Concentration[a]
Total Uranium	1.89×10^{-7}
Total Radium	1.88×10^{-7}
Total Thorium	5.02×10^{-13}
Pb-210	2.92×10^{-11}
Ac-227	4.16×10^{-7}
Pa-231	6.11×10^{-4}

CHEMICAL CONSTITUENTS (mg/L)

Constituent	Concentration[a]
Arsenic	1.64×10^{-4}
Barium	2.12×10^{-6}
Beryllium	1.85×10^{-1}
Cadmium	5.17×10^{-1}
Chromium	1.84×10^{-6}
Cobalt	2.12×10^{-3}
Copper	4.42×10^{-6}
Lead	1.16×10^{-2}
Manganese	1.59×10^{-3}
Mercury	1.17×10^{-10}
Nickel	1.76×10^{-1}
Selenium	4.37×10^{-4}
Silver	6.91×10^{-12}
Thallium	5.54×10^{-2}
Vanadium	1.98×10^{-6}
Zinc	9.58×10^{-3}
Aroclor-1248[b]	0.0
Aroclor-1254[b]	0.0

[a]Conservative concentration is calculated, assuming no retardation for the constituents within the Great Miami Aquifer.

[b]Retardation factor of 140,000 is used.

TABLE E.III-2

CONCENTRATIONS AT THE FMPC BOUNDARY
SCENARIO 1 (100 YEARS)
SILOS 3 AND 4
METAL OXIDE TANKS

RADIOLOGICAL CONSTITUENTS (mg/L)

Constituent	Concentration[a]
Total Uranium	1.59
Total Radium	2.12×10^{-7}
Total Thorium	5.02×10^{-13}
Pb-210	2.81×10^{-12}
Ac-227	2.84×10^{-9}
Pa-231	4.19×10^{-6}

CHEMICAL CONSTITUENTS (mg/L)

Constituent	Concentration[a]
Arsenic	8.44×10^{-4}
Barium	2.30×10^{-4}
Beryllium	8.53×10^{-3}
Cadmium	2.11×10^{-2}
Chromium	3.22×10^{-3}
Cobalt	1.02×10^{-1}
Copper	4.89×10^{-7}
Lead	1.63×10^{-4}
Manganese	3.74×10^{-13}
Mercury	5.46×10^{-8}
Nickel	6.31×10^{-4}
Selenium	3.19×10^{-3}
Silver	8.74×10^{-6}
Thallium	6.70×10^{-3}
Vanadium	2.24×10^{-3}
Zinc	1.61×10^{-5}
Aroclor-1248	0.0
Aroclor-1254	0.0

[a]Conservative concentration is calculated, assuming no retardation for the constituents within the Great Miami Aquifer.

TABLE E.III-3

CONCENTRATIONS IN THE GREAT MIAMI AQUIFER RECEPTOR AT THE WASTE UNIT SCENARIO 2 (500 YEARS) SILOS 1 AND 2 K-65 SILOS

RADIOLOGICAL CONSTITUENTS (mg/L)

Constituent	Concentration[a]
Total uranium	1.39×10^{-5}
Total radium	1.38×10^{-5}
Total thorium	3.68×10^{-11}
Pb-210	2.14×10^{-8}
Ac-227	9.92×10^{-8}
Pa-231	1.46×10^{-4}

CHEMICAL CONSTITUENTS (mg/L)

Constituent	Concentration[a]
Arsenic	1.20×10^{-2}
Barium	1.55×10^{-4}
Beryllium	4.39×10^{-2}
Cadmium	1.23×10^{-1}
Chromium	1.35×10^{-4}
Cobalt	1.55×10^{-1}
Copper	3.24×10^{-4}
Lead	8.50×10^{-1}
Manganese	1.16×10^{-1}
Mercury	8.56×10^{-9}
Nickel	1.29×10^{1}
Selenium	3.20×10^{-2}
Silver	5.06×10^{-10}
Thallium	1.32×10^{-2}
Vanadium	1.45×10^{-4}
Zinc	7.02×10^{-1}
Aroclor-1248	0.0
Aroclor-1254	0.0

[a]Retardation factor (Rf) = 1.

TABLE E.III-4

CONCENTRATIONS IN THE GREAT MIAMI AQUIFER RECEPTOR AT THE WASTE UNIT SCENARIO 2 (500 YEARS) SILOS 3 AND 4 METAL OXIDE TANKS

RADIOLOGICAL CONSTITUENTS (mg/L)

Constituent	Concentration[a]
Total uranium	5.83×10^{1}
Total radium	7.77×10^{-6}
Total thorium	1.84×10^{-11}
Pb-210	1.03×10^{-10}
Ac-227	1.04×10^{-7}
Pa-231	1.54×10^{-4}

CHEMICAL CONSTITUENTS (mg/L)

Constituent	Concentration[a]
Arsenic	3.09×10^{-2}
Barium	8.41×10^{-3}
Beryllium	3.12×10^{-1}
Cadmium	7.72×10^{-1}
Chromium	1.18×10^{-1}
Cobalt	3.72
Copper	1.79×10^{-5}
Lead	5.96×10^{-3}
Manganese	1.37×10^{-11}
Mercury	2.00×10^{-6}
Nickel	2.31×10^{-2}
Selenium	1.17×10^{-1}
Silver	3.20×10^{-4}
Thallium	2.45×10^{-1}
Vanadium	8.22×10^{-2}
Zinc	5.89×10^{-4}
Aroclor-1248	0.0
Aroclor-1254	0.0

[a]Retardation factor (Rf) = 1.

E.III.4.0 CONCLUSIONS

The fate and transport analysis is a conservative estimate of concentrations of the constituents of concern at a hypothetical receptor under two scenarios. The results of this analysis indicate that a potential plume from the two waste units within Operable Unit 4 could exceed Fernald operable unit action levels for several constituents under both scenarios.

To improve the fate and transport analysis, it would be necessary to incorporate the results from additional sampling. Of particular importance would be the collection of waste and vadose zone material to allow for the determination of leachate concentration, and site-specific partitioning coefficient values through the use of leach tests.

ATTACHMENT E.IV
MODELING OF CONCENTRATIONS IN FOOD PRODUCTS

E.IV.1.0 CONCENTRATION IN VEGETABLES

The equations used to estimate exposure to radionuclides and chemicals via ingestion of vegetables irrigated with contaminated water was from the Nuclear Regulatory Commission (NRC) regulatory guidance (1977). The two-step process first involved the calculation of the concentration of the chemical in the plant, followed by the calculation of intake. Input values for parameters used to model concentrations of contaminants in food products are presented in Table E.IV-1. The model used to estimate the concentration in vegetables was:

$$C_{iv} = d_i \left[\frac{r[1 - \exp(-\lambda_{Ei} t_e)]}{Y_v \lambda_{Ei}} + \frac{f_i B_{iv}[1 - \exp(-\lambda_i t_b)]}{P \lambda_i} \right] \exp(-\lambda_i t_h)$$

where

- C_{iv} = concentration of the chemical in the edible portion of the crop (pCi/kg)
- d_i = deposition rate from irrigated water (pCi/m²/hr) (equals concentration in water (pCi/L) x average irrigation rate (L/m²/hr)
- r = fraction of deposited activity retained on crops
- Y_v = agricultural productivity by unit area (kg/m²)
- λ_{Ei} = effective removal rate constant for the crop (hr⁻¹)
- t_e = period of crop exposure during growing season (hrs)
- f_i = fraction of the year crops are ingested
- B_{iv} = concentration factor for uptake of chemical from soil by edible parts of the crop (pCi/kg wet weight per pCi/kg dry soil)
- λ_i = radioactive decay constant (radionuclides only) (hr⁻¹)
- t_b = period of time for which soil is exposed to contaminated water (hrs)
- P = effective surface density for soil (kg(dry soil)/m²)
- t_h = holdup time that represents the time interval between harvest and consumption of food (hrs).

Once the concentration in vegetation has been determined, intake can be estimated as:

$$I_v = (C_v)(IR)(FI)(EF)(ED))/(BW)(AT)$$

where

- I_v = intake of chemical in vegetation (mg/kg/day)
- C_v = concentration in irrigated vegetable (mg/kg)
- IR = ingestion rate (mg/day)
- FI = fraction ingested from contaminated source
- EF = exposure frequency (days/yr)

TABLE E.IV-1

INPUT PARAMETERS FOR MODELING CONCENTRATIONS OF CONTAMINANTS IN FOOD PRODUCTS

VEGETABLE PARAMETERS	
Irrigation rate:	8.00E-02 L/m²/hr
Fraction of deposited activity retained on crops:	2.50E-01
Removal rate by weathering:	2.10E-03 L/hr
Time of exposure of crops during growing season:	1.44E+03 hr
Agricultural yield:	1.50E+00 kg/m²
Fraction of year crops are irrigated:	3.80E-01
Concentration in edible parts from root uptake:	1.70E-02
Period for which soil is exposed to contaminated water:	1.31E+05 hr
Effective surface density:	2.25E+02 kg/m²
Time between harvest and consumption:	2.40E+01 hr
Exposure frequency:	365 days/yr
Exposure duration:	70 yrs
Fraction ingested from contaminated source:	1.0
FORAGE PARAMETERS	
Irrigation rate:	8.00E-02 L/m²/hr
Fraction of deposited activity retained on crops:	2.50E-01
Removal rate by weathering:	2.10E-03 L/hr
Time of exposure of crops during growing season:	7.20E+02 hr
Agricultural yield:	8.00E-01 kg/m²
Fraction of year crops are irrigated:	3.80E-01
Concentration in edible parts from root intake:	1.70E-02
Period for which soil is exposed to contaminated water:	1.31E+05 hr
Effective surface density:	2.25E+02 kg/m²
Time between harvest and consumption:	2.16E+03 hr
DRINKING WATER PARAMETERS	
Exposure frequency:	365 days/yr
Exposure duration:	70 yrs
Fraction ingested from contaminated source:	1
ANIMAL PRODUCT PARAMETERS	
Exposure frequency:	365 days/yr
Exposure duration:	70 yrs
Fraction of milk/beef/ingested from contaminated source:	0.75
SEDIMENT PARAMETRES	
Exposure frequency:	274 days/yr
Exposure duration:	6 yrs

ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (equals the exposure duration x 365 days/yr) (days).

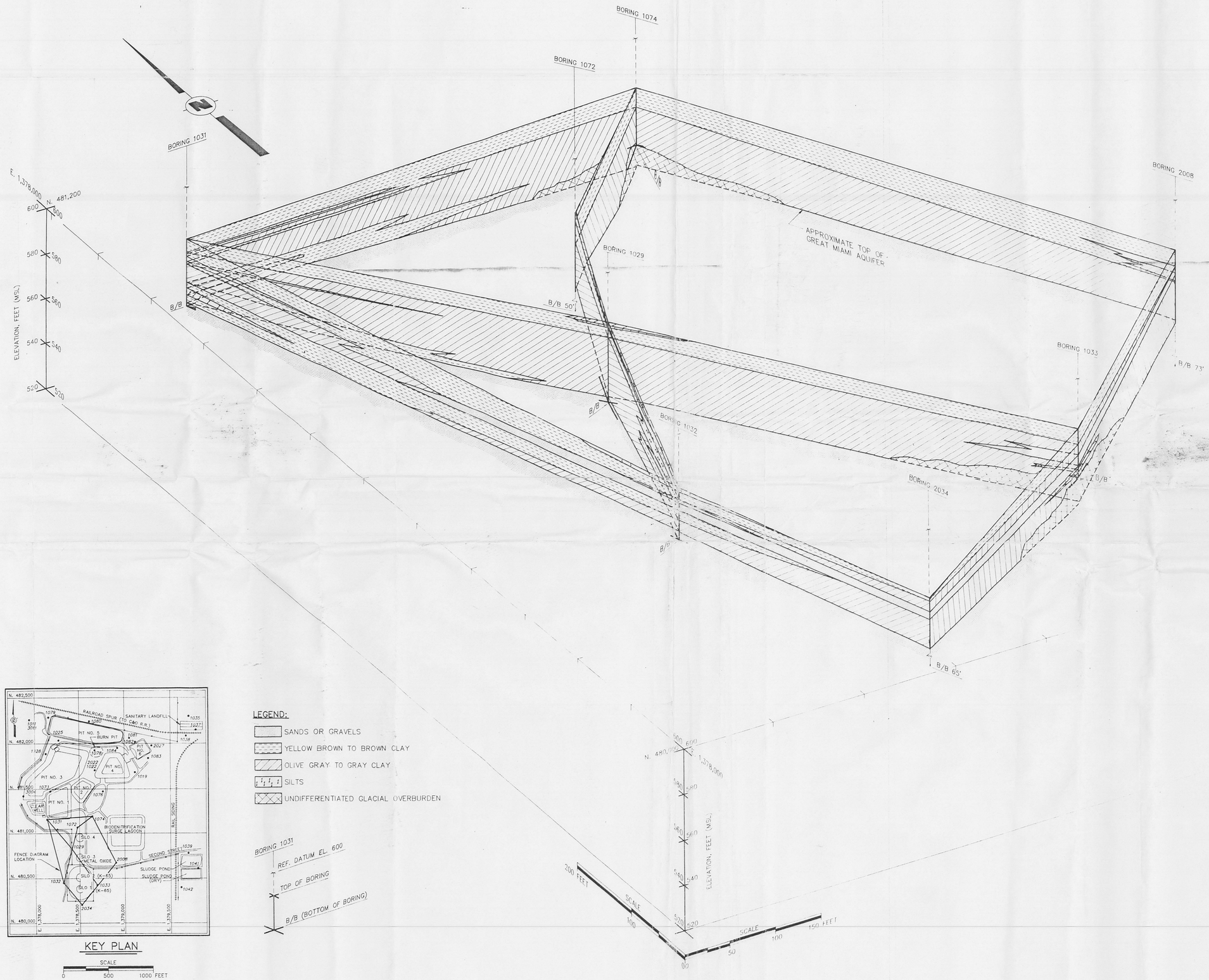
E.IV.2.0 CONCENTRATION IN ANIMAL PRODUCTS

As in the quantification of intake following exposure to vegetables, the concentration in animal products must be estimated prior to the determination of intake. The concentration of chemical consumed in animal products, such as beef or milk, was determined using the following equation from the NRC regulatory guide (1977):

$$C_{iA} = F_{iA}[(C_{iF})(Q_F) + (C_{iAW})(Q_{AW})]$$

where

C_{iA} = the concentration of the chemical in the animal product (mg/kg)
F_{iA} = element (stable) transfer coefficient that relates the daily intake rate by an animal to the concentration in an edible portion of the animal product (mg/L) for milk per mg/day or mg/kg for beef per mg/day)
C_{iF} = concentration of chemical in forage (mg/kg)
Q_F = consumption rate of contaminated forage by an animal (kg/day)
C_{iAW} = concentration of chemical in water (mg/L)
Q_{AW} = consumption rate of contaminated water by an animal (L/day).



KEY PLAN

SCALE
0 500 1000 FEET

LEGEND:

- SANDS OR GRAVELS
- YELLOW BROWN TO BROWN CLAY
- OLIVE GRAY TO GRAY CLAY
- SILTS
- UNDIFFERENTIATED GLACIAL OVERBURDEN

BORING 1031
REF. DATUM EL. 600
TOP OF BORING
B/B (BOTTOM OF BORING)

OPERABLE UNIT 4
GLACIAL OVERBURDEN
FENCE DIAGRAM

584

1567

303317-E78 (GW)

106 864_1