received
10/5/00 ch

DOE/OR/07-1895/V1&D1
PRIMARY DOCUMENT

Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Volume 1 of 4
Main Text

September 2000

I-04411-0001

CLEARED FOR PUBLIC RELEASE

BECHTEL
JACOBS
Bechtel Jacobs Company LLC

DOE Contract No. DE-AC05-98OR22700
Job No. 23900
September 25, 2000

Mr. W. Don Seaborg
Paducah Site Manager
Department of Energy
P.O. Box 1410
Paducah, KY 42002-1410

Subject: *D1 Remedial Investigation (RI) Report (Volumes 1—4) for Waste Area Grouping (WAG) 3 at the Paducah Gaseous Diffusion Plant, Primary Document, September 2000, DOE/OR/07-1895&D1*

Dear Mr. Seaborg:

Enclosed for issuance to the regulatory agencies is the subject document (a letter with suggested text is attached for use in the issuance). Per the Federal Facility Agreement (FFA), this document is to be transmitted to the regulatory agencies by September 30, 2000. Comments on the noted document are due back to the Department of Energy, per the FFA, within 90 calendar days of this date (i.e., December 29, 2000). Distribution of this document is being made in accordance with the *Standard Distribution List for Bechtel Jacobs Company LLC Primary and Secondary Documents (06/12/00).*

Please call Jim Skridulis (5056) of my staff if you have questions or require additional information.

Sincerely,

Gordon L. Dover
Paducah Manager of Projects

GLD:dm
LTR-PAD/EP-DM-00-0074

Enclosure: Subject document

Attachment: Suggested text letter

c: P. A. Gourieux
C. S. Jones
A. K. Phelps
R. A. Pratt
J. C. Skridulis
M. A. Tagoe
P. W. Willison
File-EMEF-DMC-PAD-RC

Department of Energy
Oak Ridge Operations
Paducah Site Office
P.O. Box 1410
Paducah, KY 42001

September 26, 2000

Mr. Carl R. Froede Jr., P.G.
United States Environmental Protection Agency
Region IV
DOE Remedial Section
Federal Facilities Branch
Waste Management Division
61 Forsyth Street
Atlanta, Georgia 30303

Mr. Michael V. Welch, P.E.
Manager
Hazardous Waste Branch
Kentucky Department for Environmental Protection
14 Reilly Road, Frankfort Office Park
Frankfort, Kentucky 40601

Dear Mr. Froede and Mr. Welch:

D1 REMEDIAL INVESTIGATION REPORT (VOLUMES 1-4) FOR WASTE AREA GROUPING 3 AT THE PADUCAH GASEOUS DIFFUSION PLANT, SEPTEMBER 2000, DOE/OR/07-1895&D1

Enclosed for your review is the subject document. In order to maintain the current Federal Facilities Agreement schedule, we are requesting your comments by December 31, 2000. If you have any questions or require additional information, please call David W. Dollins at (270) 441-6819.

Sincerely,

W. D. Seaborg

W. Don Seaborg, Site Manager
Paducah Site Office

Enclosure

cc w/enclosure:
M. Guffey, KDEP/Frankfort
T. Taylor, KDEP/Frankfort

CERTIFICATION

Document Identification: *D1 Remedial Investigation Report (Volumes 1—4) for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Primary Document, September 2000, DOE/OR/07-1895&D1*

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons directly responsible for gathering the information, the information submitted is to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

U.S. Department of Energy (DOE)
Owner and Operator

W. Don Seaborg
W. Don Seaborg, Paducah Site Manager

9/25/00
Date Signed

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons directly responsible for gathering the information, the information submitted is to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Bechtel Jacobs Company LLC
Co-Operator

Gordon L. Dover, Paducah Manager of Projects

9/25/00
Date Signed

DOE/OR/07-1895/V1&D1
Primary Document

Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Vol. 1. Main Text

Date Issued—September 2000

Prepared by
TN & Associates, Inc. and
CDM Federal Programs Corporation
Paducah, Kentucky
under General Order 18B-99345C

Prepared for the
U.S. Department of Energy
Office of Environmental Management

BECHTEL JACOBS COMPANY LLC
managing the
Environmental Management Activities at the
East Tennessee Technology Park
Oak Ridge Y-12 Plant Oak Ridge National Laboratory
Paducah Gaseous Diffusion Plant Portsmouth Gaseous Diffusion Plant
under contract DE-AC05-98OR22700
for the
U.S. DEPARTMENT OF ENERGY

TN & Associates, Inc. and
CDM Federal Programs Corporation

contributed to the preparation of this document and should not be considered eligible contractors for its review.

PREFACE

This integrated *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE/OR/07-1895/V1-V4&D1) was prepared in accordance with requirements of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and the Resource Conservation and Recovery Act of 1976 (RCRA).

In accordance with Sect. IV of the Federal Facilities Agreement for the Paducah Gaseous Diffusion Plant, this integrated technical document was developed to satisfy both CERCLA and RCRA corrective action requirements. The phases of the investigation process are referenced by CERCLA terminology within this document to reduce the potential for confusion.

CONTENTS

VOLUME 1

VOLUME 2

VOLUME 3

VOLUME 4

FIGURES

TABLES

ACRONYMS

ABS	absorption factors
ACO	Administrative Consent Order
ADC	analog to digital converter
amsl	above mean sea level
ARAR	applicable or relevant and appropriate requirement
ASTM	American Society for Testing and Materials
BERA	baseline ecological risk assessment
bgs	below ground surface
BHHRA	baseline human health risk assessment
BMP	Biological Monitoring Program
BSV	below screening value
CDM Federal	CDM Federal Programs Corporation
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
CLP	Contract Laboratory Program
CNS	central nervous system
COC	chemical of concern
COD	chemical oxygen demand
COE	U.S. Army Corps of Engineers
COPC	chemical of potential concern
COPEC	chemical of potential ecological concern
cpm	counts per minute
CPT	cone penetrometer test
CSL	Close Support Laboratory
DAF	dilution-attenuation factor
DGS	Deep Groundwater System
DNAPL	dense, nonaqueous-phase liquid
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
dpm	disintegrations per minute
DPT	direct push technology
DQO	data quality objective
DWRC	dual-wall reverse circulation
ECD	electron capture detector
EDD	electronic data deliverable
ELCD	electrolytic conductivity detector
ELCR	excess lifetime cancer risk
EM	electromagnetic
EMEF	Environmental Management and Enrichment Facilities
EPA	U. S. Environmental Protection Agency
ER	Environmental Restoration
ERWM	Environmental Restoration and Waste Management
FFA	Federal Facilities Agreement
FOP	field operating procedure
FS	feasibility study

GC	gas chromatograph
GM	Geiger-Mueller
GI	growth index
GSA	generator storage area
HASP	health and safety plan
HDPE	high density polyethylene
HI	hazard index
HPGe	high-purity germanium
HSA	hollow stem auger
HU	hydrologic unit
IATA	International Air and Transportation Association
ICP	inductively coupled plasma
I.D.	inside diameter
ID	identification
IDLH	immediately dangerous to life or health
IDW	investigation-derived waste
IEUBK	Integrated Exposure Uptake Biokinetic (model)
KDEP	Kentucky Department of Environmental Protection
KPDES	Kentucky Pollutant Discharge Elimination System
LCD	Lower Continental Deposits
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
LMES	Lockheed Martin Energy Systems, Inc.
LOAEL	lowest observed adverse effect level
MCA	multichannel analyzer
MCL	maximum contaminant level
MDA	minimum detectable activity
MDL	method detection limit
MEPAS	Multimedia Environmental Pollutant Assessment System
MMES	Martin Marietta Energy Systems, Inc.
MS	mass spectrometer
MSA	method of standard additions
MS/MSD	matrix spike/matrix spike duplicate
NAPL	nonaqueous-phase liquid
ND	non-detect
NGVD	National Geodetic Vertical Datum
NOAEL	no observed adverse effect level
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
O.D.	outside diameter
OOCE	out-of-control event
ORO	Oak Ridge Operations
OU	operable unit
OVM	Organic Vapor Monitor
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PEL	permissible exposure limit
PEMS	Project Environmental Measurements System
PGDP	Paducah Gaseous Diffusion Plant

PID	photoionization detector
POC	pathway of concern
PPE	personal protective equipment
PVC	polyvinyl chloride
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
RDA	Recommended Dietary Allowance
RESRAD	residual radioactivity
RfD	reference dose
RFD	request for disposal
RFI	RCRA Facility Investigation
RGA	Regional Gravel Aquifer
RI	remedial investigation
RME	reasonable maximum exposure
RPD	relative percent difference
rpm	revolutions per minute
RPP	Radiation Protection Program
SAA	satellite accumulation area
SDWA	Safe Drinking Water Act of 1974
SI	site investigation
SMO	Sample Management Office
SOP	standard operating procedure
SSL	Soil Screening Level
STEL	short-term exposure limit
SVOA	semivolatile organic analyte
SWMU	solid waste management unit
TAL	Target Analyte List
TCE	trichloroethene
TCL	Target Compound List
TLD	thermoluminescent dosimeter
TLV	threshold limit value
TN&A	TN & Associates, Inc.
TOC	total organic carbon
TRU	transuranic
TVA	Tennessee Valley Authority
UCD	Upper Continental Deposits
UCRS	Upper Continental Recharge System
USEC	United States Enrichment Corporation
USGS	U.S. Geological Survey
VOA	volatile organic analyte
WAC	waste acceptance criteria
WAG	Waste Area Grouping
WKWMA	West Kentucky Wildlife Management Area

EXECUTIVE SUMMARY

This report describes an environmental investigation conducted by the U.S. Department of Energy (DOE) in 1999 at the Paducah Gaseous Diffusion Plant (PGDP). The primary focus of the investigation was to collect sufficient information about surface soil, subsurface soil, and shallow groundwater to (1) evaluate potential sources of contamination, (2) determine if the contaminant sources are contributing to contamination already known to exist in the Regional Gravel Aquifer (RGA) and the McNairy Formation groundwater or surface water, (3) assess risks to human health and the environment posed by this contamination, (4) determine if remedial actions are required to reduce these risks, and (5) support selection of an appropriate remedial action. The investigation was conducted in accordance with the Federal Facilities Agreement for PGDP, which coordinates the requirements of the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

The subjects of the investigation were three solid waste management units (SWMUs) and the groundwater underlying them. The SWMUs investigated were SWMU 4, C-747 Contaminated Burial Cell; SWMU 5, C-746-F Classified Burial Yard; and SWMU 6, C-747-B Burial Yard. These three SWMUs have been grouped together for RCRA and CERCLA investigations because all are burial units. This grouping is referred to as Waste Area Grouping (WAG) 3.

The investigation included collecting samples of soil and water and analyzing the samples for volatile organics, semivolatile organics, polychlorinated biphenyls (PCBs), metals, and radionuclides. An on-site screening of alpha, beta, and gamma activities was used to identify the samples that might require additional speciation analysis in a fixed-base laboratory.

C-747 Contaminated Burial Cell (SWMU 4)

The C-747 Contaminated Burial Cell (SWMU 4) is located in the western half of PGDP, south of the C-749 Uranium Burial Ground (SWMU 2) and the C-404 Low-Level Waste Burial Ground (SWMU 3). The C-747 burial ground was operated from 1951 to 1958 and was used to dispose of various PGDP wastes, including radiologically contaminated and noncontaminated trash and excess equipment [consisting of steel, MONEL (a nickel alloy), and other metals]. Disposal was performed in several burial cells excavated to a depth of approximately 15 ft below ground surface (bgs).

Sampling of the soils within SWMU 4 indicated PCBs at depths of approximately 3 ft bgs, trichloroethene (TCE) and various degradation products of TCE (including vinyl chloride and cis-1,1-dichloroethene) in soils immediately adjacent to and under the burial cells, and various radionuclides, including the following radioisotopes: plutonium-239/240, uranium-234/235/238, neptunium-239, and radium-226.

The nature and extent of contaminants in groundwater at SWMU 4 are generally similar to the nature and extent of contaminants in the subsurface soils. Because the Upper Continental Recharge System (UCRS) has a downward groundwater gradient, most of the contamination within the UCRS groundwater is located immediately adjacent to or underneath the burial cells.

C-746-F Classified Burial Yard (SWMU 5)

The C-746-F Classified Burial Yard (SWMU 5) is located south of the C-746-P Clean Scrap Yard and west of the C-747-B Burial Ground (SWMU 6) in the northwest corner of PGDP. The C-746-F Burial Yard operated from approximately 1965 to 1987 and was used to dispose of security-classified weapons components, radionuclide-contaminated scrap metal, and slag from nickel and aluminum smelters. Wastes were placed in a series of 10- by 10-ft trenches excavated 6–15 ft bgs. A security fence that restricts access to the burial yard surrounds the SWMU.

Isolated occurrences of TCE, metals, PCBs, dibenzofuran, and polycyclic aromatic hydrocarbons were the only contaminants found in the surface, subsurface, or groundwater media. Due to the security restrictions imposed, only surface soils (to a maximum depth of 12 in. bgs) were sampled within the security fence surrounding the SWMU. Furthermore, no samples were collected from within the burial cells. Five angled borings were drilled from the perimeter of the SWMU and terminated underneath the burial cells. The absence of any significant contaminants suggests that SWMU 5 is not currently a source of contamination to the groundwater and surface water operable units.

C-747-B Burial Yard (SWMU 6)

The C-747-B Burial Yard (SWMU 6) is located immediately east of the C-746-F Classified Burial Yard (SWMU 5) and is geologically and hydrogeologically similar to SWMU 5. The site consists of five separate burial cells (designated as Burial Cells H, I, J, K, and L and excavated to an approximate depth of 6–8 ft bgs) that were used for disposal from approximately 1960 to 1971. Wastes disposed of at SWMU 6 include magnesium metals from the machine shop, exhaust hood blowers from the C-710 building, drums of aluminum scrap, and a single modine trap.

As with SWMU 5, sampling at SWMU 6 did not encounter contaminant trends indicating widespread contamination at the site. Minimal detections of PCBs, radionuclides, and metals were detected in the soils and shallow groundwater.

WAG 3 RGA and McNairy Groundwater Evaluation

The evaluation of groundwater at WAG 3 indicated that SWMU 4 is a contributor to groundwater contamination in the RGA. This conclusion is based on the fact that borings installed downgradient of SWMU 4 in the RGA had higher levels of volatile organic and radiological contaminant concentrations than the borings installed upgradient of SWMU 4, indicating that SWMU 4 is contributing to the Southwest Plume at PGDP. SWMU 5 does not appear to be contributing contaminants to the RGA or McNairy groundwater. TCE was identified in RGA samples at SWMU 6, but this contamination is part of the Northwest Plume. The absence of any TCE or other volatile organic analytes in the UCRS groundwater precludes SWMU 6 as a contaminant source to the RGA or McNairy groundwater.

Baseline Risk Assessment

The baseline risk assessment uses information collected during the recently completed remedial investigation of WAG 3 and the results of previous risk assessments for SWMUs in WAG 3 to characterize the baseline risks posed to human health and the environment from contact with contaminants in soil and groundwater. In addition, the baseline risk assessment uses results of fate and transport modeling to estimate the baseline risks posed to human health through contact with receiving media impacted by contaminants migrating off-site from the various sources in WAG 3. The ecological assessment focuses on exposure to contaminants in surface soil. Evaluation of off-site streams is deferred to the surface water operable unit investigation. Baseline risks are those that may be present now or in the future in the absence of corrective or remedial actions. Methods used for fate and transport modeling are presented in Chap. 5 of Vol. 1, Appendix B of Vol. 4 [Multimedia Environmental Pollutant Assessment System (MEPAS)], and Appendix C (RESRAD) of Vol. 4.

Consistent with regulatory guidance and agreements contained in the approved human health risk assessment methods document (DOE 1996), the baseline human health risk assessment (BHHRA) evaluates land use scenarios that encompass current use and several hypothetical future uses of the WAG 3 SWMUs and the areas to which contaminants may migrate. The following land use scenarios and exposure routes are assessed:

- Current on-site industrial—direct contact with surface soil (0–1 ft bgs);
- Future on-site industrial—direct contact with surface soil and use of groundwater drawn from aquifers below WAG 3;
- Future on-site excavation scenario—direct contact with surface and subsurface soil (0–16 ft bgs);
- Future on-site recreational scenario—ingestion of game exposed to contaminated surface soil;
- Future on-site rural resident—direct contact with surface soil, use of groundwater drawn from aquifers below WAG 3, and ingestion of vegetables grown in this area; and
- Present and future off-site resident—use of groundwater drawn from aquifers at the PGDP security fence.

Also consistent with regulatory guidance and the strategy for ecological risk assessment of source units (DOE 1993, EPA 1998), the baseline ecological risk assessment evaluates risks under both current and potential future conditions to several ecological receptors that may come into contact with contaminated media at or migrating from sources in WAG 3.

For all SWMUs in WAG 3, the cumulative human health systemic toxicity and excess lifetime cancer risk (ELCR) exceed the accepted standards of the Kentucky Department of Environmental Protection (KDEP) and the U.S. Environmental Protection Agency (EPA) for one or more land use scenarios when assessed using default exposure parameters. The land use scenarios for which risks exceed *de minimis* levels [i.e., for KDEP, a cumulative hazard index (HI) of 1 or a cumulative ELCR of 1.0E-06, and for EPA, an HI of 1 and a range of 1.0E-04-1.0E-06 for ELCR] are summarized in Table ES.1.

Table ES.1. Land use scenarios for which human health risk exceeds *de minimis* levels

Land use scenario	Site		
	SWMU 4	SWMU 5	SWMU 6
Systemic toxicity[a]			
Current industrial worker			
Exposure to soil	X[b]	–	–
Future industrial worker			
Exposure to soil	X[b]	–	–
Exposure to RGA groundwater	X[c]	X[c]	X[c]
Exposure to McNairy groundwater	X[c]	X[c]	X[c]
Future on-site rural resident[a]			
Exposure to soil	X[b]	X[b]	X[b]
Exposure to RGA groundwater	X[c]	X[c]	X[c]
Exposure to McNairy groundwater	X[c]	X[c]	X[c]
Off-site rural resident			
Exposure to groundwater[d]	X	X	X
Future recreational user[a]			
Exposure to soil	–	–	–
Future excavation worker			
Exposure to soil and waste	X[c]	X[b]	X[c]
Excess lifetime cancer risk			
Current industrial worker			
Exposure to soil	X	X	X
Future industrial worker			
Exposure to soil	X	X	X
Exposure to RGA groundwater	X	X	X
Exposure to McNairy groundwater	X	X	X
Future on-site rural resident[d]			
Exposure to soil	X	X	X
Exposure to RGA groundwater	X	X	X
Exposure to McNairy groundwater	X	X	X
Off-site rural resident[e]			
Exposure to groundwater	X[e]	–	–
Future recreational user[d]			
Exposure to soil	–	X	–
Future excavation worker			
Exposure to soil and waste	X	X	X

Notes: Land use scenarios where risk exceeded the benchmark levels (HI of 1/ELCR of 1.0E-06) are marked with an "X." Land use scenarios where risk did not exceed a benchmark level are marked with a "–."

[a] Results for a child are presented for systemic toxicity for the future recreational user and the future on-site rural resident.

[b] These land use scenarios are of concern even though lead was not detected.

[c] Lead is present, and the land use scenario is of concern whether or not the element is included in the assessment.

[d] Values for excess lifetime cancer risk for the future recreational user and the future on-site rural resident are for lifetime exposure.

[e] Based on the results of contaminant transport modeling, "X" indicates that the location contains a source of unacceptable off-site contamination.

Exceedingly high HIs have been computed for land use scenarios, SWMUs, and media in which lead was detected (HIs of up to 2,390,000). This finding may be attributed to the use of a very conservative (1.0E-07 mg/kg-day) reference dose value, provided by KDEP. Where lead was detected, the metal was the overwhelming risk driver. To investigate the uncertainty associated with this finding, the systemic toxicity associated with contaminants at WAG 3 was assessed throughout this BHHRA by both including and excluding lead as a chemical of potential concern. This strategy allowed the identification of other contaminants contributing to significant levels of systemic toxicity and highlighted HIs that exceeded EPA's benchmark (i.e., HI >1) in the absence of lead.

Since the three SWMUs comprising WAG 3 provide a small area of grassy habitat suitable for ecological receptors, an ecological risk assessment was carried out to evaluate risks from current and potential future exposure of terrestrial plants, soil invertebrates, and terrestrial wildlife to chemicals in WAG 3 surface soil.

Maximum concentrations of a number of analytes were near background levels or exceeded background levels or benchmarks at only a few sampling stations. However, some contaminants were marked as chemicals of potential ecological concern (COPECs) based on the results of screening contaminant concentrations against ecological benchmarks. These COPECs are summarized in Table ES.2.

Table ES.2. Summary of chemicals with maximum detected concentrations resulting in ecological hazard quotients greater than 1 for one or more nonhuman receptor groups

	Site		
Receptor group	**SWMU 4**	**SWMU 5**	**SWMU 6**
Plants[a]	Chromium, nickel, vanadium[b], zinc[b]	Aluminum, arsenic[b], chromium, nickel[b], zinc	Nickel[b], zinc[b]
Soil invertebrates[a]	Chromium, copper	Chromium, zinc, fluoranthene, phenanthrene	Zinc[b]
Terrestrial wildlife[c]	Chromium	Aluminum	None

[a] Plant and soil invertebrate results are based on maximum detected concentrations or activities.

[b] Greater than surface soil background concentration at only one station in the SWMU.

[c] Terrestrial wildlife results are based on comparison of maximum exposure estimates to lowest observed adverse effect levels.

1. INTRODUCTION

1.1 PURPOSE OF REPORT

The Paducah Gaseous Diffusion Plant (PGDP), located in western Kentucky (Fig. 1.1), is an active uranium enrichment facility owned by the U.S. Department of Energy (DOE). On July 1, 1993, DOE leased the plant production operations facilities to the United States Enrichment Corporation (USEC). On April 1, 1998, Bechtel Jacobs Company LLC replaced Lockheed Martin Energy Systems, Inc. (LMES) in implementing the Environmental Management and Enrichment Facilities (EMEF) Program, which includes this investigation.

In June 1994, PGDP was placed on the National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). Both Resource Conservation and Recovery Act of 1976 (RCRA) and CERCLA requirements have been coordinated in the Federal Facilities Agreement (FFA) that has been negotiated by DOE, the U.S. Environmental Protection Agency (EPA), and the Commonwealth of Kentucky. The FFA is intended to satisfy the requirements for an interagency agreement under Sect. 120 of CERCLA.

To focus investigations toward the most effective and efficient remedial actions, operable units (OUs) have been defined. These OUs consist of two types: source control units (i.e., units that may contribute contamination to other units) and integrator units (i.e., units that "collect" contamination from source control units—in the specific instance of PGDP, the groundwater and surface water units). Five OUs exist at PGDP: groundwater, surface water, surface soil, burial grounds, and a comprehensive sitewide OU (DOE 1998b).

The subject of this investigation was the Waste Area Grouping (WAG) 3 burial ground solid waste management units (SWMUs) (SWMUs 4, 5, and 6) which are a portion of the burial grounds OU. This document reports the results of the remedial investigation (RI) conducted at WAG 3 (shown on Fig. 1.2). The WAG 3 SWMUs were considered potential contributors of trichloroethene (TCE) to groundwater on the west and north sides of PGDP. The objectives of the RI were to collect data necessary to evaluate the nature and extent of contamination (including migration pathways), to determine the human health and ecological risk associated with each SWMU, and to collect the data necessary to evaluate and determine the appropriate remedial actions for each SWMU. These data will be incorporated into subsequent studies focusing on remedial action for the affected OUs.

1.2 WAG 3 BACKGROUND INFORMATION

WAG 3 consists of three sites:

(1) **C-747 Contaminated Burial Yard (SWMU 4).** The C-747 Contaminated Burial Yard is located in the western section of the plant area. SWMU 4 (which covers an area of approximately 286,700 ft^2) is bounded on the north by Virginia Avenue, on the east by 6th Street, and on the west by 4th Street (Fig. 1.2). The C-747 Burial Yard was in operation from 1951 to 1958 for the disposal of radiologically contaminated and uncontaminated debris originating from the C-410 UF$_6$ feed plant. SWMU 4 may have also received sludges designated for disposal at the C-404 burial grounds. The source of these sludges is unknown,

but the WAG 3 RI Work Plan (DOE 1998a) indicated that the sludges potentially included uranium-contaminated solid waste and technetium-99-contaminated magnesium fluoride. The total volume of material disposed of at this site is unknown. Potential contaminants associated with this SWMU include uranium, technetium-99, metals, and TCE.

(2) **C-746-F Classified Burial Yard (SWMU 5).** The C-746-F Burial Yard is located in the northwestern section of the plant area. SWMU 5 (which covers an area of approximately 197,400 ft^2) is located adjacent to the C-746-P Clean Scrap Yard to the north, Ditch 001 on the south, the C-747-B Burial Ground to the east, and Patrol Road 1 to the west (Fig. 1.2). SWMU 5 was in operation from 1965 to 1987. Disposal pits were located on a grid system consisting of 10- by 10-ft cells excavated to a depth of 6 to 15 ft below ground surface (bgs). The burial pits were used for the burial of security-classified weapons components, some radionuclide-contaminated scrap metal, and slag from the nickel and aluminum smelters. Metals and radioisotopes were the primary potential contaminants of interest at this SWMU.

(3) **C-747-B Burial Ground (SWMU 6).** The C-747-B Burial Ground is located in the northwestern section of the plant area east of SWMU 5 (Fig. 1.2). SWMU 6 was in operation from 1960 to 1976. The entire burial area covers an area of approximately 13,500 ft^2, which is divided into five separate burial cells (Areas H, I, J, K, and L). The excavated depths of the cells are reported to be 6 to 8 ft bgs. Each of the burial cells was used for the disposal of a different waste:

- Area H: magnesium scrap
- Area I: eight exhaust fans contaminated with perchloric acid
- Area J: aluminum scrap
- Area K: magnesium scrap
- Area L: UF_6 condenser

1.3 PREVIOUS INVESTIGATIONS

Following the discovery of off-site groundwater contamination, DOE and EPA entered into an Administrative Consent Order (ACO) pursuant to CERCLA in November 1988. The primary purpose of the ACO was to formalize requirements for determining the nature and extent of off-site contamination and to ensure that appropriate actions were taken to mitigate immediate risks posed to human health and the environment. As part of the ACO, DOE conducted a two-phase site investigation (SI) from 1989 to 1992 (referred to in this report as the Phase I and Phase II investigations). This SI confirmed the widespread presence of groundwater contamination with two large, reasonably distinct contaminant plumes emanating from PGDP. One plume was found leaving PGDP in the northwest corner of the plant (Northwest Plume) and the other plume exits the eastern side of the plant (Northeast Plume) (Fig. 1.3). The Northwest Plume has TCE and technetium-99 as the primary chemicals of concern, and the Northeast Plume has TCE as the primary chemical of concern (CH2M HILL 1991, 1992).

From 1992 through 1994, two investigations further defined the off-site plumes and showed a third distinct technetium-99 plume located adjacent to the Northwest Plume. The Northwest Plume investigation consisted of installing drive-point profiles along five transects oriented perpendicular to the plume to better define the three-dimensional distribution of TCE and technetium-99 in the Regional Gravel Aquifer (RGA) (MMES 1995). The Northeast Plume investigation included collecting data from four off-site transects as well as several on-site transects to provide the areal and vertical extent of contamination (DOE 1995). One of the key findings of these two investigations was the discovery of significantly elevated concentrations of TCE at the base of the RGA, which is highly suggestive of a dense, nonaqueous-phase liquid (DNAPL) source at depth. Another key finding was the connection of the Northwest Plume with the site of a former TCE leak near the C-400 Building, establishing this site as the primary source for the Northwest Plume. Recent investigations conducted at WAG 27 (DOE 1999a) and the Data Gaps Area (DOE 2000a) have identified a third distinct TCE plume (Southwest Plume) in the RGA on the west side of PGDP.

Some sampling of all three SWMUs in WAG 3 was conducted during the Phase II investigation. (Results of the investigation that are relevant to WAG 3 are provided in Chap. 4.) Investigators encountered limited amounts of various volatile organic analytes (VOAs), semivolatile organic analytes (SVOAs), metals, and radioisotopes. The conclusion in the Phase II report was that none of the WAG 3 SWMUs were significant contributors to off-site contamination found in surface water or groundwater.

1.4 PROJECT SCOPE

1.4.1 Scope

The general scope of this project was to conduct an RI at the three SWMUs comprising WAG 3.

The primary focus of the RI was to collect sufficient information about existing and potential contamination in surface and subsurface soils and the shallow groundwater of the Upper Continental Recharge System (UCRS) to support an assessment of risks to human health and the environment and the selection of actions to reduce these risks, if required. If chemicals of potential concern (COPCs) were detected in the UCRS beneath a SWMU, the RGA and McNairy Formation were evaluated for contamination. Based on the geology of the McNairy Formation, it was expected that migration of contaminants through the formation is impeded by the Levings Member, which serves as an aquitard in the PGDP area. Based on this assumption, all of the initial deep soil borings were terminated at the top of the Levings Member of the McNairy Formation (approximately 150 ft).

The following list summarizes the activities that were conducted as part of the RI:

(1) collection of geophysical and radiological data and surface soil, subsurface soil, surface water, and groundwater samples;

(2) field screening and laboratory analysis of the samples;

(3) evaluation of nature and extent of contamination related to each source unit;

(4) numeric modeling of contaminant fate and transport, and estimation of future exposure point concentrations at the DOE property boundary; and

(5) determination of ecological and human health risks associated with each site.

A data quality objective (DQO) process was used to focus the sampling strategy on SWMU-specific media, contamination, and migration pathways, and identifying data needs. Table 1.1 summarizes the goals that were identified for the RI. The subsequent chapters of this report describe the methods used to achieve these goals (Chap. 2), the environmental data derived (Chap. 3), the nature and extent of contamination (Chap. 4), contaminant fate and transport (Chap. 5), and a baseline risk assessment summary (Chap. 6). Chapter 7 of this report then summarizes and synthesizes these data and provides SWMU-specific answers to the questions identified from the DQO process and listed in Table 1.1.

1.4.2 Rationale for Field Sampling

The investigative approach and analytical requirements were generally the same for the three SWMUs. Release mechanisms and migration pathways were identical for each of the three SWMUs (i.e., leaching out of burial cells and migrating into the groundwater). With some SWMU-specific differences, the COPCs were generally the same (i.e., SWMU 5 included radon analysis in the groundwater). The sample strategy targeted the subsurface soils and groundwater adjacent to and below the burial cells, and the material buried in the cells. Surface soil samples were collected at perimeter locations around each SWMU to determine the potential for runoff from the burial cells.

A surface geophysical survey and surface radiological survey were conducted at each SWMU to determine the extent of the burial cells (based on the geophysical survey) and any radioactive "hotspots" that would require a focused investigation. Subsurface soils and groundwater samples were collected using a variety of drilling and direct push methods. These samples were collected to assess migration of COPCs out of the burial cells and into surrounding soils and the groundwater. Contingency samples were planned to follow-up and delineate the extent of any contamination identified in the initial sampling.

1.5 REPORT ORGANIZATION

The WAG 3 RI report is organized into 8 chapters and 10 appendixes and is presented in four volumes. The contents of Vol. 1 are described below while Vols. 2 and 3 contain appendix material referenced in this volume. Volume 4 presents the baseline risk assessment. Figures and tables appear at the end of each chapter in which they are referenced, so as not to disrupt the flow of the report.

Chapter 1 of this report presents a brief overview of the sites, as well as the rationale for RI field sampling. This section also discusses current and past activities conducted at PGDP.

Chapter 2 presents the investigative methods used to sample the various media, the analytical sampling parameters, health and safety monitoring, decontamination practices, and waste management practices for the investigations.

Chapter 3 presents a description of the natural and cultural environmental settings at PGDP and provides specific information on the geology, hydrology, and hydrogeology of the three SWMUs comprising WAG 3.

Chapter 4 presents a discussion of the nature and extent of the contamination at each site as concluded from analyses of the data collected during this and previous investigations.

Chapter 5 presents a discussion of the fate and transport of the contamination at each site. A conceptual site model has been developed in which exposure pathways of potential concern are discussed and contaminant persistence is evaluated. Models of contaminant transport are also presented.

Chapter 6 presents a summary of the baseline risk assessment, which is contained in Vol. 4, including results of previous studies, identification of chemicals of concern (COCs), the exposure assessment, the toxicity assessment, the risk characterization, conclusions, and site-specific remedial action goals.

The final chapters (7 and 8) present the conclusions and references, respectively, of this report.

AutoCAD FILE: 1999006-6290-A-0007.dwg

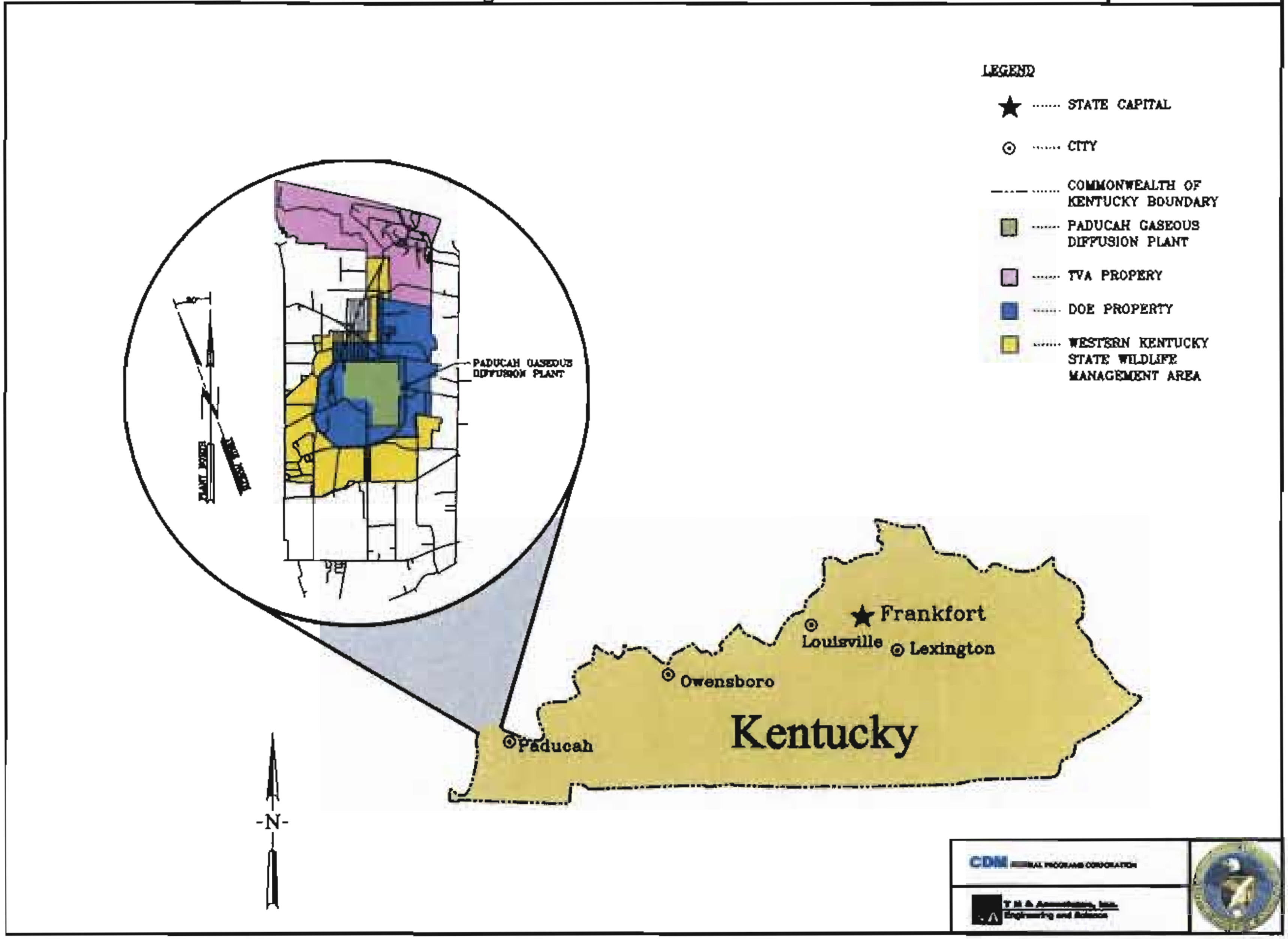


Fig. 1.1. General site location map for the Paducah Gaseous Diffusion Plant (PGDP)
Paducah, Kentucky

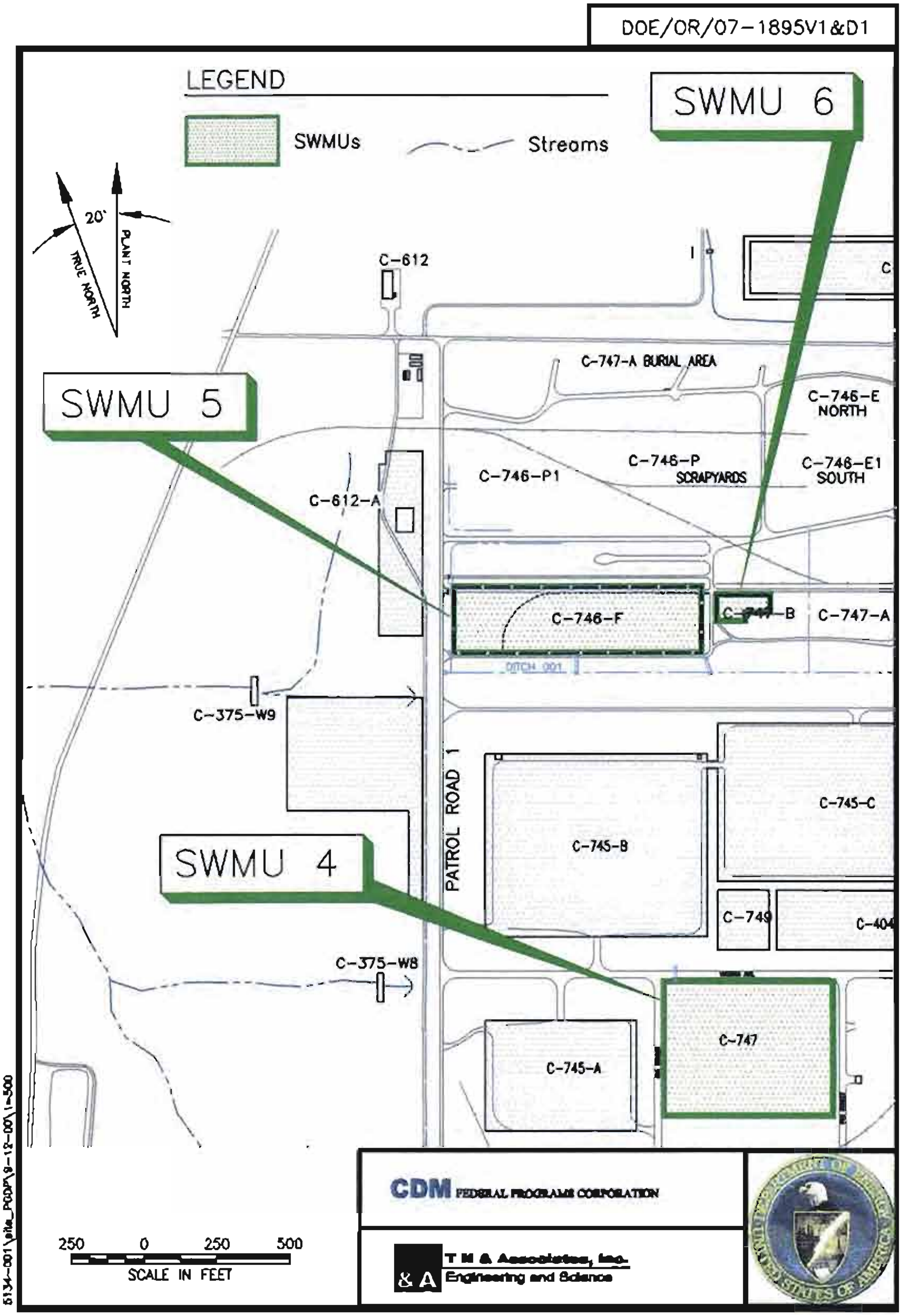
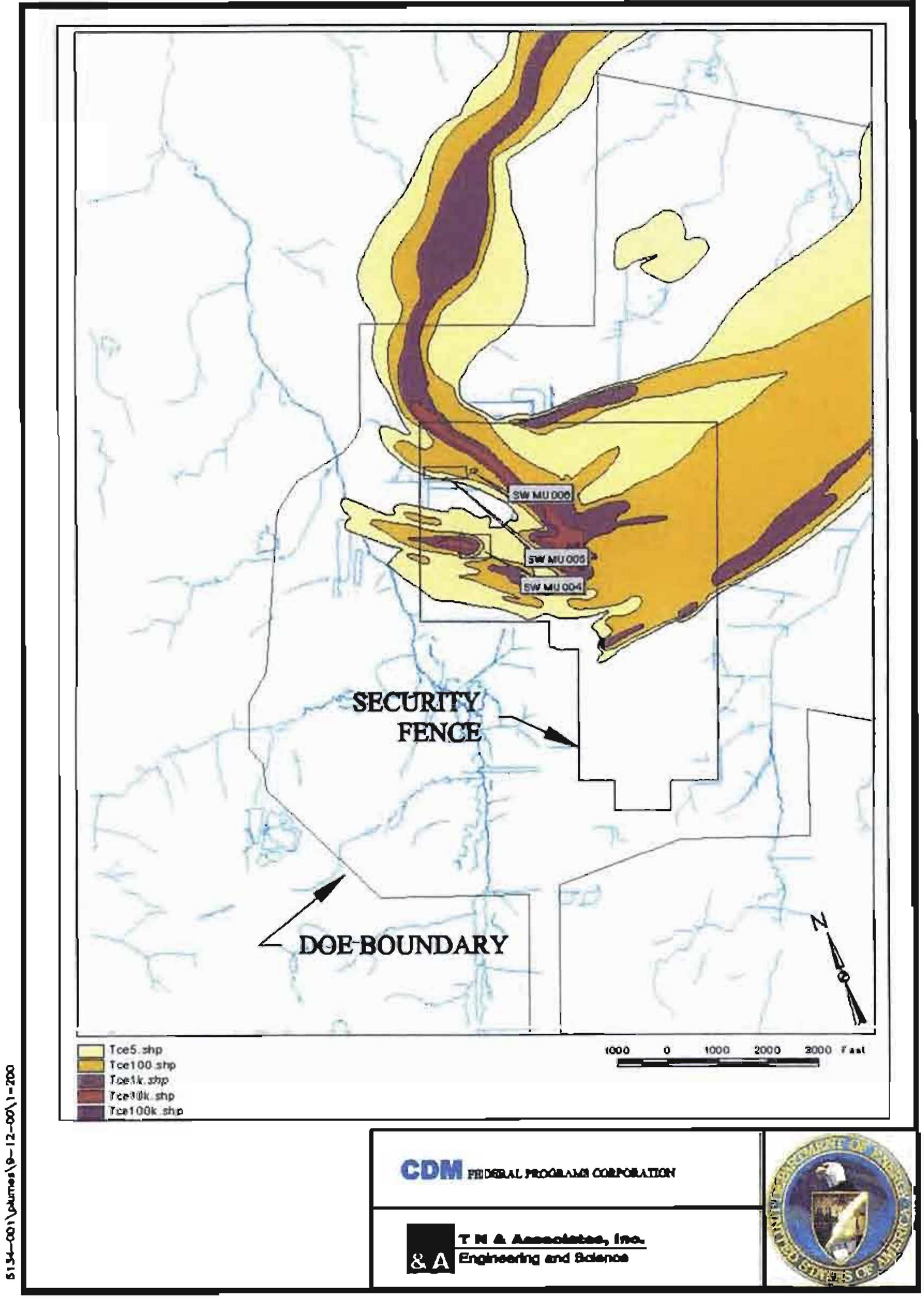


Fig. 1.2. WAG 3 map.



Source: BJC/PAD-169, May 2000

Fig. 1.3. Offsite TCE plumes at PGDP

Table 1.1. Goals identified for the WAG 3 RI

Goal 1: Nature of Source Zone

1-1: What are the suspected contaminants?
1-2: What are the plant processes that could have contributed to the contamination? When and over what duration did releases occur?
1-3: What are the concentrations and activities at the source?
1-4: What are the area and volume of the source zone?
1-5: What are the chemical and physical properties of associated material at the source areas?

Goal 2: Extent of Source Zone and Contamination in Soil and Secondary Sources At All Units

2-1: What are the past, current, and potential future migratory paths?
2-2: What are the past, current, and potential future release mechanisms?
2-3: What are the contaminant concentrations or activity gradients?
2-4: What are the vertical and lateral extents of contamination?
2-5: What is the relationship of the UCRS gradient to the source, to surface water bodies, and to the RGA?

Goal 3: Determine Subsurface Transport Mechanisms And Pathways

3-1: What are the contaminant migration trends?
3-2: To what area is the dissolved-phase plume migrating?
3-3: What are the effects of underground utilities and plant operations on migration pathways?
3-4: What is the role of the UCRS in contaminant transport?
3-5: What are the physical and chemical properties of the formations and subsurface matrices?

Goal 4: Support Evaluation Of Remedial Alternatives

4-1: What are the possible remedial technologies applicable for this unit?
4-2: What are the physical and chemical properties of media to be remediated?
4-3: Are cultural impediments present?
4-4: What is the extent of contamination (geologic limitations presented by the source zone or secondary source)?
4-5: What would be the impact of action on and by other sources?
4-6: What would the impact of an action at the source be on the integrator units?
4-7: What are stakeholders' perceptions of contamination at or migrating from the source zone or secondary sources?

Goal 5: Support Continuing Characterization Of Surface Water And Groundwater Integrator Units

5-1: What is the stratigraphy (as it relates to the entire PGDP facility)?
5-2: What would be the impact of action on and by other sources?
5-3: What is the hydrological information necessary to support facility-wide modeling?
5-4: At what point do potential releases enter into the integrator units?

2. FIELD INVESTIGATION

This chapter presents a description of the field investigation activities and methods used during the WAG 3 RI. Major topics include sampling activities, procedures, and equipment, as well as analyses conducted on samples. Chapter 6 of the WAG 3 RI Work Plan (DOE 1998a) specified the sampling methods and locations that collected the data required by the work plan. This data collection strategy (which includes surface, geophysical, and radiological surveys and various types of intrusive borings and media sampling) is summarized in Tables 6.6, 6.14, and 6.17 of the work plan. These tables have been modified and carried into this report (Tables 2.1, 2.2, and 2.3) and supplemented with the actual data collection activities performed. These data are presented in a way that allows comparison between what was specified in the work plan and what was actually performed during the WAG 3 RI. Subsequent sections of this chapter discuss in detail (or reference appropriate appendixes where the detail in included) the various data collection activities and the quality objectives achieved.

Two fundamental types of data were derived from this investigation:

- **Field Data.** This type of data includes the data derived from the geophysical surveys, infiltrometer data, radiological surveys, lithologic logging of boreholes, and the results of the geotechnical tests performed on samples. These data are incorporated into the Chap. 3 discussions on the natural setting at PGDP and are ultimately used in determining the transport mechanisms (which determine nature and extent) of contaminants mobilized in the WAG 3 SWMUs.

- **Analytical Data.** These data are the analytical results from the media samples collected. These data, after being assessed, validated, and screened, are presented in Chap. 4.

All sampling at PGDP was conducted in accordance with the medium-specific procedures set forth in the Paducah EMEF Program Procedures Manual. These procedures are consistent with EPA Region 4 Standard Operating Procedures (SOPs) (EPA 1996a).

2.1 SURFACE GEOPHYSICAL SURVEYS

A surface geophysical survey was performed at each of the WAG 3 SWMUs in March 1999. A Geonics EM-31 terrain conductivity meter, a Geonics EM-61 electromagnetic metal detector, and a Sensors and Software Noggin ground-penetrating radar unit were used to record subsurface data, collecting data along established grids for each SWMU. This survey was used to delineate the outlines of the burial cells and, in the case of SWMU 4, a previously unknown burial cell was identified. Data derived from this survey were used to support the selection of subsequent sampling points. Appendix A contains the geophysical survey report.

2.2 SURFACE RADIOLOGICAL WALKOVER SURVEYS

Surface radiological surveys were performed at each of the WAG 3 SWMUs in August 1999. The survey was intended to identify areas of twice background [measured in counts per minute (cpm)]. The survey employed hand-held radiological instruments recording points on a 30-ft grid. Appendix B contains copies of the field records. Results of the survey are incorporated into Chap. 4, description of nature and extent of contamination.

Before the beginning of the survey, wooden stakes were driven near the perimeter of the SWMU on a 30-ft spacing to be used to lay out a grid. Each grid cell was assigned an alphanumeric designation, which was used to identify the cell during the walkover.

2.2.1 Equipment and Procedure

2.2.1.1 Radiological walkover instrumentation

Radiological instruments consisted of Ludlum 2221 Digital Scalar/Ratemeters with Ludlum 44-10 2×2 sodium iodide, obtained from a third party vendor. The instruments were response matched from the vendor so that response between instruments at both background radiation levels and to a 0.54 mR/hour source was within approximately 2% of one another. In accordance with the manufacturer's recommendations, a daily response check was performed to ensure the meters responded within 20% of baseline values determined at the beginning of the task.

2.2.1.2 SWMU background determination

The WAG 3 Work Plan called for an action limit of twice background for additional investigation. Due to the proximity of the SWMUs to an active uranium hexafluoride (UF_6) cylinder yard, a background value could not be determined at these sites. For the purposes of this investigation, the background value was determined through the use of grid node readings. The average values taken at the individual nodes were used to determine the background in the grid cell. This method of determining background is appropriate as long as the nature of the contamination is localized and isolated. The results of the walkover survey indicate that this was a valid assumption.

2.2.1.3 SWMU walkover

Once the grid nodes were surveyed and the background readings documented, the walkover of the SWMUs commenced. The walkover was performed in accordance with procedure PTSA-2006. The survey methodology involved holding the ratemeter at waist level and holding the NaI probe as near to the ground as possible without allowing the probe to contact the ground. The survey technician walked the grid cell in alternating parallel paths at approximately 1.5 ft/s while swinging the probe in a pendulum motion. Survey paths were approximately 5 ft from each other. Any noticeable increase in the count-rate caused the survey technician to pause and investigate further. At the completion of each grid cell, the results were documented and the technician moved to the next cell.

2.2.2 In Situ Gamma Spectrometry of SWMUs 4, 5, and 6

An in situ gamma spectrometry investigation of SWMUs 4, 5, and 6 was performed from September 27 to 30, 1999. Canberra Oak Ridge LLC was subcontracted to perform the investigation. Sampling locations were based on the results of the radiological walkover investigation. Seven samples were collected in SWMU 4, three samples were collected in SWMU 5, and four samples were collected in SWMU 6. An eighth sample was scheduled to be collected in

SWMU 4; however, the presence of a drill rig at the proposed sampling location prevented the collection of the sample. In accordance with the subcontract guidelines, the samples were collected over a 2 m × 2 m × 15 cm area, with count times sufficient to reach a minimum detectable activity (MDA) for uranium of 30 picocuries per gram (pCi/g). Due to the proximity of an active UF_6 cylinder yard to the investigated SWMUs, several background measurements to account for the "shine" from the yard were performed. Additionally, a 2 in. thickness of lead shielding was placed along the vertical axis of the detector to reduce background and lower the MDA. The in situ instrument underwent daily pre- and post-measurement source response checks to ensure that the collected data were valid.

2.3 INFILTROMETER TESTS

Infiltrometer tests were performed at four locations in WAG 3, two at SWMU 4, and one each at SWMUs 5 and 6. The test measures soil hydraulic conductivity by recording water movement into and through the overlying soil. This information, coupled with precipitation, can be used to calculate recharge rates to underlying aquifers. Appendix C contains copies of the field notes and other data.

2.3.1 Introduction

The infiltrometer test is designed for the field measurement of soil hydraulic conductivity. In particular, the concern often lies with the rate of water movement through clay liners of waste cells, for characterizing water movement below the waste cell to predict contaminant movement and to measure the infiltration of drainage into soils and sediment above the waste cell. The latter is the interest of this study. This field study was designed to aid in projecting the amount of water that would move into the vadose zone above the waste cells and would be available as a possible transport vehicle of any contaminant through the cell.

For the SWMUs of interest, each test was conducted on the surface soils. Testing can be conducted at depth if required by removing the overburden. Infiltrometers typically measure conductivity at the soil surface, whereas permeameters may be used to determine conductivity at different depths within the soil profile. The infiltrometer employs the use of two concentric rings placed at a depth in the soil and filled with a liquid of interest. Liquids other than water can be used to calculate a more accurate infiltration rate of a spilled contaminant. The principle of operation is that a constant volume of water infiltrating the soil contained within the infiltrometer ring is measured over a period of time.

It is important to note that the field-measured infiltration rate and the laboratory-derived hydraulic conductivity are not the same, although they do have similar units. Likewise, they cannot be directly related without knowing the hydraulic boundary conditions of the field site, such as hydraulic gradient and the extent of lateral flow. The procedures used followed the standard test method for infiltration rate of soils in field using a double-ring infiltrometer [American Society for Testing and Materials (ASTM) D 3385-94].

2.3.2 Background

Infiltrometer test methods measure the rate of infiltration at the soil surface that is influenced by both the saturated hydraulic conductivity and the capillary effect of the soil. Capillary effect refers to the ability of dry soil to pull away water from a zone of saturation and is determined by the pore size, texture, structure, and initial moisture content of the soil at the time of testing. Infiltrometer hydraulic conductivity measurements are for both field-saturated and unsaturated flow. There is a distinction between saturated (K_s) and field-saturated (K_{fs}) hydraulic conductivity. True saturated conditions seldom occur in the vadose zone because of entrapped air except over an impermeable layer that would result in a perched water table. Only during an infiltration event, such as precipitation or leaking pond/waste cell, do field-saturated conditions develop.

Because the results of this study are compared to precipitation events, a review of the infiltration process, and a discussion of the parameters that effect infiltration are included. Some assumptions are applied to the experiment and its qualitative analysis. There are four components to precipitation once it reaches the ground. *Interception* occurs when vegetation stops the precipitation from reaching the ground causing evaporation rates to be higher than otherwise. This effect is of more concern in wooded areas and higher grasses, unlike the WAG 3 study area. *Evaporation*, from ground or plant surface, is the phenomena of the water molecules changing from a liquid to gas and transferring back into the surrounding air. Small puddles and surface depressions are classified as a *depression storage* because of their capacity to temporarily store water that is released once they are full, spilling the water to the surrounding area. *Infiltration*, the pathway of greatest concern, is the act of the water percolating through the rock, soil, or combination of the two. A final phenomena of precipitation results when the first three components have been satisfied and the infiltration capacity has been exceeded, *surface runoff*.

A saturated hydraulic conductivity test is based on Darcy's Equation for saturated flow, which assumes saturated homogenous flow. Additional assumptions of the test include:

- the movement of water into the soil is one-dimensional, downward;
- equipment effects are minimal and can be disregarded;
- the pressure of the soil gas does not impede the downward flow of the wetting front;
- the wetting front is distinct;
- dispersion of clays in the surface layer of fine-grained soils is insignificant; and
- the soil is nonswelling or its effects are minimal.

The double-ring infiltrometer procedure consists of using two concentric rigid rings at a ratio of 2:1 driven into the soil and partially filling the rings with a liquid of known density, temperature, pH, and viscosity—in this case, water. Once filled, a constant water level is maintained in the inner ring. The purpose of the outer ring is to promote one-dimensional, vertical flow beneath the inner ring. The volume of water that is added to maintain the constant level is the volume of water that infiltrates the soil for each time interval (i.e., infiltration rate). This volume is then converted to an incremental infiltration velocity and plotted against elapsed time. The maximum steady state or average incremental infiltration velocity is equivalent to the infiltration rate; and, the minimum rate at which a soil, in a saturated condition, can absorb water is generally termed the infiltration capacity of the soil. The rate that soil absorbs precipitation is a function of its transmissibility. Infiltration is controlled by surface conditions, whereas the transmissibility is controlled in part by characteristics such as porosity, permeability, grain size, material type, etc. The transmissibility is the rate at which water moves through the soil, vertically or horizontally.

2.3.3 Infiltrometer Construction and Test Procedures

The bottom of the outer ring was set at approximately 15 cm bgs and the inner ring was set at approximately 12 cm bgs. The outer ring was placed deeper to maximize the unilateral flow effects against the water in the inner tube. Due to the extremely dry conditions of the test sites (rainfall for August through September was approximately 0.3 in., resulting in exceptionally hard ground), the rings were not driven into the surface; rather, a narrow trench was excavated. The trench was then filled with an extremely viscous grout mixture and the rings were placed into the trenches. A ring-to-ground seal was ensured before adding water by tamping the grout against the rings and allowing the grout to set for at least 12 hours. Water was supplied to the rings via two mariotte tubes (graduated cylinders with stopcocks and vented top caps).

Before the experiments began, area and volume measurements of the inner ring, the annular space of the rings, and the mariotte tubes were determined along with the existing weather conditions. Each mariotte tube was filled and capped before water was added to the rings. Water was added to the outer ring first, which promotes a subsurface water dam for the water added to the inner tube, so that infiltration can occur immediately upon adding the inner ring water. For each site, the water level was maintained at approximately 15 cm and the tests were performed for a period of 8 hours. Water level measurements were taken every 15 minutes during the first hour, 30 minutes for the second hour, then hourly for the remainder of the test. The shorter intervals at the beginning are to allow for the accelerated infiltration that can occur as the soils saturate. As the soils approach field saturation, the infiltration rate decreases.

During testing in conditions that favor evaporation, the rate of evaporation needs to be measured and the infiltrometer needs to be configured to minimize the evaporation at less than 20%. This can be accomplished by placing a semi-airtight lid that covers both rings. The water level was maintained by continuously monitoring the ring water levels and manually adding the water via the stopcocks. Once a fairly constant infiltration rate was achieved, the flow rate of the mariottes was adjusted to equalize the infiltration rate and the rate at which water was added to the rings.

2.3.4 Calculations

The following equation was used for calculating the incremental infiltration rate (V_{ir}) at each site. As stated before, the objective is to convert the volume of liquid used during each measured time interval into an infiltration rate which can then be compared to the field-saturated hydraulic conductivity of the soils.

$$V_{ir} = \Delta V_{ir} / [(A_{ir})(\Delta t)]$$

where,

V_{ir} = inner ring incremental infiltration rate (cm/hour),
ΔV_{ir} = inner ring volume of liquid used during time interval from mariotte tube (cm^3),
A_{ir} = area of inner ring (cm^2),
Δt = time interval (hour).

Due to the influences of the vegetation, often a vegetation parameter and growth index (GI) are added to allow for these interferences. This is demonstrated in use of the Holtan model for determination of the infiltration capacity (infiltration rate):

$$f = GI\,(aS_a^{1.4} + f_c)$$

where,

f = the infiltration capacity (in./hour),

GI = Growth index which has been developed by expressing experimental data on daily evapotranspiration for several crops as a percentage of the annual maximum daily rate,

a = the vegetation parameter in relation to the available storage connected to the surface as a function of root density,

S_a = available storage in the surface layer in inches of water equivalent,

f_c = the constant rate of infiltration after long wetting (in./hour).

The data analysis is based on the assumption that minimum infiltration rates prevail for the duration of the rain event. In actuality, the infiltration rate varies according to rainfall rates and soil conditions. For an adequate discussion and analysis of the acquired data, the soil at each test site has to be sufficiently described and placed into a specific category based on its lithologic characteristics and the qualitative infiltration rates as determined from the infiltrometer tests. These four soil groups have been pre-determined by the Soil Conservation Service. *Group A soils* have a high infiltration rate, even when saturated, with the minimum infiltration rate range from 0.3 to 0.5 in./hour. These soils mainly consist of well to moderately well-drained sands and gravels and they normally have a high transmission rate. *Group B soils*, with a moderate infiltration rate and minimum rate in the range of 0.15 to 0.3 in./hour, mainly consist of moderately well to well-drained, fine to moderately coarse texture and include the sandy loams and shallow loess. *Group C soils* have minimum infiltration rates in the range from 0.05 to 0.15 in./hour and consist of a layer that impedes downward movement of water. They have a moderately fine to fine texture and are commonly the clay loams, shallow sandy loams, soils low in organic content and high in clay content. They also have low transmission rates. The final group, *Group D soils* have a high runoff potential as having very low infiltration rates, minimum range of 0 to 0.05 in./hour. These soils mainly consist of clay soils.

Applicable Procedures

ASTM Procedure D 3385-94, "Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer." Annual Book of ASTM Standards, Vol. **04.08**, pages 326–332.

ASTM Procedure D 5093-90, "Standard Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer with a Sealed-Inner Ring." Annual Book of ASTM Standards, Vol. **04.08**, pages 86–91.

ASTM Procedure D 5126-90, "Standard Guide for Comparison of Field Methods for Determining Hydraulic Conductivity in the Vadose Zone." Annual Book of ASTM Standards, Vol. **04.08**, pages 99–108.

2.4 CONE PENETROMETER TESTS

A cone penetrometer test (CPT) system was employed at each of the WAG 3 SWMUs. The CPT data were collected to help characterize the UCRS hydrogeology and to pick potential groundwater sampling points for the subsequent drilling to be performed at each SWMU [direct push technology (DPT), dual-wall reverse circulation (DWRC), hollow stem auger (HSA), and angled HSA]. The data results are included in Chaps. 3 and 4. The CPT logs are contained in Appendix D.

2.4.1 Cone Penetrometer System

A 24-ton mobile hydraulic CPT system was employed to determine hydrogeologic characterization of the overburden lithology at selected sites. The CPT logs were reviewed to aid in the selection of sample intervals designated for the collection of subsurface soil and water samples. A total of six CPT boring locations was completed—three in SWMU 4, two in SWMU 5, and one in SWMU 6 (Table 2.4). During the WAG 3 investigation, the conductivity/piezocone was used to provide a digital signal for in situ inference of permeability, conductivity, and soil type. The entire system is mounted in a dual-axle truck containing all system components including recording, processing and printing devices, power take-off hydraulic rams, and downhole equipment (samplers, rods, and drive tips). For each location, the cone penetrometer was pushed using the dual hydraulic system (45,000 lb of downward force and 53,000 lb of pulling force) until refusal or the predetermined depth.

The cone penetrometer provided electrical readouts of cone-point resistance and sleeve friction of subsurface materials to aid in the identification of soil types. In addition, electrical conductivity was measured for pore water calculations. These values were recorded at a constant rate of 2 cm/s. A fourth measurement, rod inclination, was recorded during each downhole survey. Although not used for the direct inference of the soil lithology, the inclination of the boring was used to correct the tip stress measurement and guide the operator in keeping the rods in a vertical position. The data were transmitted via a cable inside the rod string as an analog signal to the on-board processor and archived for later use. Upon completion of the CPT survey at each location, the hole [less than 2 in. inside diameter (I.D.)] was grouted from the bottom up using a pressure grouting technique with tremmie pipe.

2.4.2 Stratigraphy Determination

From the recorded corrected tip stress/resistance (q_c) and sleeve friction (f_s), the friction ratio (f_r) provides the greatest interpretive tool to determine the relative amounts of clay, silt, sand, and gravel. The unit is equally capable of determining mixtures of these four basic soil types as well. In general, as the tip resistance decreases, the effective clay content increases. Between the two f_r endpoints, soils are mixtures of clayey-sands to silty-clays relative to the calculated f_r value. From the numerous surveys, the UCRS is generally comprised of silty-sandy clays with silty sand lenses. There is also a fairly compact sandy gravel layer, which appeared at about 15–20 ft bgs. When encountered, the cone was unable to penetrate the top of the terrace (gravel zone).

2.5 MEDIA SAMPLING

Sampling of surface soil, subsurface soil, and groundwater was conducted at various points throughout each SWMU. The specific details of the sampling methods and the equipment employed to collect the samples are described below. Maps showing the sampling points are in Chap. 3.

2.5.1 Surface Soil Sampling

Twenty-five surface soil samples were collected in WAG 3. In accordance with PGDP EMEF Procedure PTSA-4201, "Surface Soil Sampling," the uppermost 12 in. of soil was sampled as follows: first, the surface vegetation was removed from the sampling location, and then a stainless steel hand auger (3 in. I.D.) was used to obtain the required amount of sample material. Hand augers are designed to collect surface and shallow subsurface soil samples and are applicable to a variety of soil conditions including sand, silt, and clay.

VOA samples were collected from approximately 6 in. bgs. VOA collections required a precleaned 10-cc syringe. The tip was removed from the syringe and pressed into the bottom of the boring, which resulted in soil being forced into the syringe. Then the syringe was withdrawn from the hole and approximately 4 cc of soil were extruded into two 40-mL vials containing equal amounts of deionized water and hexane. A second VOA sample was collected for the off-site laboratory from the same immediate sample section. The soil was placed directly into an unpreserved 4-oz., septum top, wide-mouth jar. The jar was filled to the top and packed tightly to ensure no headspace. The remaining sample material was placed in a clean stainless steel bowl, homogenized, and prepared in accordance with PGDP EMEF Procedure PTSA-4204 IAD, "Composite Sample Preparation." Upon completion of sampling, the hole was backfilled with grout.

2.5.2 Subsurface Soil Sampling Methods

Subsurface soil samples were collected in accordance with PGDP EMEF Field Operating Procedure (FOP) PTSA-4202-IAD, "Subsurface Soil Sampling." Before the collection of the samples, each site was prepared by covering the ground under the entire drilling truck and the sample preparation area with a 6-mil plastic sheet. Exclusion and construction zones were installed at the perimeter of the plastic cover.

Soil samples were placed in prelabeled containers and sealed. The outer surface of the container was cleaned, scanned, and affixed with a radiological label to identify the outer radioactivity level of the container. The containers were secured with a custody seal and inserted into zippered plastic bags before being packed in an insulated cooler. The cooler contained ice to maintain a 4°C (±2°C) temperature.

The first samples collected were for VOAs. Approximately 4 cc of soil were placed into each 40-mL vial, which contained an equal amount of deionized water and hexane. In addition, a second VOA sample was collected and placed into an unpreserved 4-oz., septum top, wide-mouth jar. The remaining sample material was placed into a clean stainless steel bowl, homogenized, and prepared in accordance with PGDP EMEF Procedure PTSA-4204 IAD, "Composite Sample Preparation." Lithologic interpretation was completed concurrently with sample preparation following PGDP EMEF Procedure PTSA-1203, "Lithologic Logging." Lithologic logs of all the borings are contained in Appendix E.

2.5.2.1 Direct push technology

UCRS subsurface soil samples were collected using DPT. The DPT allows a discrete interval of soil to be obtained and a water sample to be extracted from a specific depth. DPT sampling produces a minimal amount of investigation-derived waste (IDW) compared to other methods. Samples obtained by this method are noted throughout this report with the prefix "DPT."

The DPT equipment for WAG 3 was a truck-mounted unit. Samples were extracted from the subsurface by a 30- by 1.5-in. I.D. sampler with a removable acetate liner. Table 2.5 details the DPT soil sampling conducted in WAG 3. The sampler was comprised of a stainless steel outer barrel with cutting edge, drive-tip piston assembly, drive-tip sleeve, and removable liner. The sampler was pushed into the ground with the piston assembly in the locked position. At the desired depth interval, the piston assembly spring would be released, and the sample push continued. The piston assembly would move up inside the liner and outer barrel with the liner being filled with soil. Once the sampler was filled, it was extracted from the boring, and the liner containing the sample was removed.

2.5.2.2 Hollow stem auger/angled hollow stem auger

The HSA/angled HSA was used to retrieve soil samples for chemical and geotechnical analyses (Table 2.6). The HSA provides a fast means of advancing a borehole through many types of soil while still collecting samples. Samples obtained by this method are noted throughout this report with the prefix "HSA" or angled HSA. For soil borings, a 4.5-in. I.D. auger (5-ft lengths) was advanced with a center drag bit. When the specified depth was reached, the center bit/rods were removed, and a sample was collected using a 3-in. by 30-in. split spoon with a plastic liner. The spoon was advanced using a 140-lb hammer with a 30-in. drop. Upon retrieval of the split spoon, the sample was field screened for total beta and volatiles. The liner was split, and the VOA samples were removed. The remaining samples were homogenized and packed in accordance with PGDP EMEF Procedure PTSA-4204 IAD, "Composite Sample Preparation." Upon completion of the last sample, the bit and rods were removed and 1-in. polyvinyl chloride (PVC) tremmie pipe lowered for grouting. The grout was a high-suspended solids (30%) bentonite matrix mixed to achieve a weight of between 10 and 11 lb/gal.

2.5.3 Groundwater Samples

A total of 114 groundwater grab samples was collected by three methods during the WAG 3 RI. For the collection of deeper samples (RGA and McNairy), DWRC drilling was used. The majority of shallow UCRS groundwater samples were obtained by DPT or angled HSA; however, a limited number of UCRS samples were acquired via DWRC drilling. For RGA, grab samples were attempted at 5-ft intervals throughout its entire thickness. Also, grab samples were usually attempted at two intervals in the UCRS and one interval in the upper part of the McNairy Formation. The purpose of these samples was to obtain a vertical profile of groundwater contamination. A single groundwater sample was collected for each DPT borehole, usually at terminal depth. Groundwater collected for metal analysis was submitted as unfiltered after having been filtered with 0.5- and 0.045-micron filters. All other analyses were conducted on unfiltered samples only.

2.5.3.1 DWRC drilling and groundwater sampling

DWRC drilling was used to drill 11 borings during the WAG 3 investigation. The total depth of the borings ranged from 100 to 160 ft. Groundwater samples were collected from multiple water-bearing zones during the drilling of each borehole. Samples obtained by this method are noted throughout this report with the prefix "SB." Table 2.7 displays the DWRC groundwater samples collected.

Reverse circulation drilling uses dual-wall pipe, top drive rotation, and a side inlet for injecting air in a closed, recirculating system. The drilling fluid (air) is injected through the side inlet swivel and down between the outer pipe and inner pipe of the dual tube drill system. The air and cuttings are directed to the center of the drill bit and then forced to the surface through the inner pipe at a very high velocity. The cuttings are discharged into a sampling cyclone where air is removed and velocity dampened. The cuttings are then collected and described by the rig geologist.

A Schramm T450W Rotadrill truck-mounted drill rig was used for the DWRC borehole drilling. The dimensions of the rods and bit were as follows: 1.75-in. I.D. for the inner rod, 4-in. I.D. for the outer rod, and a 5.25-in. tricone roller bit. The borings were advanced using 20-ft and 5-ft lengths of pipe. Soil cuttings were shoveled from the discharge tub (where they were collected after being discharged through the cyclone separator) into 55-gal drums. Water was pumped from the trough into a 1200-gal tank at the end of each day, or as needed during the day. The IDW (soil and water) was then transported to the waste management facility.

Upon achieving total depth, the borehole was logged (gamma ray and neutron) in both the descending and ascending directions (see Sect. 2.6). The borehole was then grouted to surface using a high solids grout (Pure Gold—30% solids) with a weight between 10 and 11 lb/gal.

The primary purpose for drilling the boreholes was to collect groundwater samples. A casing was continuously advanced during DWRC drilling, leaving only the bottommost portion of the formation open. Cuttings and formation fluids were then flushed up the drill string to a cyclone separator at the surface. This type of drilling reduces the potential for cross-contamination because samples are acquired from a limited portion of the aquifer and drilling discharges do not contact the annulus as they exit the borehole.

Once a sampling zone was identified, a pump was lowered to the bottom of the hole. Purging and sampling were completed using a QED Well Wizard™[1] bladder pump. The use of these pumps allowed low-flow-rate purging and sampling, which significantly reduces the turbidity of the sample. Selected water quality parameters including pH, temperature, and specific conductivity were monitored during purging and sampling using a Hydac™[1] or Horiba™[1] water quality meter. Purging was discontinued when (1) pH stabilized to within 0.50 unit, (2) specific conductivity stabilized to within 10% (µmhos/cm), and (3) temperature stabilized to within 1 °C. Upon stabilization of the parameters, the flow rate was adjusted to approximately 100 mL/min for sample collection. In some cases, the flow rate had to be increased slightly (up to 200 mL/min) to maintain consistent flow.

---

[1] Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

All samples were collected directly from the pump discharge line into appropriate containers. For intervals with very slow recharge rates, purging could not be completed. After the groundwater samples were containerized, a site safety professional scanned the container in the field using a direct-measure radioactivity meter, wiped the container, and compared the readings against the free release criteria. A label was secured with tape, and the container was placed in a resealable plastic bag. The bags were then packed in ice within coolers and kept at a temperature of 4°C (±2°C).

2.5.3.2 DPT groundwater sampling

A DPT rig was used to collect 23 UCRS groundwater samples for the WAG 3 RI (Table 2.8). Samples were collected in accordance with PGDP EMEF FOP PTSA-4303-IAD, "Groundwater Sampling." The sampling tool dimensions were 30-in. by 0.5-in. outside diameter (O.D.) with 0.004-in. vertically slotted screen. Water samples were collected with a stainless steel bailer capable of collecting approximately 200 mL.

In most instances, a groundwater sample was obtained at the terminal depth of the DPT boring after all soil samples had been collected and the boring had achieved a static water level. Grab samples would be attempted in the lower portion of the UCRS (greater than 35 ft bgs) if a saturated coarse sand was observed in the soil sample. If no sand was present at terminal depth, a 5-ft 0.010-slotted PVC screen and riser (1.25-in. O.D.) was set to allow later sampling. Sampling of these well points was normally within 48–72 hours. Temporary well points were not constructed with sand pack, bentonite seals, or grout.

All sample bottles were cleaned and dried, surface scanned for radioactivity, custody sealed, affixed with a radioactivity screening label, placed in individual zippered baggies, and placed in an ice-filled cooler for temporary storage after collection of the sample as described.

2.5.4 HSA/Angled HSA Groundwater Sampling

The HSA and angled HSA were used to collect UCRS groundwater samples for this investigation. During drilling, a 4.5-in. I.D. auger was advanced to the targeted depth for groundwater collection. If groundwater was present in sufficient quantities, then a 2-in. stainless steel bailer was lowered into the borehole and the groundwater sample was collected. The HSA/angled HSA groundwater samples collected are shown in Table 2.9.

2.6 BOREHOLE GEOPHYSICAL LOGGING

Borehole geophysical logs, consisting of natural gamma and compensated neutron density, were run in each RGA/McNairy boring through the drill pipe. The geophysical logs were run in both down-hole and up-hole directions for quality assurance (QA). The borehole geophysical logs are included in Appendix F.

2.6.1 Natural Gamma Radiation

Gamma logging of a borehole is a passive measure of the natural radiation of rocks and soils. The down-hole gamma-ray measurement allows the differentiation between clay and other lithologies by using the natural occurrence of potassium-40, uranium-238, and thorium-232 in the shales. A clay or clayey sand can be distinguished from a clean sand because of the higher gamma-ray emissions of those radioisotopes in the shale component. Measurements are usually made with a Geiger-Mueller (GM) counter, and the results depend on:

- Radioactivity of surrounding formation
- Borehole diameter
- Type of drilling fluids
- Type and thickness of casing
- Position of probe in hole (centered)

The interpretation of the results is on a qualitative basis and is primarily used to aid in the determination of where sand, as opposed to clay, is the dominant constituent.

2.6.2 Neutron Logging

Neutron logging is used for the determination of soil or rock porosity and water content. It is also used to provide a water level measure. A neutron probe contains a radioactive source and a detector. Neutrons emitted from the source are slowed and scattered by the collision with hydrogen nuclei. Once slowed, neutrons are captured by the nuclei. Because hydrogen atoms exist in the soils and rock predominantly as moisture or free water in open pore spaces, an increase in the amount of water is correlated to an increase in the number of neutrons that have been captured by the hydrogen atoms. Rocks with a higher saturated porosity will have a lower neutron count than low-porosity soils/rocks. When logged above the water table, results are indicative of lower soil moisture, not saturated porosity.

2.7 ANALYTICAL METHODS

During the analytical program for the WAG 3 RI, the following laboratories were used:

- Close Support Laboratory (CSL) located on-site equipped with four gas chromatographs (GCs), one each for screening soil and groundwater samples for TCE and its degradation products (VOAs), one for screening soil and groundwater samples for SVOAs, and one for screening soil and groundwater samples for polychlorinated biphenyls (PCBs) (ONSITE Environmental Laboratories, Inc., Freemont, California).

- CSL located on-site equipped with a gas proportional radioactivity counter for gross alpha and gross beta screening of soil and water samples, a gamma spectrometer for gamma screening of soil, and a liquid scintillation counter for technetium-99 screening of water (Paragon Analytics, Inc., Ft. Collins, Colorado).

- Fixed-base laboratories for soil and groundwater samples (USEC Portsmouth, Ohio, laboratory; USEC C-710 PGDP laboratory; and IT-Middlebrook, Knoxville, Tennessee, laboratory).

- Fixed-base laboratory for geotechnical samples (Southwest Research Institute, San Antonio, Texas).

The CSLs were demobilized in October 1999, while the final HSA investigations were being conducted. After demobilization of the CSLs, all radiological and organic sample analyses were conducted at the fixed-base laboratories.

COPCs associated with various SWMUs investigated in the WAG 3 RI were compiled in the WAG 3 RI Work Plan (DOE 1998a) based on the results of previous investigations (Table 2.10). The process by which previous sampling results were used to develop the list of COPCs at each SWMU is outlined in Chap. 6 of the WAG 3 RI Work Plan. Narrative discussions and/or tabulated results of previous sampling, method detection limits (MDLs), and applicable screening parameters used during the screening process for each WAG 3 SWMU are provided in Sects. 6.1, 6.2, and 6.3 of the WAG 3 Work Plan.

CSL screening techniques permitted quantitative measurement of contaminant levels with near fixed-base sensitivity, while reducing turnaround time to help guide the field sampling effort and also reducing the overall cost of field and analytical services for the WAG 3 RI. In particular, field screening was relied upon to assess the presence of TCE and its degradation products, SVOAs, radionuclides, and PCBs. An on-site GC, using a modified version of the current SW-846 8021 method for VOAs (SW8021B), was used to perform field screening for TCE and its degradation products. Soil samples were analyzed for TCE and its degradation products using a hexane extraction preparation method, followed by direct injection of the hexane extract into a GC with electrolytic conductivity and photoionization detection in sequence. Water samples were analyzed on a separate GC, using standard purge and trap sample introduction, and sequential electrolytic conductivity and photoionization detection, as specified by the SW8021B method. An on-site GC equipped with a mass spectrometer (MS) detector using a modified version of the SW-846 8270 method for SVOAs (SW8270C) was used to perform field screening for SVOAs. An on-site GC, using a modified version of the SW-846 8082 method for PCB analysis (SW8082), was used to perform field screening for PCBs. A low-background, gas-flow, proportional analyzer was used to perform field screening for gross alpha and beta activities. A liquid nitrogen-cooled, high-purity germanium (HPGe) detector and multichannel analyzer were used to perform field screening for gamma activity. A liquid scintillation counter was used to perform field screening for technetium-99 activity.

Results of field laboratory radiological screening were used to implement the radiological analysis procedures found in Sect. 5.11.1 of the WAG 3 RI Work Plan (DOE 1998a), until the field radiological screening laboratory was demobilized during the investigation of SWMU 4. These procedures represented a radiological screening process for soils and water developed by DOE with input and concurrence from the regulatory agencies involved at PGDP. The procedures called for radiological walkover surveys of all WAG 3 SWMUs, followed by field laboratory screening of soil samples with activities greater than two times background, and field laboratory screening of all water samples to determine the gross alpha to gross beta ratio. All soil samples greater than two times background and all water and sediment samples were to be screened for total uranium by gamma spectroscopy and for gross alpha and beta activity. Gross alpha and beta screening of soil, sediment, and water samples, and gamma spectroscopy screening of soil samples for uranium and daughter isotopes, as well as americium-241, were performed in the field radiological screening laboratory while it was in operation. The fixed-base laboratory performed all water and soil screening analyses for gross alpha and beta activity, and for total uranium required by the WAG 3 RI Work Plan after demobilization of the CSL. Likewise, all soil and water samples were to be screened for technetium-99 in the field radiological screening laboratory, with 10% confirmation by fixed-base laboratory analyses. All water samples were screened for technetium-99 in the field radiological screening laboratory while it was in operation with 10% fixed-base laboratory confirmation; all soil samples were analyzed for technetium-99 by the fixed-base laboratory. After demobilization of the CSLs, soil and water samples were analyzed for technetium-99 by the fixed-base laboratory.

For SWMU 5 only, tritium analyses were required by the WAG 3 RI Work Plan (DOE 1998a) if the gross beta to alpha activity from field laboratory radiological screening analyses exceeded a 2:1 ratio. Three tritium analyses were performed on archived samples collected during the WAG 3 RI (all non-detects). However, only six samples collected (three water and three soil samples) had gross beta and alpha results that exceeded the threshold ratio. None of the samples where the 2:1 ratio was exceeded had individual gross alpha or beta activities, which exceeded the threshold criteria for further speciation analyses, as explained below. In addition, for the soil analyses, only one of the gross beta results slightly exceeded twice the calculated beta background [41.4 pCi/g versus 38.2 pCi/g (19.1 pCi/g × 2)]. For this sample, when the technetium-99 result is added to the background activity of other beta-emitting radioisotopes that have been detected at PGDP, the observed gross beta activity is almost completely accounted for (41.4 pCi/g versus 38.5 pCi/g). Beta-emitting radioisotope background values were taken from the appropriate tables in the previously reported background study, *Background Levels of Selected Radionuclides and Metals in Soils and Geologic Media at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 1997). No similar background values for groundwater were available for comparison with the three groundwater results where the 2:1 ratio was exceeded. However, all gross beta results for these groundwater samples were less than 20 picocuries per liter (pCi/L), with the accompanying technetium-99 results appearing to account for the observed gross beta activity in each sample.

According to the procedures for radiological analyses presented in Sect. 5.11.1 of the WAG 3 RI Work Plan (DOE 1998a), if the ratio of alpha to beta activity was determined during field laboratory screening to be less than 3:1, further fixed-base speciation analysis was not required, and samples collected for this purpose were not to be analyzed. However, as the field investigations for the WAG 3 RI and the concurrent WAG 28 RI and the WAG 8 site evaluation progressed, few samples exhibited a gross alpha to beta ratio in excess of 3:1, even while having significantly high gross alpha and/or beta activity. As a result, it was decided to capture additional speciation data on these samples with significant activity, particularly water samples with exceedances of the Kentucky Department of Environmental Protection (KDEP) criteria for speciation analysis of groundwaters due to alpha activity (15 pCi/L). Therefore, as for the concurrent WAG 28 RI and the WAG 8 site evaluation, speciation analysis thresholds of 15 pCi/L gross alpha activity in groundwater samples and 50 pCi/g gross alpha or beta activity in soil samples were established and used for the remainder of the project. For all samples that exceeded any of these established thresholds, fixed-base speciation analyses were also conducted. Fixed-base speciation analyses included gamma and alpha spectroscopy. These analyses were used to provide radionuclide-specific data for samples which exhibited screening activities indicative of the potential presence of anthropogenic radiological contaminants from PGDP operations.

In addition, a minimum of 10% of the total number of samples (by matrix) were split and submitted to a fixed-base laboratory for analysis. These samples provided definitive data to confirm the results from the CSL screens. A separate sample aliquot was collected from each sample interval scheduled for fixed-base laboratory analysis. This sample aliquot was analyzed at the CSL radiochemistry laboratory, where it underwent radiation screening to facilitate proper U.S. Department of Transportation (DOT) shipment to the off-site laboratories. A wipe sample also was collected from the exterior of each sample container in the field. The WAG 3 RI sample shipping team determined whether the samples could be shipped off-site for analysis based on field wipe sample results and radiological screening sample results compared to the DOT-, International Air and Transportation Association (IATA)-, and DOE-specified limits. The project DOT shipping specialist also prepared the shipment in accordance with DOT and IATA regulations for shipment of dangerous goods, if warranted.

2.7.1 Close Support Laboratory Methods

Two CSLs were mobilized to field screen soil and groundwater samples. The samples were analyzed for:

- VOAs (TCE; cis- and trans-1,2-dichloroethene; 1,1-dichloroethene; vinyl chloride)
- SVOAs [current Contract Laboratory Program (CLP) Target Compound List (TCL) analytes]
- PCBs (Aroclors-1016, -1221, -1232, -1242, -1248, -1254, -1260)
- Gross alpha and gross beta activity
- Gamma activity (americium-241, uranium-235, thorium-234, protactinium-234m, cesium-137, cobalt-60, soils only)
- Technetium-99 activity (water only)

2.7.1.1 Methods and equipment

Table 2.11 indicates the types of analyses performed in the CSLs.

2.7.1.2 CSL VOA analysis for soil samples (hexane extraction)

One photoionization detector (PID)/electrolytic conductivity detector (ELCD)-equipped Hewlett-Packard HP5890 Series II GC was used to analyze VOAs in soil samples. A modification of the current version of the SW8021B method was used for these analyses. Decontaminated, non-sterile syringes (with ends cut off) were used to transfer an approximately 5-g aliquot of undisturbed soil from the sampling sleeve (soil core) to a 40-mL vial containing 5-mL deionized water and 5-mL hexane. The hexane extracts the VOAs from the soil/water solution. In the laboratory, surrogate-spiking solution was added to the hexane layer, and a syringe was used to sample the hexane layer in the vial. The hexane, along with the VOAs dissolved in it, was directly injected into the GC for analysis.

2.7.1.3 CSL VOA analysis for water samples

One PID/ELCD-equipped Hewlett-Packard HP5890 Series II GC was used to analyze VOAs in water samples. An OI Analytical Discrete Purging Multisampler (Model DPM-16) was used to conduct purge and trap sample introduction of aqueous samples for VOA analyses. A modification of the current version of the SW8021B method was used for these analyses. The method utilizes the purge and trap process as a sample introduction technique (SW5030B) for water samples. The purge was performed with a flow of helium through samples of water, followed by collection of the halogenated volatile organics in a multiple-phase sorbent trap at ambient temperature. After the purge cycle was completed, the trap was heated and backflushed, desorbing all trapped compounds into a GC column. GC analysis allows separation of these compounds from either the hexane extract or the desorbed trap, and detection with the ELCD and the PID. Quantitative analysis was achieved by comparison of sample values with standard values.

2.7.1.4 CSL SVOA analysis for water and soil samples

One Hewlett-Packard HP5890 Series II GC was equipped with a Hewlett-Packard HP5972 MS detector and used to assess levels of SVOAs in water and soil samples. A measured volume of aqueous sample, usually 1 L, at a specified pH (acidic or basic), was serially extracted with methylene chloride by using a separatory funnel. The extract was dried, concentrated, and, as necessary, exchanged into a solvent compatible with the cleanup or determinative step to be used. For soil samples, a 30-g sample was mixed with anhydrous sodium sulfate to form a free-flowing powder. This was solvent extracted using sonication. The extract was separated from the sample by vacuum filtration or centrifugation. The extract was then ready for cleanup and/or analysis following concentration. The analytes were then introduced into the GC/MS system by injecting the extract onto a narrow bore fused silica capillary column. The GC was temperature programmed to separate the compounds before detection by an MS, which was used to provide both qualitative and quantitative information. Quantitation was achieved by comparing the response of a major (quantitation) ion relative to an internal standard using a five-point calibration curve.

2.7.1.5 CSL PCB analysis for water and soil samples

Two Hewlett-Packard HP5890 Series II GCs were equipped with halogen-sensitive electron capture detectors (ECDs) and used to assess levels of PCB contamination in soil and water samples. One instrument served as a qualitative confirmation instrument, with a different column than the primary instrument used for quantitation. Water and soil samples were prepared similarly as for SVOA analysis, except that hexane was used for the extraction solvent. The samples were then introduced into the GC/ECD system by injecting the extract onto a narrow bore fused silica capillary column. The GC was temperature programmed to separate the compounds before detection by the ECD, which is used to provide both qualitative and quantitative information. Quantitation is achieved by comparing the response of the ECD on the column to a five-point curve response. A second instrument with a different column is used to analyze all positive result extracts for qualitative confirmation of Aroclor species.

2.7.1.6 CSL radiological analysis procedures

When appropriate for the sample matrix, SW-846 methods were used. When SW-846 methods were not available or not appropriate, other nationally recognized methods such as other EPA, DOE, and ASTM methods were used. The following procedure manuals were used as references for radiological analysis:

- *Prescribed Procedures for Measurement of Radioactivity in Drinking Water*, EPA-600/4-80-032 (EPA 1980)

- *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, SW-846 (EPA 1986)

- *Radiochemistry Procedures Manual*, Eastern Environmental Radiation Facility, EPA 520/5-84-006 (EPA 1984)

- *Environmental Measurements Laboratory Procedures Manual*, HASL-300 (DOE 1982).

Gross alpha and gross beta assessments were performed using a Tennelec Series 5 Low Background Gas Proportional Counter.

Gamma activity was assessed in soils using a liquid-nitrogen cooled HPGe detector linked to an analog to digital converter (ADC) and stored in a multichannel analyzer (MCA). The stored MCA data are interpreted by a complex software program, generating results in units of radioactivity per unit sample volume.

Technetium-99 activity was assessed in water samples by filtering the water through 3M Empore Technetium Rad disks, then rinsing with deionized water to eliminate possible tritium presence, and counting on a liquid scintillation counter using a window determined by analysis of standards.

2.7.1.7 CSL data qualifiers

The following data qualifiers were used for CSL results reporting:

A. Organic Analyses

U	Indicates compound was analyzed for but not detected.
J	Indicates a sample concentration value less than the reporting limit, but above the MDL.
E	Identifies compounds whose concentrations exceed the calibration range of the GC/MS instrument for that specific analysis.
D	Identifies all compounds in a reanalysis previously identified in an analysis at a lower dilution factor.

B. Radiological Analyses

U or A	Indicates compound was analyzed for but not detected.

2.7.1.8 Analytical methods, sample containers, and preservation requirements

Table 2.12 indicates the analytical methods and sample requirements for CSL analysis.

2.7.2 Fixed-Base Laboratory Methods

The USEC Portsmouth laboratory; IT-Middlebrook, Knoxville, Tennessee, laboratory; and the USEC C-710 laboratory performed fixed-base laboratory analyses of soil and groundwater samples. These laboratories were contracted through the DOE Oak Ridge Operations (ORO) Sample Management Office (SMO) and are DOE-approved, Nuclear Regulatory Commission-licensed laboratories. SW-846 methods were used for all samples, except those parameters for which other methods are necessary. The analysis followed SW-846 protocols, and "Forms Only" data packages were provided along with electronic data deliverables (EDDs). Table 2.13 summarizes the analytical methods, sample container, and preservation requirements for the fixed-base laboratory analyses. Filtered and unfiltered analyses were performed on metals only. All other analyses were performed using unfiltered samples.

Analyses of two inorganic analytes, lithium and total strontium, were supplied during the WAG 3 RI; however, these metals were not identified as COPCs and are not part of the CLP Target Analyte List (TAL) proposed in the WAG 3 RI Work Plan (DOE 1998a). The analyses were supplied when the laboratory scope of work specified SW-846 methods. In a similar manner, boron was included in the reported analytical results for the historical data.

Fixed-Base Laboratory Data Qualifiers

The following data qualifiers were used for fixed-base laboratory results reporting:

Inorganic Analysis

B	This flag is used when the analyte is found in the associated blank as well as in the sample.
U	The analyte was analyzed for but not detected.
J	Indicates an estimated value.
E	The reported value is estimated because of the presence of interference. An explanatory note must be included under comments on the cover page (if the problem applies to all samples) or on the specific Form I-in (if it is an isolated problem).
M	Duplicate injection precision was not met.
N	Spiked sample recovery was not within control limits.
S	The reported value was determined by the method of standard additions (MSA).
W	Postdigestion spike for furnace atomic absorption analysis is out of control limits (85–115%), while sample absorbance is less than 50% of spike absorbance.
X	Other specific flags may be required to properly define the results.
*	Duplicate analysis was not within control limits.
+	Correlation coefficient for the MSA is less than 0.995.

Organic Analysis

U	Indicates compound was analyzed for but not detected.
J	Indicates an estimated value. This flag is used under the following circumstances: (1) when estimating a concentration for tentatively identified compounds where a

1:1 response is assumed and (2) when the mass spectral and retention time data indicate the presence of a compound that meets the pesticide/Aroclor identification criteria, and the result is less than the contract-required quantitation limit but greater than zero.

P	This flag is used for a pesticide/Aroclor target analyte when there is greater than 25% difference for detected concentrations between the two GC columns.
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.
E	This flag identifies compounds whose concentrations exceed the calibration range of the GC/MS instrument for that specific analysis.
D	This flag identifies all compounds identified in an analysis at a secondary dilution factor.
X	Other specific flags may be required to properly define the results.
Y	Indicates matrix spike/matrix spike duplicate (MS/MSD) recovery and/or relative percent difference (RPD) failed to meet acceptance criteria.

2.7.3 Analytical Data Quality

2.7.3.1 Precision, accuracy, representativeness, completeness, and comparability

Precision, accuracy, and completeness objectives for fixed-base laboratory measurements during the WAG 3 RI are presented in Table 8.2 of the WAG 3 RI Work Plan (DOE 1998a). CSL laboratory precision and accuracy objectives are presented in Table 2.14. An assessment of the precision, accuracy, representativeness, completeness, and comparability of field laboratory data measurements and fixed-base laboratory analytical data was performed. The results of this assessment are discussed in the following paragraphs.

Precision

"Precision" is defined as the degree of agreement between repeated (replicate or duplicate) measurements of one property using the same method or technique. Field duplicate samples are collected as a measure of precision of the sample collection and analytical process. In addition, laboratory duplicates, laboratory control sample/laboratory control sample duplicates (LCS/LCSDs), and/or MS/MSDs can be used to measure analytical precision. The RPD between the duplicate sample results is calculated and compared to the appropriate QA objective. For this field program, field duplicate samples were collected for all media at a frequency of 5%. The organic CSL objectives for precision were usually met, with the exception of some very infrequent high RPDs on some semivolatile MS/MSD results. The radiological CSL objectives for precision were always met; however, precision calculations were not performed for duplicate samples with less than 3 times the MDA. Table 2.14 contains summary information on the WAG 3 RI CSL data precision, including average observed RPD information and the CSL RPD limit for each monitored analyte in both water and soil matrices.

Accuracy

"Accuracy" is defined as the degree of agreement of a measurement with an accepted reference or true value. Accuracy of laboratory analyses is estimated through the analysis of blank spikes, matrix spikes, or surrogate spikes. These laboratory quality control (QC) samples are analyzed as required by the appropriate analytical method. The recovery of each spiked analyte is calculated and compared to the appropriate QA objective. The organic CSL objectives for accuracy were usually met, with very few exceptions, mostly on heavily contaminated samples and/or where matrix interference was clearly indicated. The radiological CSL objectives for accuracy were always met. Table 2.14 contains summary information on the WAG 3 RI CSL data accuracy, including average observed spike recovery information and the CSL control limits for each spiked analyte in both water and soil matrices.

Representativeness

"Representativeness" is defined as the degree to which data accurately and precisely represent the nature and extent of contamination. The data collected during the RI were both accurate and precise. The samples required in the WAG 3 RI Work Plan (DOE 1998a) to define the nature and extent of contamination were collected using standardized procedures designed to provide a true representation of the location sampled. Standardized, accepted analytical methods or modified standard methods, using National Institute of Standards and Technology traceable standards, were used to ensure that accurate, reproducible data were generated. Based on these criteria, the data from the WAG 3 RI were deemed representative.

Completeness

"Completeness" is defined as a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained. In this RI, "overall completeness" refers to the percentage of valid measurements versus the total measurements planned. Table 8.2 of the WAG 3 RI Work Plan (DOE 1998a) specified an "overall completeness" objective of 90% for all analyses performed for both soil and groundwater matrices. Overall completeness includes both sampling completeness and laboratory analytical data completeness. Sampling completeness refers to the percentage of samples collected versus the total samples planned. Laboratory analytical data completeness refers to the percentage of non-rejected (i.e., results that can be used for decision-making purposes without supplemental data) analytical results reported by the laboratories versus the total number of results expected.

This RI report includes data from base project samples, which were expected to be collected if possible, and from contingency samples, which were collected only at the direction of the Bechtel Jacobs Company. In the planning stage of the project, these potential contingency samples were "planned" to the extent possible by populating the Project Environmental Measurements System (PEMS) database with all possible contingency sample identifications (IDs), and analysis parameters for each SWMU based on the WAG 3 RI Work Plan (DOE 1998a). Completeness for these samples cannot be discussed in the same manner as the base project samples. Also, for both base project and contingency samples, samples were collected for fixed-base radiological speciation analyses, which were not analyzed unless preliminary field laboratory screening data indicated an exceedance of the threshold criteria. These samples were similar to the potential contingency samples in that they were planned at the beginning of the project in the PEMS database and must also be considered when assessing overall completeness.

Overall, for all analyses, the WAG 3 RI achieved completeness of 57% for the base project. The laboratory analytical data completeness for the base project was 92%. These figures do not consider the fixed-base radiological speciation analyses, which were "planned" but almost all of which were not conducted since the field laboratory screening threshold criteria were very rarely exceeded.

Overall data completeness for soil was 38% for the base WAG 3 RI project; with contingency sample locations included and compared to base project expectations, overall WAG 3 RI soil data completeness was 52%. Even with contingency sample data included in the base completeness calculation, overall completeness objectives for soil were not met for most parameters. WAG 3 RI overall completeness goals were met for permeability and total organic carbon soil data. Soil sampling and overall soil data completeness for technetium-99 was only slightly below the 90% goal at 87% when contingency locations and data were included and compared to base project expectations. VOA soil sampling completeness for fixed-base laboratory Method 8260 analyses was next best at 83% with contingency locations included; however, due to the large number of rejected data, overall VOA fixed-base Method 8260 soil data completeness was only 49%. Including the limited amount of CSL VOA samples and data, overall VOA soil data completeness increased to 52%; however, the CSL only analyzed VOA samples for TCE and its degradation products by the hexane extraction method. Of the remaining soil parameters, the majority had sampling completeness in the 60% to 70% range, with similar overall data completeness, because no data other than fixed-base laboratory Method 8260 soil data were rejected. SVOA sampling and overall soil data completeness was lowest at 51%. The overall soil completeness was affected by sampling difficulties (i.e., broken DPT sampling rods during drilling operations into waste cell areas) and by rejection of 4378 fixed-base Method 8260 VOA data points (34% of the total fixed-base laboratory VOA soil data by Method 8260, and 7.6% of all the WAG 3 soil data) due to gross holding time exceedances. Also due to the early demobilization of the CSL, rejected fixed-base laboratory Method 8260 VOA soil data could not be "confirmed" by CSL field screening data for TCE and its degradation products.

Overall completeness for groundwater was 41% for the base project; with contingency sample locations included and compared to base project expectations, overall WAG 3 RI groundwater data completeness was 46%, as was the case for soil. Even with contingency sample data included in the base completeness calculation, overall completeness objectives for groundwater were not met for most parameters. WAG 3 overall completeness goals were met for chemical oxygen demand, pH, and turbidity data. VOA groundwater sampling completeness for fixed-base Method 8260 analyses was next best at 68%, with contingency locations included. Of the remaining groundwater parameters, sampling completeness was in the 40% to 60% range, with similar overall data completeness. SVOA and cyanide sampling and overall groundwater data completeness was lowest at 42%. Overall groundwater completeness was mostly affected by sampling difficulties (i.e., no groundwater encountered during drilling operations).

Comparability

"Comparability" is defined as the degree of confidence with which one data set can be compared to another. Data collected for this investigation were generally collected according to the WAG 3 RI Work Plan (DOE 1998a) and its Quality Assurance Project Plan (QAPP), and all field changes were approved by Bechtel Jacobs Company. The overall comparability of the data collected in the WAG 3 RI to historical data is good.

The organic CSL screening data generated for the WAG 3 RI, particularly for PCBs, was comparable, although of higher quality than previous organic CSL screening data. This increase in quality is based mainly on the use of surrogates, second source LCSs, and MS/MSDs for all WAG 3 RI organic CSL methods. WAG 3 RI CSL PCB analyses were performed using a GC with ECD detection, providing Aroclor speciation data not obtainable by immunoassay test kits previously used for CSL PCB analyses, and much lower detection limits, in addition to the above-mentioned QC checks.

The use of different gross beta (i.e., strontium-90 versus technetium-99) and gross alpha (i.e., americium-241 versus uranium-238) standards in the radiological CSL for the WAG 3 RI may have had some impact on comparability, both with historical radiological CSL data, and with current and historical fixed-base confirmation data. Differences in the sample preparation techniques used by the WAG 3 RI radiological CSL and the fixed-base laboratories used for the WAG 3 RI and previous investigation radiological CSLs may also have had an impact on current radiological CSL data comparability with both historical radiological CSL data, and with current and historical fixed-base radiological confirmation data.

Since the fixed-base laboratories used similar analytical methodology, there should be an extremely high degree of confidence in the comparability of the current and historical fixed-base definitive data.

2.7.3.2 Surveillances

Bechtel Jacobs Company and TN & Associates, Inc./CDM Federal Programs Corporation (TN&A/CDM Federal) conducted surveillances of the field activities and the CSLs. Surveillances covered the following: CSL activities, sample management activities, log keeping and chain-of-custody documentation, equipment decontamination, waste management activities, sampling activities, implementation of quality-assured data policies, and well installation and development. TN&A/CDM Federal, as requested, corrected the findings from all surveillances. The ORO-SMO conducted laboratory surveillances of the fixed-base laboratories.

2.7.3.3 Data quality objectives

DQOs are qualitative and quantitative criteria used to establish requirements for sample collection and analysis and are based on the intended uses of the data. The overall intent of DQOs is to generate data of appropriate quality to support the assessment of risks to human health and the environment and the selection of remedial actions. DQOs were documented in the approved WAG 3 RI Work Plan (DOE 1998a) and were implemented as documented in the Field Sampling Plan and QAPP.

The DQO process was used to focus the sampling strategy on SWMU-specific media contamination and migration pathways. In addition, this process was used to identify the data requirements for the potential remedial action alternatives.

Decisions to be made during the RI process included a determination of whether releases have occurred and whether remediation of the site will be required. Using risk-based analysis of data generated during the WAG 3 investigation, a determination was made for each of the sites according to the following rules:

- Where no contamination or contamination not presenting unacceptable risk to human health or the environment were found at the site, a determination for no further action was made.

- Where contamination presenting unacceptable risks to human health and the environment was found but the risks were not imminent or immediate, a subsequent feasibility study was performed.

- Where contamination presenting imminent, immediate, unacceptable risks to human health and the environment was found, a determination for implementing interim remedial actions was considered. The interim measures may include institutional controls or temporary stabilization to prevent further contaminant migration and/or degradation.

The results of the DQO process and decision rules analysis are presented in Chap. 7.

2.7.3.4 CSL performance

All data generated at the CSL were of sufficient quality to support the project decision-making process. Detection limits were method- and matrix-specific. CSL reporting packages included sample results, summary information and/or chromatograms/raw instrument output for all QC samples and/or calibrations, chain-of-custody information, sample preparation and run logs, and other supporting documentation and data summaries. Reporting of CSL data conformed to standard SW-846 documentation for each analytical batch by date.

Included in the documentation were initial and continuing instrument calibration performance results, determination of MDLs, identification and quantification of compounds and analytes detected, and laboratory QC sample results. Selected data were conveyed to the data coordinator for direct download into the project database. The lead chemist reviewed results before the data were input into the project database. The following criteria were reviewed to determine acceptability:

- Holding times—All holding times were met.

- Initial calibration—All initial calibrations met acceptance criteria. If initial calibration criteria were not met, the instrument was recalibrated prior to use.

- Continuing calibration checks—Most continuing calibration checks met acceptance criteria. If continuing calibration criteria were not met, the failure was noted in the case narrative and/or in Out-of-Control Event (OOCE) Sheets in each data package, and, in some cases, the affected samples were reanalyzed.

- Method blanks—If target compounds were found in the blank above the reporting limit and also in the associated samples, the samples were reprepared and reanalyzed.

- Laboratory duplicates and/or MS/MSDs—Most laboratory duplicates and/or MS/MSDs were within the acceptance criteria. If not, the problem was noted in the case narrative and/or OOCE Sheets with each data package.

- LCSs—An LCS was analyzed with every batch. LCSs very rarely failed to meet acceptance criteria. For some SVOA analyses, one or two of the target LCS analytes may have failed, but if these were not detected in the associated samples, no action other than notation in the case narrative and generation of an OOCE Sheet was taken.

- Surrogate standards—All organic CSL methods used surrogates with QC acceptance criteria. Samples were routinely reprepared and/or reanalyzed if surrogate recoveries were outside QC acceptance criteria. Surrogate failures were infrequent, with the majority coming during the analysis of high-suspended solids in water samples for SVOAs and PCBs.

In general, all CSL data were assessed as usable for their intended purpose (field screening). During the course of the project, the CSLs were audited internally by the TN&A/CDM Federal Team, as well as by DOE and Bechtel Jacobs Company, against criteria normally used for fixed-base definitive data laboratories. With the exception of fixed-control limits versus statistically derived control limits from project QC sample data, most of the field analyses were conducted with very little deviation from the definitive data methods upon which the field laboratories' SOPs were based. For VOA parameters, average soil spike recoveries ranged from 77% to 98%, and average water spike recoveries ranged from 92% to 120%. For volatile spike/spike duplicate results, the average RPD ranged from 4.2% to 5.1% for water and from 8.0% to 8.8% for soil. For PCB analyses (spiked with Aroclor-1254), spike recoveries averaged 110% for water and 94% for soil, and RPDs averaged 5.9% for water and 4.9% for soil. For the 11 spiked SVOA parameters, average spike recoveries ranged from 23% to 83% for water and from 29% to 111% for soil. Average RPDs for SVOA spiked parameters ranged from 10.2% to 23.3% for water and from 8.1% to 12.6% for soil. Radiological spike analyses were performed on both water and soil matrices for gross alpha, gross beta, technetium-99, and three gamma spec parameters (americium-241, cesium-137, and cobalt-60). Average control spike recoveries for these parameters ranged from 95% to 111% recovery. Table 2.14 presents the average precision and accuracy numbers for spiked parameters analyzed at the CSLs.

Field laboratory results were confirmed by sending 10% of field laboratory samples to fixed-base laboratories for analysis. The agreement between field and fixed-base laboratory results was assessed by calculating RPDs for each parameter analyzed at both laboratories. [The average RPD was 131% between results from samples split between the field and fixed-base (USEC, PGDP) laboratories for all parameters in both water and soil samples.] When the RPD calculations were performed only on split samples with above detection limit results from both the field screening and fixed-base laboratories, the results were significantly better. The RPD for gross beta analyses, where the results were not correctable for method differences between the field and fixed-base laboratories (in either soil or water samples) due to the lack of background data, was highest at 138%. For the remaining parameters, the highest RPD was 85% for SVOA analyses (all soil results). Only one gamma spectroscopy sample was detected above the MDA for both field and fixed-base laboratories, and the RPD between the results was 61% (a soil sample). The RPD for gross alpha analyses was 36% (predominantly soil results). The RPD for VOA analyses was 30% (all water results). Technetium-99 analyses showed the best agreement when only considering detections above the field laboratory MDA of 17 pCi/L at 18%.

2.7.3.5 Fixed-base laboratory performance

Fixed-base laboratory performance was based on the results of laboratory QC samples, MS/MSD analysis, and adherence to laboratory procedures through data validation. The laboratories are audited annually by ORO-SMO and are contracted to follow the Analytical Master Specification documents for various analytical chemistry protocols mandated by ORO-SMO.

Some holding time problems were reported for VOA analyses by the fixed-base laboratories used during this investigation. For the most part, these holding time exceedances were the most serious deficiencies resulting in qualification or rejection of data. Initial calibration and continuing calibration deficiencies also led to laboratory qualification of some VOA data and rejection of some data during data validation. Specific laboratory problems with the data were addressed and resolved during the data assessment phase.

2.7.3.6 Comparison of trichloroethene results in soils analyzed using hexane extraction versus conventional methods

The WAG 3 RI is another investigation at PGDP that used hexane extraction/direct injection methodology for analysis of TCE and its degradation products in soils. The methodology had been refined on smaller projects, most notably in support of the recent technology demonstration, and incorporated in the PGDP subsurface soil sampling procedure. The method is still relatively new, and most fixed-base laboratories are not equipped to use it, although the most recent update of SW-846 incorporates a variation of the approach used in Method SW5035 for soil sampling/analysis of VOA compounds. In this study, VOA soil samples were analyzed at the organic CSL using the hexane extraction/direct injection technique, and a section of sample sleeve was sent to the fixed-base laboratory for traditional purge and trap analysis. As results were received from the fixed-base laboratory and compared with the CSL results, it became obvious that the results of the two methods were not directly comparable. The CSL always returned higher values than the fixed-base laboratory, when TCE and its degradation products were detected above the method's MDL. On average, the CSL reported TCE values significantly greater than those reported by the fixed-base laboratory. In general, as TCE concentrations increase, the difference in the results from the two methods decreases and there is generally good agreement between the two methods, although slight differences may still be observed due to the differences in analytical equipment.

The comparison demonstrated the effectiveness of using hexane extraction for chlorinated solvents in soil. This method, however, does have several disadvantages: (1) MDL is 1 mg/kg or 1 ppm and (2) the hexane method masks other VOAs.

2.7.3.7 Data validation

Data validation is a process performed for a data set by a qualified individual independent from sampling, laboratory, project management, and other decision-making personnel for the project. In the data validation process, the laboratory adherence to analytical method requirements is evaluated. The TN&A/CDM Federal Team validated definitive data collected for this RI according to the following procedures:

- EMEF Intersite Procedure Environmental Restoration and Waste Management (ERWM)/Environmental Restoration (ER)-P2209, "Radiochemical Data Verification and Validation," Rev. 0

- EMEF Intersite Procedure ERWM/ER-P2210, "Volatile and Semivolatile Data Verification and Validation," Rev. 0

- EMEF Intersite Procedure ERWM/ER-P2211, "Pesticide and PCB Data Verification and Validation," Rev. 0

- EMEF Intersite Procedure ERWM/ER-P2212, "Inorganic Data Verification and Validation," Rev. 0

As part of the data review process, findings were qualified as necessary to reflect data validation results. The following qualifiers were assigned by the data validators:

U	The material was analyzed for, but was not detected. The associated numerical value is the quantitation limit.
J	Estimated value, either because QC criteria were not met or because the amount detected is below the documented quantitation limit.
UJ	Undetected, but the number reported as the quantitation limit is an estimated value.
NJ	Presumptively present at an estimated quantity.
R	Rejected, so data are of "information only" quality and should be supplemented with additional data for decision-making.
=	Data were validated; however, no qualifier was added.
X	Data were not validated.

Data generated by the fixed-base laboratories were independently validated on a frequency of 10%. Actual data records indicate that 26% of the overall analytical data were validated.

The data package for SWMU 4 (base sample set) was validated for parameters including VOAs, metals, cyanide, PCBs, SVOAs, and radiological analyses. Of the 57,276 total data points, 14,745 were validated. A review of the data validation summary report indicates that the majority of data quality parameters, including MS/MSD recovery and RPD criteria, for the validated data package were within established method-specific limits. Grossly exceeded holding times affected significant portions of the VOA groundwater and soil data in this package. Other quality problems for individual samples and/or analytes were identified in the validated package; in particular, there were repeated instances of laboratory blank and field QC contamination affecting VOA analytes, such as acetone and methylene chloride, and problems with continuing and initial calibrations for some of the same VOA analytes. Of the overall analytical data, 4378 data points (29.7% of the validated data or 7.6% of all WAG 3 data) were rejected with 3003 (94%) of these being VOA data points.

2.7.4 Data Management

The WAG 3 PEMS was used to manage field-generated data; import laboratory-generated data; add data qualifiers based on data verification, validation, and assessment; and transfer data to Paducah's Oak Ridge Environmental Information System. PEMS included a tracking system to identify, track, and monitor each sample and associated data from point of collection through final data reporting. The system included field measurements, chain-of-custody information, and a tracking system for tracking hard-copy data packages and EDDs. PEMS also included information for field planning and data evaluation.

All data packages and EDDs received from the laboratory were tracked, reviewed, and maintained in a secure environment. When first received, data packages were assigned a document control number and then logged into a tracking system. The following information was tracked: sample delivery group numbers, date received, document control number, number of samples, sample analyses, receipt of EDDs, and comments.

The data verification processes for laboratory data were implemented for both hard-copy data and EDDs. The data packages were reviewed to confirm that all samples had been analyzed for the requested parameters. Discrepancies were reported to the laboratory and the data validators. As part of a series of internal integrity checks within PEMS, a check was run to identify which of the requested samples and analyses were not received in an EDD. Hard copy data packages were checked to confirm agreement with the associated EDD. Integrity checks in PEMS were also used to check the list of compounds generated by the laboratory to confirm that data were provided for all requested analytes. Discrepancies were reported to the laboratories for responses and/or correction and to the data validators.

Data verification within PEMS included standardization of analytical methods, chemical names and units, as well as checks for holding time violations and detections above background values.

In verifying the data for the unvalidated data, several VOAs were noted to have missed holding times. These data points were qualified accordingly. Validation qualifiers from the TN&A/CDM Federal data validators were manually input into PEMS.

PEMS system requirements included backups, security, change control, and interfacing with other data management systems. PEMS was housed on the Paducah EMEF network. System backups were performed nightly following standard Paducah EMEF network protocol. Updates made to the files were copied to a computer backup tape each night, and an entire backup was performed each week.

Security of PEMS and data used for the data management effort was considered essential to the success of the project. The security protocol followed by the data management team was consistent with that of the Paducah EMEF network. Access to the network is password-protected. Access to PEMS was limited, on an as-needed basis, to the data management personnel. Read-write, graded access to PEMS was limited to the data management team, which consisted of the PEMS Coordinator and the supporting data entry staff. The data management staff assisted other project members with data needs from PEMS by running requested queries.

Each sampling location and sample collected during the WAG 3 RI was assigned a discrete identification number, which consisted of a four-part alpha/numeric sequence. For example:

004-018-WA-095

Each segment of the sequence is used to designate information concerning the location from which a sample was collected, the medium from which it was collected, the nature of the sample, and the depth from which the sample was collected. The first three-digit code is a location definition corresponding to the SWMU from which the sample was collected. For example, "004" would indicate SWMU 4. This code is followed by another three-digit code used to define the boring or location within the SWMU (or area) from which the sample was collected. For example, "018" would indicate the 18th boring drilled in that area. The two-letter sequence is used to indicate the nature of the sample. The first letter identifies the matrix of the sample. Examples of the letters used to identify specific matrices include S, W, and L to identify soil, water, and sludge matrices, respectively. The second letter identifies the sequence of multiple samples collected from the same location or the type of QC sample for field QC samples collected. For example, "A" designates an original field sample, "B" or "C" designates a second or third sample collected during another sampling event at the same location (i.e., a resampling). The letter "D" is used to designate a field duplicate sample. "E" designates an equipment rinsate sample, "F" designates a field blank sample, "R" designates refrigerator storage blank for VOAs, and "T" designates a trip blank sample. A "Q" was used for source water samples from the potable water and deionized water used during the project. The predetermined three-digit field is used to designate the approximate depth from which the sample was to have been collected. For example, "095" would mean the sample was to have been collected at 95 ft. In conclusion, for the example above, the sample identification code reads: *within SWMU 4, from boring location 18, a water sample was collected at approximately 95 ft bgs.*

2.7.5 Data Assessment

A large volume of data was generated during the concurrent WAG 28 RI, WAG 8 site evaluation, and WAG 3 RI. With up to five field teams using four different drilling methods to collect samples and six laboratories involved in sample analysis, the opportunities for problems, inconsistencies, and errors were significant. To confirm that the data set could be used in the decision-making process, the RI team performed various checks and reviews during and after the fieldwork to maintain data consistency and identify problem areas. These checks and reviews included electronic verification and manual assessments by the RI team, as well as independent validation of fixed-base laboratory data. More than 40,178 records were reviewed during the WAG 3 RI data assessment.

2.7.5.1 Field data

Field data consist of data generated by the on-site CSLs and measurements taken in the field during a sampling event. For example, measurements taken in the field during a groundwater sampling event included water temperature, specific conductivity, dissolved oxygen, and pH. The CSLs measured concentrations of TCE and its degradation products in soil and groundwater, SVOAs in soil and groundwater, and PCBs in soil and groundwater and also measured gross alpha and beta activity in soil and groundwater, gamma activity in soil, and technetium-99 activity in water.

The field preliminary CSL data underwent daily reviews by the lead chemist, and data management personnel reviewed final CSL data as a means of identifying data entry errors, missing data, and inconsistencies. The data management personnel used numerous queries within a database to provide checks of the PEMS database and identify problems. The PEMS Coordinator and other data management staff reviewed all queries, reporting results to the lead chemist and other project key personnel. Based on these reviews, questions and problems were noted and submitted to the CSL laboratory managers for resolution and correction. The types of problems found included missing or incorrect sample depths, missing or incorrect data qualifiers, and mis-keyed data. An additional review was also performed, comparing data against expected conditions to assess whether the results "made sense" within the context of the investigation during data assessment.

2.7.5.2 Fixed-base data

The fixed-base data consist of data generated by the off-site laboratories contracted for the project. These laboratories provided analyses of VOAs, SVOAs, PCBs, dioxins/furans, metals, radioisotopes, feasibility study parameters, and soil properties. Ten percent of the fixed-base data was submitted to WAG 3 team validators for independent validation of the data quality. The validation included (but was not limited to) review of sample holding times, minimum detection limits, analytical blanks, matrix spikes, laboratory duplicates, surrogates, and instrument calibrations. When appropriate, a qualifier was added to the data. The team validators submitted a report on the data package when the package was returned to the RI team. The results of the validation were then included in the data set. Questions and problems with fixed-base data were noted during data assessment and submitted to the Bechtel Jacobs Company SMO representative for laboratory responses, resolution, and correction, as appropriate.

2.7.5.3 Final review

After each data package was received from the fixed-base laboratory and loaded into the PEMS database, a final review and assessment of all the data were completed. This effort included electronic verification, database queries targeting known problem areas, and manual assessment. For manageability, the data packages were divided by SWMU.

Electronic verification was used to compare the data set against various reference values, specifically, holding time exceedances for all analyses and background exceedances for metals and radioisotopes in soils. Data records for all samples that exceeded holding times were flagged with a "T" in the verification field. Data records for all metals and radioisotopes in soils that exceeded established background levels for the site were flagged with an "I" in the verification field.

In conjunction with electronic verification, a set of data assessment queries was developed. These queries were designed to check the internal consistency of the database and to identify all analytes detected, the concentration and distribution of the analytes detected within the volume of soil and groundwater investigated, and the samples that might have been impacted by various problems that are inevitable during the course of a major investigation. The underlying data assessment questions consistently asked were "Does this number make sense, and what does it mean?"

QC samples were reviewed as a part of the data assessment process. These samples included equipment rinsate samples, trip blanks, refrigerator blanks, field blanks, and a comparison of field duplicate results. During the assessment of these samples, no problem areas were identified. In each case where analytes were detected in a QC sample, either there were no detections of the analytes in the associated field samples, or the field sample result(s) were greater than 10 times the concentration of the analytes detected in the associated QC sample.

Holding time exceedances were a problem, particularly for some VOA analyses. All holding time exceedances were identified during the verification process. During the assessment process, the impact of those exceedances was evaluated. Analyses for organics and certain metals are particularly sensitive to holding times, whereas analyses for most metals and for radioisotopes are less sensitive. Both the analyses to be performed and the length of the holding time exceedances were evaluated to assess the potential impact. Records for those samples judged to be significantly impacted were assigned an assessment flag of "BL-T" meaning that the result may be biased low due to holding time exceedance. A total of 3010 out of 40,178 records (7.5%) in the database were assigned the "BL-T" flag.

The "R" assessment flag was used to reject data that did not pass the review process. Rejected data included, for example, chemicals that have not been used on-site or results that made no sense, for example, if the dissolved concentration of a metal in groundwater exceeded the total concentration of the metal in the same sample. If the detected dissolved concentration was greater than 10%, the dissolved metal result was considered questionable. Also included as rejected data were samples with gross holding time exceedances. A portion of the VOA analyses conducted by the fixed-base laboratories had such exceedances. A total of 3179 out of 40,178 records (7.9%) in the database were assigned the "R" flag. Only these data were excluded from use in the evaluation of contaminant nature and extent or fate and transport.

2.7.6 Field QC Procedures

EPA, DOE, the Commonwealth of Kentucky, and PGDP procedures require that field QC samples be collected to assess data quality. The QC samples collected and analyzed included:

- Equipment rinsates
- Source blanks (water supply samples)
- Trip blanks
- Field blanks
- Duplicate samples
- Refrigerator blanks

2.7.6.1 Equipment rinsates

Equipment rinsates were scheduled to be collected at a frequency of 1 in 20 samples. Appendix G provides the data from the equipment rinsate samples. A total of 23 equipment rinsates was collected during the project. Equipment rinsate samples were designated as XXX-XXX-WE-XXX samples in Appendix G.

2.7.6.2 Water supply samples

Source blanks of deionized water and potable water used for equipment decontamination were collected two times during the project. Four water supply samples were collected during the project. Water supply samples (source blanks) are designated as PO (potable water) X-XXX-WQ-XXX samples and DI (deionized water) X-XXX-WQ-XXX samples in Appendix G.

2.7.6.3 Trip blanks

Trip blanks were collected at a frequency established by the direction of the Bechtel Jacobs Company. A total of 88 trip blanks were analyzed during the project. Appendix G provides the results of the trip blank samples. Trip blank samples are designated as XXX-XXX-WT-XXX samples in Appendix G.

2.7.6.4 Field blanks

Field blanks were scheduled to be collected at a frequency of 1 in 20 samples. Appendix G provides the data from the field blanks. A total of 23 field blanks were collected during the project. Field blank samples are designated as XXX-XXX-WF-XXX samples in Appendix G.

2.7.6.5 Duplicate samples

Field duplicates were collected and sent to the CSLs and fixed-base laboratories for analysis. Field duplicates were scheduled to be collected at a frequency of 10% of the total number of field samples collected by matrix. A total of 116 soil and 76 water duplicate samples were collected during the project. Appendix G provides the results of the duplicate samples. Field duplicate samples are designated as XXX-XXX-WD-XXX for water field duplicates and XXX-XXX-SD-XXX for soil field duplicates.

2.7.6.6 Refrigerator blanks

Refrigerator blanks were collected and analyzed every 2 weeks during the project. Because the WAG 3 RI field investigation was conducted simultaneously with the WAG 28 RI, Data Gaps, and the WAG 8 site evaluation field investigations, these refrigerator blanks were divided among all four projects for which samples were being collected and stored before analysis. Eight refrigerator blanks were assigned to the WAG 3 RI. Refrigerator blank samples are designated as XXX-XXX-WR-XXX samples in Appendix G.

2.8 CIVIL SURVEY

Upon completion of the activities associated with the sampling points, soil borings, and piezometers, a final survey of the location and elevation was conducted. The surveying was conducted in accordance with the Paducah EMEF engineering specifications. The civil survey was performed by a state registered and licensed surveyor of the Commonwealth of Kentucky. Site locations were surveyed on the Kentucky State Plane Coordinate System and the PGDP Plane Coordinate System. Benchmarks and reference points were supplied by the Bechtel Jacobs Company Civil Engineering Department. Grid coordinates were measured to an accuracy of plus or minus 0.01 ft and tied to the U.S. Geological Survey (USGS) National Geodetic Vertical Datum (NGVD) of 1927 and the North American Datum of 1983. Elevations were measured to a hundredth (0.01) of a foot. Surveying field activities were documented in field logbooks for archiving. The civil survey data are included in Appendix H.

2.9 HEALTH AND SAFETY MONITORING

To protect the health and safety of personnel during field activities, site safety professionals were assigned to observe, monitor, direct, and document each activity. In addition, a Radiation Protection Program (RPP) was implemented to assure adherence to PGDP and DOE regulations.

Two major categories of monitoring were performed, work area monitoring and employee biological monitoring.

2.9.1 Work Area Monitoring

Several of the drilling and sampling locations for the WAG 3 RI were within the boundaries of known areas of surface radiation contamination. Before field activities began, an initial site radiation survey was performed covering a 60- by 60-ft area around the point of sampling or drilling. The purpose of the survey was to assure that the members of the sampling crew and the equipment were properly protected and to assure that surface contamination, if present, was properly managed. All radiation abnormalities were reported immediately to the EMEF Health Physics Department and the project construction engineer.

Once the site had been thoroughly scanned for radiation and proper actions had been taken to protect workers from site hazards, equipment was moved in and work zones (with barriers) were established. These zones included an outer construction zone and an inner exclusion zone. The exclusion zone was a strictly controlled area. Every person or item that passed into this zone was considered potentially contaminated and could not be removed until fully scanned for radiation. This was accomplished by discrete measurements with the Ludlum 2224 and smear counting using the Ludlum 2929.

Once the ground surface was broken at a work site, air was continuously monitored with direct read instruments until field activities were completed. Tools and equipment in direct contact with soil were scanned for potential radiological contamination before being cleared. If levels were above the release limits, the material was bagged and properly tagged. After bagging, additional surveys were conducted to confirm that levels were below the release limits. The material was then moved to a designated area until it could be properly decontaminated. Instrument readings were recorded in the site safety professional's logbook. Typically, readings were recorded from soil cuttings created during the drilling operations, air space monitoring at the drilling location, smears and direct measurements, and readings that met or exceeded the project action levels specified in the Health and Safety Plan (HASP).

The work area was also monitored to prevent overexposure to temperature extremes. On-site ambient temperature was measured and discussed on a daily basis. Cold and heat stress monitoring of personnel was conducted in the work area by a site safety professional. This monitoring included close scrutiny of personnel behavior, obvious signs of overexertion, and heart rates of exposed personnel. Heart rate checks were performed periodically during each exposure period.

Excessive noise was surveyed at each source of elevated noise. These sources included drill rigs, pressure washing equipment, generators, and other items equipped with combustion engines. Sound level monitoring data were recorded in the Health and Safety logbook. Sound level surveys were performed with a Quest Model 2700 sound level meter at each source of elevated noise. Working conditions in the vicinity of this equipment were checked at regular intervals to confirm that the site was properly delineated with hearing conservation signs and to reassess the use of proper personal protective equipment (PPE). Hearing protection was required at any levels equal to or above 85 decibels.

2.9.2 Routine Employee Biological Monitoring

All personnel who were required to enter a zone of potential contamination were required to participate in the Bechtel Jacobs Company Biological Monitoring Program (BMP). As part of this program, personnel wore thermoluminescent dosimeter (TLD) badges to track possible radiation exposure; in addition, quarterly urinalysis was conducted to document radiological ion uptake. The 29 *Code of Federal Regulations* (CFR) 1910.120 requirements were used for training and biological monitoring of WAG 3 field employees, including a physical examination consisting of blood analysis, audiometric testing, respiratory testing, and cardiopulmonary testing.

Upon arrival at the project site, and before any participation in site work, employees were issued a TLD by Bechtel Jacobs Company Health Physics Department personnel, and each person provided a urine sample to establish a baseline. The TLDs were exchanged and analyzed on a quarterly basis. The internal dose evaluation was performed each month and at the end of project participation.

2.9.3 Level B Upgrade

Background

During the course of work performed in SWMU 4, a subcontract worker was collecting a groundwater sample using a bailer. The worker noticed an odor coming from the augers and the area was evacuated while the safety officer took readings of the borehole using an Organic Vapor Monitor (OVM). The OVM reading was 2009 ppm. During the evacuation of the area, the worker who was collecting the groundwater sample began to feel dizzy and weak. The field crew assisted the worker in the removal of his PPE, monitored him for radiation contamination, and transported him to the PGDP C-200 First Aid Station and subsequently to Western Baptist Hospital. He was treated and released to regular duty the same day.

In response, the PGDP Emergency Squad mobilized to the location that evening, donned Level B PPE, and closed the well after taking readings on the ambient air. (Sampling data collected are noted in Table 2.15.) Several days later, after re-entry planning, project personnel (in Level B PPE) reopened the well, collected some in situ air samples (Table 2.16), and completed collection of the groundwater sample that was in progress when the sampler was overcome by noxious gases.

The borehole and ambient air monitoring data indicate the presence of volatile constituents (but only TCE as registered by the detector tubes) in the air. The groundwater sample indicated the presence of TCE and cis-1,2-dichloroethene, with trace amounts of vinyl chloride and chloroform. An evaluation of air samples collected from within the angled boring indicated the presence of TCE, chloroform, 1,2-dichloroethene, vinyl chloride, carbon tetrachloride, and 4-methyl-2-pentanone. Table 2.16 lists the sample results and pertinent exposure values. These data are from samples collected within the borehole and were not from the atmosphere in the breathing zone. Based on the levels of the chemicals detected in the air samples, which were collected after the initial event, it is assumed that, at a minimum, the driller's helper may have been exposed to those chemicals.

Actions Taken

As a result of the changes in conditions and contaminants, the WAGs 3/8/28 and Data Gaps HASP was modified to reflect upgrading the PPE to Level B. The Level B upgrade included the following:

- Long-sleeve company clothing
- Tyvek™[2] long-sleeve coveralls with booties and hoods
- Steel-toed work boots
- Chemical-resistant rubber over-booties
- Latex gloves
- Nitrile gloves
- Type C respiratory protection, continuous flow, supplied air (Level B)
- Leather or cotton work gloves
- A personnel detector tube (worn by one member of the drilling crew)

During drilling operations continuous radiation monitoring was performed on the soil that was removed from the borehole. Air monitoring was performed during the drilling activities when the ground was broken, at 15-ft drilling intervals, during sampling, and during grouting. The air was sampled using a PID and detector tubes for the following contaminants:

- carbon tetrachloride,
- TCE,
- chloroform,
- methyl isobutyl ketone, and
- vinyl chloride.

As a result of the increased hazards associated with the work at the WAG 3 SWMUs, other intrusive work (e.g., groundwater level monitoring) was suspended. The only intrusive activity that carried forward was the angled HSA drilling and sampling.

2.10 WASTE HANDLING PRACTICES

A variety of potentially contaminated and noncontaminated wastes were generated during the RI activities. All wastes generated as a result of field-related investigative activities had the potential to contain contaminants related to past work activities. The drilling and sampling investigative activities resulted in the generation of IDW. This required the subcontractor to write a waste generation plan that concurs with the requirements stated in the Waste Acceptance Criteria (WAC) document (Bechtel Jacobs Company 1999). The waste generation plan included waste minimization, segregation, waste generation forecast, proper containerization, labeling/marking, characterization, handling, storage, transportation, and disposal.

2.10.1 IDW Drilling Solids

IDW solids were generated by DPT, HSA, DWRC drilling, and manual sampling operations for surface soil and sediment. All IDW solids were placed in appropriately labeled pails and drums according to applicable regulations and PGDP procedures.

DPT sampling generated minimal IDW. The majority of solid waste generated by the DPT method was PPE and plastic sheeting used as ground cover under the rig and sampling area.

---

[2] Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

The DWRC and HSA drilling techniques generate significant quantities of IDW solids and liquids. This mixture was separated at the drill site: the solids were placed into 55-gal drums, and the liquids into 375 to 1200-gal poly tanks and transported to the C-752-C decontamination pad for final separation. Any remaining IDW liquids that separated from the solids in the 55-gal drums were decanted out of the drum, and the remaining solids were dumped into roll-off bins. The liquids containing a mixture of mud, silt, clay, and water were separated by natural gravity settling, by the addition of flocculation chemicals, and by processing the water through a filter press. The filter press removed the sand, silt, and clay-size particles from the water matrix. The solids were placed into properly labeled roll-off bins along with the drum solids.

A total of 41.15 yd^3 of IDW was generated during the WAG 3 RI. IDW liquids associated with solids were captured by processing soils through the filter press and placing the liquid into 1000-gal mobile poly tanks. This water was then transferred into 21,000-gal tanks before testing and discharge into Outfall 001.

2.10.2 Well IDW Water, Well Development Water, Decontamination Rinsate, and Purge Water

Water generated during the WAG 3 RI was placed into 375- to 1200-gal poly tanks and transported to the C-752-C Decontamination Pad. If a field analysis showed that the water was free of contamination, the water was pumped through the filter press to remove all visual solid particles. Clear water from the filter press was captured into 1000-gal mobile poly tanks and transferred into 21,000-gal tanks located at the C-612-A Clamshell Area.

To date, a total of over 3185 gal of IDW, well development, decontamination, and purged water has been generated. A total of 63,000 gal of water has passed all PGDP, local, state, and federal discharge limits and has been released into Outfall 001.

Decontamination water was generated from the cleaning of drilling and sampling equipment. All water was collected into Sumps 1–4 located at the C-752-C Decontamination Pad. Water from all sumps was cross-referenced with all field and waste sampling laboratory sampling data results, and all water that was deemed noncontaminated was pumped through the filter press and transferred into the tanks at the C-612-A Clamshell Area. Solids that were not pumped with the water were collected and placed into the solid roll-off bins.

Wastewater generated from the laboratories was collected and temporarily stored at generator storage area (GSA)/satellite accumulation areas (SAAs) located outside each laboratory. Each container was sampled and, if found noncontaminated, was mixed with other clear water and pumped through the filter press.

All water generated by this project was sampled and analyzed for PCBs, radionuclides, VOAs, and SVOAs required by Kentucky Pollutant Discharge Elimination System (KPDES) Outfall Permits. No wastewater from the drilling, sampling, laboratory, or decontamination operations has exceeded applicable concentrations; therefore, it has not been necessary to transfer IDW liquids into storage for later disposal.

2.10.3 PPE and Plastic Sheeting

Modified Level D was the highest level of PPE worn, as required by the WAG 3 HASP. All used PPE was considered IDW. Laboratory analyses for each of the borings was cross-referenced to IDW samples. The waste type of the PPE and sampling refuse were the same as the corresponding IDW. All noncontaminated PPE and refuse were bagged per each boring, labeled, and dated. The bags were placed into roll-off bins for disposal in the PGDP sanitary landfill.

In accordance with field screening and laboratory data results, PPE and plastic determined to be contaminated was placed in appropriately labeled drums and managed according to applicable regulations and PGDP protocol. To date, seven drums of PPE and plastic have been transferred into storage. A total of 40.6 yd^3 of clean, noncontaminated PPE and plastic has been placed into three roll-off bins and properly labeled and submitted for landfill disposal.

2.10.4 Laboratory Waste

Used sample containers, PPE, residual soil, and wastewater were generated by laboratory operations. Soil, water, and PPE were combined with the associated waste streams for each boring and processed according to PGDP protocol. At present, no waste has been determined to be RCRA, Toxic Substances Control Act, or low-level (radioactive) waste and transferred into storage.

2.10.5 IDW Forms

Request for disposal (RFD) forms and Waste Container Log Sheets were completed as the waste was generated at the work site. PGDP supplied all required forms as needed. Completed forms were delivered to the PGDP EMEF Waste Disposal Coordinator for approval.

2.10.6 IDW Labeling

IDW containers were carefully labeled or marked in accordance with PGDP's WAC requirements.

2.10.7 IDW Storage

GSAs and SAAs were established as needed. The GSA and SAA were set up and inspected in accordance with PGDP WAC procedures. Each month inspection forms were submitted as required.

2.10.8 Types of Containers

Solid IDW that was generated at each boring location was containerized in 55-gal open top drums with a minimum rating of DOT 1A2/X400/S and lined with a 15-mil-thick plastic liner and an absorbent pad. IDW liquids were stored in 375-, 1200- and 21,000-gal tanks located at the C-752-C Decontamination Pad and the C-612-A Clamshell Area.

2.10.9 IDW Characterization, Sampling, and Analysis

Waste analyses were performed using EPA-approved procedures as applicable. Analysis required for hazardous waste classification was performed in accordance with EPA SW-846 (1986).

Wastewater analysis was performed in accordance with the Clean Water Act of 1972 and/or Safe Drinking Water Act of 1974 procedures.

2.11 DECONTAMINATION PRACTICES

All drilling rigs and drilling-related equipment such as drill rods, casing, liners, and bits were steam-cleaned at C-755, C-416, and C752-C Decontamination Pads. Decontamination of drill and sampling equipment was conducted in accordance with PGDP EMEF Procedure PTSA-5001-IAD, "Decontamination of Drilling-Related Equipment."

The drilling equipment was thoroughly steam-cleaned and rinsed and then allowed to air dry. The drill string was then wrapped in plastic and placed on the drilling rig and transported to the next boring site. The decontamination water was collected in sumps and processed through the filter press in conjunction with IDW liquids for the removal of suspended solids. The clear water was transported and transferred into a 21,000-gal frac tank.

Sampling equipment such as bowls, spoons, knives, and spatulas, including all stainless steel field sampling equipment, was decontaminated in accordance with PGDP EMEF Procedure PTSA-5002-IAD, "Decontamination of Field Equipment." The decontamination process occurred in the following order:

- rinsed with potable water,
- washed and scrubbed with phosphate-free detergent and water,
- rinsed with clean tap water,
- rinsed with deionized water,
- rinsed with isopropanol,
- rinsed with deionized water,
- air dried, and
- wrapped in aluminum foil.

Table 2.1. Summary of sampling and analysis activities for SWMU 4

Location	Activity	Quantity	Sampling interval (ft bgs)
		(proposed actual)	
C-746 Contaminated Burial Yard	Waste/soils	7 locations	Midpoint (~10) Base (~18) (depths include 2–3 ft fill)
		5 locations	Waste sampling was discontinued at SWMU 4 due to high levels of radioactivity and recurring equipment breakage problems (e.g., broken DPT rods)
	Leachate within waste disposal cell	Contingency for sampling leachate within waste disposal cells, if encountered	At depth encountered
		None	No leachate identified in waste cells
	CPT	2 locations	C60
		3 locations	0–38 0–42 0–60
	Drainage swale samples	5 locations	0–1
		5 locations	0–1
	Surface soil samples	2 locations (and all soil boring locations)	0–1
		Total 8 (6 samples from 0–1 ft at DPT locations, 2 surface soil locations)	0–1
	Soil boring—angled HSA	8 locations	Discrete intervals identified by CPT or 0–1 3–5 8–10 13–15 28–30 43–45 Top HU3 (55–60)
		8 locations	10–12 24–26 31–33 42–44 49–51 58–60

Table 2.1 (continued)

Location	Activity	Quantity (proposed actual)	Sampling interval (ft bgs)
C-746 Contaminated Burial Yard (cont.)	Soil boring—DPT, HSA (vertical)	3 locations	Discrete intervals identified by CPT or 0–1 3–5 8–10 13–15 28–30 43–45 Top HU3 (55–60)
		34 locations 30 DPT 4 HSA	DPT HSA 0–1 19–21 3–6 23–25 10–13 39–41 13–16 49–51 22–25 37–40 47–50 57–60 Actual sample quantity and depths varied from location to location depending on site conditions.
	Soil boring (RGA/McNairy)	2 locations	Top, middle, and bottom of RGA
		3 locations	No analytical samples were collected from the RGA, only lithologic samples
	Soil borings (angled and vertical)—UCRS groundwater (DPT, angled HSA, HSA, and DWRC)	11 locations	Interval identified by CPT (~40)
		27 locations total (16 DPT, 8 angled HSA, 3 DWRC)	Depth varied from boring to boring; angled HSA samples were collected near the UCRS–RGA interface (~60 ft)
	RGA/McNairy groundwater[a]	2 locations	5-ft intervals in RGA, 2–3 samples from McNairy
		3 locations	(Same intervals as specified in work plan—1 to 2 McNairy samples)
	Geophysical survey	1 each	NA
		1 each	EM-31 terrain conductivity, EM-61 metal detector
	Temporary piezometers (vertical soil boring locations)	3 locations (2 piezometers at each location)	UCRS (HU2 interval and base of HU1 unit)
		6 locations	One round of water level measurements was collected before work suspended due to Level B upgrade

[a] All RGA soil borings included borehole geophysics consisting of gamma and neutron logs.

NA – Not applicable

Table 2.2. Summary of sampling and analysis activities for SWMU 5

Location	Activity	Quantity (proposed actual)	Sampling interval (ft bgs)
C-746-F Classified Burial Yard	CPT	2 locations	0–60
		2 locations	0–60
	Drainage swale/ ditch samples	7 locations	0–1
		7 locations	0–1
	Soil boring–angled HSA	5 locations	Discrete intervals identified by CPT or 0–1 3–5 8–10 13–15 28–30 43–45 Top HU3 (55–60)
		5 locations	10–12 24–26 31–33 42–44 49–51 58–60
	Soil boring—DPT, HSA (vertical)	3 locations	Discrete intervals identified by CPT or 0–1 3–5 8–10 13–15 28–30 43–45 Top HU3 (55–60)
		5 locations (3 DPT/ 2 HSA) (Soil samples were not collected from all depth intervals due to refusal)	DPT HSA 0–1 19–22 16–19 22–25 20–23 35–38 34–37 48–51 41–44 48–51 57–60
	Soil boring (RGA/McNairy)	4 locations	Top, middle, and bottom of RGA
		2 locations	No analytical samples were collected from the RGA, only lithologic samples
	Surface soil radiological survey	Over entire area	NA
		Conducted	
	Surface soil sampling	3 locations	0–1
		6 locations 3 DPT, 3 surface soil locations	0–1

Table 2.2 (continued)

Location	Activity	Quantity (proposed actual)	Sampling interval (ft bgs)
C-746-F Classified Burial Yard (cont.)	Soil borings (angled and vertical)—UCRS groundwater	8 locations	Interval identified by CPT (~40)
		8 locations 3 DPT 5 angled HSA	DPT samples from UCRS angled HSA from interface of UCRS–RGA
	RGA/McNairy groundwater[a]	4 locations (1 upgradient/ 1 downgradient and 2 for groundwater integrator unit)	5 ft intervals (RGA); 2–3 samples from McNairy above Levings Member
		2 locations	Same as proposed
	Geophysical survey	1 each	NA
		1 each	EM-31 terrain conductivity, EM-61 metal detector
	Temporary piezometer	3 locations (2 piezometers at each location)	UCRS (HU2 interval and base of HU1 unit)
		1 location	One round of water level measurements was collected before work suspended due to Level B upgrade

[a] All RGA soil borings included borehole geophysics consisting of gamma and neutron logs.

NA – Not applicable

Table 2.3. Summary of sampling and analysis activities for SWMU 6

Location	Activity	Quantity (proposed actual)	Sampling interval (ft bgs)
C-747-B Burial Yard	Waste/soils	7 locations	Midpoint (~10) Base (~18) (depths include 2–3 ft fill)
		5 locations	Two or three soil samples were collected from each boring at depths ranging from 0–15 ft bgs. These samples are representative of the lithology within the burial cells although differentiation between the waste materials and UCD was not readily apparent. Waste sampling was discontinued due to high levels of radioactivity
	Leachate within waste disposal cell	Contingency for sampling leachate within waste disposal cells, if encountered	At depth encountered
		None	No leachate identified in waste cells
	CPT	1 location	0–60
		1 location	0–60
	Drainage swale/ ditch samples	3 locations	0–1
		3 locations	0–1
	Soil boring—angled HSA	5 locations	Discrete intervals identified by CPT or 0–1 3–5 8–10 13–15 28–30 43–45 Top HU3 (55–60)
		5 locations	10–12 24–26 31–33 42–44 49–51 58–60
	Soil boring—DPT, HSA (vertical)	3 locations	Discrete intervals identified by CPT or 0–1 3–5 8–10 13–15 28–30 43–45 Top HU3 (55–60)
		11 locations 9 DPT 2 HSA (Note all intervals were sampled at each boring due to refusal)	DPT HSA 0–1 10–13 3–6 16–19 6–9 20–23 9–12 35–38 15–18 48–51 18–21

Table 2.3 (continued)

Location	Activity	Quantity (proposed / actual)	Sampling interval (ft bgs)
C-747-B Burial Yard (cont.)	Soil boring (RGA/McNairy)	2 locations	Top, middle, and bottom of RGA
		2 locations	No analytical samples were collected from the RGA, only lithologic samples
	Surface soil radiological survey	Over entire area	NA
		Conducted	
	Surface soil sampling	5 locations	0–1
		3 DPT, 2 surface soil locations	
	Soil borings (angled and vertical)—UCRS groundwater	8 locations	Interval identified by CPT (~40)
		14 locations 9 DPT (8 samples) 5 angled HSA	Interval varied from boring to boring (no water from DPT 006-010)
	RGA/McNairy groundwater[a]	2 locations (1 upgradient/ 1 downgradient)	5-ft intervals (RGA); 2–3 samples from McNairy above Levings Member
		2 locations	Same as proposed except only 1 sample from McNairy
	Geophysical survey	1 each	NA
		1 each	EM-31 terrain conductivity, EM-61 metal detector and ground-penetrating radar
	Temporary piezometer (vertical soil boring locations)	3 locations (2 piezometers at each location)	UCRS (HU2 interval and base of HU1 unit)
		4 locations	One round of water level measurements was collected before work suspended due to Level B upgrade

[a] All RGA soil borings included borehole geophysics consisting of gamma and neutron logs.

NA – Not applicable

Table 2.4. CPT surveys

Site	Locations	Total depth
SWMU 4	3	38, 42, and 60 ft
SWMU 5	2	60 ft each
SWMU 6	1	60 ft
Total	6	320 ft

Table 2.5. DPT soil sampling

Site	Number of locations	Number of soil samples
SWMU 4	30	140
SWMU 5	3	13
SWMU 6	9	34
Total	42	187

Table 2.6. HSA/angled HSA soil sampling

Site	Number of locations	Number of soil samples
SWMU 4	12	54
SWMU 5	7	34
SWMU 6	7	40
Total	26	128

Table 2.7. DWRC groundwater sampling

Site	No. of locations	No. of water samples
SWMU 4	3	35
SWMU 5	2	18
SWMU 6	2	18
Total	7	71

Table 2.8. DPT water sampling

Site	Number of locations	Number of water samples
SWMU 4	16	16
SWMU 5	3	3
SWMU 6	9	8
Total	28	27

Table 2.9. HSA/angled HSA groundwater sampling

Site	No. of locations	No. of water samples
SWMU 4	8	9
SWMU 5	5	5
SWMU 6	5	6
Total	18	20

Table 2.10. WAG 3 preliminary COPCs[a]

Soil	Groundwater
SWMU 4	
Metals (Al, As, Ba, Be, Ca, Cd, Cr, Fe, Pb, Mg, Mn, Hg, Ni, and V)	Metals (same as SWMU 4 soils)
Radionuclides (^{234}U, ^{235}U, ^{238}U, ^{237}Np, and ^{99}Tc)	Radionuclides (same as SWMU 4 soils)
	TCE and breakdown products (cis-1,2-dichloroethylene, trans-1,2-dichloroethylene, vinyl chloride, etc.)
SWMU 5	
Semivolatile organic compounds	Semivolatile organic compounds
Metals (Al, Ba, Be, Cd, Cr, Mn, Na, and V)	Metals (Fe, Mg, Mn, Na, Se, and V)
Radionuclides (^{238}U)	Radionuclides (^{241}Am, ^{137}Cs, ^{60}Co, ^{3}H, ^{239}Pu, ^{234}U, ^{238}U, ^{237}Np, ^{226}Ra, ^{222}Rn, ^{182}Ta, and ^{230}Th)
	TCE and breakdown products
SWMU 6	
Metals	Metals
Radionuclides	Radionuclides
TCE and breakdown products	TCE and breakdown products
PCBs	PCBs

[a] *Source*: WAG 3 RI Work Plan (DOE 1998a).

Table 2.11. CSL analyses

Analysis	Parameters	Prep. method (matrix)	Analytical method
VOA	TCE and TCE degradation products	SW-846 5030B (water)	Modified SW-846 8021B
VOA	TCE and TCE degradation products	Hexane extraction (soil)	Modified SW-846 8021B
SVOA	CLP semivolatile TCL analytes	SW-846 3510C (water)	Modified SW-846 8270C
SVOA	CLP semivolatile TCL analytes	SW-846 3550B (soil)	Modified SW-846 8270C
PCB	Seven PCB Aroclors	SW-846 3510C (water)	Modified SW-846 8082
PCB	Seven PCB Aroclors	SW-846 3550B (soil)	Modified SW-846 8082

Table 2.12. Analytical methods and sample requirements for CSL screening samples

Parameter	Matrix	Holding time	Reporting limit	DL	Container	Preservative
VOA	Water	14 days	1 μg/L	0.1 μg/L[a]	Two 40-mL clear glass vials with Teflon™ [b] septa	HCl; cool to 4°C
	Solid	14 days	500 μg/kg	100 μg/kg[a,c]	One 40-mL glass vial with Teflon™ [b]-lined lid	Cool to 4°C, 5-mL deionized water, 5-mL hexane
SVOA	Water	7 days	10 μg/L	7.6 μg/L[a]	Two 1-L amber glass	Cool to 4°C
	Solid	14 days	500 μg/kg	μg/kg[a,c]	4-oz. widemouth glass jar with Teflon™ [b]-lined lid	Cool to 4°C
PCBs	Water	7 days	100 μg/L	μg/L[a]	Two 1-L amber glass	Cool to 4°C
	Solid	14 days	500 μg/kg	μg/kg[a,c]	4-oz. widemouth glass jar with Teflon™ [b]-lined lid	Cool to 4°C
Gross alpha	Water	6 months	5 pCi/L	4 pCi/L	One 1-L plastic jar	None
Gross beta			5 pCi/L	3 pCi/L		
Gross alpha	Solid	6 months	55 pCi/g	7 pCi/g	8-oz. PP Lermer Jar	None
Gross beta			55 pCi/g	6 pCi/g		
Technetium-99	Water	6 months	17 pCi/L	15 pCi/L	One 1-L plastic jar	None
Gamma activity	Solid	6 months	55 pCi/g	5 pCi/g[d]	8-oz. PP Lermer Jar	None

[a] Median MDL of all target analytes.

[b] Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

[c] Soil MDLs dependent on moisture content and actual sample size.

[d] Median MDA of all target radionuclides except for Pa-234m; Pa-234m MDA = 206 pCi/g.

Table 2.13. Analytical methods, preservation, and container type for all samples analyzed by fixed-base laboratories

Analysis	Analytical method	Container type	Preservative
		Soil	
TCL metals	SW-846 6010A SW-846 7060 SW-846 7471 SW-846 7740	2- or 4-oz. widemouth HDPE	None
Hexavalent chromium	SW-846 7196	2- or 4-oz. widemouth HDPE	None
Cyanide	SW-846 9014-Total	4-oz. widemouth HDPE	None
PCBs	SW-846 8082	4-oz. widemouth amber glass	4°C
Radiological	RL-7111 EPA 901.1 HASL-300 SW-846 9310 RL-7116	4 or 8-oz. widemouth HDPE	None
TCL SVOA	SW-846 3550/8270	4-oz. widemouth amber glass	4°C
TCL VOA	SW-846 8260A or Modified SW-846 8021B	2-oz. widemouth glass with Teflon™[a]-septa or one 40-mL glass vial with Teflon™[a]-lined lid	4°C
pH	SW-846 9045	2-oz. widemouth HDPE	None
Geotechnical analyses	ASTM D422 ASTM D954	Shelby Tube	None
Percent moisture Bulk density	ASTM D2218 (percent moisture) ASTM D854-92 (bulk density)	8-oz. widemouth HDPE or plastic bag	None
TOC	SW-846 9060	4-oz. widemouth amber glass	
		Groundwater	
Major ion analysis	EPA 310.2 SW-846 9056 EPA 376.1 EPA 340.2	250-mL HDPE 125-mL HDPE	Cool to 4°C
TCL metals	6010 7060 7130 7420 7470 7740 7840	Three 1-L plastic Two bottles filtered (0.45 and 5 μm) and one unfiltered	Cool to 4°C, HNO_3, pH < 2

Table 2.13 (continued)

Analysis	Analytical method	Container type	Preservative
Hexavalent chromium	SW-846 7196	250-mL HDPE	Cool to 4°C
Cyanide	SW-846 9010B	1-L HDPE	Cool to 4°C, NaOH to pH >12
PCBs	SW-846 8082	1-L amber glass bottle with Teflon™[a]-lined lid	Cool to 4°C
Radiological	RL-7122 (EPA 900.0) RL 7100 RL-7124 TIMS-3 RL-7104 (Radon)	1-L HDPE 1-L HDPE 500-mL Boston Round HDPE 1-L HDPE 20-mL scintillation vial	HNO_3, pH < 2 (all except Radon) Cool to 4°C, mineral oil (Radon)
TCL SVOA	SW-846 3510/8270	1-L amber glass bottle with Teflon™[a]-lined lid	Cool to 4°C
TCL VOA	SW-846 8260A	Three 40-mL glass vials with Teflon™[a]-septa	Cool to 4°C, HCl, pH < 2
TOC	SW-846 9060	250-mL amber glass	Cool to 4°C H_2SO_4, pH < 2
Silica	EPA 370.1	250-mL HDPE	Cool to 4°C
Redox potential	ASTM 2580B	250-mL HDPE	Cool to 4°C
COD	EPA 410.4	250-mL amber glass	Cool to 4°C H_2SO_4, pH < 2
Total suspended solids Total dissolved solids	EPA 160.1 EPA 160.2	1-L HDPE	Cool to 4°C
Oil and grease	EPA 413.1	1-L amber glass	Cool to 4°C H_2SO_4, pH < 2

[a] Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

Table 2.14. Average spike recovery (%R) and duplicate RPD for the WAG 3 RI CSLs

Parameter	Water				Soil			
VOA	%R (MS/MSD)	Control Limits (%)	RPD (%)	RPD Limit (%)	%R (MS/MSD)	Control Limits (%)	RPD (%)	RPD Limit (%)
Vinyl chloride	96/98	50–150	4.9	30	80/75	50–150	8.8	30
1,1-dichloroethene	100/100	50–150	5.1	30	90/85	50–150	8.5	30
cis-1,2-dichloroethene	109/112	50–150	4.2	30	92/89	50–150	8.7	30
trans-1,2-dichloroethene	92/92	50–150	4.2	30	92/89	50–150	8.8	30
TCE	119/121	50–150	4.2	30	99/97	50–150	8.0	30
PCBs	%R (LCS/LCSD)	Control Limits (%)	RPD (%)	RPD Limit (%)	%R (MS/MSD)	Control Limits (%)	RPD (%)	RPD Limit (%)
Aroclor-1254	107/113	50–150	5.9	30	93/94	50–150	4.9	30
SVOA	%R (LCS/LCSD)	Control Limits (%)	RPD (%)	RPD Limit (%)	%R (MS/MSD)	Control Limits (%)	RPD (%)	RPD Limit (%)
Phenol	26/20	12–110	13.9	42	64/62	26–90	8.5	35
2-Chlorophenol	63/53	27–123	16.3	40	68/65	25–120	9.9	50
1,4-Dichlorobenzene	64/58	36–97	12.1	28	55/53	28–104	8.6	27
N-Nitroso-di-n-propylamine	78/70	41–116	13.3	38	66/61	41–126	8.7	38
1,2,4-Trichlorobenzene	62/56	39–98	13.3	28	55/52	38–107	8.1	23
4-Chloro-3-methylphenol	59/52	23–97	17.7	42	60/60	26–103	11.6	33
Acenaphthene	86/77	46–118	10.2	31	90/76	31–137	10.4	19
4-Nitrophenol	16/17	10–80	23.3	50	54/57	11–114	10.3	50
2,4-Dinitrotoluene	88/78	24–96	21.4	38	69/70	28–89	11.7	47
Pentachlorophenol	34/30	9–103	17.2	50	28/31	17–109	12.6	47
Pyrene	73/72	26–127	9.2	31	128/94	35–142	9.3	36

Table 2.14 (continued)

Technetium-99	%R (LCS/MS)	Control Limits (%)	RPD Dup(%)	RPD Limit (%)	%R	Control Limits (%)	RPD Dup(%)	RPD Limit (%)
^{99}Tc	102/99	50–150	6.0	50	NA	NA	NA	NA

Gamma Spectroscopy	%R	Control Limits (%)	RPD Dup(%)	RPD Limit (%)	%R (LCS)	Control Limits (%)	RPD Dup(%)	RPD Limit (%)
Gamma activity (^{241}Am)	NA	NA	NA	NA	95	50–150	NC	50
Gamma activity (^{137}Cs)	NA	NA	NA	NA	105	50–150	40.9	50
Gamma activity (^{60}Co)	NA	NA	NA	NA	99	50–150	NC	50

Gross Alpha/Beta	%R (LCS)	Control Limits (%)	RPD Dup(%)	RPD Limit (%)	%R (LCS)	Control Limits (%)	RPD Dup(%)	RPD Limit (%)
Gross alpha	109	50–150	10.6	50	111	50–150	16.1	50
Gross beta	101	50–150	10.9	50	101	50–150	11.5	50

NA = Not Analyzed by the CSL in this matrix
NC = Not Calculated due to insufficient data

Table 2.15. Ambient air sample data from SWMU 4

Instrument	Readings	
Combustible gas indicator readings (upon opening the borehole)	O_2	10.9%
	H_2S	4 ppm
	LEL	11%
	CO	371 ppm
Photoionization detector	10.2 eV	45 ppm
	11.7 eV	500 ppm
Detector tubes TCE tube 132L Polytech #4, Section 6 (CO, phosphine, phosgene, HCN, mercaptans, ethylene, acetylene, H_2S)	Elevated TCE (in excess of 70 ppm)	

Table 2.16. Tedlar™[a] Bag and Summa™[a] Canister airborne contaminant levels

Name	Chemical symbol	Molecular weight	Tedlar™ Bag (ppm)	Summa™ Canister 1 (ppm)	Summa™ Canister 2 (ppm)	Ceiling value (ppm)	IDLH value (ppm)	PEL (ppm)	TLV (ppm)	STEL (ppm)	Comments
Vinyl chloride	$CH_2{=}CHCl$	62.5	68.6	—	—	5	ND	1	5	—	Carcinogen
Chloroform	$CHCl_3$	119.4	86.7	—	26	50	500	50 (ceiling)	10	—	Carcinogen
Trichloroethene	$ClCH{=}CCl_2$	131.4	246	410	1100	200 300– (5 minutes maximum peak in any 2 hours)	1000	100	50	100	Carcinogen
Carbon tetrachloride	CCl_4	153.8	366	410	120	None	200	None	5	10	Carcinogen
1,2-Dichloroethene	$C_2H_4Cl_2$	99.0	328	420	110	100 200– (5 minutes maximum peak in any 2 hours)	50	50	10	—	Carcinogen
4-Methyl-2-pentanone (MIBK)	$CH_3CoCH_2CH(CH_3)_2$	100.2	—	510	200	—	500	100	5	10	CNS

[a] Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

CNS = Central nervous system
IDLH = Immediately dangerous to life or health
ND = Not determined
PEL = Permissible exposure limit
STEL = Short-term exposure limit
TLV = Threshold limit value

3. PHYSICAL CHARACTERISTICS OF WAG 3

This chapter presents the physical and ecological characteristics of the PGDP in general and the WAG 3 SWMUs in particular. A discussion of region- and PGDP-wide characteristics is followed by SWMU-specific discussions that explore the specific and unique aspects of each SWMU that would influence contaminant release and migration. Some of the physical aspects will not vary across the SWMUs (e.g., temperature and precipitation). In other cases, very little variation is evident due to similarity in the three SWMUs (e.g., ecology and soil). These aspects of the physical characteristics of the WAG 3 SWMUs, therefore, are not discussed in detail. These aspects of the SWMUs that do differ (particularly the subsurface geology and hydrogeology) are discussed in sufficient detail to support subsequent evaluations of the nature and extent and the fate and transport of contaminants exiting the WAG 3 burial cells and entering the external environment.

The on-site physical characteristics of PGDP have been detailed in previous investigations by Clausen et al. (1992b), CH2M HILL (1992), CDM Federal (1992), and EDGe (1989). Miller and Douthitt (1993), TCT-St. Louis (1991), and Wehran (1981) have addressed the off-site physical characteristics. For this report, previous investigations of the geology and hydrogeology were used to describe the regional physical characteristics of western Kentucky and summarize the physical characteristic data compiled for the PGDP area during the WAG 3 RI.

SWMU-specific data collected during the WAG 3 RI included infiltrometer data, subsurface lithologic data, and hydraulic conductivity of the UCRS soils. These data are incorporated into the SWMU-specific discussions.

3.1 REGIONAL TOPOGRAPHY AND SURFACE WATER

The PGDP lies in the Jackson Purchase Region of western Kentucky between the Tennessee and Mississippi Rivers, bounded on the north by the Ohio River (Fig. 3.1). The confluence of the Ohio and Mississippi Rivers is approximately 20 miles downstream (southwest) from the site. The confluence of the Ohio and Tennessee Rivers is approximately 15 miles upstream (east) from the site. The western Kentucky region has gently rolling terrain between 330 and 500 ft above mean sea level (amsl). Tributaries of the Ohio, Tennessee, and Mississippi Rivers dissect the region. All creeks that drain the site flow northward toward the Ohio River. Specific details of regional hydrology and hydrogeology are presented in Sect. 3.8. Characteristics of the soils existing in western Kentucky, including PGDP, are discussed in Sect. 3.3. The dominant topographic features are nearly level to gently sloping dissected plains with shallow, narrow valleys and ridgetops and steep ridge slopes and valley sides. The elevations of the stream valleys in the dissected plains are up to 100 ft lower than the adjoining uplands.

There are approximately 100 small lakes and ponds on DOE property (TCT-St. Louis 1991). Seven settling basins and 17 gravel pits are also located on DOE property. A wetland area covering 165 acres exists immediately south of the confluence of Bayou Creek and Little Bayou Creek (TCT-St. Louis 1991). Local elevations range from 290 ft amsl along the Ohio River to 450 ft amsl in the southwestern portion of PGDP near Bethel Church Road. Generally, the topography in the PGDP area slopes toward the Ohio River at an approximate gradient of 27 ft per mile (CH2M HILL 1992). Ground surface elevations vary from 360 to 390 ft amsl within the PGDP boundary area.

3.2 METEOROLOGY

The PGDP region has a humid-continental climate characterized by extremes of both temperature and precipitation. Figures 3.2 and 3.3 summarize the average monthly temperature and precipitation for the PGDP region between 1984 and 1996. The plots are based on data generated at Barkley Field (regional airport), located southeast of PGDP. The 13-year average monthly precipitation is 3.96 in., varying from an average of 2.59 in. in August to an average of 4.72 in. in February. The 13-year average monthly temperature is 57.9°F, varying from 34.5°F in January to 79.5°F in July.

Recent information on wind direction and speed was obtained from Barkley Field for 1996. Figure 3.4 illustrates average wind speed and direction. The average prevailing wind has a speed of 7.9 mph and is south to southwest. Generally, stronger winds are recorded when the winds are from the southwest.

3.3 SOIL

The general soil map for Ballard and McCracken Counties indicates that three soil associations are present within the vicinity of PGDP (USDA 1976): the Rosebloom-Wheeling-Dubbs association, the Grenada-Calloway association, and the Calloway-Henry association. The predominant soil association in the PGDP immediate property is the Calloway-Henry association, which consists of nearly level, somewhat poorly to poorly drained, medium-textured soils on upland positions. Several other soil groups also occur in limited areas of the region, including the Grenada, Falaya-Collins, Waverly, Vicksburg, and Loring.

The soils in the vicinity of PGDP tend to have a low buffering capacity, with a pH ranging from 4.5 to 5.5. Low pH values are often associated with high cation exchange capacities, so these factors may alter the mobility of soil contaminants (particularly metals) (Birge et al. 1990). The cation exchange capacities measured during the recently completed WAG 6 RI ranged from 8.92 to 69.8 milliequivalents per liter (DOE 1998c).

3.4 POPULATION AND LAND USE

Primary land uses at PGDP include industry and wildlife management; secondary uses include agriculture and recreation. The West Kentucky Wildlife Management Area (WKWMA) and sparsely populated agricultural lands surround PGDP. The closest communities to the plant are Heath, Grahamville, and Kevil, which are located within 5 miles of DOE reservation boundaries. The closest municipalities are Paducah, Kentucky, located 15 miles east of the facility; Cape Girardeau, Missouri, which is approximately 40 miles west of the plant; and the cities of Metropolis and Joppa, Illinois, which are located north to northeast of the plant across the Ohio River from PGDP (Fig. 3.5).

Historically, the economy of western Kentucky has been based on agriculture, although there has been increased industrial development in recent years. PGDP employs approximately 2500 people, and the Tennessee Valley Authority (TVA) Shawnee Steam Plant, less than 10 miles to the west, employs 500 people (Oakes et al. 1987). Total population within a 50-mile radius of PGDP is approximately 500,000, of which approximately 50,000 people live within 10 miles of the plant. McCracken County, where PGDP is located, has a population of approximately 62,879 (verbal communication, Paducah Chamber of Commerce, Dec. 7, 1998).

In addition to the residential population surrounding the plant, WKWMA draws thousands of visitors each year for recreational purposes: hunting, fishing, horseback riding, hiking, bird watching, and sanctioned field trials for hunting dogs. According to WKWMA management, an estimated 5000 anglers visit the area each year.

3.5 ECOLOGY

The following sections give a brief overview of the terrestrial and aquatic systems at PGDP. A more detailed description, including an identification and discussion of sensitive habitats and threatened/endangered species, is contained in the *Investigation of Sensitive Ecological Resources Inside the Paducah Gaseous Diffusion Plant* (CDM Federal 1994) and *Environmental Investigations at the Paducah Gaseous Diffusion Plant and Surrounding Area, McCracken County, Kentucky* (COE 1994).

3.5.1 Terrestrial Systems

The terrestrial component of the PGDP ecosystem includes the plants and animals that use the upland habitats for food, reproduction, and protection. The communities range from an oak and hickory forest in areas that have been undisturbed to managed fence rows and agricultural lands in the more developed areas. Within the WKWMA, approximately 1100 acres are dedicated to agricultural uses. The main crops in the PGDP area include soybean, corn, tobacco, and various grain crops such as millet. Through managed crop use, about 20% of the agricultural harvest is left in place for resident and transient game.

Old field grasslands constitute approximately 2000 acres of the WKWMA. Much of this herbaceous community is dominated by members of the *Compositae* family and various grasses. Woody species, such as red maple, are also occasionally present. Some of this area includes remnant prairie, as indicated by the presence of eastern gammon and Indian grasses. The shrub community represents a more diverse habitat, including both herbaceous and woody species. Within WKWMA, approximately 800 acres consist of scrub-shrub habitat. Dominant trees include cherry, persimmon, sumac, young hickory, and red maple. Where the more forested areas occur, there are hickory, three species of oak, as well as scattered growths of sweetgum and hackberry. Forest and shrub tracts alternate with fence rows and transitional edge habitats along roads and power transmission-line corridors. Elm, locust, oak, and maple, with an understory of sumac, honeysuckle, blackberry, poison ivy, and grape, dominate fencerow communities. Herbaceous growth in these areas includes clover, plantain, and numerous grasses.

Mice, rabbits, and a variety of other small mammals frequent open herbaceous areas. Birds identified in the area include red-winged blackbirds, quail, sparrows, and predators such as hawks and owls. In transitional areas, including fencerows, low shrub, and young forests, a variety of wildlife are present, including opossum, vole, mole, raccoon, and deer. Birds typically found in the transitional areas include red-winged blackbirds, shrikes, mourning doves, quail, turkeys, cardinals, and meadowlarks. Several groups of coyotes also reside in areas around PGDP. In addition to the larger mammals, mature forests contain squirrels, songbirds, and great horned owls. Muskrat and beaver are found in the aquatic habitats of the PGDP area. Many species of waterfowl also use these areas, including wood ducks, geese, herons, and various other migratory birds. Various reptiles, amphibians, and terrestrial invertebrates (e.g., insects and spiders) are present in all areas. Domestic livestock is abundant in surrounding farmlands.

3.5.2 Aquatic Systems

The aquatic communities in and around the PGDP area that could be impacted by plant discharges include two perennial streams, Bayou Creek and Little Bayou Creek; the North-South Diversion Ditch; a marsh located at the confluence of Bayou Creek and Little Bayou Creek; and other smaller drainage areas. The dominant taxa in the surface water include several species of sunfish, especially bluegill and green sunfish, as well as bass and catfish. Bluegills, green and longear sunfish, and stonerollers dominate shallow streams, characteristic of the two area creeks.

3.5.3 Wetlands and Floodplains

Wetlands were identified during the 1994 U.S. Army Corps of Engineers (COE) environmental investigation of 11,719 acres surrounding PGDP. In that investigation, 1083 separate wetland areas were identified and grouped into 16 vegetation cover types (COE 1994). Wetlands inside the plant security fence are confined to portions of drainage ditches traversing the site (CDM Federal 1994). Functions and values of these areas as wetlands are low to moderate (Jacobs 1995); these areas provide some groundwater recharge, floodwater retention, and sediment/toxicant retention. While the opportunity for these functions and values is high, the effectiveness is low due to water exiting the area quickly via the drainage system. Other functions and values (e.g., wildlife benefits, recreation) are very low.

At PGDP, three bodies of water cause most area flooding: the Ohio River, Bayou Creek, and Little Bayou Creek. A floodplain analysis performed by COE (1994) indicated that much of the built-up portions of the plant lie outside the 100- and 500-year floodplains of these streams. In addition, this analysis indicated that ditches within the plant area can contain the expected 100- and 500-year discharges.

3.6 REGIONAL CONCEPTUAL MODEL

Figure 3.6 displays a conceptual model of the geology and hydrogeology at PGDP, and is applicable to the geology at WAG 3. Surficial deposits are comprised of the Upper Continental Deposits (UCD), which includes the UCRS. The UCRS is a groundwater unit in the uppermost 60 ft of sediments that consists of laterally and horizontally discontinuous lenses. Groundwater movement in the UCRS is predominantly downward to the RGA, a regional aquifer encountered at approximately 60 ft bgs. The RGA generally flows to the north, with localized gradients ranging from northeast to nearly due west. The RGA overlies the Clayton and McNairy formations. The following sections describe, in detail, the components of this regional conceptual model.

3.7 PGDP GEOLOGY

3.7.1 Geologic Setting

PGDP is located in the Jackson Purchase Region of western Kentucky, which represents the northern tip of the Mississippi Embayment portion of the Coastal Plain Province (Fig. 3.7). The Jackson Purchase Region is an area of land that includes all of Kentucky west of the Tennessee River. The stratigraphic sequence in the region consists of several hundred feet of unconsolidated Cretaceous, Tertiary, and Quaternary sediments unconformably overlying an erosionally truncated Paleozoic bedrock. A lithostratigraphic column of the Jackson Purchase Region is shown in Fig. 3.8.

Within the Jackson Purchase Region, the basement rock is Precambrian age with overlying exposed material primarily of Devonian and Holocene age having a maximum thickness of 12,000–15,000 ft. The Devonian stratum crops out along the western shore of Kentucky Lake while Mississippian carbonates form the nearest outcrop of bedrock and are exposed approximately 9 miles northwest of PGDP in southern Illinois (Clausen et al. 1992a). The Coastal Plain deposits unconformably overlie Mississippian carbonate bedrock and consist of the following: the Tuscaloosa Formation, the sand and clays of the Clayton/McNairy Formations, the Porters Creek Clay, and the Eocene sand and clay deposits (undivided Jackson, Claiborne, and Wilcox Formations). Continental deposits unconformably overlie the Coastal Plain deposits, which are in turn covered by loess and/or alluvium.

3.7.2 Geology

Bedrock

The entire PGDP area is underlain by Mississippian carbonates. This bedrock consists of dark gray limestone with some interbedded chert and shale. Regionally the Mississippian strata dip gently to the south. (Bedrock was not encountered in any of the WAG 3 RI borings.)

McNairy Formation

In the Late Cretaceous, a sea encroached northward, leading to deposition of the McNairy Formation (Clausen et al. 1992b). In the southeastern part of the Jackson Purchase Region, the McNairy Formation consists of mostly sand. The dominant lithology of the McNairy Formation in the PGDP area is a dark gray to bluish-gray, micaceous, often pyritic or lignitic clay with interbedded silt and fine- to medium-grained, silty clayey sands. In an occasional deep boring, a silty sand facies of the McNairy was encountered immediately below the RGA. The middle portion of the McNairy is tentatively correlated to the Levings Member of Illinois. It is described as a lignitic silt in Illinois but as a series of silty, clayey sands extending from approximately 160 to 225 ft bgs in Kentucky.

The Clayton Formation is Paleocene in age but is difficult to differentiate from the underlying McNairy Formation. The two formations are discussed as one geologic unit (the McNairy Formation) in this report because of the lithologic similarity and uncertainty associated with placement of the contact.

The Upper Cretaceous McNairy Formation was the oldest unit investigated during the WAG 3 RI. Soil borings in SWMUs 4, 5, and 6 were drilled into the upper portion of the McNairy

Formation. Local elevation differences at the top of the McNairy can be attributed to differential erosion caused by streams that flowed over this unconformable surface during Pleistocene glacial episodes (Clausen et al. 1992a).

Continental Deposits

Pleistocene Continental Deposits unconformably overlie the McNairy Formation throughout the PGDP area. Ancestral rivers bordered the Jackson Purchase Region in approximately the same position as the present Tennessee, Ohio, and Mississippi Rivers (Olive 1980). Increased flow in the ancestral Tennessee River, combined with large sediment loads, resulted in the formation of an alluvial fan in the area of the confluence of the Ohio and Tennessee Rivers (Olive 1980). The Continental Deposits resemble a large, low-gradient, alluvial fan that covered much of the region and eventually buried the erosional topography.

Erosion and reworking of alluvial fan deposits have resulted in the present thickness and distribution of the Continental Deposits. The thicker sequences of Continental Deposits represent valley fill deposits and can be informally divided into a lower unit (gravel facies) and an upper unit (clay facies). The two distinct facies are as follows.

Lower Continental Deposits (LCD). The LCD are found throughout the plant area and to the north, but pinch out to the south, southeast, and southwest against and along the slope of the Porters Creek Terrace. The LCD are a gravel facies consisting of chert gravel in a matrix of poorly sorted sand and silt that rests on an erosional surface representing the beginning of the valley fill sequence. The LCD were deposited on an irregular east-west trending erosional surface exhibiting steps or terraces. Alluvial terraces are former floodplains corresponding to different glacial events. The gravel deposit averages 30 ft thick, but some thicker deposits (as much as 50 ft) are found in deeper scour channels.

The Pleistocene age LCD are a prominent fluvial gravel facies beneath PGDP and are considered to be the lower part of the RGA. These coarser-grained sediments unconformably overlie the finer-grained Cretaceous McNairy Formation as a Pleistocene erosional surface. The top of this erosional surface rises to the east and south of PGDP. The LCD are primarily distinguished from the overlying UCD by a coarser grain size.

The dominant lithology of LCD is a poorly sorted, brownish-yellow to strong brown chert gravel with occasional sand and silt. Immediately above the gravel facies, a fine- to medium-grained pale yellow to brownish-yellow silty sand was present over most of the investigative area. This sand was encountered at a depth of 60–80 ft and is approximately 10–15 ft thick. The sand thins toward the southeast and is absent in the southwest portion of the PGDP area. Due to the complex nature of the depositional environment in which the LCD and UCD were deposited, the contact separating the two is locally gradational. This makes it more difficult to determine the units' boundaries and thicknesses.

The top of the gravel facies often mirrors the top of the lower McNairy Formation as it was deposited above an unconformable surface. The LCD thickness was observed to vary significantly between sites. On the western side of SWMU 4, the LCD were observed to be between 70 and 80 ft thick.

Upper Continental Deposits. The UCD are primarily a fine-grained, clastic facies varying in thickness from 15 to 55 ft that consist of clayey silt with lenses of sand and occasional gravel. The UCD are differentiated from the underlying LCD by grain size. The UCD represent sediments deposited in a fluvial and lacustrine environment (Finch 1967, Frye et al. 1972). Widespread lacustrine sedimentation occurred along the present Ohio River and Tennessee River valleys when tributaries became choked with sediments released during periods of glacial recession. Damming of these tributaries created slackwater lakes where the fine-grained sediments comprising the UCD were deposited. Depending on stages of glaciation, periods of lacustrine deposition were followed by periods of erosion. As aggradation of the fluvial system continued, stream gradients in the ancestral Tennessee River and tributaries lessened. Lower gradients likely favored a transition from a braided environment to a meandering environment.

The UCD is generally comprised of three zones in the area of SWMUs 4, 5, and 6. The uppermost zone consists of silty clay to clayey silt to a depth of 15–20 ft in the north. The middle zone consists of poorly sorted, dark yellowish-brown to yellow-brown silty sands and gravels that are interbedded with silts and clays. The middle zone differs from the upper zone by the presence of sand/gravel lenses and an increase in silt content. These coarser-grained sediments are prevalent between 20 and 40 ft bgs. The clay content of the UCD generally increases significantly near the base so that the dominant lithology is a silty clay with minor occurrences of lenticular sand and gravels. This silty clay unit acts as a semiconfining layer above the RGA. The contact between the middle and lower zones is dominantly gradational, but it can be locally sharp. The lower zone is present to the east and south of PGDP and consists of approximately 10 ft of yellowish-grayish-brown silty clay with minor sand content. All the UCD units rise and thin as they approach the Porters Creek Terrace to the south.

Surface Soil/Loess/Fill

The surface and near surface deposits found in the vicinity of PGDP are Pleistocene to recent in age and consist of loess and alluvium. Only the most recent (Illinoisan- and Wisconsinan-aged) deposits are represented in the sedimentary sequence. Both units are composed of clayey silt or silty clay and range in color from yellowish-brown to brownish-gray or tan, making field differentiation difficult. Loess deposits overlie UCDs throughout the WAG 3 area.

As discussed in Sect. 3.3, the predominant soil association in the vicinity of PGDP is the Calloway-Henry association (USDA 1976). The fragipan subsurface horizon within this soil is a densified silty or loamy layer, which may be cemented by amorphous material. Excavation and construction activities at PGDP over the past 45 years have reduced the continuity of the fragipan layer and increased vertical drainage throughout the plant area (CH2M HILL 1992).

3.8 HYDROLOGY AND HYDROGEOLOGY

Surface Water

Information presented herein regarding the surface water setting at PGDP was derived from *Results of the Site Investigation, Phase II, Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (CH2M HILL 1992). PGDP is located in the western portion of the Ohio River drainage basin. The plant is within the drainage areas of Bayou Creek and Little Bayou Creek and is situated on the divide between the two creeks (see Fig. 3.1).

Bayou Creek is a perennial stream with a drainage area of approximately 18.6 square miles. It generally flows northward from approximately 2.5 miles south of the plant site to the Ohio River, and extends along the western boundary of the plant. Little Bayou Creek, also a perennial stream, originates within WKWMA, flows northward to the Ohio River, and extends along the eastern boundary of the plant. The approximate drainage area of Little Bayou Creek is 8.5 square miles (CH2M HILL 1992). The confluence of the two creeks is approximately 3 miles north of the plant site, just upstream of the location at which the creeks discharge into the Ohio River. The drainage areas for both creeks are generally rural; however, they receive surface drainage from numerous swales that drain residential and commercial properties, including WKWMA, PGDP, and the TVA Shawnee Steam Plant. A major portion of the flow in both creeks north of PGDP is effluent water from the plant, discharged through KPDES-permitted outfalls. Deer Lick, Snake Creek, and Slough Creek drain the northwestern portion of the PGDP boundary.

The USGS maintains gauging stations on Bayou Creek 4.1 and 7.3 miles from the Ohio River and a station on Little Bayou Creek 2.2 miles upstream from its confluence with Bayou Creek. The mean monthly discharge at Bayou Creek varies from 6.53 to 60.7 ft^3/s at the downstream station and 6.53 to 60.7 ft^3/s at the upstream station. The mean monthly discharge on Little Bayou Creek ranges from 0.89 to 33.5 ft^3/s.

Man-made drainages receive storm water and effluent from PGDP. The plant monitors 17 outfalls, which have a combined average daily flow of approximately 4.9 mgd (Clausen et al. 1992b). Water flow in these ditches is intermittent based on seasonal rainfall. The plant ditches are generally considered to be located in areas where the local groundwater table is below the bottoms of the ditch channels. Therefore, the ditches probably function as influent (losing) streams most of the time, resulting in some discharge to the subsurface.

Surface water bodies in the vicinity of PGDP include the Ohio River, Metropolis Lake (located east of the Shawnee Steam Plant), and small ponds, clay and gravel pits, and settling basins scattered throughout the area. There is a marshy area just south of the confluence of Bayou Creek and Little Bayou Creek. The smaller surface water bodies are expected to have only localized effects on the regional groundwater flow pattern.

Groundwater

The local groundwater flow system in the vicinity of PGDP exists primarily within unconsolidated sediments. Information presented herein regarding the groundwater setting at PGDP was derived from the *Report of the Paducah Gaseous Diffusion Plant Groundwater Investigation Phase III* (Clausen et al. 1992b). The regional hydrogeology discussion is intended to provide a general overview of the groundwater flow regime for PGDP.

The regional groundwater flow system occurs within the Mississippian Bedrock, Cretaceous McNairy Formation, Eocene Sands, Pliocene Terrace Gravel, Pleistocene LCD, and UCD. Terms used to describe the hydrogeologic flow system are the McNairy Flow System, Eocene Sands, Pliocene Terrace Gravel, RGA, and UCRS. Specific components have been identified for the regional groundwater flow system and are defined in the following paragraphs.

Paleozoic Bedrock Aquifer

Limestone, believed to be the Mississippian-aged Warsaw Limestone, subcrops beneath PGDP. Groundwater production from the bedrock aquifer comes from fissures and fractures and from the weathered rubble zone near the top of the bedrock. The bedrock aquifer was not encountered during the WAG 3 RI.

McNairy Flow System

The McNairy Flow System consists of the interbedded layers and/or lenses of Cretaceous-aged silty/clayey sand, clay, sand, and occasional gravels. Regionally, the sand in the McNairy Formation is an excellent aquifer in the southeastern part of the Jackson Purchase Region. The McNairy Formation grades from mostly sand in those areas to containing significant amounts of silt and clay near PGDP (Clausen et al. 1992a). Regionally, the McNairy recharges along areas of outcrop in the eastern part of the region, near Kentucky Lake and Lake Barkley (Davis et al. 1973). Water movement is north and northwest toward discharge areas in Missouri and along the Ohio River.

The McNairy Formation subcrops beneath the plant at depths ranging from about 90 to 120 ft. Sand facies account for 40–50% of the total formation thickness of approximately 225 ft. In areas where the RGA overlies the McNairy Flow System and where the RGA is in direct hydraulic connection with coarser-grained sediments of the McNairy Formation, the McNairy flow is coincident with that of the RGA. The presence of McNairy Formation sands immediately below the RGA would promote potential downward flow of groundwater; however, because the sands below the RGA are of limited extent, substantial downward flow of groundwater does not occur. Groundwater flow in the McNairy is considered coincidental with the RGA having a lateral component to the north-northwest.

Davis et al. (1973) reported values of hydraulic conductivity for the McNairy Flow System ranging from 1.4×10^{-8} to 4.7×10^{-2} cm/s. During the WAG 27 RI, values of hydraulic conductivity were measured from 8.2×10^{-8} to 1.1×10^{-3} cm/s (DOE 1999b). The range of five orders of magnitude difference is due to depositional heterogeneity within the McNairy Formation.

Regional Gravel Aquifer

The RGA consists of a Pleistocene gravel deposit overlying the erosional surface of the McNairy Formation and is the primary aquifer within the local flow system. Toward the southern part of PGDP, the RGA pinches out against the Porters Creek Terrace (Fig. 3.9). In the north-central portion of the plant site, the lower gradients are a result of the thickened Pleistocene sequence containing higher fractions of coarse sand and gravel. Northward, near the Ohio River, the hydraulic gradient increases as a result of either a thinner section of the RGA or low-permeability bottom sediments in the Ohio River.

Regional groundwater flow within the RGA trends north-northeast toward base level represented by the Ohio River. The hydraulic gradient varies spatially but is on the order of 1.0×10^{-4} to 1.0×10^{-3} ft/ft (Clausen et al. 1992b). Hydraulic conductivities for RGA range from 4.0×10^{-2} cm/s (100 ft/day) to 5.3×10^{-1} cm/s (1500 ft/day) (Jacobs 1997). These values are based on slug tests, pump tests, grain-size distribution, and groundwater modeling. Variations in grain size distribution and sorting accounts for the range of hydraulic conductivity values reported for the RGA. These variations are characteristic of fluvial depositional environments. The RGA is recharged by infiltration from the UCRS and some underflow from the terrace gravels that are in the southern portion of PGDP.

Upper Continental Recharge System

The UCRS consists of the surface loess and UCD, primarily clayey silt with lenses of sand and occasional gravel. The UCRS is subdivided into three general horizons:

- Hydrogeologic Unit 1 (HU1)—loess and alluvium,
- HU2—an intervening sand and gravel interval, and
- HU3—a lower silt and clay interval.

These horizons are highly subjective, but each exhibits clear features that stand out throughout the investigation area. "UCRS" generally refers to the sand and gravel lithofacies of HU2, but also the silty clays of HU3 that confine the uppermost water-saturated units. The HU2 permeable units are only seasonally saturated and may be considered perched groundwater aquifers.

UCRS groundwater flows downward into the RGA, hence, the term "recharge system." Strong vertical gradients exist between the UCRS and RGA, which display hydraulic head differences of as much as 30 ft. Head differences between the RGA and UCRS indicate a primarily downward gradient from the UCRS to RGA. Horizontal flow in the UCRS may exist nearer to the Porters Creek Terrace and further south as HU3 increases in grain size to a sandy clay in the southeast.

When the HU2 layer is saturated, historical data show that hydraulic conductivity values range from 3.7×10^{-6} to 3.97×10^{-5} cm and storage coefficients range from 7.43×10^{-3} to 5.9×10^{-2} (DOE 1998c) suggesting that this lower clay unit serves as an aquitard above the more permeable RGA. Perched groundwater has been measured to 20 ft bgs.

Regionally, the UCRS thickness ranges from 0 ft to 50 ft. In a study by Clausen et al. (1992a), UCRS hydraulic conductivity values ranged from 1×10^{-8} to 1×10^{-2} cm/s. Samples collected during the WAG 3 RI displayed values of hydraulic conductivity that ranged from 2.8^{-5} to 8.4^{-9} cm/s (Table 3.1). Variations in the hydraulic conductivity are a result of the highly variable lithologies (ranging from silty clays to sand and gravel lenses).

3.9 WAG 3 PHYSICAL CHARACTERISTICS

The following sections address the physical characteristics at WAG 3.

3.9.1 WAG 3 Surface Features

The PGDP facility generally consists of areas where (1) improvements have been made and permanent structures exist, (2) asphalt or gravel roads were constructed, (3) UF_6 cylinder storage yards are present, and/or (4) former burial grounds have been developed. The three SWMUs for the WAG 3 RI—4, 5, and 6—can all be classified as burial grounds, and none of the three have had improvements since termination of waste disposal activities (see Fig. 1.2). The WAG 3 SWMUs are drained by ditches that discharge into KPDES outfalls and Bayou Creek west of the plant.

SWMU 4 (Fig. 3.10) encompasses an area of 5⅓ acres. SWMU 4 is bounded on the north by Virginia Avenue, on the east by 6th Street, on the west by 4th Street, and on the south by an active railroad spur. This SWMU is an open grass field that at one time was used for the burial and disposal of various waste materials in designated burial cells. There have not been any permanent structures. A short, narrow, gravel road that enters from 4th Street is nearly completely grass covered. Except for this rarely used road, the entire site is covered with a variety of field grasses and clovers. The site (as well as the other two SWMUs) is routinely mowed by the PGDP grounds crew—typically once a month from April through September. SWMU 4 is bounded on three sides (north, east, and west) by shallow drainage swales that direct surface runoff to the northwest corner of the site. Surface runoff passes beneath Virginia Avenue through a drainage culvert where it is discharged into Ditch 015 (also known as KPDES Outfall 015). The ground surface of the burial area has been graded so that surface runoff is directed toward the surrounding drainage swales. There is an elevation difference of approximately 10 ft between the highest point in the SWMU to the adjacent drainage swales.

SWMU 5 is a classified burial area of approximately 4⅓ acres in the northwest section of the facility (Fig. 3.11). Unnamed gravel roads parallel the northern and southern boundaries while the security Patrol Road lies to the west. On the east side, a third gravel road connects the other two and has an offshoot at the center to the east. The SWMU is fenced to limit access to authorized personnel only. The ground surface is covered with short grasses and various flowering herbaceous plants. It is topographically higher near the center and there are no surface structures. The topographic relief is about 20 ft from the boundaries of the SWMU near the fenceline to the center of the burial area, which is offset to the east. Outside the SWMU fence, shallow drainage swales less than 1 ft in depth and about 4 ft wide direct surface runoff to Ditch 001, located approximately 50 ft south.

SWMU 6 is due east of SWMU 5 and is approximately ⅓ acre (Fig. 3.12). This area is relatively flat and is bounded to the north by a set of abandoned railroad tracks, to the east by a 5-ft-wide by 4-ft-deep drainage ditch that drains into Ditch 001, and unnamed gravel roads to the west and south. The ditch is very intermittent with water present only during extensive rain events. The ground surface is medium to tall grasses (up to 3 ft high) with occasional pockets of young trees and shrubs. Approximately 50% of the surface area has been used to store radioactively contaminated equipment and materials. These items include industrial forklifts and transport carts, flatbed trailers, generators, concrete pipes, and other miscellaneous items. This equipment storage area was inaccessible during the investigation except through the use of angled HSA sampling techniques.

As noted earlier, native surface soils at PGDP are part of the Calloway-Henry Association. However, at the SWMUs comprising WAG 3, it is likely that extensive reworking of the surface [as a result of the burial cell excavations and associated construction activities (e.g., road building)] has resulted in removal of much of the native soil cover. At both SWMUs 4 and 5, a cap up to approximately 3 ft thick has been placed over the burial cells (at SWMU 4 it appears that the cap covers the entire SWMU). At SWMU 6, it is uncertain how much of the surface cover is native material and how much is anthropogenic fill/cover. Regardless, it is likely that the ground surface at SWMU 6 has been reworked to the extent that any native soils present may not exhibit their native properties of infiltration.

Results from the infiltrometer tests for all three SWMUs were influenced by the drought conditions prevailing in the region; therefore, there was an initial delay in the infiltration rate (field observation). Under normal conditions, the water would infiltrate the soil quicker because soil moisture content would be at its normal level. However, during these tests, infiltration was retarded until the soil moisture increased, allowing a wetting front to develop. Once this was achieved, the rate of infiltration increased for about 30 minutes, peaked, then began to decrease. Unique to the site located in the southwest corner of SWMU 4, a very rapid decrease in infiltration with a second breakthrough is displayed in the data/graph. This was likely the result of a less permeable layer with a lower transmissivity at depth that, once permeated, allowing the infiltration rate to re-establish. There was no delay in the infiltration rate for both sites in SWMU 4 because, the day before these tests, rain allowed some hydration of the soils. SWMU 5 data are slightly erratic. Although precautions were taken to eliminate the effects of the rain that occurred after initiating the test, it is apparent the infiltration rate data appear influenced. However, the pattern and trend of the infiltration rate are still evident. SWMU 6's data display normal infiltration rates, albeit under dry conditions. Appendix C contains tables and graphs of the test data for SWMUs 4, 5, and 6.

The infiltration rate curves illustrate that the infiltration rate is initially high and tends to decrease over time as the soils become saturated. In nature though this is not normally the case. Once the rainfall ceases, there is a recovery of the infiltration capacity with time. This is evident in the data from SWMU 5 where there were periods of rainfall which decreased the infiltration rate and a recovery is noted as the rate later increased. Based on the incremental infiltration rate data collected and soil descriptions taken from the surface soil samples, the test areas are of Group C with normal to low infiltration rates. During a rain event, infiltration occurs until the rainfall rate exceeds the infiltration capacity. At this point, surface runoff occurs.

3.9.2 WAG 3 Geology and Hydrogeology

Across the PGDP site, the regional geology is comprised of Coastal Plain Deposits (McNairy Formation, Porters Creek Clay and Eocene Sands), LCD (comprised of RGA), UCD (comprised of HU1, HU2, and HU3), and the Surficial Loess and Alluvium. The scope of the WAG 3 RI focuses on the surface soil/loess/fill, the Continental Deposits, the McNairy Formation, and the lithologic units encountered during WAG 3 sampling activities. SWMU-specific lithologic interpretation and cross-sections are provided in the following sections and associated figures.

Lithologic logs developed from the cuttings generated during borehole drilling and used for the lithologic interpretation and cross-section construction are located in Appendix E. The geologic interpretation presented here in this report for WAG 3 is based on field information obtained during the WAG 3 RI and on existing borings and monitoring well logs from previous studies. The following sections detail each SWMU's geology.

3.9.2.1 SWMU 4 geologic interpretation

The lithology for SWMU 4 has been inferred from a total of 44 soil borings that were drilled within the SWMU and along the perimeter of the SWMU boundary. These borings include 4 DWRC borings that were advanced into the McNairy Formation, 8 angled HSA borings that were advanced under the burial cells, and 32 vertical DPT and HSA borings advanced to varying depths. From the soil borings three cross-sections were constructed (Fig.3.13). Two cross-sections have west to east orientations and intersect burial cells, and the third has a north-south orientation and also intersects burial cells. Two cross-sections, A-A' and B-B', parallel the northern and southern SWMU boundaries, respectively, while the third cross-section, C-C', parallels the western boundary of the SWMU. The SWMU 4 borings varied in depth from approximately 3 ft bgs (where refusal or very high radiological readings were encountered) to a depth of 158 ft bgs.

SWMU 4 Lithologic Cross-Sections

Cross-Section A-A' includes borings 004-028 (DWRC), 004-052 (DPT), 004-042 (DPT), 004-035 (DPT), 004-051 (DPT), 004-019 (DPT) and 004-058 (DWRC) as shown in Fig. 3.14. The upper 20 ft of soil was found to be yellowish-brown (10YR 6/8) to brown silty clays to clayey silts (identified on the cross-sections as HU1). The HU2 hydrogeologic unit extends from 20–40 ft bgs with an average thickness of 20 ft. This unit exhibits variable lithology ranging from silty clay to sandy clay to gravelly silty clay to gravel. It is likely that the coarser-grained sections represent lenses within the unit; however, the limited number of soil samples collected from borings 004-052, 004-051, and 005-019 make it difficult to determine whether there is a continuous layer or whether the coarser lithologies represent localized variations within the HU2 hydrogeologic unit. The contact between HU1 and HU2 is shown as a dashed line to reflect the uncertainty associated with the interpretation of this unit.

The HU3 unit extends from approximately 40–55 ft bgs. This unit exhibits variable lithology consisting primarily of silt and clay with varying amounts of sand and a few gravels. The variable lithology of HU3 in the area of SWMU 4 would seem to indicate that it has a reduced capacity to function as an aquitard relative to other areas of the plant. Borings 004-028 and 004-058 both penetrated through the clay unit. The HU4 sand was identified in borings 004-019 and 004-058 with an estimated thickness of 5 ft. The sand-gravel (the RGA, identified on the cross-sections as HU5) can be described as a mixture of medium-grained, well-sorted sand with varying percentages of moderately well-sorted, sub-rounded to sub-angular chert gravel. The overall color of this unit is a medium rust brown.

There appears to be a transition zone between the RGA and McNairy from approximately 105–115 ft bgs supported by the presence of gray to greenish-gray clay mixed with sand in boring 004-028. The dark gray to greenish-gray clay, characteristic of the McNairy Formation, was encountered at depths ranging from 100 ft bgs in the east to 115 ft bgs in the west. The depth to the top of the McNairy increases in boring 004-028 (115 ft bgs) in comparison to boring 004-058 (~100 ft bgs), indicating that there may be a trough in the western portion of the site. The presence of this trough is further supported by cross-sections B-B' and C-C', which exhibit similar lithologies in the western part of SWMU 4.

Cross-Section B-B' uses eight soil borings: 004-029 (DWRC), 004-033 (DPT), 004-042 (DPT), 004-041 (DPT), 004-040 (DPT), 004-039 (DPT), 004-032 (DPT), and 004-058 (DWRC) as shown in Fig. 3.15. A sandy silty clay (HU1) comprises the upper 20 ft of soil. Below HU1, the lithology consists of sandy silt and clay with interbedded layers of sand, gravel, and sandy gravelly clay (HU2). Below HU2, the soil changes to predominantly sandy silt and clay with interbedded layers of sand and gravel extending from approximately 40 to 58 ft bgs (HU3). In general, the HU3 unit exhibits variations in lithology horizontally and vertically across this cross-section. The lithology for boring 004-029 would seem to indicate that there is increased potential for downward migration of contaminants in this portion of the site because of the limited amount of silt and clay observed in this boring. The RGA (consisting of HU4 and HU5) was identified at a depth of 58–120 ft bgs. The HU4 sand was not clearly identified in boring 004-029; however, it is likely that a thin layer of sand (<5 ft) is present from 55 to 62 ft similar to boring 004-058. The RGA deepens and thickens to the west. Total thickness is 60–65 ft compared to the normal thickness of 40–45 ft across the PGDP area. Because the elevation of the RGA base is also lower (250 ft amsl versus 275 ft amsl in 004-058), this suggests a trough in the McNairy Formation surface.

The contact between the RGA and McNairy Formation was identified at the point where the lithology changed from sand or a mixture of sand and silt/clay to a clay or silty clay. This contact was identified at depths ranging from approximately 100 ft in the east to 122 ft in boring 004-029. A mixture of clay and sand was observed from 110 to 120 ft. The clay in this zone was light gray to greenish-gray in color, which is characteristic of the McNairy Formation. This observation may provide additional evidence of an erosional feature in the area of boring 004-029 where there has been mixing and deposition of basal RGA sands and clay from the upper McNairy Formation. This thickened and deepened RGA sequence west of SWMU 4 has implications related to the migration of groundwater contaminants. This "trough" is a potential pathway for materials coming from SWMU 4 (such as the DNAPL TCE) which could increase the likelihood for western migration, making SWMU 4 a likely contributor to the Southwest Plume.

Cross-Section C-C' extends north to south along the western boundary of the SWMU (Fig. 3.16). Four soil borings comprise the cross-section: 004-020 (angled HSA), 004-057 (DPT), 004-024 (angled HSA), and 004-027 (angled HSA). The lithology of this cross-section is very similar to what is seen in cross-section A-A'. Note that none of the three angled borings penetrated burial cells during the investigation. The presentation of the angled borings and the burial cells is intended to show the relationship of the angled borings to the burial cells. A review of Fig. 3.13 (plan view showing the cross-sections) seems to indicate that 004-020 and 004-024 penetrated burial cells, when in fact these borings were drilled adjacent to and under the burial cells. The perspective offered by the figure (looking east from a vantage point west of the site) on a two-dimensional surface gives the appearance that the angled borings penetrated the burial cells. A silty clay (HU1) extends to a depth of approximately 20 ft bgs. A silty sand to sandy gravelly silt zone was identified from 20–40 ft bgs (HU2). The continuity of this unit is somewhat interpretive since there is lithologic variation between the borings in the cross-section. The contacts have been shown as dashed lines to depict this uncertainty. Beneath this coarser-grained unit is a clayey silt to sandy silt with a few gravels, which is identified as the HU3 hydrogeologic unit. The contact between HU2 and HU3 is also somewhat subjective due to the lithologic variation identified from 30–60 ft bgs. The contact is shown at a depth of 40 ft based on the contacts depicted in cross-sections A-A' and B-B'.

The interpretation of the RGA and McNairy Formation for cross-section C-C' is based on the lithologies observed in cross-sections A-A' and B-B'. None of the borings in cross-section C-C' were drilled below a depth of 60 ft bgs. Based on the interpretation shown for cross-sections A-A' and B-B', cross-section C-C' lies within the trough (scour channel) located in the western portion of SWMU 4. Cross-section C-C' depicts a thickened RGA sequence and a deep contact between the RGA and McNairy Formation. This interpretation is supported based on the lithologies from DWRC borings 004-028 and 004-029. Boring 004-028 (cross-section A-A') is located in close proximity to angled HSA boring 004-020 (cross-section C-C'), whereas boring 004-029 (cross-section B-B') was drilled near angled HSA boring 004-024 (cross-section C-C').

3.9.2.2 SWMUs 5 and 6 geologic interpretation

Because SWMUs 5 and 6 are adjacent and geologically similar, they are discussed together in the following sections. Waste material in SWMU 5 was placed in trenches approximately 15 ft deep and covered with native soil. SWMU 6 contains five 6- to 8-ft-deep "waste cells" where scrap metal was buried, then covered with 3 to 5 ft of native soil.

The geology of SWMU 5 has been developed from 16 soil borings that were drilled around the perimeter of the SWMU boundaries. The SWMU is a classified burial area; therefore, no borings were drilled within the SWMU boundary. However, lithologic samples from under the SWMU were collected from angled HSA borings. Three cross-sections were developed from soil borings drilled during this investigation and from historic borings drilled in association with previous investigations (Fig.3.17). Cross-sections A-A' and B-B' parallel the northern and southern boundaries of the SWMU, respectively. Cross-section C-C' trends north–south along the eastern boundary and includes the two eastern endpoints of cross-sections A-A' and B-B'. The majority of SWMU 5 borings were drilled to 60 ft bgs. DWRC borings 005-013 and 005-026 were drilled to 158 and 160 ft deep, respectively. Historic boring H002 was drilled to 73 ft bgs.

The geology for SWMU 6 has been inferred from 18 soil borings drilled in and around the SWMU (Fig. 3.18). Five angled HSA borings were drilled to collect samples and characterize the geology under the burial area. Because of abandoned equipment in the area, two of the five angled borings (006-021 and 006-022) were terminated before reaching the soils beneath the burial cells. Two cross-sections have been developed for SWMU 6; A-A' trends northeast–southeast across the SWMU and includes seven borings, B-B' trends northeast to southwest and includes five borings. The SWMU 6 borings range in depth from 9 to 158 ft bgs. Most are between 25 and 60 ft bgs. DWRC borings 006-024 and 006-025 were drilled to 158 ft bgs with continuous sampling (for lithology) every 5 ft from ground surface to the termination depth of the boring.

SWMU 5 Lithologic Cross-Sections

Cross-Section A-A' includes borings CPT 005-025 and borings 005-15 (DPT), 005-013 (DWRC), 005-028 (HSA), 005-018 (angled HSA), 005-016 (DPT), and 005-019 (angled HSA) (Fig.3.19). The upper 18–20 ft of soil (HU1) was identified as moist to damp silty clays to clayey silts with a yellowish-brown (10YR 6/8) to brown color. A layer of gravelly, silty clay to sandy silt/clay was identified in each of the borings, except 005-013 at a depth of 18–28 ft bgs (HU2). The thickness of the layer and the concentration and physical properties of the gravel varied from boring to boring. This layer has been depicted as a laterally continuous layer; however, the thickness of the layer and lithology varied from boring to boring. Consequently, these may be discontinuous channel fill deposits frequently observed in the PGDP area.

From 40–58 ft bgs is a low permeability layer (HU3) with up to 80% clay. At some locations the clay content decreases and silt and sand increase, but the concentration of clay is high enough throughout the area to classify it as a clay with silt rather than a silty clay. As observed in boring 005-013, a 40- to 50-ft-thick layer of sand and gravel mix (HU4 and HU5) underlies this layer. This layer consists of a mixture of medium-grained, well-sorted sand with varying amounts of coarse, moderately sorted, sub-rounded to sub-angular chert gravel. The lithology is variable throughout the RGA with lithologies ranging from silty/clayey sand (HU4) to sand and gravel to silty sand with a few gravels. The bottom 5–10 ft of the RGA appears to represent a transition zone where there is an increasing silt/clay content combined with a decreasing amount of gravel. The top of the McNairy Formation was identified at 100 to 105 ft bgs. The McNairy Formation consists of a clay unit that is dark gray to greenish-gray clay, stiff to firm with low to moderate plasticity and ranging from dry to moist.

Cross-Section B-B' parallels the southern border of SWMU 5 and includes six soil borings: 005-025 (CPT), 005-022 (angled HSA), H002, 005-017 (DPT), 005-021 (angled HSA), and 005-026 (DWRC) as shown in Fig. 3.20. A sandy, silty clay is present in the upper 35–40 ft bgs (HU1 and

HU2), with a gravel lens at 18 to 28 ft bgs. This lens can be correlated across the SWMU between cross-sections A-A' and B-B' (see Fig. 3.11). Underlying the silty clay is a 20–25-ft-thick silty sandy clay layer (HU3). Boring 005-026 was the only boring in this cross-section that was drilled below the upper portion of the RGA. The lithology of the borings west of 005-026 has been inferred from cross-section A-A' and boring 005-026. The RGA sands and gravels were observed in 005-026 from 58 to 105 ft bgs. The bottom 10 ft (90 to 100 ft bgs) of the RGA consists of a well-sorted, medium-grained silty sand with varying amounts of silt and clay similar to the HU4 sand. The lithology below 100 ft was a greenish-gray dense clay which is characteristic of the McNairy Formation.

Cross-Section C-C' extends north to south along the eastern boundary of the SWMU (Fig. 3.21). Although no borings were drilled within the burial cells, this cross-section cuts across the SWMU, and the location of the buried waste material is depicted. Five soil borings, 005-019 (angled HSA), 005-020 (angled HSA), 005-012 (CPT), 005-027 (HSA), and 005-026 (DWRC), comprise the cross-section, with the two ends tying into the two other transects. The lithology of this cross-section is very similar to that of cross-sections A-A' and B-B'. From ground surface to approximately 40 ft bgs is a silty clay with a 10- to 15-ft-thick gravel lens located at approximately 18–20 ft bgs in borings 005-019, 005-026, and 005-027. These two lithofacies comprise the HU1 and HU2 hydrogeologic units. From approximately 40 to approximately 58 ft bgs is a uniformly thick silty sandy clay (HU3). Boring 005-026 is the only boring that was drilled below 60 ft bgs. The remaining soil elevations were inferred from the contacts of 005-026 and are shown as dashed lines. The silty sand from 58 to 65 ft bgs (HU4) and the sand and gravel mixtures from 65 to 105 ft bgs (HU5) comprise the RGA. From 105 to 160 ft bgs, the greenish-gray silty clay (McNairy Formation) found throughout the PGDP area was observed at SWMU 5.

SWMU 6 Lithologic Cross-Sections

Cross-Section A-A' includes borings 006-025, 006-029, 006-028, 006-012, 006-018, 006-024, and 006-027 as shown in Fig. 3.22. Borings 006-024 and -025 were drilled using DWRC; boring 006-027 used an HSA, and the other four borings used DPT. Borings 006-012 and -018 penetrated Waste Cell "J" which was originally excavated to a depth of about 6 ft. The limited lithologic information suggests that the pit was covered with native soil, silty clays and clayey silts. The upper 15 to 20 ft of soil (HU1) is comprised mainly of silty clays and clayey silts with a predominantly yellowish-brown (10YR6/8 to 10YR5/6) color and ranging from dry to moist.

A 5- to 10-ft-thick layer of gravelly silty clay to sandy silty gravel (HU2) was encountered at a depth of approximately 18–28 ft bgs. The contacts (top and bottom) are depicted with dashed lines because they have been estimated using the sample lithologies identified on the boring logs. The sample collection intervals for the borings did not identify the exact contacts where this gravelly unit started and stopped; therefore, the actual contacts may vary slightly from those shown in Fig. 3.22.

From 30–60 ft bgs is a silty sandy clay identified as the HU3 hydrogeologic unit. The lithology of this unit is variable with increasing and decreasing amounts of sand vertically and horizontally throughout the unit. A 45- to 50-ft-thick layer of silty sand and sand and gravel mix (HU4 and HU5) underlies this layer extending from approximately 58 to 105 ft bgs. The boring logs for DWRC borings 006-025 and 006-027 do not show any clear transition from HU3 into the RGA gravel (HU5). The HU4 sand unit was not identified in either of these borings; however, a thin layer (<5 ft) was identified in the HSA borings used for cross-section B-B'. It is likely that there is a thin layer of sand immediately above the gravel in cross-section A-A' that was not identified in the DWRC borings. This layer is shown in cross section A-A' using dashed lines to depict the estimated contacts between the HU4 sand and HU5 gravel or sand and gravel lithofacies. The color is orange to reddish brown. Underneath this layer is a micaceous clay unit characteristic of the McNairy Formation that is dark gray to greenish gray, stiff to firm with low to moderate plasticity and ranging from dry to moist. The top of the McNairy was identified at ~105 ft bgs and extends from this depth to the total depth (158 ft bgs) of the two DWRC borings.

Cross-Section B-B' includes borings 006-020, -028, -011, -016, and -022; the first and last were drilled at a 45° angle using HSA, while the middle three used DPT as shown in Fig. 3.23. Boring 006-011 penetrated Waste Cell "J" and boring 006-016 probably penetrated Waste Cell "K" or "H." This cross-section has similar lithology to cross-section A-A'. The upper 20 ft of soil (HU1) consists of silty clays and clayey silts with a yellowish-brown (10YR5/8 to 6/4) color and occasional light gray to light brownish-gray mottling. A layer of gravelly silty clay (HU2) was observed in borings 006-028 and 006-016 from 20 to 30 ft bgs. This unit is representative of the gravelly silty clay identified in cross-section A-A' (Fig. 3.22).

From 25 to 60 ft bgs is a layer of lower permeability silty clay (HU3) with varying amounts of silt and sand. The color ranges from yellowish-brown to light gray and is generally moist. Boring 006-016 encountered a sand lens at a depth of 37 ft bgs. The deeper HSA borings, 006-020 and -022, penetrated a fine- to coarse-grained sand layer at 55 to 60 ft bgs; the sand is sub-angular and generally well sorted and yellow-brown in color. This sand unit was not identified in the DWRC borings, but is believed to be representative of the HU4 unit. Since no borings went deeper than 60 ft, the deeper lithology for this cross-section is inferred from the lithologic data from SWMU 5 and cross-section A-A' (SWMU 6). The sand encountered above presumably grades into the sand and gravel unit (HU5) seen in the other cross-sections for SWMUs 5 and 6. The contact between the RGA and McNairy Formation is estimated to be at approximately 105 ft bgs marked by the presence of dark gray to greenish-gray clay.

3.9.2.3 SWMUs 4, 5, and 6 hydrogeologic conceptual model

The general hydrogeologic model for SWMUs 4, 5, and 6 was initially presented in the WAG 3 RI/FS Work Plan (DOE 1998a). The hydrogeologic model was one of the primary tools used to evaluate potential source areas and contaminant migration pathways to develop the sampling strategy for each of the WAG 3 SWMUs. The analytical, lithologic, and geotechnical data collected during the WAG 3 RI have been used to confirm the accuracy of the initial model and update it as necessary. The initial conceptual model was determined to be representative of the actual conditions observed during the WAG 3 RI.

Based on the data derived during the WAG 3 RI, the conceptual model for SWMUs 4, 5, and 6 is consistent with the generally accepted model used to describe the flow system north of the Porters Creek Clay terrace (Fig. 3.6). Groundwater flow through the UCRS (hydrogeologic units HU1, HU2, and HU3) to the top of the RGA is primarily downward. Some lateral dispersion may result as groundwater and contaminants migrate vertically through the sand and gravel lenses within HU2. However, groundwater within the UCRS is generally found in perched, discontinuous gravel lenses. The rate of vertical and horizontal movement (migration) is influenced by the lithology of the individual hydrogeologic units and physical properties of a particular contaminant including solubility, specific gravity, and the individual contaminant's affinity to adsorb to the surrounding soils. Downward movement is also influenced by the lithology of the individual hydrogeologic units, most notably the HU3 hydrogeologic unit which serves as the upper semiconfining unit between the UCRS and the RGA. The HU3 unit exhibits varying thickness and lithology within the

PGDP area which can impact the rate at which groundwater and/or contamination can move through the UCRS. Once groundwater reaches the RGA (HU4 and HU5), then the predominant flow is horizontal. The RGA serves as the primary exit pathway for groundwater from within the PGDP property boundary.

The burial pits/waste cells are the sources of contamination identified in the SWMU 4 soils and groundwater. Contaminants are migrating out of the waste cells as a result of water infiltrating through the cells into the underlying soils (Fig. 3.24). (The infiltrometer tests described in Sect. 3.9.1 indicate that infiltration of surface water through the cap material will occur.) Some limited lateral dispersion appears to be occurring within the HU2 sand and gravel lenses as a result of perched groundwater zones within the HU2 hydrogeologic unit. Once the contaminants reach the RGA, the rate of migration increases as a result of the higher hydraulic conductivity of the RGA sands and gravels. Regional groundwater flow is generally north to northwest in the RGA; however, there is evidence that the top of the McNairy Formation slopes to the west in the western portion of SWMU 4 (as depicted in cross-sections B-B' and C-C' for SWMU 4). This feature results from the erosion of the upper McNairy followed by deposition of alluvial sediments (e.g., sand) resulting in what appears to be a thickened RGA sequence in the western portion of SWMU 4. Chapter 4 discusses the nature and extent of contamination at SWMU 4 in detail and addresses the implications that this trough has with respect to the Southwest Plume.

The greenish-gray silty clays found beneath the RGA are indicative of the McNairy Formation. The deeper DWRC borings (nominal depth of 158 ft bgs) drilled into the upper 60 ft of the McNairy Formation and collected groundwater samples (where groundwater was encountered). The higher clay content and general absence of groundwater in quantities sufficient to collect samples suggests that the McNairy Formation serves as an aquitard limiting further downward migration of contamination at PGDP.

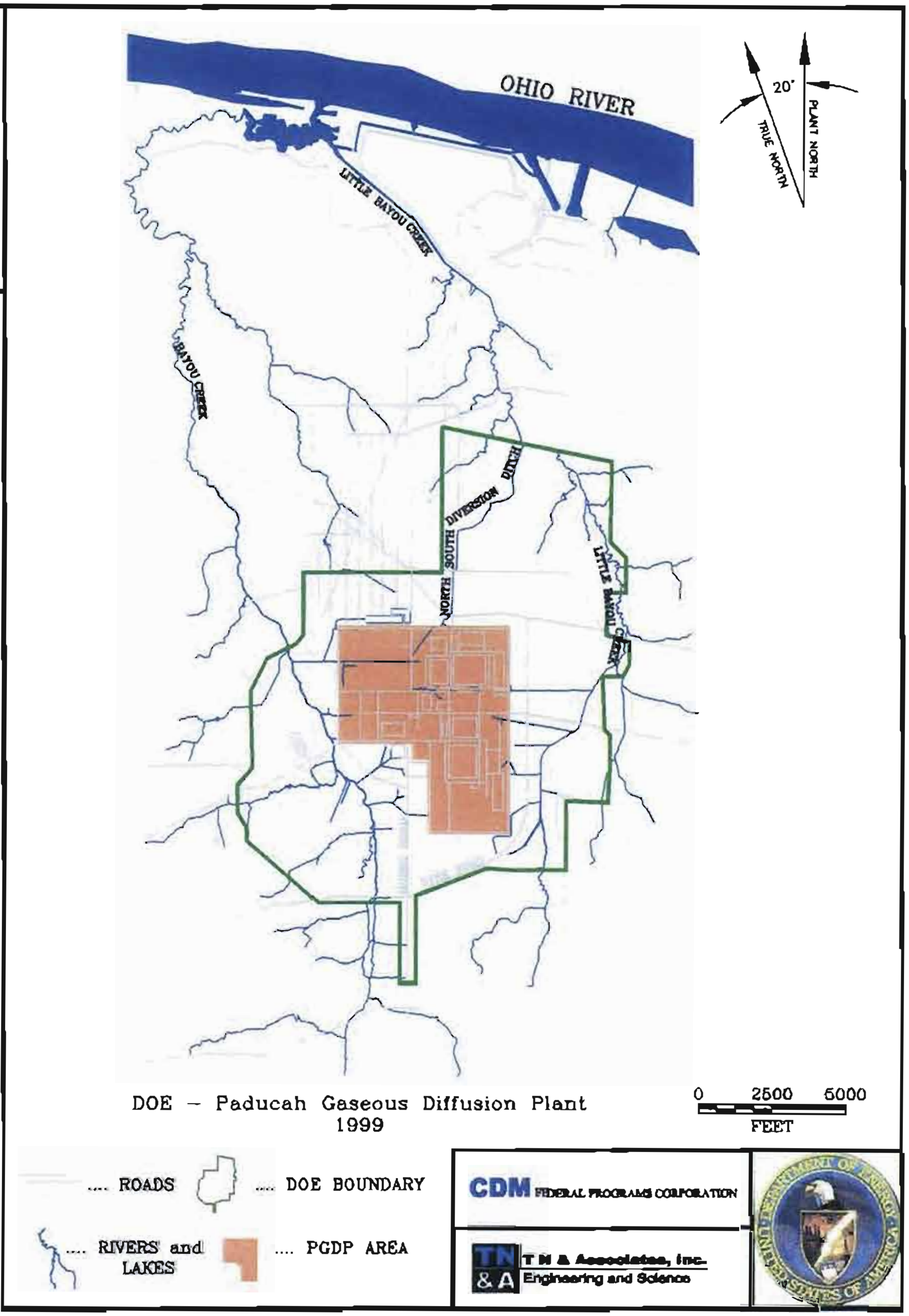


Fig. 3.1. Regional surface water drainage

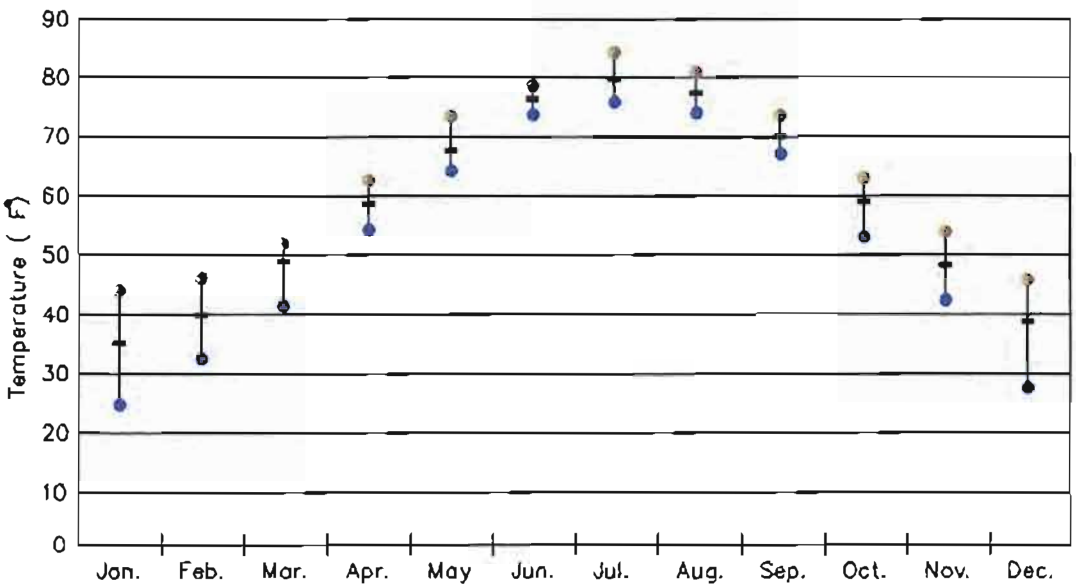


Fig. 3.2. 13 Year average temperature at PGDP;
Barkley Field, Paducah, Kentucky

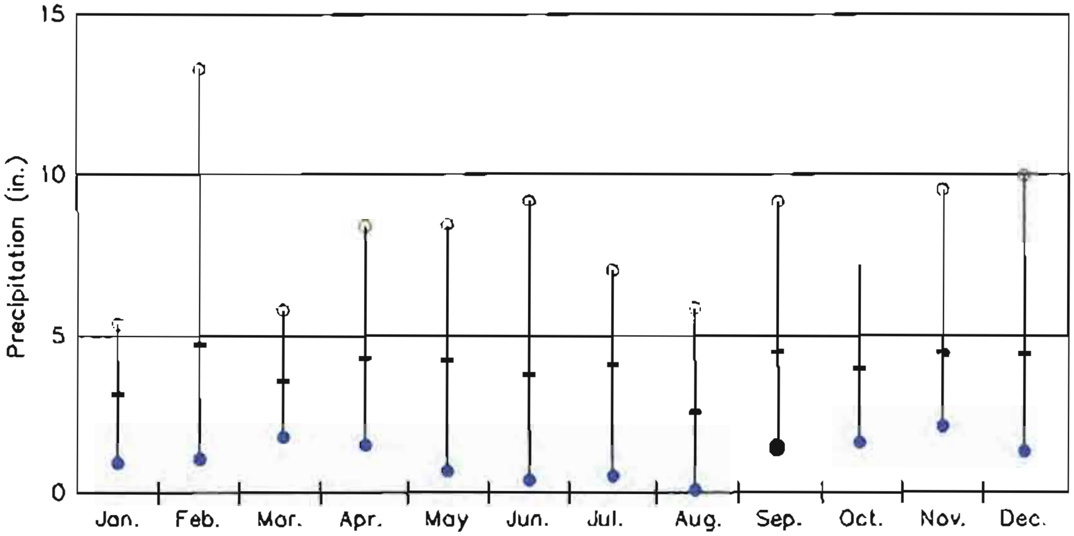


Fig. 3.3. - 13 Year average precipitation at PGDP;
Barkley Field, Paducah, Kentucky

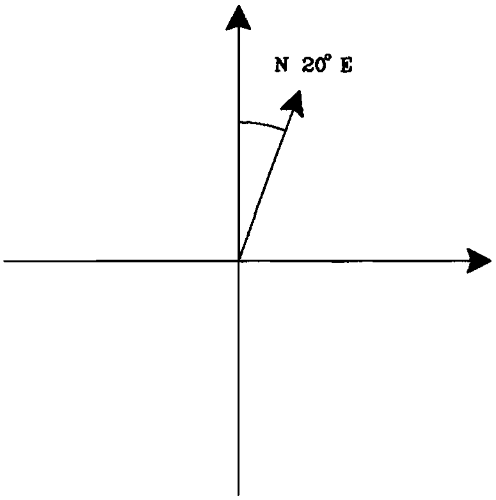
- High value for month
- Average value for month
- ● Low value for month

CDM FEDERAL PROGRAMS CORPORATION

TN & A T N & Associates, Inc.
Engineering and Science

DOE/OR/07-1895/V1&D1

PARAMETER	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR AVG.
RESULT. SPEED (MPH)	1.2	2.7	1.9	3.0	3.8	2.0	0.9	0.6	0.8	1.3	0.7	1.4	1.0
RES. DIR. (TENS OF DEGS.)	27	27	32	23	20	22	34	35	06	26	07	25	25
MEAN SPEED (MPH)	9.8	9.3	8.9	9.6	7.7	5.4	4.9	3.8	4.5	6.0	7.5	7.9	7.1
PREVAIL. DIR. (TENS OF DEGS.)	20	20	32	20	20	20	21	03	23	20	02	21	20



PREVAILING WIND DIRECTION

CDM FEDERAL PROGRAMS CORPORATION

T N & Associates, Inc.
Engineering and Science

AutoCAD FILE: 1999006-6290-A-005.dwg

Fig. 3.4. Wind speed and direction, monthly and cumulative averages for Barkley Field Paducah, Kentucky

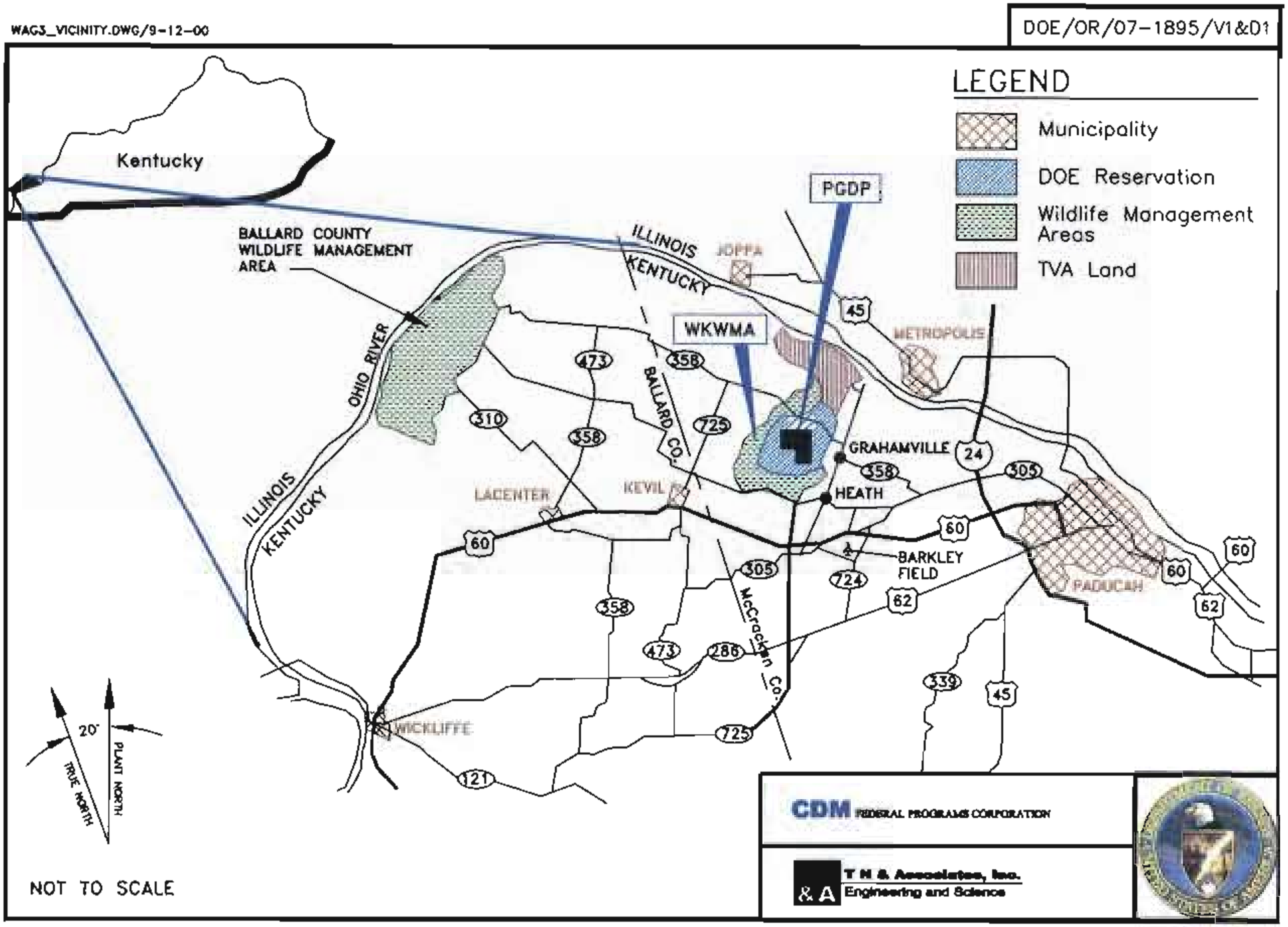
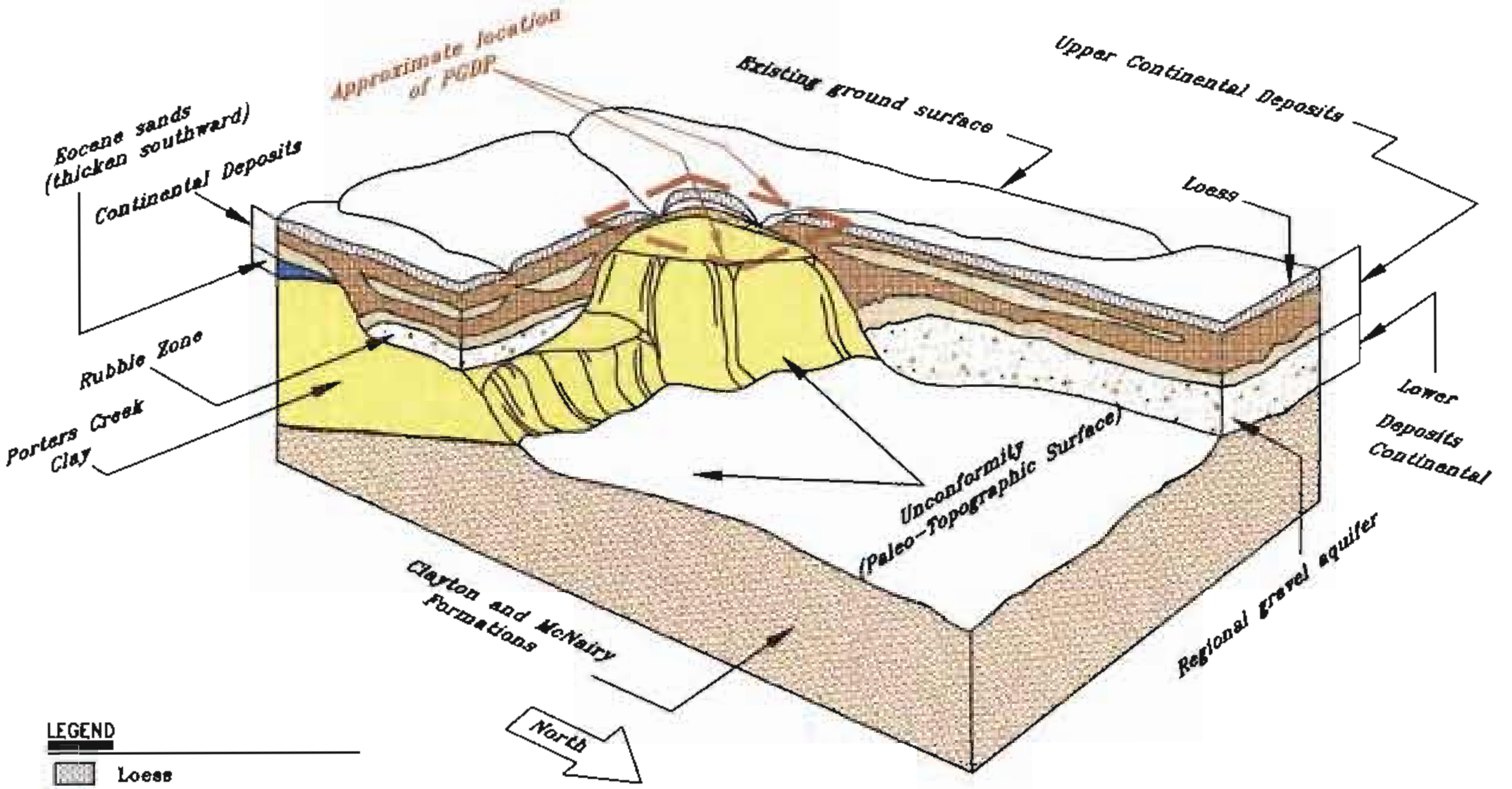


Fig. 3.5. WAG 3 vicinity map.

5134-001\PGDP_STRAT\7-12-00\NTS



LEGEND

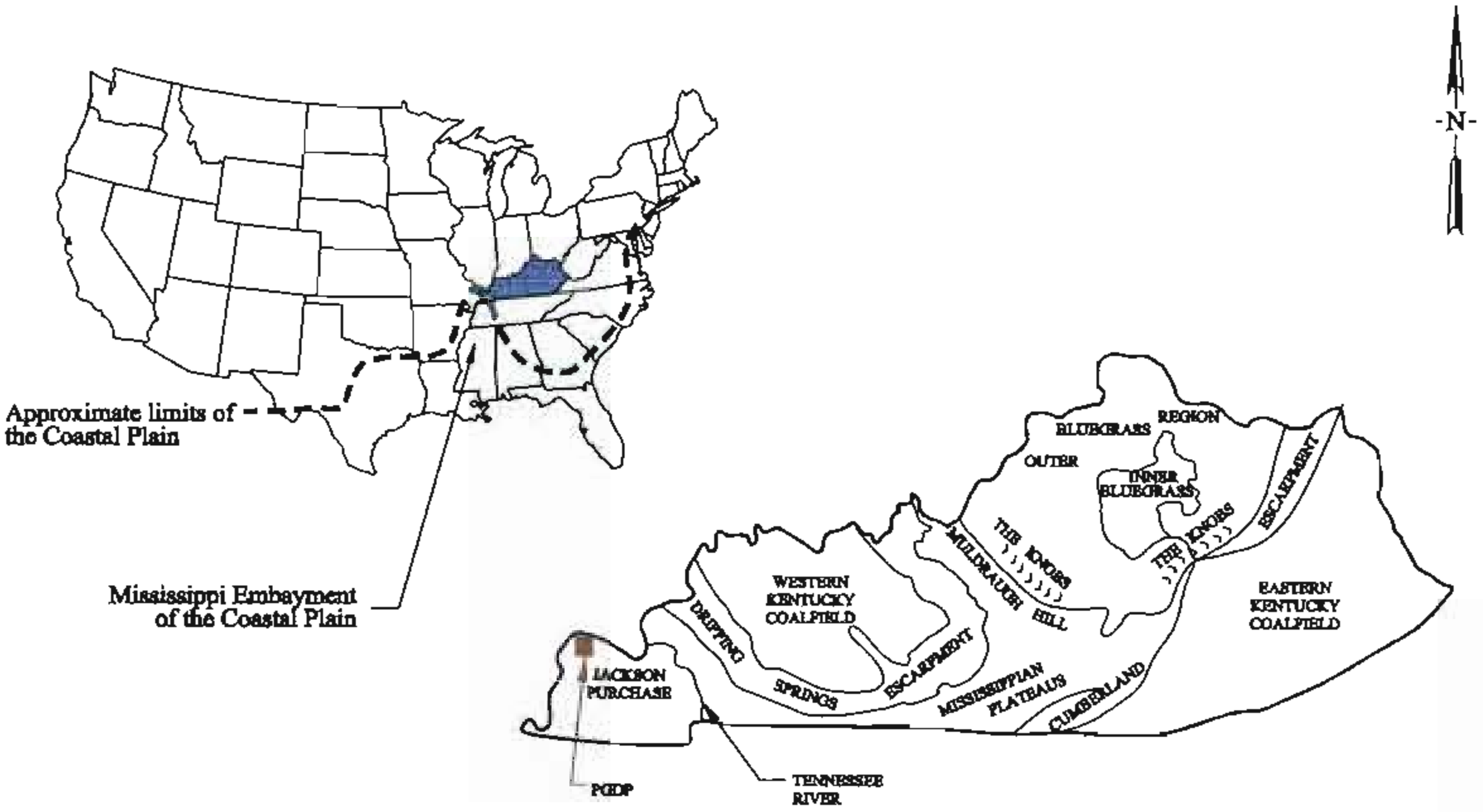
▨ Loess
🟦 Eocene sands
☐ Regional Gravel Aquifer
▨ Clayton and McNairy Formations
🟨 Porters Creek Clay
🟫 Continental Deposits - Interbedded silts/clay and sand/gravel

Source: Clausen et al. 1992a

CDM FEDERAL PROGRAMS CORPORATION

T N & Associates, Inc.
Engineering and Science

Fig. 3.6. Conceptual model of the stratigraphy in the vicinity of PGDP



CDM FEDERAL PROGRAMS CORPORATION

T N & Associates, Inc.
Engineering and Science

Fig. 3.7. Physiographic provinces for the commonwealth of Kentucky

SYSTEM	SERIES	FORMATION	THICKNESS IN FEET	DESCRIPTION	HYDROGEOLOGIC SYSTEMS	GRAPHICAL REPRESENTATION
Quaternary	Pleistocene and Recent	Aluvium	0 - 40	Brown or grey sand and silty clay or clayey silt with streaks of sand.	Upper Continental Recharge System (UCRS)	
	Pleistocene	Loess		Brown or yellowish-brown to tan to grey unstratified silty clay.		
	Pleistocene	Continental Deposits	3 - 121	Upper Continental Deposits (Clay Facies). Orange to yellowish-brown to brown clayey silt, some very fine sand, trace of fine sand to gravel. Often micaceous.		
Tertiary	Pleistocene			Lower Continental Deposits (Gravel Facies) Reddish-brown silty and sandy gravel, silt and clay.	Regional Gravel Aquifer	
	Eocene	Eocene Sands (Undiff.)	0 - 100	Red-brown, or white fine to coarse grained sand. Beds of white to dark grey clay are distributed at random.		
				White to grey sandy clay, clay conglomerate and boulders, scattered clay lenses and lenses of coarse red sand. Black to dark grey lignite clay, silt, or fine grained sand.		
	Paleocene	Porters Creek Clay	0 - 200	Dark grey, slightly to very micaceous clay. Fine grained clayey sand, commonly glauconitic in the upper part. Glauconitic sand and clay at the base. A gravel layer (Terrace Gravel) present atop the clay terrace, 2 - 8 feet thick.		
		Clayton and McNairy Formations	200 - 300	Greyish white to dark micaceous clay, often silty, interbedded with light grey to yellowish-brown very fine to medium grained sand. The upper part is mostly clay, the lower part is predominantly micaceous clay.	McNairy Flow System	
Cretaceous		Tuscaloosa Formation	?	White, well rounded or broken chert gravel with clay.		
Mississippian		Mississippian Formation	500+	Dark grey limestone and interbedded chert, some shale.		

Fig. 3.8. Lithostratigraphic column for PGDP area.

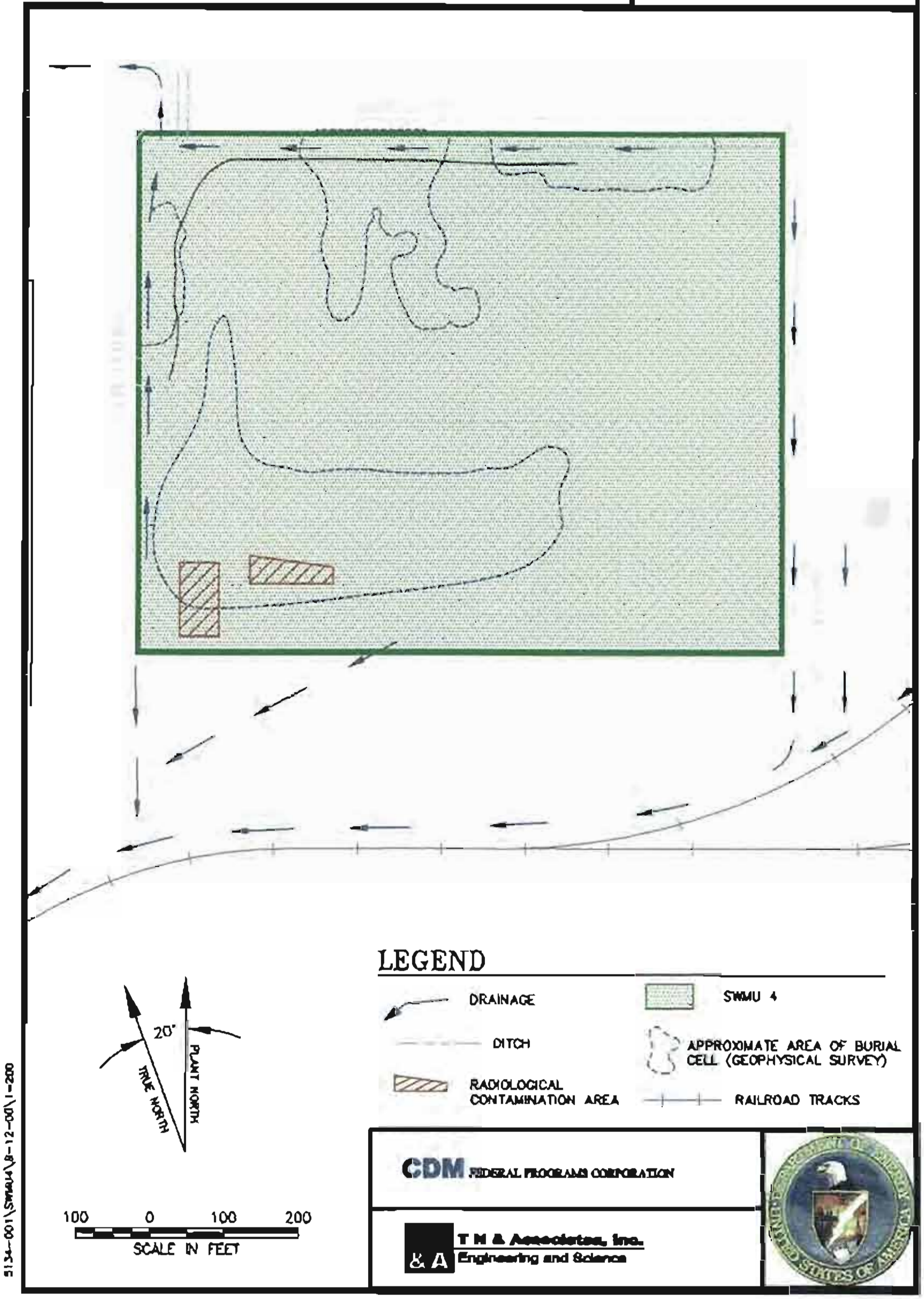


Fig. 3.10. WAG 3-SWMU 4, surface features.

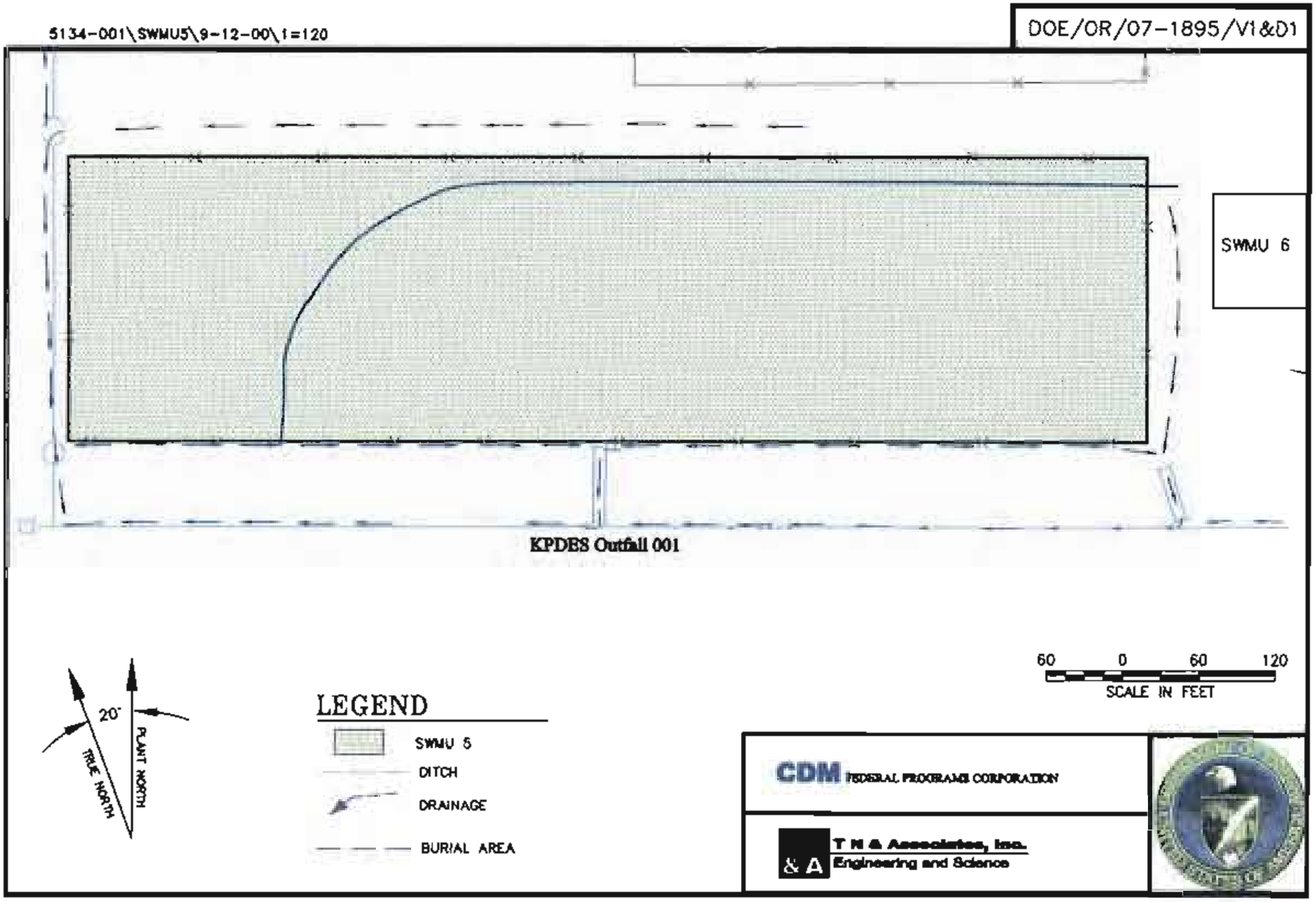


Fig. 3.11. WAG 3-SWMU 5, surface features.

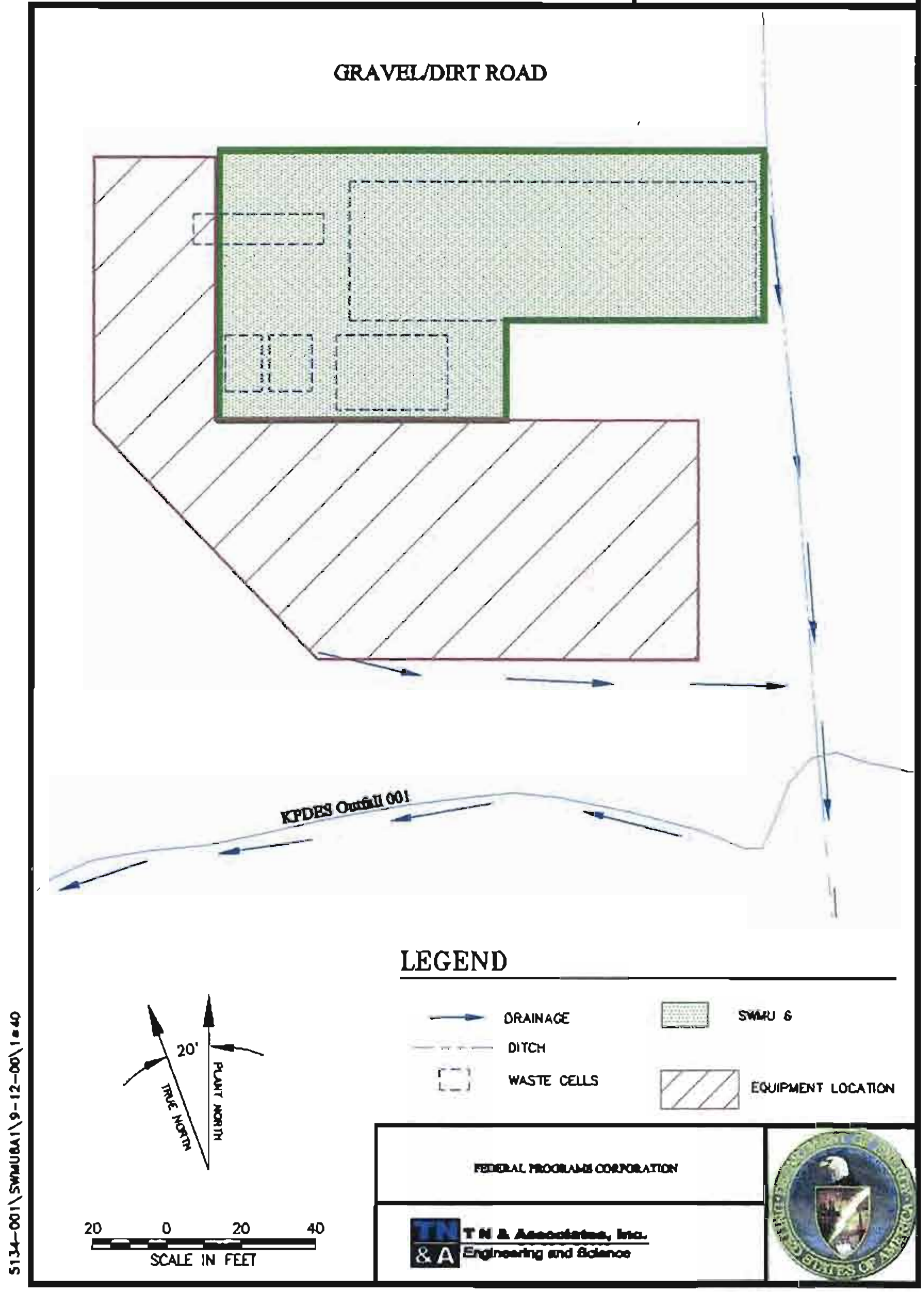


Fig. 3.12. WAG 3-SWMU 6, surface features.

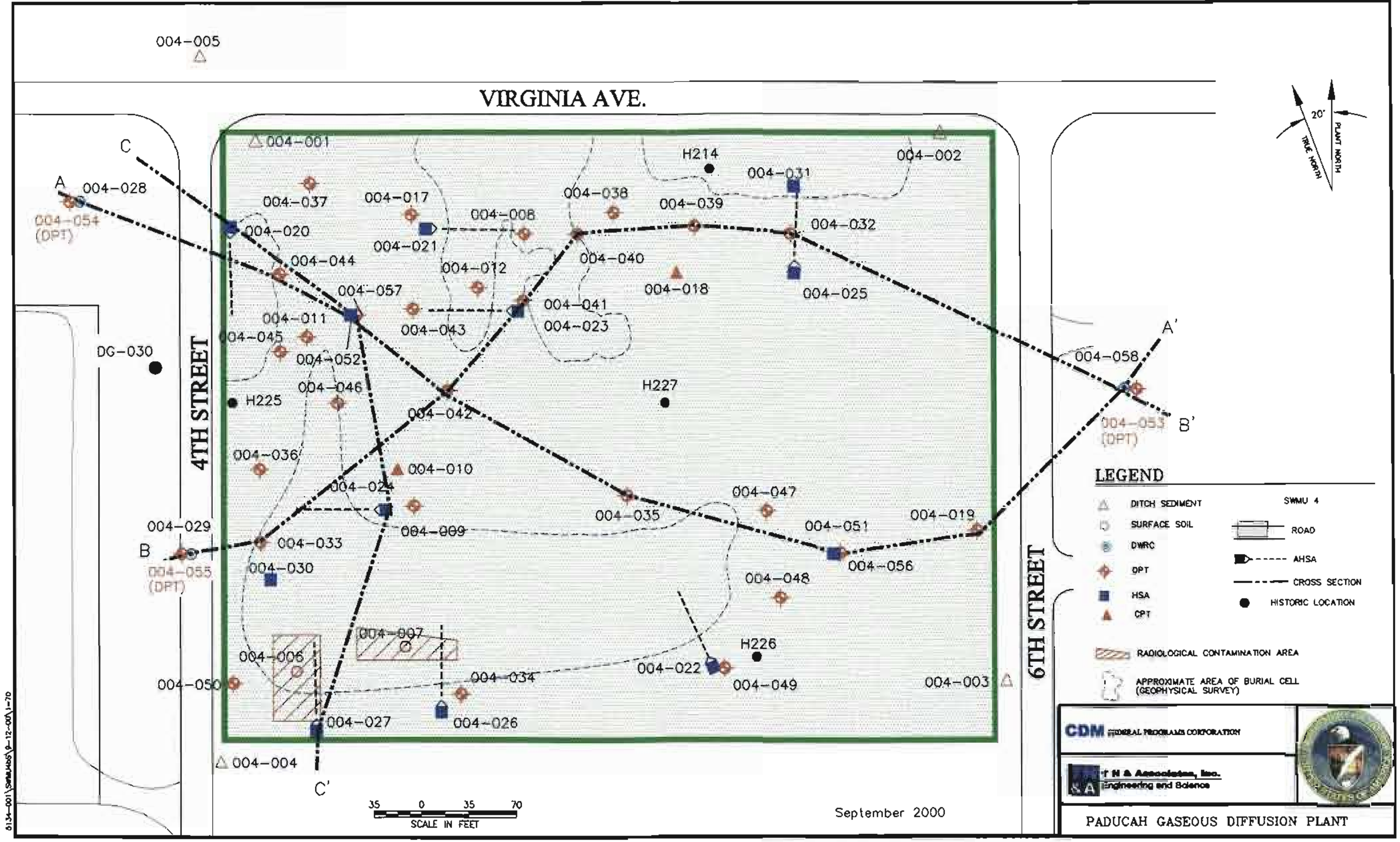
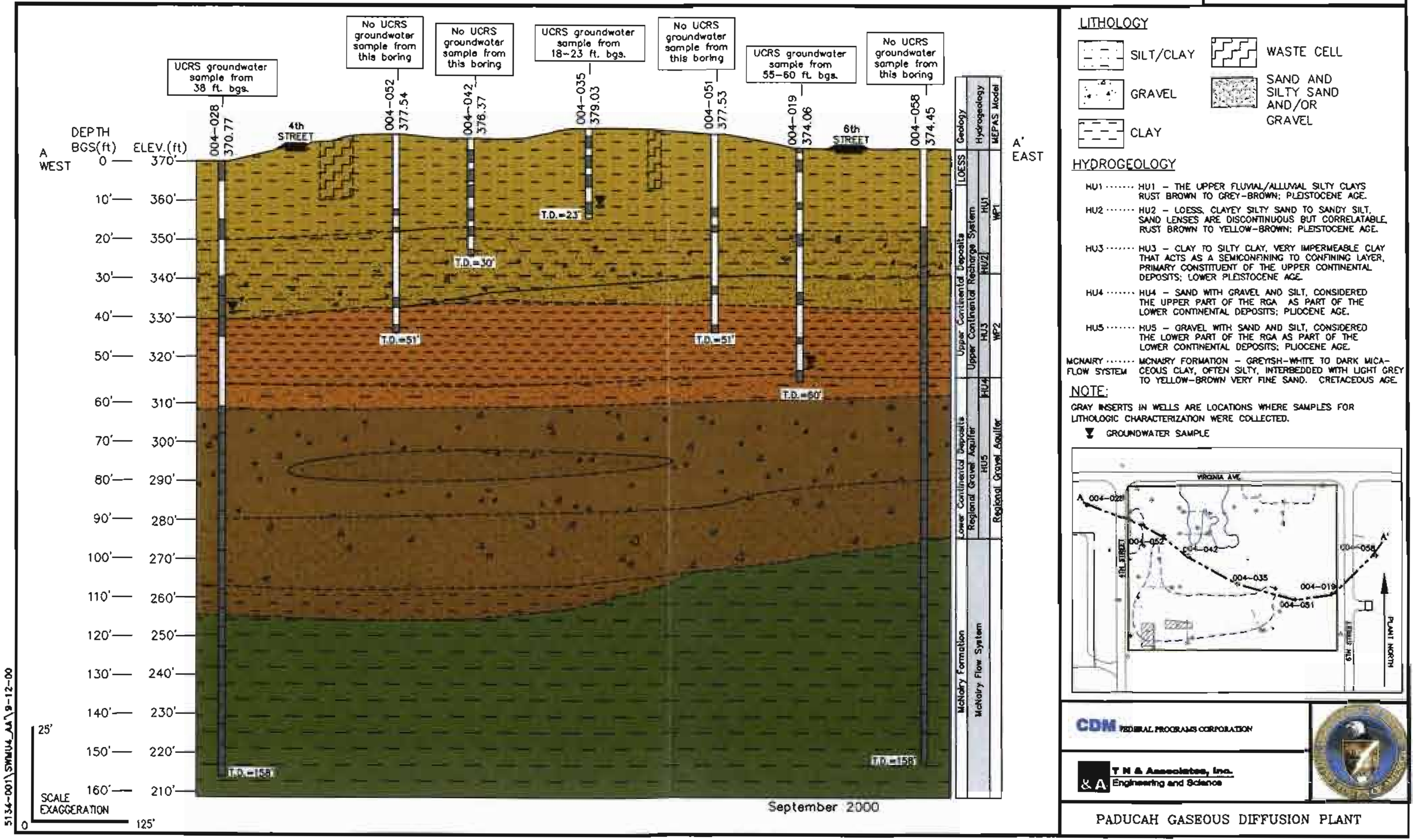


Fig. 3.13. WAG 3-SWMU 4, cross section locations.



LITHOLOGY

☷	SILT/CLAY	▨	WASTE CELL
⁘	GRAVEL	▩	SAND AND SILTY SAND AND/OR GRAVEL
☰	CLAY		

HYDROGEOLOGY

HU1 ·······	HU1 – THE UPPER FLUVIAL/ALLUVIAL SILTY CLAYS RUST BROWN TO GREY-BROWN; PLEISTOCENE AGE.
HU2 ·······	HU2 – LOESS, CLAYEY SILTY SAND TO SANDY SILT, SAND LENSES ARE DISCONTINUOUS BUT CORRELATABLE, RUST BROWN TO YELLOW-BROWN; PLEISTOCENE AGE.
HU3 ·······	HU3 – CLAY TO SILTY CLAY, VERY IMPERMEABLE CLAY THAT ACTS AS A SEMICONFINING TO CONFINING LAYER, PRIMARY CONSTITUENT OF THE UPPER CONTINENTAL DEPOSITS; LOWER PLEISTOCENE AGE.
HU4 ·······	HU4 – SAND WITH GRAVEL AND SILT, CONSIDERED THE UPPER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.
HU5 ·······	HU5 – GRAVEL WITH SAND AND SILT, CONSIDERED THE LOWER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.
MCNAIRY ······· FLOW SYSTEM	MCNAIRY FORMATION – GREYISH-WHITE TO DARK MICACEOUS CLAY, OFTEN SILTY, INTERBEDDED WITH LIGHT GREY TO YELLOW-BROWN VERY FINE SAND. CRETACEOUS AGE.

NOTE:

GRAY INSERTS IN WELLS ARE LOCATIONS WHERE SAMPLES FOR LITHOLOGIC CHARACTERIZATION WERE COLLECTED.

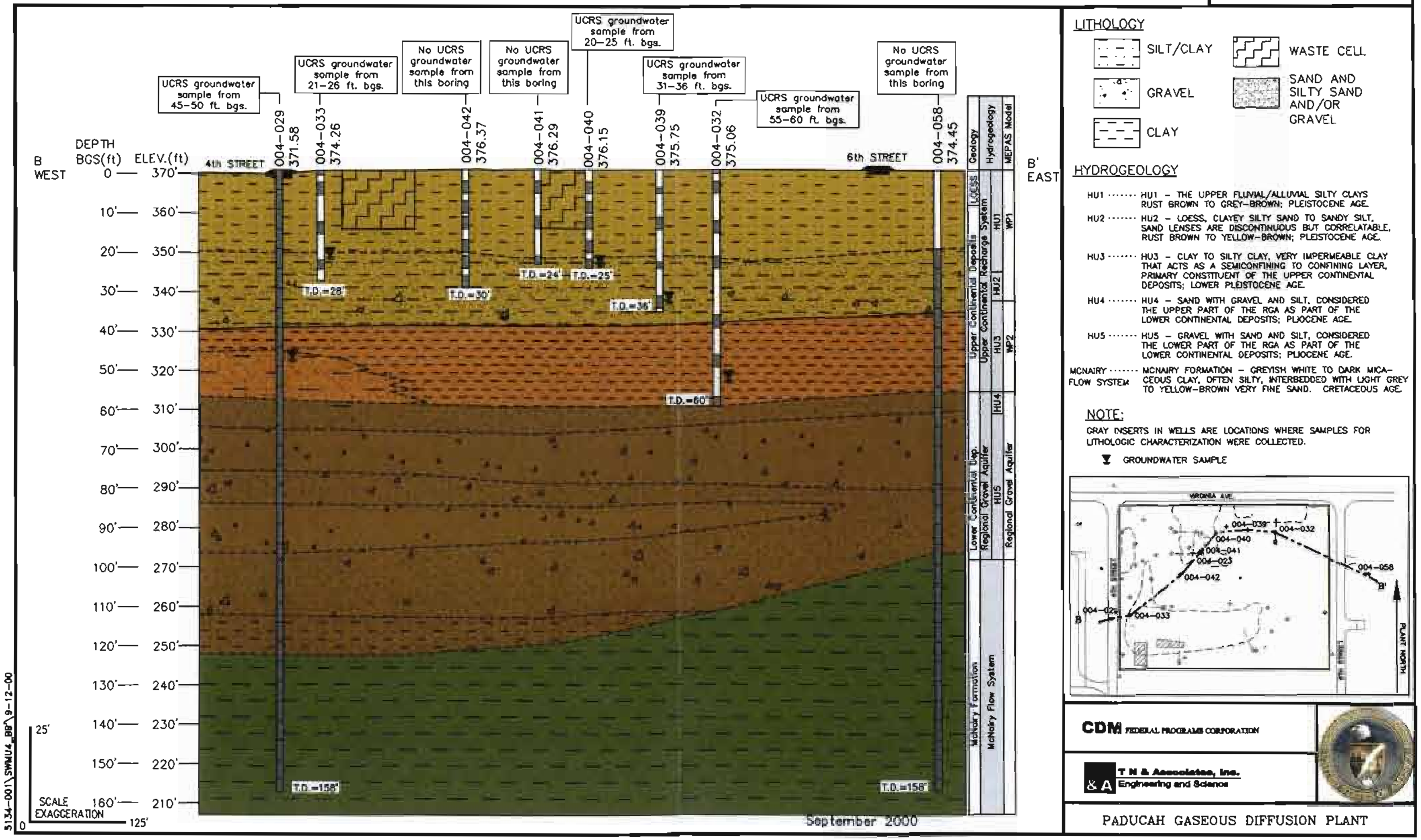
▼ GROUNDWATER SAMPLE

CDM FEDERAL PROGRAMS CORPORATION

T N & A T N & Associates, Inc.
Engineering and Science

PADUCAH GASEOUS DIFFUSION PLANT

Fig. 3.14. WAG 3-SWMU 4, lithologic cross section A-A'.



HYDROGEOLOGY

HU1 ······· HU1 – THE UPPER FLUVIAL/ALLUVIAL SILTY CLAYS RUST BROWN TO GREY-BROWN; PLEISTOCENE AGE.

HU2 ······· HU2 – LOESS, CLAYEY SILTY SAND TO SANDY SILT. SAND LENSES ARE DISCONTINUOUS BUT CORRELATABLE, RUST BROWN TO YELLOW-BROWN; PLEISTOCENE AGE.

HU3 ······· HU3 – CLAY TO SILTY CLAY, VERY IMPERMEABLE CLAY THAT ACTS AS A SEMICONFINING TO CONFINING LAYER, PRIMARY CONSTITUENT OF THE UPPER CONTINENTAL DEPOSITS; LOWER PLEISTOCENE AGE.

HU4 ······· HU4 – SAND WITH GRAVEL AND SILT, CONSIDERED THE UPPER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.

HU5 ······· HU5 – GRAVEL WITH SAND AND SILT, CONSIDERED THE LOWER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.

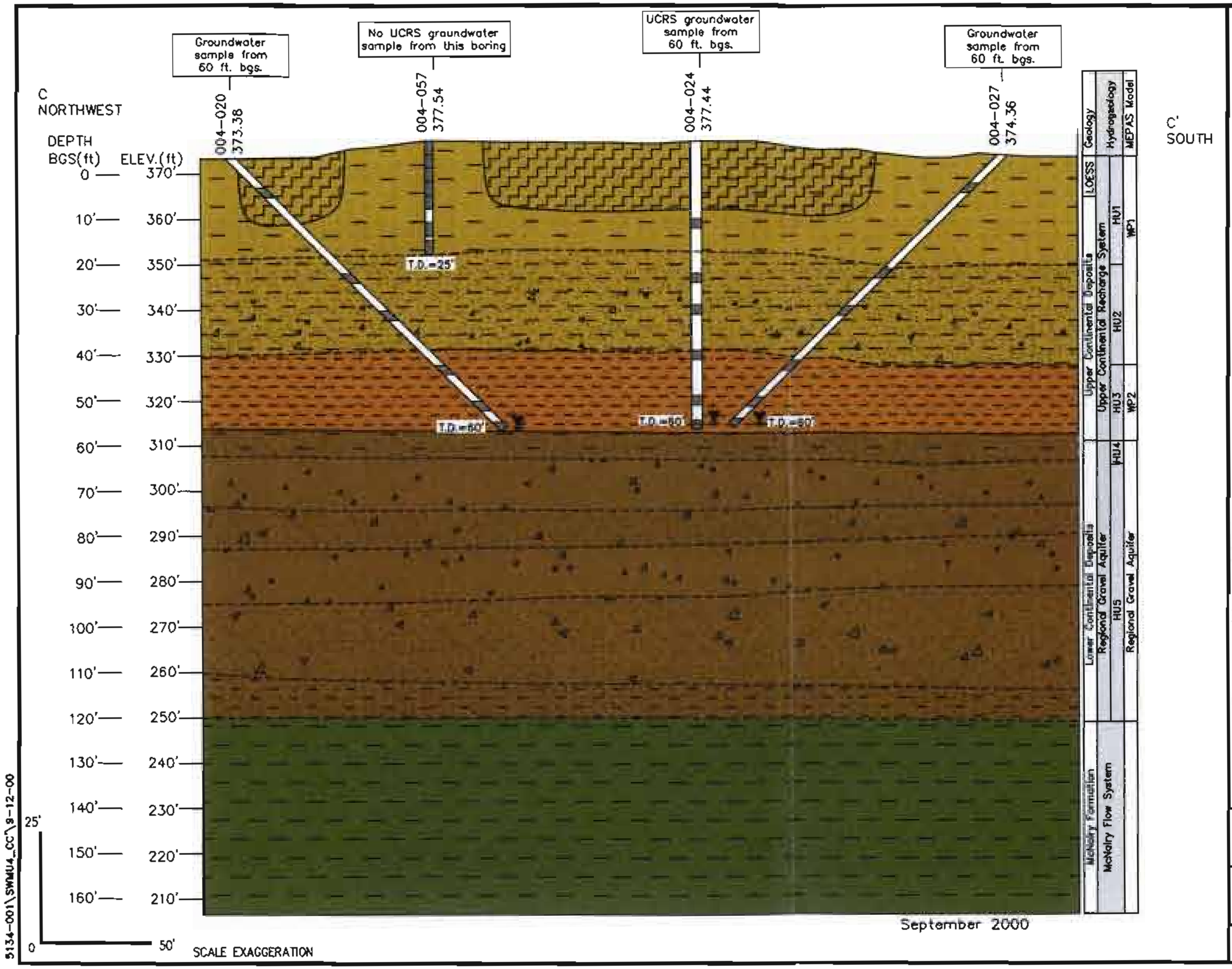
MCNAIRY FLOW SYSTEM ······· MCNAIRY FORMATION – GREYISH WHITE TO DARK MICACEOUS CLAY, OFTEN SILTY, INTERBEDDED WITH LIGHT GREY TO YELLOW-BROWN VERY FINE SAND. CRETACEOUS AGE.

NOTE:

GRAY INSERTS IN WELLS ARE LOCATIONS WHERE SAMPLES FOR LITHOLOGIC CHARACTERIZATION WERE COLLECTED.

▼ GROUNDWATER SAMPLE

Fig. 3.15. WAG 3-SWMU 4, lithologic cross section B-B'.



September 2000

LITHOLOGY

▤ SILT/CLAY

▨ WASTE CELL

⁘ GRAVEL

▩ SAND AND SILTY SAND AND/OR GRAVEL

▤ CLAY

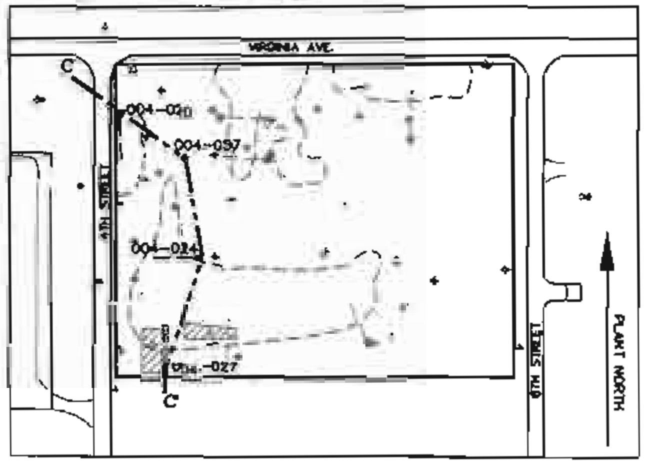
HYDROLOGY

HU1 ·······	HU1 – THE UPPER FLUVIAL/ALLUVIAL SILTY CLAYS RUST BROWN TO GREY-BROWN; PLEISTOCENE AGE.
HU2 ·······	HU2 – LOESS, CLAYEY SILTY SAND TO SANDY SILT, SAND LENSES ARE DISCONTINUOUS BUT CORRELATABLE, RUST BROWN TO YELLOW-BROWN; PLEISTOCENE AGE.
HU3 ·······	HU3 – CLAY TO SILTY CLAY, VERY IMPERMEABLE CLAY THAT ACTS AS A SEMICONFINING TO CONFINING LAYER, PRIMARY CONSTITUENT OF THE UPPER CONTINENTAL DEPOSITS; LOWER PLEISTOCENE AGE.
HU4 ·······	HU4 – SAND WITH GRAVEL AND SILT, CONSIDERED THE UPPER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.
HU5 ·······	HU5 – GRAVEL WITH SAND AND SILT, CONSIDERED THE LOWER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.
MCNAIRY FLOWSYSTEM ·······	MCNAIRY FLOWSYSTEM – GREYISH WHITE TO DARK MICACEOUS CLAY, OFTEN SILTY, INTERBEDDED WITH LIGHT GREY TO YELLOW-BROWN VERY FINE SAND. CRETACEOUS AGE.

NOTE:

GRAY INSERTS IN WELLS ARE LOCATIONS WHERE SAMPLES FOR LITHOLOGIC CHARACTERIZATION WERE COLLECTED.

▼ GROUNDWATER SAMPLE



CDM FEDERAL PROGRAMS CORPORATION

T N & A T N & Associates, Inc. Engineering and Science

PADUCAH GASEOUS DIFFUSION PLANT

Fig. 3.16. WAG 3-SWMU 4, lithologic cross section C-C'.

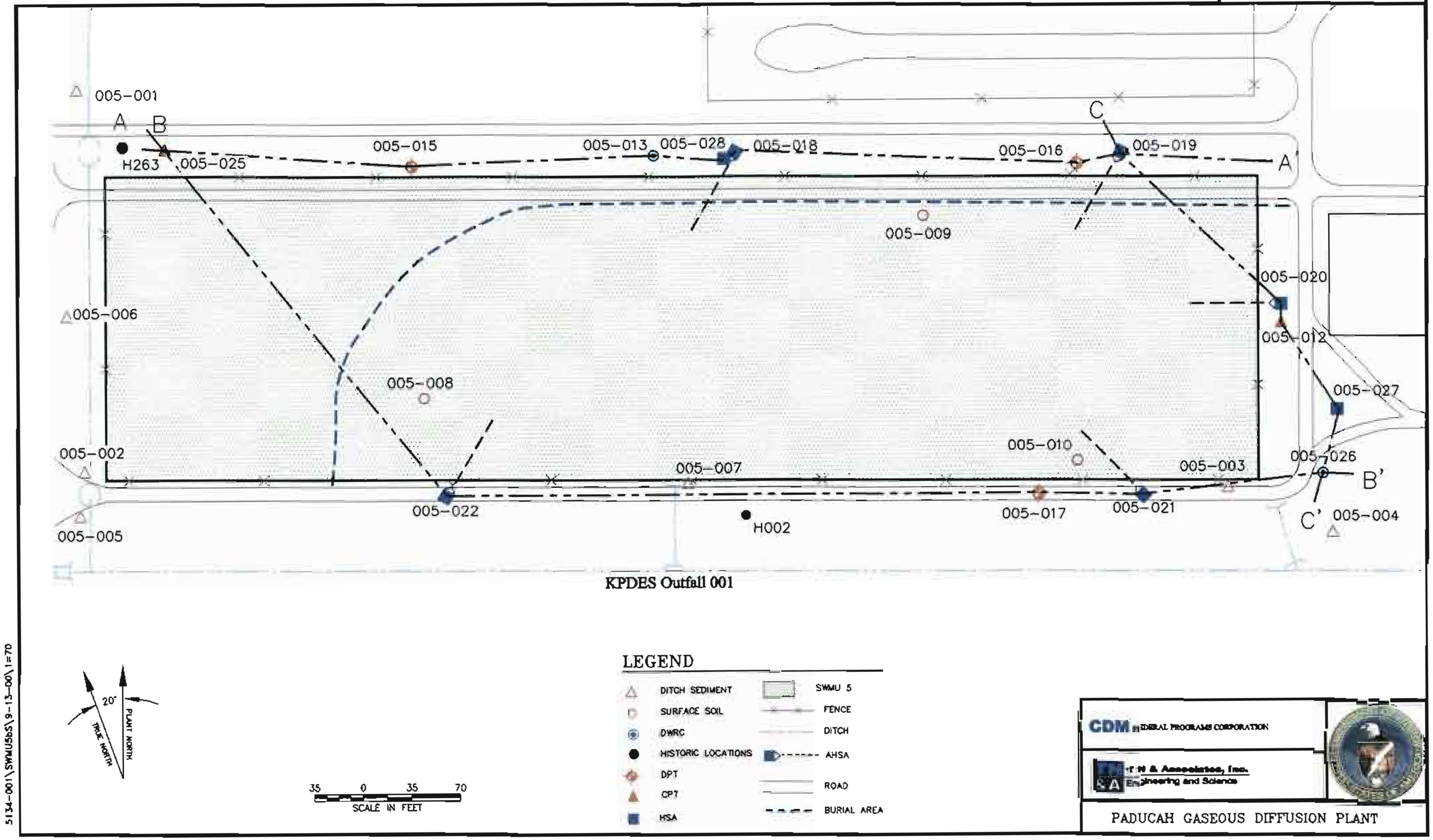


Fig. 3.17. WAG 3-SWMU 5, cross section locations.

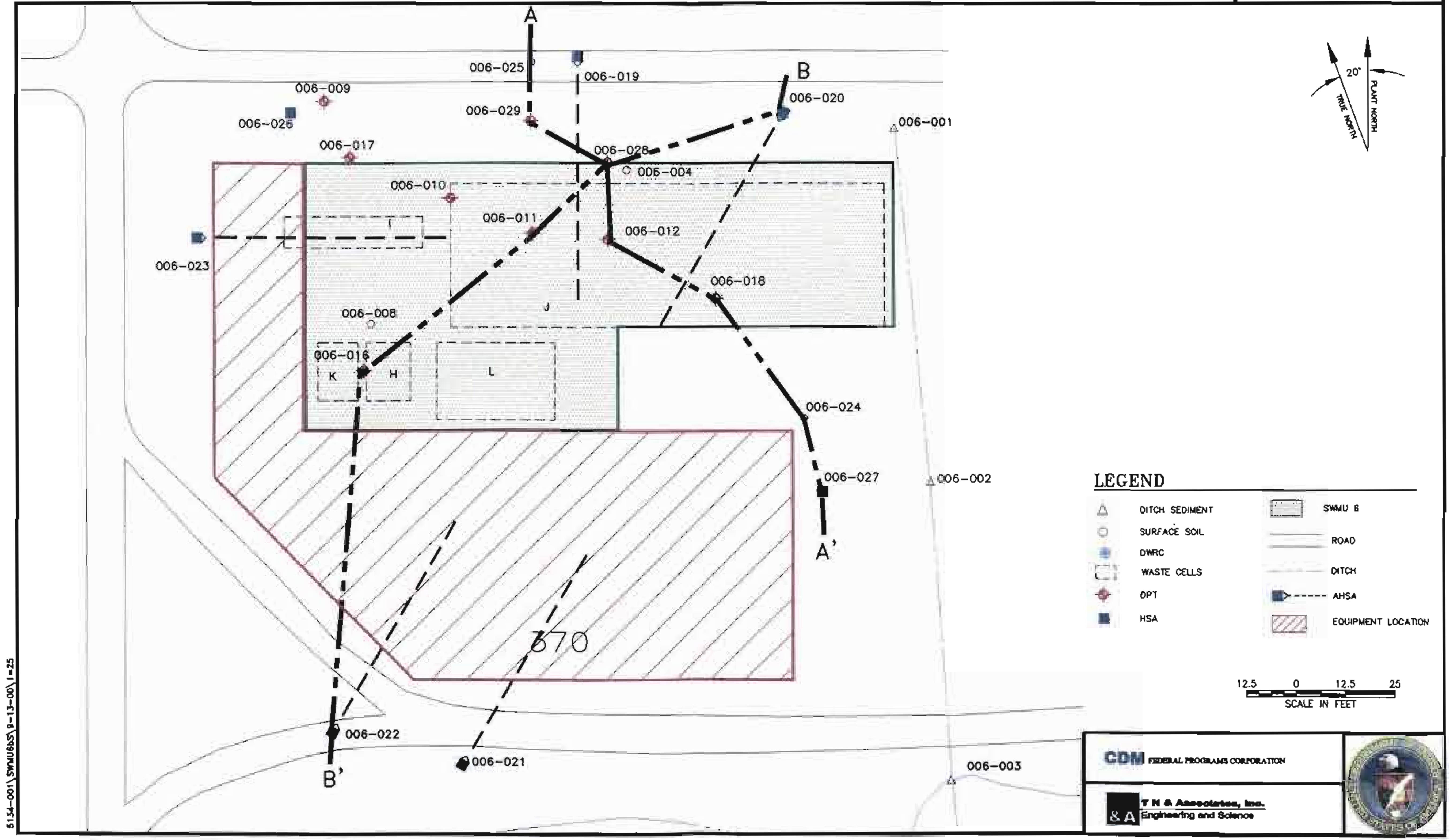
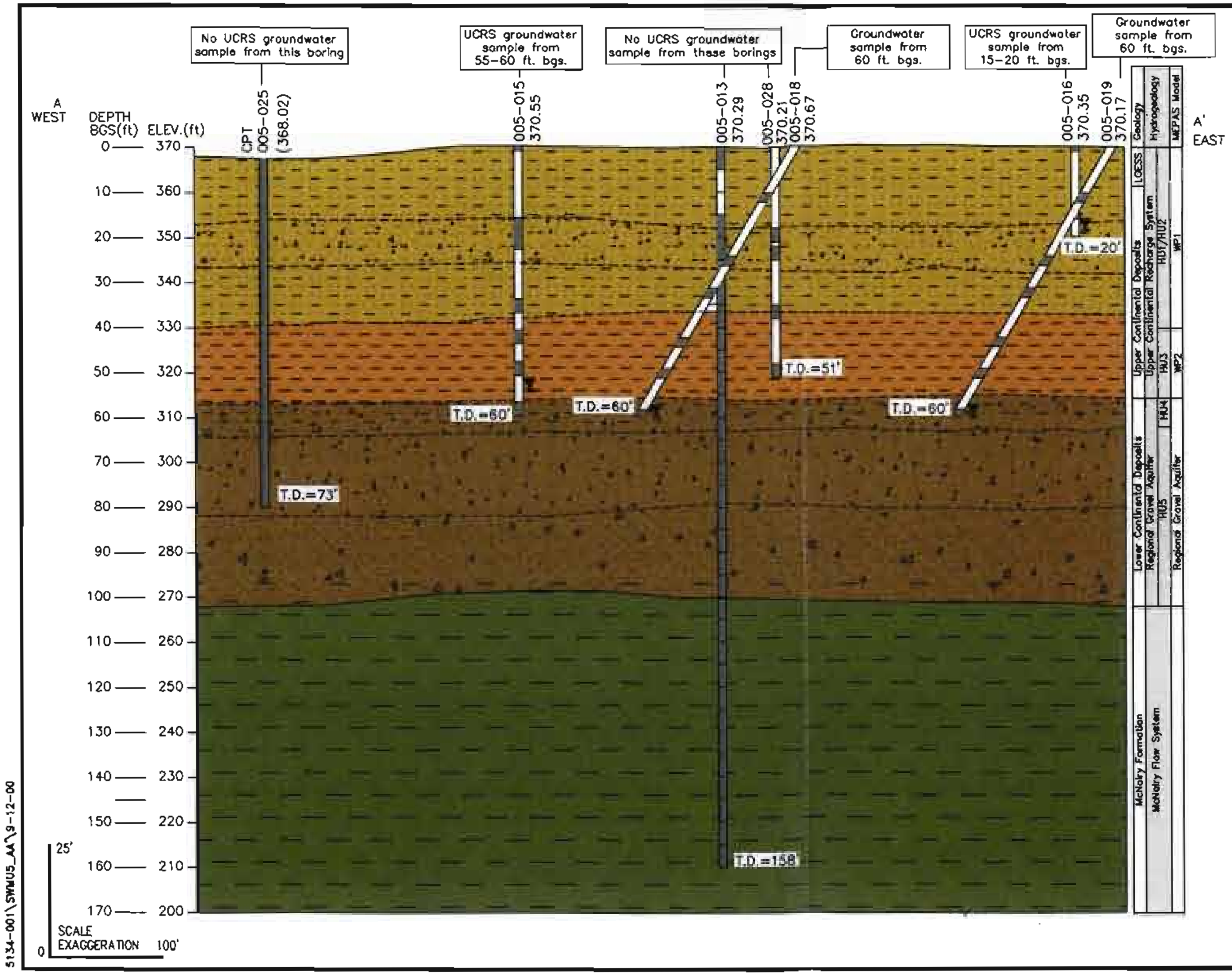


Fig. 3.18. WAG 3-SWMU 6, cross section locations.



LITHOLOGY

- ▨ SILT/CLAY
- ▨ GRAVEL
- ▨ CLAY
- ▨ WASTE CELL
- ▨ SAND AND SILTY SAND AND/OR GRAVEL

HYDROGEOLOGY

HU1 ······· HU1 – THE UPPER FLUVIAL/ALLUVIAL SILTY CLAYS RUST BROWN TO GREY-BROWN; PLEISTOCENE AGE.

HU2 ······· HU2 – LOESS, CLAYEY SILTY SAND TO SANDY SILT, SAND LENSES ARE DISCONTINUOUS BUT CORRELATABLE, RUST BROWN TO YELLOW-BROWN; PLEISTOCENE AGE.

HU3 ······· HU3 – CLAY TO SILTY CLAY, VERY IMPERMEABLE CLAY THAT ACTS AS A SEMICONFINING TO CONFINING LAYER, PRIMARY CONSTITUENT OF THE UPPER CONTINENTAL DEPOSITS; LOWER PLEISTOCENE AGE.

HU4 ······· HU4 – SAND WITH GRAVEL AND SILT, CONSIDERED THE UPPER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.

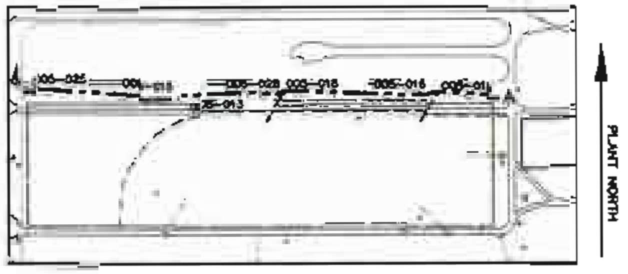
HU5 ······· HU5 – GRAVEL WITH SAND AND SILT, CONSIDERED THE LOWER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.

MCNAIRY FLOW SYSTEM ······· MCNAIRY FORMATION – GREYISH WHITE TO DARK MICACEOUS CLAY, OFTEN SILTY, INTERBEDDED WITH LIGHT GREY TO YELLOW-BROWN VERY FINE SAND. CRETACEOUS AGE.

NOTES:

GRAY INSERTS IN WELLS ARE LOCATIONS WHERE SAMPLES FOR LITHOLOGIC CHARACTERIZATION WERE COLLECTED.

⊻ GROUNDWATER SAMPLE

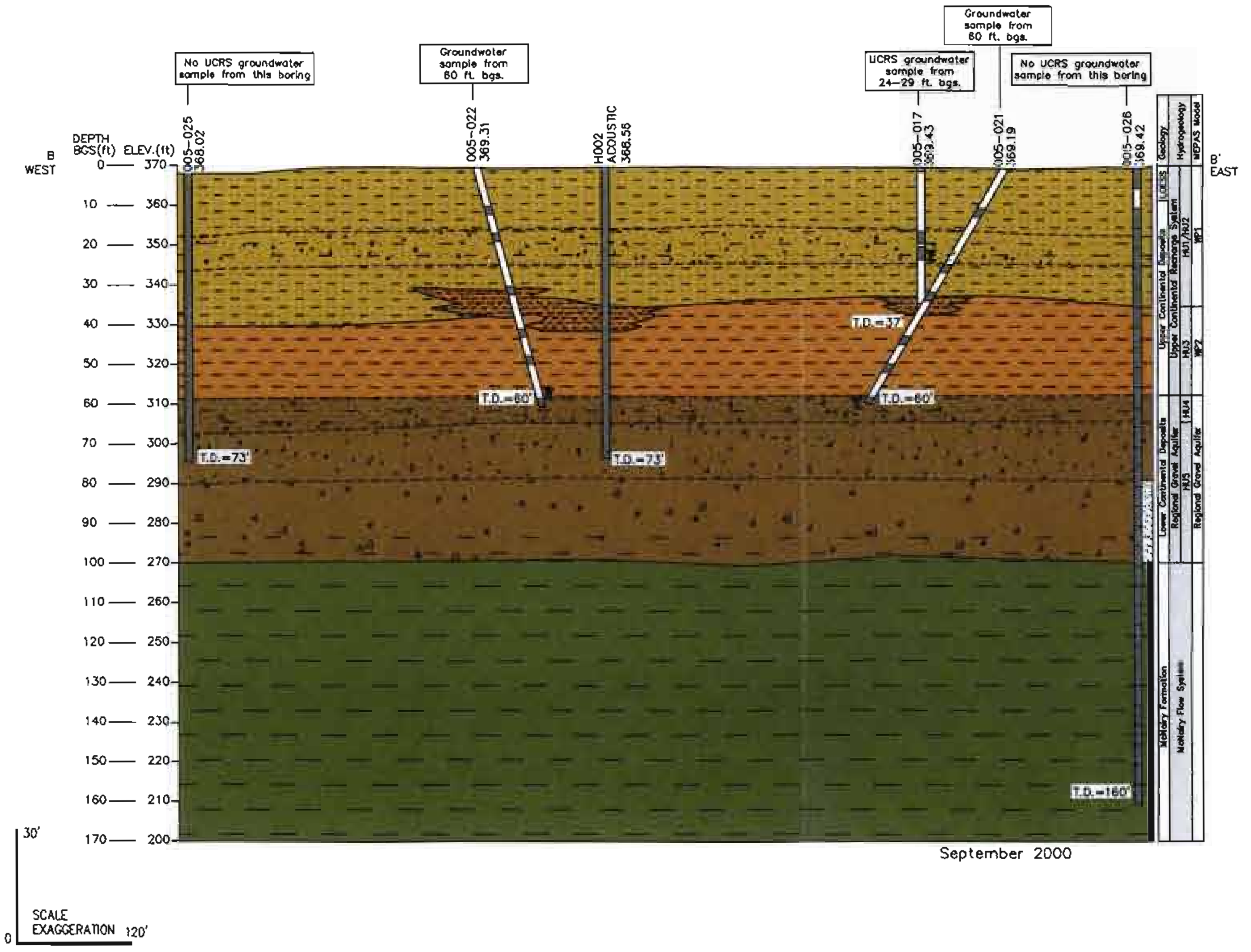


CDM FEDERAL PROGRAMS CORPORATION

T N & Associates, Inc.
Engineering and Science

PADUCAH GASEOUS DIFFUSION PLANT

Fig. 3.19. WAG 3-SWMU 5
Lithologic cross section A-A'.



September 2000

LITHOLOGY

- SILT/CLAY
- GRAVEL
- CLAY
- WASTE CELL
- SAND AND SILTY SAND AND/OR GRAVEL

HYDROGEOLOGY

HU1 ······· HU1 – THE UPPER FLUVIAL/ALLUVIAL SILTY CLAYS RUST BROWN TO GREY–BROWN; PLEISTOCENE AGE.

HU2 ······· HU2 – LOESS, CLAYEY SILTY SAND TO SANDY SILT, SAND LENSES ARE DISCONTINUOUS BUT CORRELATABLE, RUST BROWN TO YELLOW–BROWN; PLEISTOCENE AGE.

HU3 ······· HU3 – CLAY TO SILTY CLAY, VERY IMPERMEABLE CLAY THAT ACTS AS A SEMICONFINING TO CONFINING LAYER, PRIMARY CONSTITUENT OF THE UPPER CONTINENTAL DEPOSITS; LOWER PLEISTOCENE AGE.

HU4 ······· HU4 – SAND WITH GRAVEL AND SILT, CONSIDERED THE UPPER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.

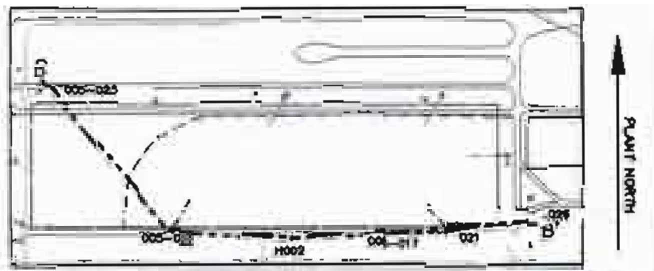
HU5 ······· HU5 – GRAVEL WITH SAND AND SILT, CONSIDERED THE LOWER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.

MCNAIRY FLOW SYSTEM ······· MCNAIRY FORMATION – GREYISH WHITE TO DARK MICACEOUS CLAY, OFTEN SILTY, INTERBEDDED WITH LIGHT GREY TO YELLOW–BROWN VERY FINE SAND. CRETACEOUS AGE.

NOTE:

GRAY INSERTS IN WELLS ARE LOCATIONS WHERE SAMPLES FOR LITHOLOGIC CHARACTERIZATION WERE COLLECTED.

▼ GROUNDWATER SAMPLE

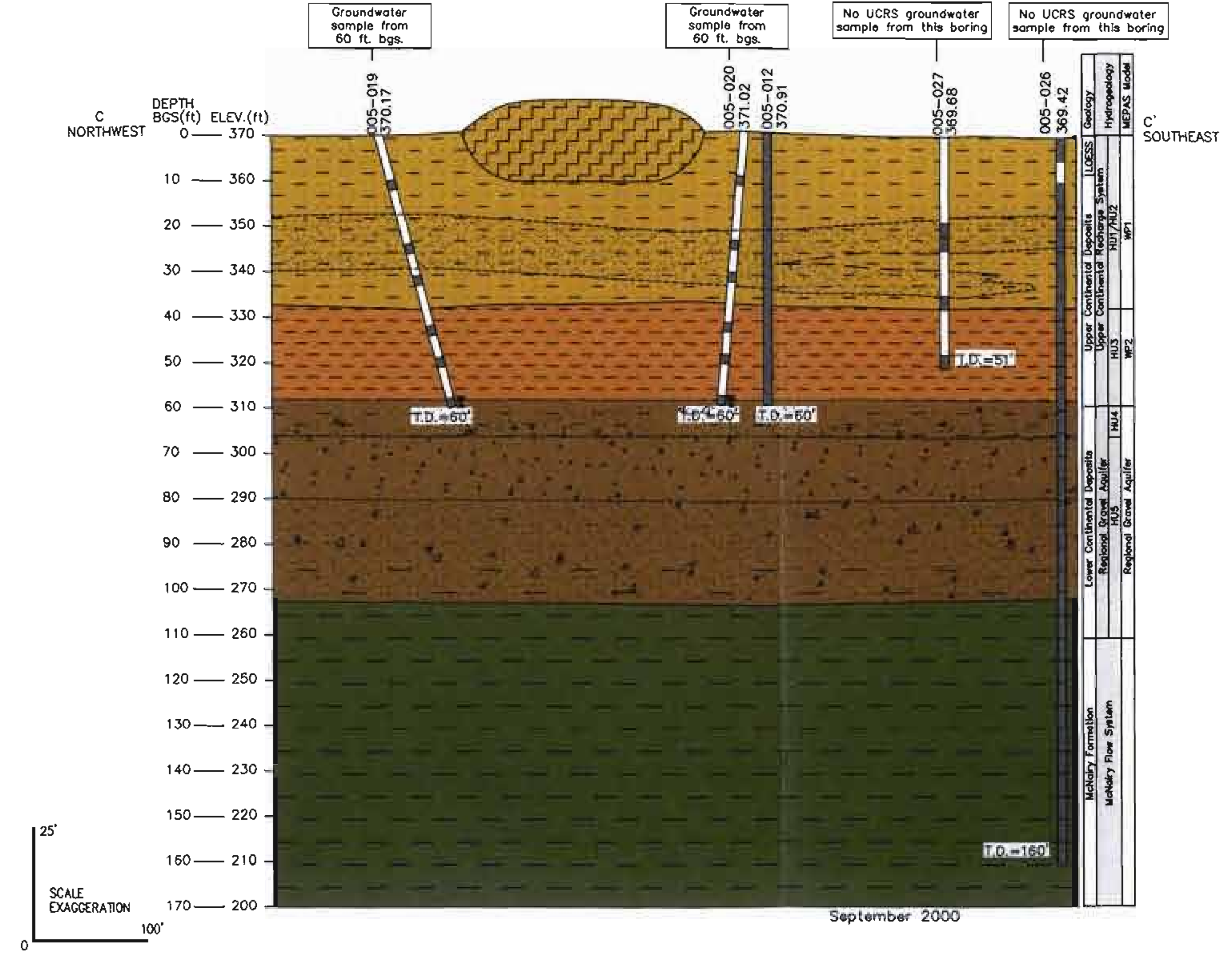


CDM FEDERAL PROGRAMS CORPORATION

T M & Associates, Inc. Engineering and Science

PADUCAH GASEOUS DIFFUSION PLANT

Fig. 3.20. WAG 3-SWMU 5, lithologic cross section B-B'



LITHOLOGY

- ▨ SILT/CLAY
- ▨ GRAVEL
- ▨ CLAY
- ▨ WASTE CELL
- ▨ SAND AND SILTY SAND AND/OR GRAVEL

HYDROGEOLOGY

HU1 ······· HU1 – THE UPPER FLUVIAL/ALLUVIAL SILTY CLAYS RUST BROWN TO GREY-BROWN; PLEISTOCENE AGE.

HU2 ······· HU2 – LOESS. CLAYEY SILTY SAND TO SANDY SILT, SAND LENSES ARE DISCONTINUOUS BUT CORRELATABLE. RUST BROWN TO YELLOW-BROWN; PLEISTOCENE AGE.

HU3 ······· HU3 – CLAY TO SILTY CLAY, VERY IMPERMEABLE CLAY THAT ACTS AS A SEMICONFINING TO CONFINING LAYER, PRIMARY CONSTITUENT OF THE UPPER CONTINENTAL DEPOSITS; LOWER PLEISTOCENE AGE.

HU4 ······· HU4 – SAND WITH GRAVEL AND SILT, CONSIDERED THE UPPER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.

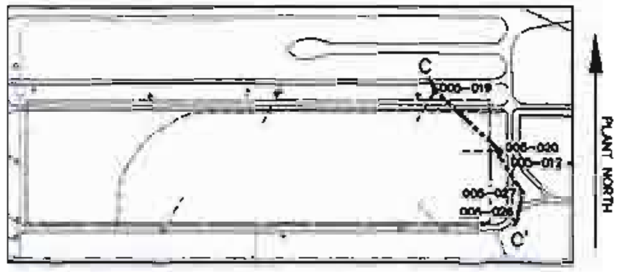
HU5 ······· HU5 – GRAVEL WITH SAND AND SILT, CONSIDERED THE LOWER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.

MCNAIRY FLOW SYSTEM ······· MCNAIRY FORMATION – GREYISH WHITE TO DARK MICACEOUS CLAY, OFTEN SILTY, INTERBEDDED WITH LIGHT GREY TO YELLOW-BROWN VERY FINE SAND. CRETACEOUS AGE.

NOTE:

GRAY INSERTS IN WELLS ARE LOCATIONS WHERE SAMPLES FOR LITHOLOGIC CHARACTERIZATION WERE COLLECTED.

▼ GROUNDWATER SAMPLE

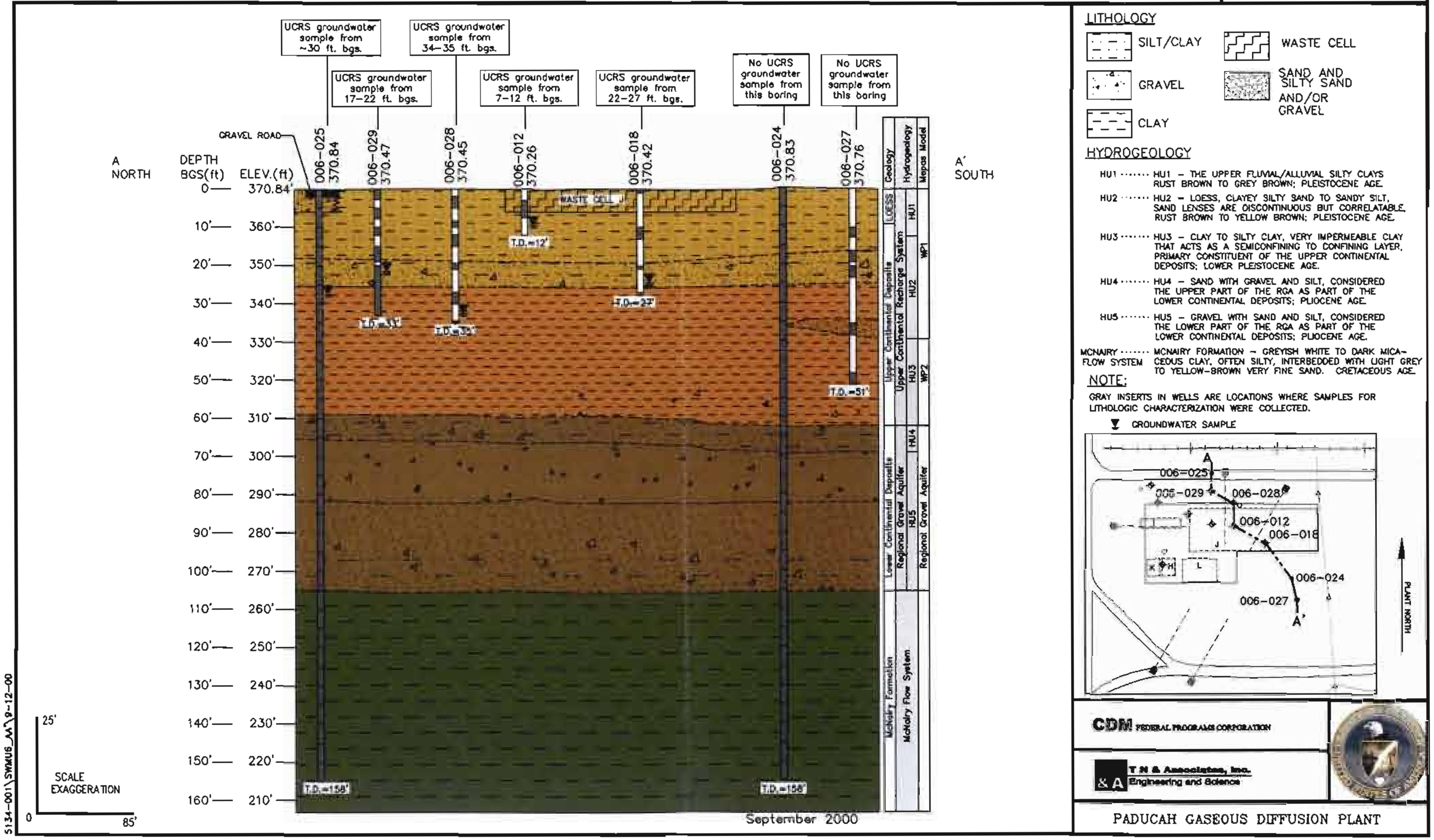


CDM FEDERAL PROGRAMS CORPORATION

T N & Associates, Inc.
Engineering and Science

PADUCAH GASEOUS DIFFUSION PLANT

Fig. 3.21. WAG 3-SWMU 5, lithologic cross section C-C'.



HU1 ······· HU1 – THE UPPER FLUVIAL/ALLUVIAL SILTY CLAYS RUST BROWN TO GREY BROWN; PLEISTOCENE AGE.

HU2 ······· HU2 – LOESS, CLAYEY SILTY SAND TO SANDY SILT, SAND LENSES ARE DISCONTINUOUS BUT CORRELATABLE, RUST BROWN TO YELLOW BROWN; PLEISTOCENE AGE.

HU3 ······· HU3 – CLAY TO SILTY CLAY, VERY IMPERMEABLE CLAY THAT ACTS AS A SEMICONFINING TO CONFINING LAYER, PRIMARY CONSTITUENT OF THE UPPER CONTINENTAL DEPOSITS; LOWER PLEISTOCENE AGE.

HU4 ······· HU4 – SAND WITH GRAVEL AND SILT, CONSIDERED THE UPPER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.

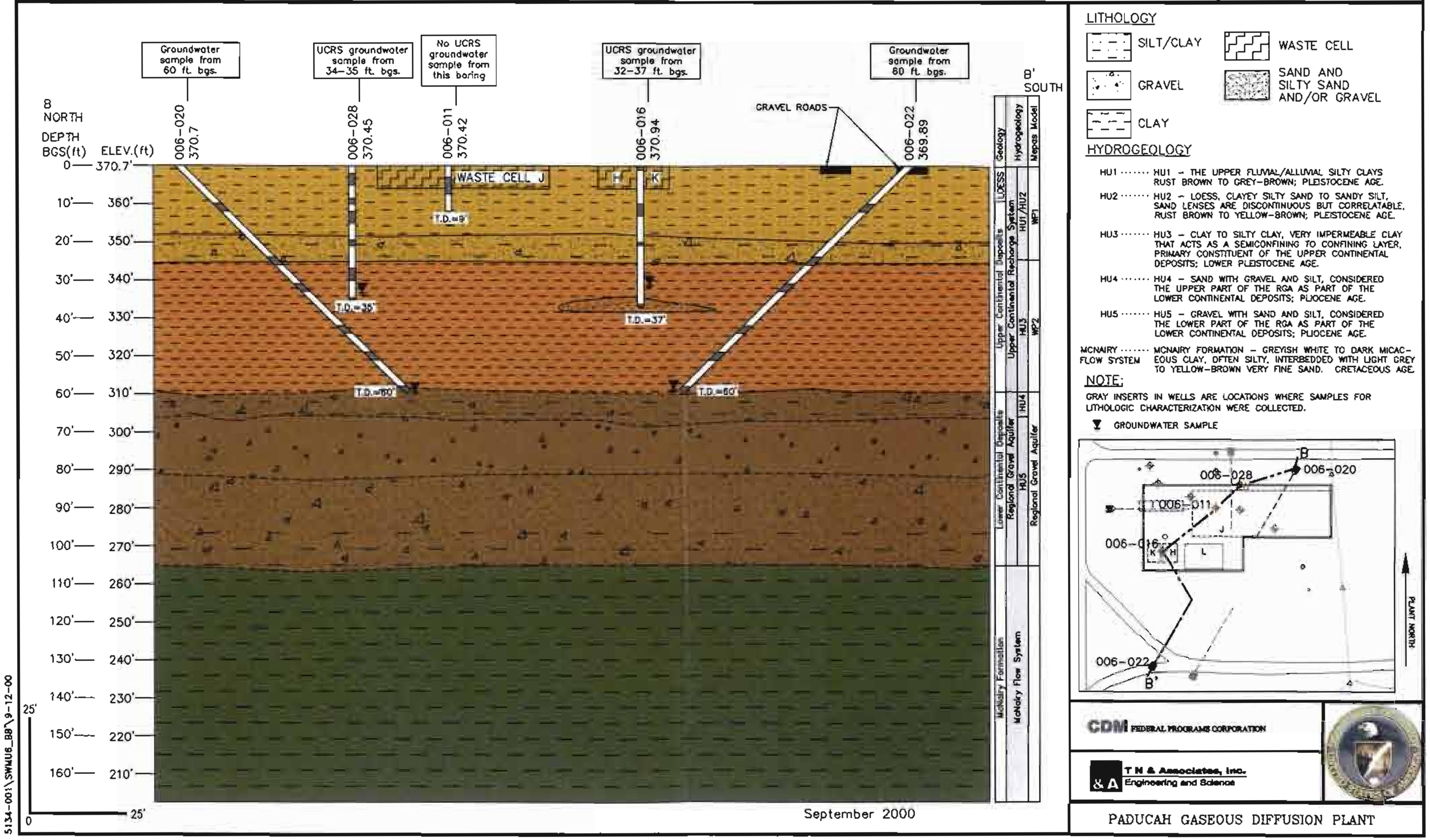
HU5 ······· HU5 – GRAVEL WITH SAND AND SILT, CONSIDERED THE LOWER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.

MCNAIRY FLOW SYSTEM ······· MCNAIRY FORMATION – GREYISH WHITE TO DARK MICACEOUS CLAY, OFTEN SILTY, INTERBEDDED WITH LIGHT GREY TO YELLOW-BROWN VERY FINE SAND. CRETACEOUS AGE.

NOTE:

GRAY INSERTS IN WELLS ARE LOCATIONS WHERE SAMPLES FOR LITHOLOGIC CHARACTERIZATION WERE COLLECTED.

Fig. 3.22. WAG 3-SWMU 6, lithologic cross section A-A'.



HYDROGEOLOGY

HU1 ······· HU1 – THE UPPER FLUVIAL/ALLUVIAL SILTY CLAYS RUST BROWN TO GREY-BROWN; PLEISTOCENE AGE.

HU2 ······· HU2 – LOESS, CLAYEY SILTY SAND TO SANDY SILT, SAND LENSES ARE DISCONTINUOUS BUT CORRELATABLE, RUST BROWN TO YELLOW-BROWN; PLEISTOCENE AGE.

HU3 ······· HU3 – CLAY TO SILTY CLAY, VERY IMPERMEABLE CLAY THAT ACTS AS A SEMICONFINING TO CONFINING LAYER, PRIMARY CONSTITUENT OF THE UPPER CONTINENTAL DEPOSITS; LOWER PLEISTOCENE AGE.

HU4 ······· HU4 – SAND WITH GRAVEL AND SILT, CONSIDERED THE UPPER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.

HU5 ······· HU5 – GRAVEL WITH SAND AND SILT, CONSIDERED THE LOWER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.

MCNAIRY FLOW SYSTEM ······· MCNAIRY FORMATION – GREYISH WHITE TO DARK MICACEOUS CLAY, OFTEN SILTY, INTERBEDDED WITH LIGHT GREY TO YELLOW-BROWN VERY FINE SAND. CRETACEOUS AGE.

NOTE:

GRAY INSERTS IN WELLS ARE LOCATIONS WHERE SAMPLES FOR LITHOLOGIC CHARACTERIZATION WERE COLLECTED.

Ꮖ GROUNDWATER SAMPLE

September 2000

CDM FEDERAL PROGRAMS CORPORATION

T N & Associates, Inc.
Engineering and Science

PADUCAH GASEOUS DIFFUSION PLANT

Fig. 3.23. WAG 3-SWMU 6, lithologic cross section B-B'.

5134-001\CONCEPTUAL\9-12-00\NTS

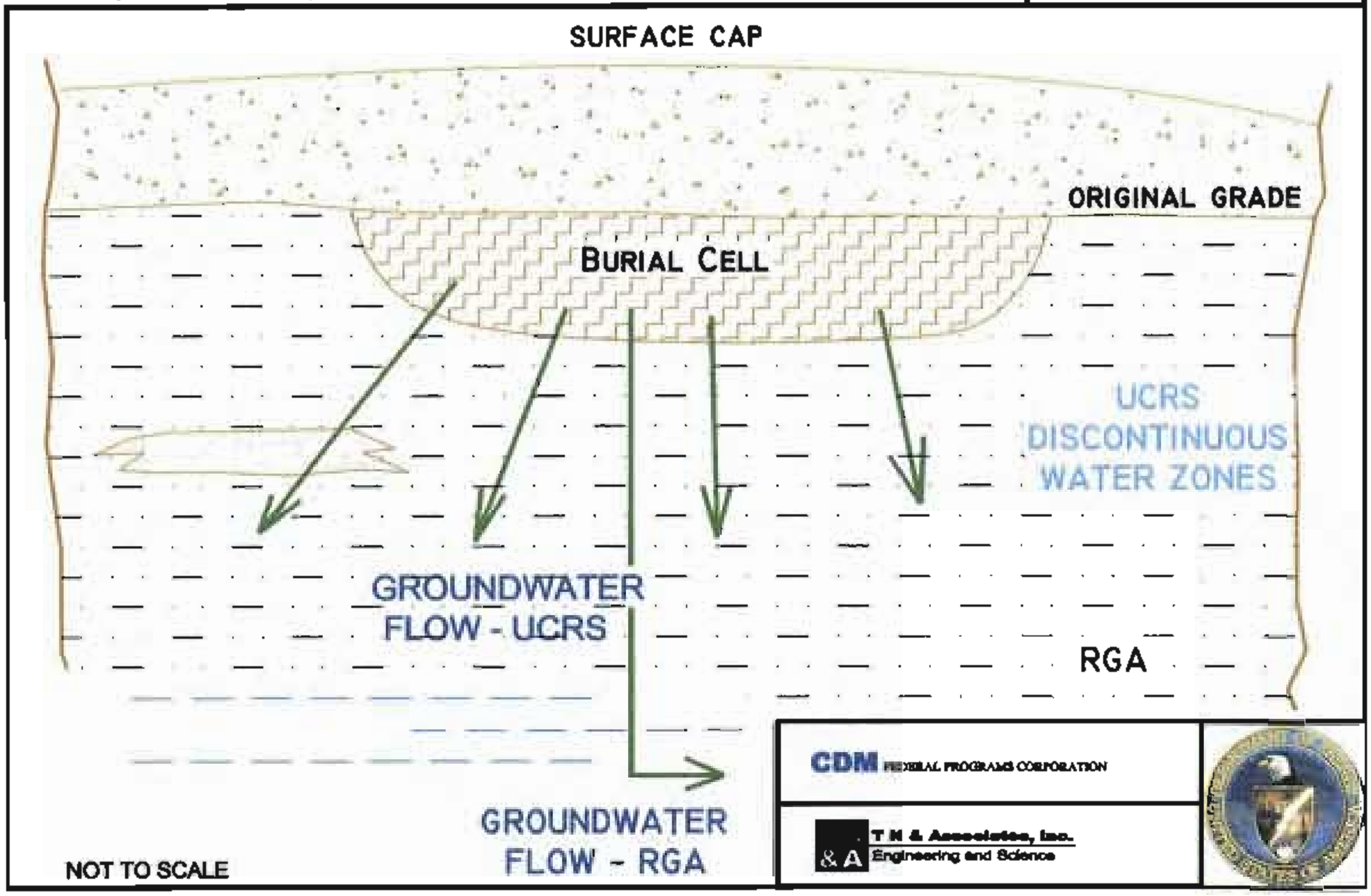


Fig. 3.24. WAG 3 - conceptual model.

Table 3.1. Hydraulic conductivity measurements of UCRS soil samples from WAG 3

Sample location	Sample depth (ft bgs)	Hydraulic conductivity (coefficient of permeability)
004-051	21	4.2^{-7} cm/s
004-051	25	3.5^{-7} cm/s
004-052	25	2.0^{-8} cm/s
004-052	42	2.8^{-5} cm/s
005-027	21	1.1^{-8} cm/s
005-027	38	7.8^{-7} cm/s
005-028	21	6.1^{-7} cm/s
005-028	38	5.9^{-8} cm/s
006-026	13	8.4^{-9} cm/s
006-026	19	1.3^{-7} cm/s
006-027	13	2.4^{-8} cm/s
006-027	19	5.7^{-8} cm/s

4. NATURE AND EXTENT OF CONTAMINATION

4.1 INTRODUCTION

As demonstrated in the previous chapters, the three SWMUs comprising WAG 3 consist of below ground burial cells in which various PGDP wastes have been placed. Infiltration from precipitation percolating through the cap material and descending through the buried waste could mobilize contaminants within the waste. Once mobilized, the most likely pathway would be down, through the UCRS soils and ultimately reaching the RGA (based on the hydrogeologic conceptual model presented in Chap. 3). Some limited lateral movement of contaminants within gravel and sand lenses would occur in the UCRS, but these pathways appear limited. Based on this, any contamination found at the WAG 3 SWMUs would be expected to be found primarily concentrated in the UCRS soils and groundwater immediately adjacent to and under the burial cells, with a lesser amount of contamination laterally out from the cells in gravel/sand lenses. However, because the predominant groundwater gradient in the UCRS is down, the majority of contamination would be expected underneath the cells, where the groundwater-entrained contaminants were leaking out the bottoms of the cells. This chapter provides data that evaluate the presence of contamination at WAG 3.

Environmental data from the three sites investigated during the WAG 3 RI field activities have been compiled, screened, and evaluated to assess the nature and extent of contaminants and to supplement previously collected historical data. Summary tables containing analytical results for each of the three sites and figures displaying the locations of selected contaminants are included at the end of this chapter. A complete report of analytical results for all samples collected during this investigation is provided in Appendix G. Appendix I contains selected analytical data collected during previous investigations of the sites that comprise WAG 3. Appendix J contains a complete list, by sample identification number, of all samples analyzed during the WAG 3 RI; it also provides information concerning which of the five analytical groups (VOAs, SVOAs, PCBs, metals, and/or radionuclides) was tested for in each sample.

The extent of contamination discussed in this report is based on the presence of contaminants in sediment, surface or subsurface soils, and groundwater. Samples from these media were analyzed for suites of constituents reported by the following analytical groups: VOAs, SVOAs, PCBs, inorganics, and radionuclides.

Following a general introduction and description of this material, the three WAG 3 sites are individually characterized. The discussion of each site begins with an introduction that summarizes the SWMU's history and site conditions. Base maps depicting sample locations, facility structures, roads, and topographic features are included in Chap. 3.

Descriptions of the known processes and possible releases from each site that may have contributed to contaminant impact follow the paragraphs that characterize the site's physical properties. An understanding of the potential releases is key to the rationale behind the sampling that was performed during the WAG 3 RI. Following the "Rationale for RI Field Sampling" section, the text focuses on describing analytical results of samples collected at each of the three sites. The text in this section includes information on contaminants encountered in the various media.

The "Summary of Findings" for each site provides a synopsis of the analytical results, including interpretations. The area at each site, the constituents involved, and the probable source or sources are described.

The PGDP site remedial objective is to select and implement actions protective of human health and the environment (DOE 1998a). The RI activities included investigations of the nature and extent of potential groundwater contamination attributable to any of the three sites. Data collected from the WAG 3 RI also will be used as a basis for remedial action decisions concerning the various OUs effected.

4.1.1 Screening Process

The data screening process used in this RI was critical for determining when analytes represented site-related contaminants rather than naturally occurring constituents in the soil or groundwater. The screening process for the nature and extent of contamination discussion is described in the following paragraphs. Appendix B of Vol. 4 of this report contains a detailed description of the screening process that was performed for the Multimedia Environmental Pollutant Assessment System (MEPAS) modeling.

The results in the WAG 3 database were screened in a multiphase process. First, data collected during this RI were screened to eliminate those sample results that were less than the minimum detection limit (or, in the case of radionuclides, did not exceed the propagation error). These data were then compared with background levels of surface and subsurface soil at PGDP as compiled from DOE (1997). Background data for groundwater are currently being collected as part of the ongoing Groundwater OU study and are not available for this report; therefore, groundwater samples with analytes above detection limits were compared to maximum contaminant levels (MCLs), if available, for specific chemicals.

Tables 4.1 and 4.2 contain the background data for PGDP used to screen WAG 3 data. Because most organics such as VOAs, SVOAs, and PCBs are not naturally occurring, background for these compounds was set at zero. Table 4.3 lists the EPA risk-based screening values also used to screen analytical data.

Seven analytes that are known to be essential nutrients and toxic only at extremely high concentrations were removed from the data set according to regulatory guidance (EPA 1995). These analytes are calcium, chlorine, iodine, magnesium, potassium, sodium, and phosphorous as phosphate. Three essential nutrients, chromium, manganese, and zinc, were not screened using this process because of toxic effects possible from exposure to these chemicals at low concentrations. The maximum detected concentration of these analytes was compared to its respective Recommended Dietary Allowance (RDA) for children to determine if it would be appropriate to remove any essential nutrients from the data set. Analytes that have maximum detected concentrations less than one-fifth of the RDA for children were removed from the data set (as agreed upon by the Commonwealth of Kentucky and EPA in the PGDP risk assessment methods document). All subsequent discussions and evaluations regarding the WAG 3 RI data nature and extent refer only to these data that exceeded the screening levels.

4.1.2 WAG 3 Groundwater

Groundwater plumes of VOAs (notably TCE) extend off-site to the north and west of PGDP (see Fig. 1.3). The Northwest Plume is delineated by a number of borings and monitoring wells in proximity to SWMUs 5 and 6. The Southwest Plume (not confirmed at the time the work plan was completed) is delineated in borings immediately west of SWMU 4. One of the objectives of the WAG 3 RI was to assess whether any WAG 3 SWMUs were currently contributing to the known plumes or if they could contribute to groundwater contamination soon. Another objective was to evaluate each SWMU's potential contribution to the elevated technetium-99 concentrations previously detected in PGDP groundwater.

To achieve these objectives, water samples were collected from the UCRS, RGA, and McNairy groundwater systems. In general, the water samples collected during the WAG 3 RI were analyzed for VOAs, SVOAs, metals, and radionuclides. Other selected parameters were measured to define the chemical and physical properties of the groundwater and subsurface soils to support fate and transport analysis.

4.1.3 Historical Data Review

Results of historical sampling at each SWMU are summarized in the sections immediately preceding the nature and extent discussion for each SWMU. The historical data were combined with the data collected from the WAG 3 RI to draw conclusions regarding contaminant nature and extent.

Historical data used in this investigation include data from several sources, but primarily the 1991 and 1992 investigations (CH2M HILL 1991 and CH2M HILL 1992) and the data gaps investigation (DOE 2000a). The 1992 investigation included a geophysical survey, a radiation walkover survey, and soil sampling. Four soil borings were drilled near the perimeter of the burial area, based on the geophysical survey, and were completed to approximately 40 ft bgs. Soil sample analyses included VOAs, SVOAs, metals, and transuranic isotopes. Samples collected from Data Gap Station 030 were used during this evaluation. This boring was installed concurrently with the WAG 3 RI borings and is located less than 200 ft due west of the SWMU 4 boundary. This boring was used to evaluate downgradient groundwater conditions.

Most of the historical groundwater results contained in the historical database were obtained before 1998 (some as early as 1991). The results of the historical groundwater analyses are in Appendix I. When appropriate, the historical groundwater data were combined with the WAG 3 RI data set to conduct the baseline risk assessment as outlined in Vol. 4 of this report.

The sampling that occurred as part of the data gap investigation was considered historical data. After an extensive review of all available data, historical data for SWMUs 4 and 5 were located, whereas none were found for SWMU 6. Borings used as data sources for SWMU 4 include DG-030, H214, H225, H226, and H227. Borings used as data sources for SWMU 5 include H002, H263, and H264.

4.2 WAG 3 SOIL AND GROUNDWATER

4.2.1 C-747 Contaminated Burial Yard (SWMU 4)

4.2.1.1 Location and physical description

The C-747 Contaminated Burial Yard is located south of the C-749 Uranium Burial Ground (SWMU 2) and the C-404 Low-Level Waste Burial Ground (SWMU 3) in the western section of PGDP. The C-747 Contaminated Burial Yard was operated from 1951 to 1958. The waste management unit containing the burial yard measures approximately 286,700 ft^2 and the yard itself was originally reported to consist of two pits that cover a combined area of approximately 8,200 ft^2. The horizontal extent of one pit was reported to measure 50 by 15 ft and the other to measure 50 by 150 ft. Both pits were reported to be excavated to a depth of approximately 15 ft bgs. The site is covered with grass. Surface water drainage swales are located along the border of SWMU 4. The flow patterns are predominantly to the north and west and to the south and west. Discharge ultimately flows into KPDES Outfall 015 and KPDES Outfall 008.

One of the burial pits was used from the beginning of plant operations until approximately 1958 to bury both radiologically contaminated and uncontaminated trash and excess equipment [consisting of steel, Monel (a nickel alloy), and other metals]. Some of the trash was burned before burial. According to PGDP personnel, a majority of the contaminated metal was buried in the northern part of the yard. When the yard was closed, a smaller pit was reported to have been excavated for the disposal of radiologically contaminated scrap metal that could not be sold. The entire burial yard was covered with 2 to 3 ft of soil material and a 6-in. clay cap was placed over the area in 1982.

Surface contamination on the solid wastes disposed at the burial yard was largely associated with natural and slightly depleted uranium from the C-410 UF_6 feed plant. The burial yard may have received technetium-99-contaminated uranium. TCE contamination on the surfaces of metal and trash disposed at the yard is suspected. According to PGDP personnel, sludges originally designated to be disposed at the C-404 burial ground may also have been placed into the C-747 Contaminated Burial Yard. These sludges may have consisted of uranium-contaminated solid waste and technetium-99-contaminated magnesium fluoride. The total quantity of wastes buried at the C-747 Contaminated Burial Yard is unknown.

In the fall of 1999, employee interviews (not associated with the WAG 3 RI investigation) led to a re-classification of the C-747 burial yard as a Classified burial yard. Access was subsequently restricted based on security considerations. Also during the fall of 1999, a small (~3 ft across and ~3 ft deep) sinkhole developed in the southern burial cell. This sinkhole was subsequently back-filled with soil.

4.2.1.2 Practices and release description

No releases from SWMU 4 have been previously documented; however, contaminants may have been released to the environment from surface water infiltration and/or groundwater contact with buried materials resulting in groundwater contamination. There is the potential for leachate to collect in the drainage ditches located on the periphery of the SWMU; however, this is unlikely because the buried waste is below the drainage ditches, and no evidence of leachate has been reported for SWMU 4. When the burial yard was closed, the area was covered with 2 to 3 ft of soil, and an additional 6-in. layer of clay was placed over the top in 1982. Surface soil contamination resulting from the disposal operation is highly unlikely due to the addition of the soil and clay.

4.2.1.3 Location and results of previous sampling

SWMU 4 was investigated in 1992 (CH2M HILL 1992). This investigation included a geophysical survey, radiation walkover, and collection of soil samples from four boreholes. The geophysical survey consisted of an electromagnetic (EM) conductivity survey performed to delimit the location of the site burial pits, followed by a limited magnetometer survey to define selected EM anomalies. Survey data were collected at 10-ft intervals along north-south oriented grid lines that were initially 20 ft apart and then 10 ft apart in areas requiring additional data. Results of the geophysical survey indicated the presence of four main anomalous areas interpreted to be buried metal wastes located in the western two-thirds of the site.

The radiation walkover consisted of a low-level gamma radiation survey conducted with an Eberline SPA-3, which is an instrument consisting of a Sodium Iodide Scintillation Crystal and photomultiplier tube coupled with a count rate meter. Shielded and unshielded GM detector measurements were also taken as part of the radiation walkover. Systematic cone-shielded gamma measurements were taken at 25-ft increments throughout the site, and GM measurements were taken on all 50-ft grid intersections and at the center of each grid.

Data from the cone-shielded gamma survey indicated elevated readings in the east, north, and west perimeter ditches surrounding the site; however, these readings did not exceed the "three-times background" criteria established for the survey. Localized contamination (approximately 13,200 to 31,200 cpm) was detected along the western half of the southern edge of the site. Several unshielded readings >100 cpm were detected during the GM survey of the northern edge of the site. In most cases, when the elevated unshielded readings were observed, the shielded readings were at or near background levels. This phenomenon would indicate that the primary contaminants were beta emitters, such as technetium-99. The GM survey also detected elevated count rates throughout the center of the west perimeter ditch, the north perimeter ditch, and in localized areas in the east perimeter ditch. At one location at the southwest corner of the site, a reading of 868 cpm (unshielded) and 720 cpm (shielded) was observed, suggesting the presence of gamma-emitting radionuclides.

Results of the geophysical and radiation walkover surveys were used to select locations for four soil borings at the C-747 site. These borings (H214, H225, H226, and H227) were located on all four sides of the burial area and were drilled to the approximate depth of the top of the RGA. Three surface soil samples (H383, H384, and H385) were collected to evaluate the geotechnical parameters of the cover material placed over buried waste areas at the site. In addition, infiltrometer tests (DR17, DR18, and DR19) were conducted at the surface sampling locations for use in estimating the infiltration rate for the material on the burial ground.

Results of the surface soil sample physical characteristics and results of the infiltrometer testing are presented in Table 4.4. These results indicate that the cap placed over the C-747 Contaminated Burial Yard consists of a clean clay which has a laboratory permeability in the range of 10^{-6} cm/s. The four borings located at the site were drilled to a depth of 40 ft bgs, and soil samples were generally collected continuously in 5-ft intervals over the entire depth of each boring.

Analytical results for organic compounds and inorganic elements (metals and radiological) detected in the soil boring samples are presented in Table 4.5. Samples from H227 detected VOAs, metals, SVOAs, and radiological constituents in the near surface soil horizon. One PCB compound (Aroclor-1254) and one dioxin compound (octachlorodibenzo-p-dioxin) were also detected in the surface samples of this boring. Results for the H214 and H225 subsurface soil samples indicate the presence of metals and radiological constituents in the near surface soil horizon, and metals only at depth. The lowermost 5-ft interval of boring H214 (30-45 ft) contained no contaminants above reference levels (background concentrations used in the Phase II SI). VOAs were detected in the bottom sampling interval of the H225 boring. Results for the H226 boring samples indicate the presence of metals in the near surface soils, and VOA contamination at depth. The lowermost 10-ft interval of boring H226 was absent of any contaminants above reference levels.

No groundwater samples were collected as part of previous SWMU 4 investigations, except DG-030, which was done (contemporaneously) with the WAG 3 RI. However, groundwater samples have been collected for two SWMUs located in the immediate vicinity of the C-747 Contaminated Burial Yard. These SWMUs are the C-749 Uranium Burial Ground (SWMU 2) and the C-404 Low-Level Waste Burial Ground (SWMU 3). SWMUs 2 and 3 are located directly north across Virginia Avenue from SWMU 4. Three RGA wells (MW-333, MW-93, and MW-95) are located to the north and northeast from SWMU 4. In addition, one UCRS well is located to the northeast. Sampling results from these wells indicate the presence of radiological and metals contamination as well as some VOAs including TCE (110 μg/L) and some SVOAs.

Radiological screening surveys over some of the SWMU 4 area were conducted in May and June of 1996 by Lockheed Martin Utility Services Health Physics technicians. Instruments used for the screening were Ludlum 12 44-9, Ludlum 2221, and Bicron RSO-5. Results indicated that two small areas required flagging and demarcations as Contamination Areas. These areas are located on the western portion of the SWMU (see Fig. 3.10). A small hole is located in one of the Contamination Areas (approximately 1 ft in diameter). The count inside this hole from the survey is 399,000 disintegrations per minute (dpm) β/λ (96-BOPSC-0250-S). A majority of the ditches surrounding the SWMU are also flagged as Contamination Areas with counts up to 119,700 dpm β/λ (96-BOPSC-0264-S).

4.2.1.4 Rationale for RI field sampling

The sampling approach for SWMU 4 was designed to evaluate whether there had been releases from the SWMU and, if so, to characterize the nature of the contamination and determine the extent of the impact to surface soils, subsurface soils, and groundwater from these releases. SWMU 4 was identified in the 1992 investigation as a potential source of TCE and technetium-99 in UCRS and RGA groundwater because of the possible burial of TCE and technetium-99-contaminated waste. Sampling conducted during the 1992 investigation did not indicate that C-747 was a significant contributor of TCE or technetium-99 contamination; however, the 1992 investigation did not sample UCRS groundwater in the area surrounding SWMU 4. Historical information indicates a potential for uranium and technetium-99 contamination based on past burial practices; therefore, uranium and technetium-99 were considered preliminary COPCs. Metals and radionuclides were also identified as preliminary COPCs identified in subsurface soils from the 1992 investigation. Additional data were needed to further characterize the UCRS, provide the information necessary to conduct the human health and ecological risk assessments, and evaluate remedial alternatives, if necessary.

The sampling strategy for SWMU 4 targeted the UCRS and the soils immediately surrounding the buried wastes. The wastes buried in SWMU 4 are reported to include trash, scrapped equipment [steel, Monel (a nickel alloy), etc.], and sludges.

4.2.1.5 Nature and extent of contamination

This RI investigation began with a surface geophysical survey to delineate subsurface anomalies. These anamolies were correlated with existing information to identify the outlines of the burial cells. During the geophysical investigation, a previously unidentified burial cell (located in the northeastern corner of the SWMU) was identified. The next phase of the investigation was the delineation of subsurface stratigraphy with multiple CPT logs to identify water-bearing units within the UCRS. This activity was followed by DPT sampling of surface and subsurface soil intervals from the UCRS and, where present, groundwater from the UCRS. Some of the DPT borings were advanced outside the burial cells to assess migration of contamination laterally out from the cells, and some of the DPT borings were advanced into the pits in an effort to assess contaminant source. [After encountering various difficulties (i.e., broken push rods and high levels of contamination) investigators discontinued further sampling within the burial cells.] TCE, other volatiles (some breakdown products of TCE), and radiological contaminants were identified in several of the borings. Four vertical HSA borings were placed in the interior to collect soil samples and to collect groundwater samples (if present). Two of these borings were advanced into burial cells and encountered high levels of radiological contamination. Seven angled HSA borings were advanced to investigate the extent and levels of contamination under the burial cells. These borings encountered the highest levels of volatile organics (in some cases, several orders of magnitude higher than the levels encountered in the DPT locations surrounding the burial cells). The highest levels of contamination were found under the burial cells, validating the conceptual model for the site (i.e., contamination present in the burial cells is seeping out the bottom of the cells and, driven by downward moving groundwater, is migrating into the RGA) (Fig. 3.17). Four borings were drilled into the RGA around the perimeter of the SWMU, one to the east (generally upgradient) and three to the west (generally downgradient). These borings sampled the level of contaminants in the RGA and provided some data to determine the extent of contribution of TCE from SWMU 4 to the existing TCE plume in the RGA. Based on the data derived, SWMU 4 is believed to be a major TCE source and is currently contributing to the Southwest Plume. Five sediment samples (discussed separately) were obtained from the drainage around the perimeter of the SWMU.

The following discussion on the nature and extent of contamination focuses first on the surface and sediment soils. Then the subsurface soils are evaluated. Groundwater for the UCRS, RGA, and the McNairy are then discussed. In the discussion section of each media, analytes that represent potential contaminants of concern (based on the screening process described in Sect. 4.1) are identified and discussed. The analytical data for all media and all analytes at all depths are displayed in referenced tables and figures. These tables and figures are referred to in the following discussion on the nature and extent of contamination.

Geophysical Survey

The geophysical survey conducted at SWMU 4 in March 1999 generally validated the results of previous surveys. In addition, a previously unknown burial cell was discovered in the northeast corner of the SWMU. All of the subsurface anomalies identified in the geophysical survey were subsequently targeted for intrusive sampling and analysis.

Radiological Survey

A radiological walkover survey was conducted at SWMU 4 in August 1999. Activity levels over the SWMU generally varied from about 21,000 cpm in the southeastern part of the SWMU to about 70,000 cpm in the northwestern part of the SWMU. Two small areas with contamination levels greater than twice background were noted in the southwestern part of the SWMU. The maximum activity in this area was about 200,000 cpm, with a background of about 30,000 cpm. Also, a small area in the southern part of the SWMU had activity of 53,000 cpm, with a background of about 30,000 cpm.

Surface Soils—Analytical Results

Samples collected from the 0-1-ft interval consisted of surface soil samples collected in the cap material from the DPT borings and two surface soil samples from the radiologically contaminated areas in the southwest portion of the SWMU. The samples were analyzed for VOAs, SVOAs, PCBs, and TAL metals and screened for radiological constituents. Eight surface soil samples were collected. All results that exceeded detection limits and screening values are displayed in Table 4.6 and Fig. 4.1.

Organics—VOAs. Acetone was detected at a historical site (H214) and methylene chloride was detected at 004-032.

Organics—SVOAs. One SVOA was detected in one of the historic surface soil samples, 4-methyl-3-penten-2-one at H214.

Organics—PCBs. No PCBs were detected in the surface soils at SWMU 4.

Inorganics. Iron and chromium were the only metals detected in the surface soils at SWMU 4 above screening values.

Radionuclides. Gross alpha measurements for the surface soils ranged up to 85 pCi/g. Gross beta measurements ranged up to 114 pCi/g. Isotopes above detection limits and screening levels included uranium-234, -235, -238, total uranium, thorium-234, neptunium-237, and plutonium-239/240.

Sediment Soils—Analytical Results

Five sediment samples were collected from the four ditches around the SMWU 4 perimeter (004-001, -002, -003, and –004) and one ditch northwest of the SWMU (004-005). The samples were intended to provide data to assess surface soil contaminated by runoff at the SWMU 4 perimeters and 004-005 was intended to assess migration off the SWMU. Table 4.7 and Fig. 4.1 display this information.

Organics—VOAs. No VOAs were detected in sediments at SWMU 4.

Organics—SVOAs. One SVOA was detected in 004-002.

Organics—PCBs. PCBs were detected in all five sediment samples (though only two, 004-002 and 004-005, exceeded screening levels).

Inorganics. Only one metal was detected above screening levels (iron in 004-005).

Radionuclides. Gross alpha measurements for sediments ranged up to 123 pCi/g. Gross beta ranged up to 289 pCi/g. Specific radioisotopes detected included plutonium-239/240, thorium-234, uranium (total plus -234, -235, and -238), americium-241, cesium-137, and technetium-99. (The last three radioisotopes were detected only in 004-005.)

Subsurface Soils—Analytical Results

Subsurface soil samples were collected using DPT, vertical HSA, and angled HSA drilling methods at selected intervals throughout the UCRS. The samples were analyzed for VOAs, SVOAs, PCBs, and TAL metals and screened for radiological constituents.

Organics—VOAs. VOAs were encountered at depths ranging from 3 ft to 60 ft (Table 4.8). Major contaminants include TCE, vinyl chloride, and cis-1,2-dichloroethene. In general, the concentrations of these contaminants increased with depth and were most prevalent in angled HSA borings under the burial cells and in the vertical HSA and DPT borings immediately adjacent to the burial cells. Figure 4.2 shows TCE concentrations in subsurface soils and Fig. 4.3 shows all other VOAs in subsurface soils.

Organics—SVOAs. Concentrations of several SVOAs were detected in subsurface soils collected from SWMU 4 (Table 4.9). The predominant SVOA was di-n-butyl phthalate detected in 18 borings at depths from 5 to 60 ft bgs. Figure 4.4 displays the locations and depths of the SVOA contaminants.

Organics—PCBs. Several types of PCBs (PCB-1260, -1248, -1254, and -1016) were detected at depths between 3 and 11 ft bgs (Table 4.10). Concentrations ranged up to 27,000 µg/kg and were detected at ten sampling points throughout the SWMU. In addition, dioxin was detected in the same depth interval in one of the historic data points (H227). The distribution of total PCBs is shown in Fig. 4.5.

Inorganics. Table 4.11 highlights those metals that were detected above screening levels in the subsurface soil samples at SWMU 4. Unlike the surface soils, the subsurface soils at SWMU 4 contained several inorganic constituents above the analytical detection limit. However, when compared to screening values, only aluminum, chromium, cobalt, iron, lead, and manganese exceeded all screening criteria.

Radionuclides. Gross alpha activities (Table 4.12 and Fig. 4.6) for the subsurface soils ranged from 2.02 to 3076.71 pCi/g and gross beta activities (Table 4.13 and Fig. 4.7) ranged from 0.76 to 3253.97 pCi/g. Numerous isotopes were also detected, including total uranium, uranium-234, -235, -238 (Fig. 4.8), plutonium-239/240, protactinium-234, neptunium-237, and thorium-230 and –234 (Table 4.14). Figure 4.9 displays the distribution of radioisotopes (other than uranium) detected in subsurface soils at SWMU 4.

UCRS Groundwater—Analytical Results

UCRS groundwater samples were collected from vertical boreholes when UCRS groundwater was encountered in quantities to sample, and from angled HSA boreholes at total depth (again when groundwater was in sufficient quantity to sample). At intervals above total depth of the boring, groundwater samples were collected when CPT logs indicated the presence of a water-bearing zone. In the original planning for the RI, the UCRS was expected to extend to a depth of 60 ft bgs. During drilling, sands encountered at approximately 58 ft bgs suggested a transition zone on an unusually high RGA surface. Groundwater samples collected at the 60 ft interval likely represent the interface between UCRS and RGA groundwater, and contaminants encountered at this interval are likely originating from the SWMU 4 burial cells and not from other sources (unlike the RGA, which likely has a mix of SWMU 4 and other PGDP site contaminants comprising the Southwest Plume).

Organics—VOAs. VOAs detected in UCRS groundwater at SWMU 4 include TCE and its degradation products (Table 4.15). Figure 4.10 displays the location of TCE detections in UCRS groundwater. The VOA 2-butanone (also known as methyl ethyl ketone) was detected in one sample. VOAs were detected above the screening levels in 19 borings. The shallowest detection was at 19 ft bgs, and detections continued in several of the borings to the base of the UCRS (Fig. 4.11).

Organics—SVOAs. Two SVOAs were detected in the UCRS groundwater—bis(2-ethylhexyl)phthalate at 004-020 (60 ft bgs) and diethyl phthalate at 004-009 (40 ft bgs) (Table 4.16 and Fig. 4.11).

Organics—PCBs. PCBs were detected at 60 ft bgs in borings 004-025 and 004-026 (Table 4.17 and Fig. 4.11).

Inorganics. Metals detected in UCRS groundwater above screening levels included aluminum, arsenic, beryllium, cadmium, cobalt, iron, manganese, strontium, and zinc (Table 4.18).

Radionuclides. Groundwater samples from the UCRS (Fig. 4.11) displayed gross alpha activity ranging from 15.6 to 5,270 pCi/L, and gross beta activity ranging from 5.4 to 1,490 pCi/g (Tables 4.19 and 4.20). Technetium-99 was detected in 18 borings and ranged from 16.3 to 1640 pCi/L (Table 4.21 and Fig. 4.12). Uranium-235 was detected in four borings (Table 4.21).

RGA Groundwater—Analytical Results

VOAs were detected in the RGA, ranging in depths to 113 ft bgs [displayed in Table 4.15 and Figs. 4.10 (TCE) and 4.13]. All groundwater occurrences are consistent with the conceptual model showing that contaminants are leaching out of the bottom of the burial cells and are generally migrating downward to the RGA, then moving laterally with the RGA groundwater flow. Of particular significance is an evaluation of the presence of VOAs in the groundwater samples collected from the DWRC borings at 004-028, 004-029, and DG-030 (generally considered to be downgradient in the RGA relative to SWMU 4) and in 004-058 (approximately upgradient of SWMU 4 in the RGA). TCE is the only VOA contamination in 004-058 at relatively low levels (less than or equal to 80 µg/L). In the borings considered to be downgradient, VOAs detected are TCE, at levels up to 10,000 µg/L, and TCE degradation products, at levels as high as 200 µg/L for cis-1,2-dichloroethene.

Radiological constituents detected in the RGA at SWMU 4 consisted of technetium-99 (Fig. 4.12) and related gross alpha/beta activity and uranium-235 (Fig. 4.13). Table 4.21 shows the results of technetium-99 and uranium-235 analyses. The distribution of technetium-99 is somewhat similar to that of TCE [i.e., prevalent in the western portion of the SWMU and in the borings west of the SWMU (Fig. 4.12)].

Three types of samples were prepared for inorganic analysis of the RGA water: (1) unfiltered samples providing total concentration of the inorganic analytes, (2) 0.45μ filtered samples providing dissolved concentrations of inorganic analytes, and (3) 5μ filtered samples providing concentrations of the dissolved phase and the colloidal phase. Table 4.22 provides the average, minimum, and maximum concentration in each sample type. A review of the results shows that the high concentrations of several metals is due to the presence of suspended sediments. Additionally, the aluminum present in the RGA groundwater is partitioned in a colloidal phase.

McNairy Groundwater —Analytical Results

Four borings were advanced into the McNairy Formation around SWMU 4. Of the four borings, two (004-028 and 004-058) were able to sample the McNairy Formation. The other two borings (DG-030 and 004-029) were unable to collect groundwater samples in the McNairy due to an absence of water. No contamination was identified in the McNairy Formation except for one technetium-99 detection of 37 pCi/L at 158 ft bgs in 004-058 (Table 4.21), with an accompanying measurement of 24.7 pCi/L of gross beta (Table 4.20).

4.2.1.6 Summary of findings

Volatiles are present in the subsurface soil, UCRS groundwater, and RGA groundwater at SWMU 4. The majority of VOAs detected are TCE and its degradation products. The majority of the samples in which TCE was detected in both subsurface soils and UCRS groundwater are beneath or adjacent to the burial cells and are generally below 23 ft bgs. This suggests that sources of TCE have been disposed of in the burial cells, and these sources have been mobilized by precipitation infiltrating through the surface soils, down through the cells, and into the underlying soils. The distribution of the data suggests that various “slugs” of TCE have broken out at different times. (Another explanation for the data distribution is the heterogeneous nature of the UCRS soils, allowing varying migration rates as these “slugs” pass through relatively permeable sands and relatively impermeable silts and clays.) This is indicated by borings where TCE was detected at varying depths. In these borings (displayed on Fig. 4.2) levels of TCE vary with depth, sometimes decreasing with depth (suggesting a recent release of a large quantity that is slowly descending, such as is shown in borings 004-022 and 004-026). In other borings, the data do not indicate a similar trend, especially in the TCE degradation products (such as is shown in boring 004-027). In the RGA, VOAs are encountered in the three DWRC borings drilled west of the SWMU, while lower levels of VOAs are encountered east of the SWMU. Based on available data, groundwater flow in the RGA is generally west at SWMU 4. These data indicate that a small quantity of VOAs are present immediately upgradient of SWMU 4, and a much greater quantity of VOAs are present immediately downgradient of SWMU 4, suggesting that SWMU 4 is a source of VOA contamination to the RGA (specifically the Southwest Plume). In both soils and groundwater, the highest levels of contamination were detected in the angled boring under the burial cells. Levels of contamination around the periphery of the cells are several orders of magnitude lower or, in some cases, not detected at all (graphically displayed in Fig. 4.14).

PCBs were detected at SWMU 4 at depths of 3–6 ft bgs. Within this horizon, radiological contamination (including gross alpha, beta, and various radioisotopes) was also detected. In several of the borings, gravel (typically used on gravel pads and driveways) was encountered. It is postulated that this horizon represents the original grade at the time the burial cells were in use. Most of the PCB detections were encountered in borings outside but adjacent to the burial cells. A potential explanation could relate to waste handling practices, resulting in spills on the gravel pad.

This latter might also explain the high radiological detects found at this horizon. One detection of dioxin was also recorded in a historical boring. While the OCDD result is a possible laboratory artifact, the supporting historical data package is unavailable to confirm this. OCDD is a naturally occurring congener which is a product of combustible materials, but without further information from the hard-copy data package, it is not possible to conclude that this was a laboratory induced artifact.

Radiological activity, including high levels of various radioactive isotopes, was detected primarily around the southwest burial cell. Radiological contamination was also detected in the burial cell in the northeast corner. Historical information indicated that some process building wastes were disposed of in the SWMU 4 burial cells, and this waste may be the source of the radiological contamination. Technetium-99 is found in the RGA around SWMU 4 and in the UCRS groundwater under SWMU 4.

No contamination was identified in the McNairy Formation except for one sample in which technetium-99 was detected at 37 pCi/L at 158 ft bgs in 004-058. Because this boring is considered upgradient of SWMU 4, the source is not considered to be SWMU 4. (Note that the McNairy/RGA contact is deeper in SWMU 4 than is typically seen in other areas of PGDP. At the west end of SWMU 4, the top of the McNairy Formation appears to be ~120 ft bgs.)

Metals were identified in SWMU 4 that exceeded screening values (however, due to uncertainty of laboratory methods, the actual concentrations of these analyses could be within background ranges). The source of these metals is unknown, but if they do represent contamination, then it is likely originating from material buried at the site.

4.2.2 C-746-F Classified Burial Yard (SWMU 5)

4.2.2.1 Location and physical description

The C-746-F Classified Burial Yard is located south of the C-746-P Clean Scrap Yard and west of the C-747-B Burial Ground in the northwest section of PGDP (see Fig. 1.2). The burial yard consists of disposal pits that cover an area of approximately 197,400 ft^2. According to plant personnel, disposal pits at the site were located on a grid system and consisted of approximately 10- by 10-ft cells excavated to depths of approximately 6 to 15 ft. The C-746-F Classified Burial Yard is an inactive landfill that was used from approximately 1965 to 1987 for the burial of security-classified weapons components, some radionuclide-contaminated scrap metal, and slag from nickel and aluminum smelters. Waste placed in the yard disposal pits was covered with 2 to 3 ft of soil. To date, the far western end of the yard has not been used for waste burial. The site is covered with grass. Surface water drainage swales are located along the north, west, and south boundaries of the C-746-F Classified Burial Yard. Surface water runoff from the C-746-F site and other vicinity SWMUs flows along these drainages into Ditch 001 located south of the burial yard. Ditch 001 then flows west into Outfall 001.

Surface contamination on some solid wastes disposed of at the C-746-F Classified Burial Yard was associated with natural or slightly depleted uranium. The burial yard may be a source of technetium-99 resulting from technetium-99-contaminated uranium disposed at the yard. Records suggest that weapons components containing tritium, cobalt-60, and tantalum-182 may have been placed into the burial yard. The site is not believed to be a likely source of TCE contamination, and the total quantity of wastes buried at the yard is unknown. Chemically unstable or incompatible compound/metal wastes are thought to have been placed here too. This conclusion is supported by the occurrence of an underground fire (thought to have occurred circa 1975–1976) in the southeast corner of the yard. This fire burned for several weeks, and individuals observing the fire reported that the ground surface appeared to become unstable. The source and/or cause was never determined, and the fire extinguished itself without intervention. There are no data on any potential contaminant releases resulting from this fire.

4.2.2.2 Location and results of previous sampling

Previous investigations of the C-746-F Classified Burial Yard involved collection of soil samples from boring H002, which was located along the southern edge of the site and was drilled to a depth of approximately 73 ft bgs (Table 4.23). Soil samples were collected in 6-ft intervals for the entire depth of the boring. Three groundwater monitoring wells were installed at the site in 1983. One of the wells, MW-52, was located near the south side of the site, and the other two, MW-53 and MW-54, were located near the north side of the site. All of these monitoring wells were completed within the RGA.

Several investigation activities were conducted in 1992 at SWMU 5. Subsurface soil samples were collected and an additional groundwater monitoring well was installed. Two soil boreholes were drilled in ditches along the edge of the site. Boring H263 was located at the northwest corner of SWMU 5 and the other, H264, at the southwest corner. Both borings were drilled to a depth of approximately 6 ft bgs, and soil samples were collected from the top 1-ft interval of the boring and then in 2-ft intervals to 6 ft. One groundwater monitoring well, MW-190, was installed and completed within the UCRS. During the installation of this well, soil samples were collected at depths of 5 to 10 ft and 10 to 20 ft.

Results of analyses from the deep soil boring, H002, indicated the presence of VOAs, SVOAs, and metals at various depths.

Results for boring H-263 indicated the presence of SVOAs and metals in the shallow subsurface. However, surface and near-surface contamination at boring H263 may reflect impact from other source areas rather than from the C-746-F site because these borings were located in plant drainage ditches.

Results for the groundwater samples collected from MW-52 and MW-54 indicated the presence of metals. Samples from MW-53 and MW-190 contained metals, radionuclides, and TCE (Table 4.24).

4.2.2.3 Rationale for RI field sampling

The sampling strategy for SWMU 5 was to target the soils immediately surrounding and beneath the buried waste (UCRS) and the soils and groundwater associated with the RGA. The sampling approach had been designed to evaluate whether there have been releases from SWMU 5 and, if so, to characterize the nature of the contamination. The sampling was also designed to determine the extent of the impact to the surface soils, subsurface soils, sediments, and groundwater from any release that may have occurred. Metals and radionuclides were the primary COPCs for the investigation sampling although VOAs and SVOAs were analyzed as well.

4.2.2.4 Nature and extent of contamination

The SWMU 5 investigation began with a geophysical survey. Then, two CPT surveys to 60 ft bgs were conducted, one on the northeast side and the other to the west of SWMU 5. These surveys delineated the basic stratigraphy in the UCRS for selection of intervals that would be likely to produce water sufficient for sampling. Following the CPT surveys, DPT surface and subsurface soil and water sampling occurred at three locations. The DPTs had a maximum penetration depth of 60 ft bgs. Subsequent sampling was carried out by means of HSA, DWRC, and angled HSA.

Geophysical Survey

The surface geophysical survey that was conducted at SWMU 5 in March 1999 identified subsurface anomalies presumed to be the burial cells. The location and extent of anomalies were consistent with previous information of the location of the burial cells.

Radiological Survey

A radiological walkover survey was conducted at SWMU 5 in August 1999. Activity levels over the SWMU varied from about 12,000 cpm in the northwest part of the SWMU to about 52,000 cpm in the southeast part of the SWMU. No areas within the SWMU boundary were found to have activity greater than twice background.

Surface Soils—Analytical Results

Surface soil includes samples collected from locations at 0–1 ft bgs, but not from drainage ditches, where sediment samples are collected. Constituents above screening values detected in surface soil samples and the borings from which they were collected are listed on Table 4.25 and shown in Fig. 4.15.

Organics—VOAs. The only VOA detected above screening values in surface soil from recent borings at 005-015 was methylene chloride.

Organics—SVOAs. Several SVOAs were detected in borings 005-010, 005-015, 005-016, and H263.

Organics—PCBs. PCBs were detected above screening levels at SWMU 5 in surface soil from only one sample, from boring 005-008.

Radionuclides. Only alpha and beta activities were detected in surface soils. Alpha activities ranged up to 18.1 pCi/g and beta activities ranged up to 34.4 pCi/g.

Sediment—Analytical Results

Sediment samples were collected from drainage ditches to determine if any surface contamination was being released from the SWMUs. All sediment was collected from depths less than 1 ft bgs. Table 4.26 provides the specific constituents, their concentrations, and the borings from which the samples were collected. Figure 4.15 graphically displays these data.

Organics—VOAs. There were no concentrations of VOAs above screening levels detected in sediment samples collected at SWMU 5.

Organics—SVOAs. Several SVOA samples had concentrations above screening levels; from locations 005-001, 005-002, 005-006, and one was from 005-007.

Inorganics. One inorganic analyte above screening levels was detected in sediment samples collected at SWMU 5, aluminum at 005-006.

Organics—PCBs. There was no concentration of PCBs above screening levels detected in sediment samples collected at SWMU 5.

Radionuclides. Alpha activities ranged up to 31.2 pCi/g and beta activities ranged up to 39.9 pCi/g. Technetium-99 and thorium-234 were the only radioisotopes detected above screening levels in sediment at SWMU 5; at locations 005-001, 005-002, 005-006, and 005-007.

Subsurface Soil—Analytical Results

Subsurface soil was collected below 1 ft bgs. Figure 4.16 provides subsurface contaminants on a map of SWMU 5.

Organics—VOAs. The VOAs detected above screening levels at SWMU 5 are 1,1,2-trichloro-1,2,2-trifluoroethane, acetone, methylene chloride, and TCE (Table 4.27). The sample that was reported to have levels of methylene chloride above screening values was analyzed outside holding times. This combined with the fact that this was the only sample indicating the presence of methylene chloride makes that analysis suspect. TCE was detected in two recent borings, 005-018 and 005-021, throughout the depths of those borings, and in H002 at 36–42 ft bgs. However, the concentrations are very low, ranging from 1.6 to 9 μg/kg. Acetone was also detected in one historic boring, H002.

Organics—SVOAs. Several SVOAs have been detected in borings at SWMU 5, but their widespread presence is not indicated. The SVOA most frequently detected, di-n-butyl phthalate, was also seen in method blanks for that analysis; consequently, the reported values may indicate laboratory rather than environmental contamination (Table 4.28). Several other SVOAs were detected in historic borings H002 and H263 in the shallow subsurface.

Organics—PCBs. No concentrations of PCBs were reported above screening levels.

Inorganics. The only inorganics with concentrations above screening levels were aluminum, chromium, cobalt, and iron (Table 4.29). The values reported for chromium, which range from 83.9 to 296 mg/kg, may indicate that chromium is a contaminant at this location (background is 16 mg/kg).

Radionuclides. Alpha activities ranged from 0.8 to 23.8 pCi/g (Table 4.30). Beta activities ranged from 1.19 to 27.6 pCi/g (Table 4.30). Technetium-99, thorium-234, and uranium-238 were detected in concentrations above screening levels in samples collected from SWMU 5.

UCRS Groundwater—Analytical Results

UCRS groundwater samples were collected from vertical boreholes when UCRS groundwater was encountered in sufficient quantities to sample, and from angled HSA boreholes at total depth (again, when groundwater was in sufficient quantity to sample). In the original planning for the RI, the UCRS was expected to extend to a depth of 60 ft bgs. During drilling, sands encountered at approximately 58 ft bgs suggested a transition zone on an unusually high RGA surface. Groundwater samples collected at the 60-ft interval likely represent the interface between UCRS and RGA groundwater, and contaminants encountered at this interval are likely not originating from the SWMU 5 burial cells. Groundwater contaminants are shown in Fig. 4.17.

Organics—VOAs and SVOAs. There were no detections of VOAs or SVOAs in groundwater above 60 ft bgs in SWMU 5.

Inorganics. Metals above screening levels are presented in Table 4.31.

Radionuclides. The only radioisotope associated with UCRS groundwater samples from SWMU 5 was technetium. It was detected at 31 pCi/L at 24–29 ft bgs in boring 005-017. There were no alpha activity readings taken on groundwater samples collected from the UCRS. The two beta activity readings were 3.9 ± 1.4 and 7.1 ± 3.1 pCi/L. (All radionuclides data in groundwater are presented in Table 4.32.)

RGA Groundwater—Analytical Results

Most of the groundwater samples collected during this RI were from the RGA. Borings 005-013 and 005-026 were DWRC, and samples were collected almost continuously at 5-ft intervals throughout the RGA. No sample was collected from 83 ft from boring 005-013; however, all other 5-ft intervals were sampled in both borings. The other borings from which RGA samples were collected are 005-018, 005-019, 005-020, 005-021, and 005-022, which are HSA borings. Each of these borings collected groundwater from 60 ft bgs.

Organics—VOAs. The only VOAs detected above MCLs were TCE and acetone. TCE was detected in borings 005-013, 005-022, and 005-026. Samples from boring 005-013 indicated the presence of TCE in all sampled intervals between 68 and 93 ft bgs. The sample from 005-022 in which TCE was above screening levels, was collected at 60 ft bgs at the contact of the UCRS and the RGA and in a region of the Northwest Plume with TCE in the upper part of the RGA. The sample from boring 005-026 that indicated the presence of TCE was collected at 78 ft bgs. TCE was analyzed for in other samples collected from 005-026, but was either below detection limits or below screening values. Acetone was detected in 005-020 at 38 µg/L (Table 4.33).

Organics—SVOAs. The two SVOAs detected above screening levels from samples collected at SWMU 5 are bis(2-ethylhexyl)phthalate, from 005-019, and pyrene, from 005-015. The analysis for bis(2-ethylhexyl)phthalate did not meet recovery standards for the laboratory control sample; therefore, the results are probably not accurate. Pyrene was detected at 005-015 at 23 µg/L (Table 4.34).

Inorganics. Inorganics detected above screening levels in samples from SWMW 5 are cobalt, iron, manganese, and zinc (Table 4.31).

Three types of samples were prepared for inorganic analysis of the RGA water: (1) unfiltered samples providing total concentration of the inorganic analytes, (2) 0.45µ filtered samples providing dissolved concentrations of inorganic analytes, and (3) 5µ filtered samples providing concentrations of the dissolved phase and the colloidal phase. Table 4.35 provides the average, minimum, and maximum concentration in each sample type. A review of the results shows that the high concentrations of several metals are due to the presence of suspended sediments. Additionally, the aluminum present in the RGA groundwater is partitioned in a colloidal phase.

Radionuclides. The radionuclides detected in SWMU 5 are radon and technetium-99. Technetium-99 was detected in borings 005-013 and 005-026, both of which were deep DWRC borings. Concentrations ranged from 14.9 to 31 pCi/L. Alpha activities ranged from 16.97 to 56.08 pCi/L. Beta activities ranged from 3.7 to 73.07 pCi/L (Table 4.32).

McNairy Groundwater

Two samples were collected from the McNairy, one each from borings 005-013 and 005-026, and both at 108 ft bgs. The analytes detected above MCLs from these two samples were iron, manganese, and technetium-99, detected at 15.8 pCi/L, with an accompanying measurement of 73.07 pCi/L of gross beta.

4.2.2.5 Summary of findings

The investigation of SWMU 5 indicates minimal contribution of contamination to the UCRS and RGA groundwater. The samples collected during this RI and during the 1991 and 1992 investigations indicate that contamination of surface soil is minimal. The SVOAs present may be due to vehicular traffic at PGDP, and the sporadic occurrence of the pesticide/herbicide dibenzofuran may result from the grounds maintenance program at PGDP.

Subsurface soils from the UCRS contain low concentrations of radioisotopes, metals, and organics. Several organics were present without any noted pattern, including very low levels of TCE in two borings. However, groundwater samples from these borings did not detect any VOA contamination.

Groundwater samples of TCE collected at depths near the contact between the UCRS and the RGA indicate the presence of the Northwest Plume under SWMU 5, but the data available do not indicate that SWMU 5 is contributing to the plume. Several inorganics were also detected in groundwater that may be naturally occurring; however, due to the lack of background information on groundwater at PGDP, this is only a supposition at this time.

Two samples were collected from the McNairy, in which small amounts of metals and technetium-99 were detected. However, these data are not sufficient to draw conclusions on the presence of contamination in that formation. Technetium-99 was detected in a sample at the interface with the RGA and could indicate some mixing at this interface.

4.2.3 C-747-B Burial Ground (SWMU 6)

4.2.3.1 Location and physical description

The C-747-B Burial Ground is located east of the C-746-F Classified Burial Yard and west of the C-746-B Transuranic (TRU) Storage Area in the northwest section of the PGDP (see Fig. 1.1). The burial ground consists of five separate burial plots (identified as Areas H, I, J, K, and L) that together cover an area of approximately 5200 ft^2. Figure 3.10 shows the location of the plots according to a report titled, *The Discard of Scrap Materials by Burial at the Paducah Plant* (Fortune 1973). Below are descriptions of each plot as presented in the Fortune report.

- **Area H—Magnesium Scrap Burial Area.** This disposal site consists of an area of about 180 ft^2 (12 by 15 ft) and is about 6 ft deep. The scrap buried at this location is magnesium in various shapes generated in the machine shop. A total of about 10 drums of scrap was buried during midsummer 1971 and a 3-ft cover of soil was placed on top of the buried drums.

- **Area I—Exhaust Fan Burial Area.** This discard pit involves 280 ft^2 (8 by 35 ft) and is about 8 ft deep. Eight exhaust hood blowers removed from C-710 were discarded to this pit. These blowers, which were about 15 in. in diameter and weighed about 100 lb each, were discarded in 1966 because of contamination with perchloric acid. Each blower was spaced about 4 ft apart in the hole and then covered with about 5 ft of soil cover.

- **Area J—Contaminated Aluminum Burial Area.** This burial site is about 4000 ft^2 (37 by 110 ft) and was excavated to a depth of about 6 ft. The contaminated scrap buried in this hole involved about 100 to 150 drums of aluminum scrap in the form of nuts, bolts, plates, trimmings, etc., generated in the converter and compressor shop. This scrap, which was buried about 1960 or 1962, was covered with about 3 ft of soil.

- **Area K—Magnesium Scrap Burial Area.** This disposal site consists of an area of about 180 ft^2 (12 by 15 ft) and is about 6 ft deep. The scrap buried at this location is magnesium in various shapes generated in the machine shop. A total of about 20 drums of scrap was buried on September 3, 1968, and December 23, 1969. A 3-ft cover of soil was placed on top of the buried drums.

- **Area L—Modine Trap Burial Area.** A single contaminated modine trap was buried in this area of about 600 ft^2 (20 by 30 ft) in a hole about 6 ft deep. The cold trap was about 4 ft in diameter, approximately 15 ft long, and weighed about 5000 lb. This equipment, which was buried on March 5, 1969, was covered with about 3 ft of soil.

A surface water drainage ditch is located east of the buried materials running north/south. This ditch drains into Ditch 001 which flows west past SWMU 5 into Outfall 001.

4.2.3.2 Location and results of previous sampling

No previous sampling activities have taken place at SWMU 6. The site was not included in earlier investigations, because it was not believed to be a contributor to off-site contamination. No known disposal of materials contaminated by TCE, PCBs, or technetium-99 has been reported.

4.2.3.3 Rationale for RI field sampling

The sampling strategy for SWMU 6 targeted the UCRS and the soils immediately surrounding the buried wastes. The wastes buried in SWMU 6 are clearly delineated on plant maps (Fortune 1973). Geophysical surveying over the burial areas attempted to confirm these delineations. Sampling of the actual waste was originally deemed necessary to confirm the detailed disposal records described above. However, after mobilization and some initial drilling, it was determined that drilling into the pits was too dangerous to pursue further drilling. In addition, auger refusal was considered likely if attempts were made. Due to the nature of the waste buried in this area, samples were collected immediately adjacent to the waste cells to determine if any contamination was being released, and, if so, to determine the nature and extent of the impact to surface soils, subsurface soils, sediments, and groundwater. It was assumed that SWMU 6 is not a contributor of TCE or technetium-99 contamination. However, due to the absence of sample data at SWMU 6, all samples were analyzed for VOAs, SVOAs, PCBs, pesticides/herbicides, and radioisotopes. Additional data were needed to further characterize the UCRS and provide the information necessary to conduct the human health and ecological risk assessments.

Metals, radionuclides, PCBs, and TCE were identified as preliminary COPCs at SWMU 6.

4.2.3.4 Nature and extent of contamination

SWMU 6 consists of the C-747-B Burial Ground and is located east of the C-746-F Classified Burial Yard (SWMU 5) and west of the C-746-B TRU Storage Area. Sampling results are discussed by media (soil and groundwater) and by horizon (surface soil, subsurface soil, and groundwater). The investigation began with the delineation of subsurface stratigraphy with one CPT log (006-005) to identify water-bearing units within the UCRS.

Geophysical Survey

There were no historical geophysical surveys of SWMU 6, so one was conducted in March 1999 to accurately locate the burial areas (waste cells). The survey confirmed the extent of Area J, but was inconclusive concerning Areas H, I, K, and L due to the presence of old equipment and machinery stored on and adjacent to the site (which prevented access to the site). Results of this survey are presented in Appendix A.

Radiological Survey

A radiation screening walkover survey was conducted across the SWMU 6 surface area in August 1999 using a sodium iodide detector. Activity levels ranged from 18,000 cpm in the southern part of the SWMU to about 42,000 cpm in the southeastern part; no areas within the SWMU boundary had an activity greater than twice background. Four samples were collected for the in situ gamma spectrometry investigation, and the only radioisotope not naturally occurring was cesium-137, which was detected in all four samples. Results from this survey are presented in Appendix B.

Surface Soils—Analytical Results

Surface soil collected from the 0–1 ft interval along with the DPT borings at SWMU 6 consisted of clayey silt with roots and little gravel. The samples were analyzed for VOAs, SVOAs, PCBs, TAL metals, and radiological constituents. No analytical results were detected above screening values for surface soil samples collected from SWMU 6.

Sediment—Analytical Results

Samples 006-001, 006-002, and 006-003 were collected from the drainage ditch/swale located east of the burial areas. This drainage feature receives surface runoff during periods of heavy rainfall.

The only analytes above detection limits or screening level in sediment samples collected at SWMU 6 were alpha activity, beta activity, di-n-butyl-phthalate, and technetium-99. As with many other samples collected during this RI, the analysis for di-n-butyl-phthalate is suspect because that compound was found in the method blank for that analysis. Technetium-99 was detected in the sample from location 006-003 at 13.9 pCi/L. Alpha activity ranged from 15.2 to 20.7 pCi/g and beta activity ranged from 19.5 to 37.8 pCi/g. Table 4.36 and Fig. 4.18 contains this information.

Subsurface Soils—Analytical Results

Subsurface soil samples were collected using various drilling methods at selected intervals throughout the UCRS. The samples were analyzed for VOAs, SVOAs, PCBs, TAL metals, and radionuclides. Sampling locations for SWMU 6 are shown on Fig. 4.18.

Organics—VOAs. Two VOAs were detected in the subsurface soils at SWMU 6 as shown in Table 4.37. Acetone was detected in three samples from three of the angled borings (006-019, 006-021, and 006-023). TCE was detected in four samples from two angled borings (006-021 and 006-022, which were drilled to the south and outside the SWMU 6 boundary). All detections had extremely low concentrations, ranging from 2.5 to 10.1 μg/kg.

Organics—SVOAs. Di-n-butyl phthalate was detected in 18 samples at SWMU 6 from 10 borings at depths ranging from 14 to 71 ft bgs. However, the method blank for this analysis had high concentrations of this compound in it. Bis(2-ethylhexyl)phthalate was detected in 006-021 at 50 ft bgs at 490 μg/kg and in 006-023 at 43 ft bgs at 600 μg/kg. Table 4.38 presents the analytical results for both compounds discussed above.

Organics—PCBs. No PCBs were detected in subsurface soils at SWMU 6.

Inorganics. Table 4.39 lists those metals that were detected above screening levels in the subsurface soil samples at SWMU 6.

The subsurface soils at SWMU 6 contained several inorganic constituents above screening levels: aluminum, arsenic, barium, beryllium, chromium, cobalt, copper, lead, manganese, nickel, and zinc (Fig. 4.18).

Chromium ranged from 43.2 to 116 mg/kg compared to a subsurface background concentration of 43 mg/kg. Cobalt ranged from 17.9 to 156 mg/kg compared to a subsurface background concentration of 13 mg/kg. Only two samples detected lead above screening levels at values of 25.2 and 35.4 mg/kg; background is 23 mg/kg.

Radionuclides. Subsurface soil samples from the UCRS were screened for radiological constituents. Gross alpha measurements ranged from 1.63 to 24.4 pCi/g and gross beta measurements ranged from 1.33 to 126.4 pCi/g. Detectable concentrations of several radionuclides were reported in the subsurface soils at SWMU 6 (Table 4.40). Technetium-99 was detected in two samples collected from borings 006-021 and 006-022 at 60 ft bgs; at 956 and 46.8 pCi/g, respectively.

UCRS Groundwater—Analytical Results

UCRS groundwater samples were collected from vertical boreholes when UCRS groundwater was encountered in sufficient quantities to sample, and from angled HSA boreholes at total depth (again, when groundwater was in sufficient quantity to sample) (Fig. 4.19). In the original planning for the RI, the UCRS was expected to extend to a depth of 60 ft bgs. During drilling, sands encountered at approximately 58 ft bgs suggested a transition zone on an unusually high RGA surface. Groundwater samples collected at the 60-ft interval likely represent the interface between UCRS and RGA groundwater, and contaminants encountered at this interval are likely not originating from the SWMU 6 burial cells.

Organics—VOAs/SVOAs. One VOA (acetone) was detected at 006-028 at a depth of 35 ft bgs as shown in Table 4.41.

Organics—PCBs. The compound PCB-1016 was detected twice in the shallow groundwater at SWMU 6. It was reported at station 006-011 at 255 µg/L at 9 ft bgs and station 006-012 contained 53 µg/L at 12 ft bgs. (This second detect of PCB is noted here, but is not shown on Table 4.42 because it did not exceed screening levels.)

Inorganics. Several metals were detected in UCRS groundwater at levels that exceeded screening values as shown in Table 4.43. These metals were aluminum, cobalt, iron, manganese, and zinc.

Radionuclides. Table 4.44 presents the results of radionuclide analyses for groundwater samples collected from SWMU 6. Gross alpha measurements for the UCRS groundwater ranged from 26.3 to 70.5 pCi/L and gross beta measurements ranged from 2.5 to 2110 pCi/L. Several radioisotopes were detected in the UCRS groundwater samples from DPT borings 006-011, -012, and –018 including neptunium-237 (006-011), technetium-99 (006-011, -012, -016, -018, -028, -029), thorium-234 (006-011 and -018), uranium-234 (006-011, -012, -016, -018), uranium-235 (006-011, -012, -016, -018), and uranium-238 (006-011, -012, -016, -018). Several of these borings were located within the contaminated aluminum burial area (Area J).

RGA Groundwater—Analytical Results

Two DWRC borings sampled the groundwater at SWMU 6 to evaluate the impact to the RGA from SWMU 6. The first boring, 006-024, was just outside the southeast corner of the SWMU boundary (upgradient). The second boring, 006-025, was located north (downgradient) of the SWMU boundary on a gravel road area. Samples were collected from both boreholes at 5-ft intervals when groundwater was present. Technetium-99 ranged from 15.3 to 119 pCi/L in samples collected from the RGA at SWMU 6. TCE ranged from 10 to 740 µg/L. Table 4.29 shows the distribution of contaminants detected in those borings (Fig. 4.19).

Three types of samples were prepared for inorganic analysis of the RGA water: (1) unfiltered samples providing total concentration of the inorganic analytes, (2) 0.45-micron filtered samples providing dissolved concentrations of inorganic analytes, and (3) 5-micron filtered samples providing concentrations of the dissolved phase and the colloidal phase. Table 4.45 provides the average, minimum, and maximum concentration in each sample type. A review of the results shows that the high concentrations of several metals is due to the presence of suspended sediments.

McNairy Groundwater

Two groundwater samples were collected from the McNairy groundwater at SWMU 6 (one sample from each DWRC boring—006-024 and 006-025). The only analytical constituent that exceeded screening values in either sample was manganese.

4.2.3.5 Summary of findings

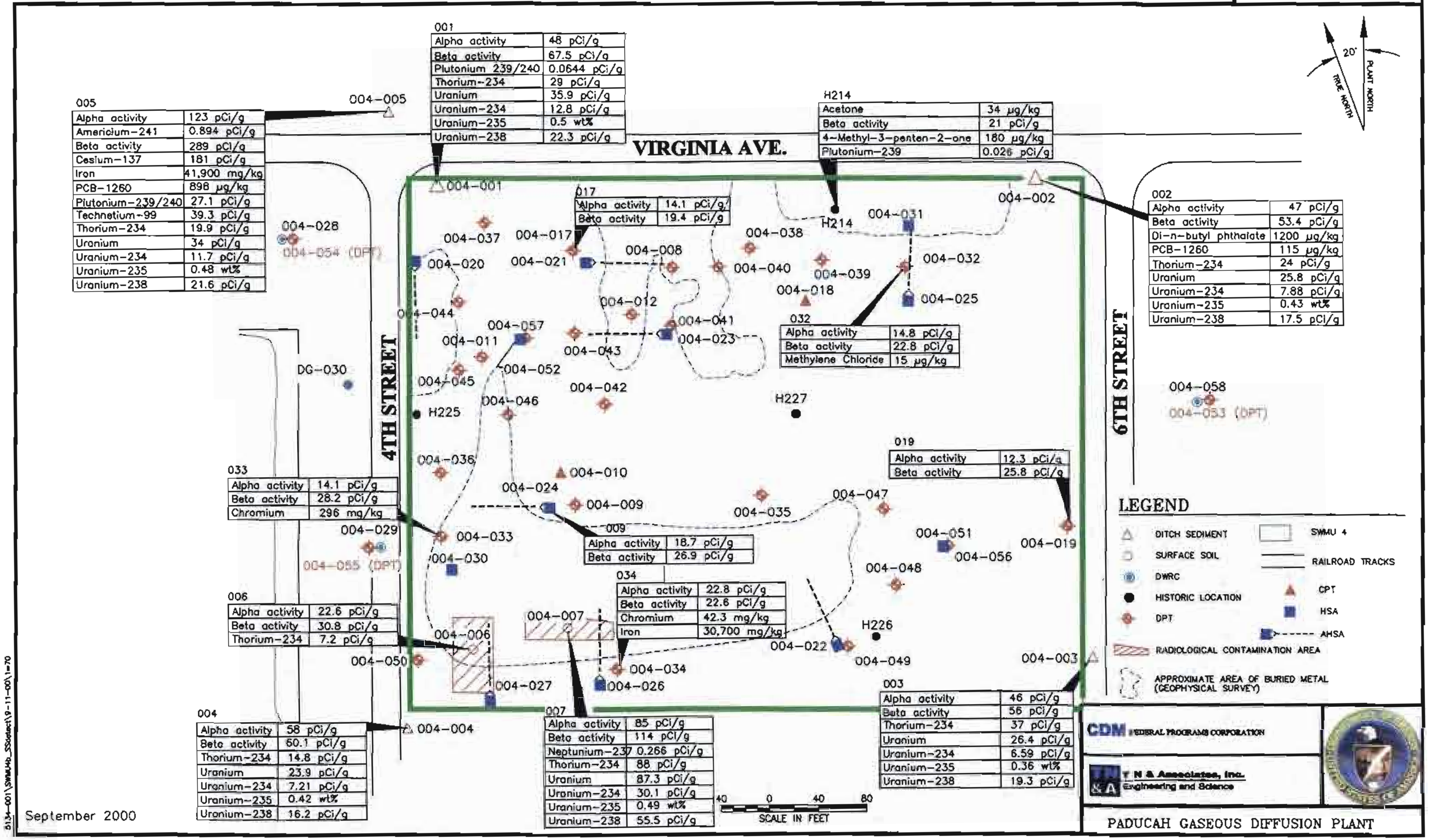
No distinct patterns of contamination that might indicate widespread contamination were discernable in the sampling at SWMU 6. VOAs in subsurface soils were limited to a few occurrences of acetone (that could be laboratory contamination). TCE was detected in very small concentrations in the two angled borings south of the SWMU. Because the TCE detected was south (generally upgradient) and not under (or very close to) any burial cells, the source of this TCE is not believed to be from SWMU 6. Residual degreasing fluids from the stockpiled equipment at the surface is a potential source.

Several radioisotopes were detected. The radioisotopes detected most frequently were technetium-99 and uranium-235 and -238. In addition to radiologically contaminated wastes buried in SWMU 6, the equipment stored at the surface has also been designated by health physics as a surface contamination area due to residual contamination on the equipment. It is likely that the source of the radiological contamination is both contaminants leaching out of the burial cells and also contaminants coming off the equipment on the surface and leaching into the subsurface.

UCRS groundwater at SWMU 6 appears limited to radiological contamination. One liquid sample (collected at a depth of 4–9 ft bgs within Burial Cell J) had concentrations of neptunium-237 and total uranium at levels suggesting that radiological contamination from the buried waste has become mobile in groundwater. (The highest beta activity in groundwater was encountered in borings that penetrated Burial Cell J.) Angled borings under the cells also encountered radiological contamination that is probably leaching out of the burial cells.

The two groundwater samples collected from the McNairy groundwater at SWMU 6 did not indicate the presence of any contaminants. In both borings advanced to the McNairy, tight clays and limited water flow were encountered, precluding the likelihood of contamination migrating into the McNairy groundwater.

SWMU 6 is located above the Northwest Plume; therefore, the presence of TCE was expected. However, the fact that TCE was not detected in UCRS groundwater samples from SWMU 6 suggests that the TCE detected in RGA groundwater beneath SWMU 6 is the result of contamination migrating beneath the site in association with the Northwest Plume.



005

Alpha activity	123 pCi/g
Americium-241	0.894 pCi/g
Beta activity	289 pCi/g
Cesium-137	181 pCi/g
Iron	41,900 mg/kg
PCB-1260	898 µg/kg
Plutonium-239/240	27.1 pCi/g
Technetium-99	39.3 pCi/g
Thorium-234	19.9 pCi/g
Uranium	34 pCi/g
Uranium-234	11.7 pCi/g
Uranium-235	0.48 wt%
Uranium-238	21.6 pCi/g

001

Alpha activity	48 pCi/g
Beta activity	67.5 pCi/g
Plutonium 239/240	0.0644 pCi/g
Thorium-234	29 pCi/g
Uranium	35.9 pCi/g
Uranium-234	12.8 pCi/g
Uranium-235	0.5 wt%
Uranium-238	22.3 pCi/g

H214

Acetone	34 µg/kg
Beta activity	21 pCi/g
4-Methyl-3-penten-2-one	180 µg/kg
Plutonium-239	0.026 pCi/g

017

Alpha activity	14.1 pCi/g
Beta activity	19.4 pCi/g

002

Alpha activity	47 pCi/g
Beta activity	53.4 pCi/g
Di-n-butyl phthalate	1200 µg/kg
PCB-1260	115 µg/kg
Thorium-234	24 pCi/g
Uranium	25.8 pCi/g
Uranium-234	7.88 pCi/g
Uranium-235	0.43 wt%
Uranium-238	17.5 pCi/g

032

Alpha activity	14.8 pCi/g
Beta activity	22.8 pCi/g
Methylene Chloride	15 µg/kg

019

Alpha activity	12.3 pCi/g
Beta activity	25.8 pCi/g

033

Alpha activity	14.1 pCi/g
Beta activity	28.2 pCi/g
Chromium	296 mg/kg

009

Alpha activity	18.7 pCi/g
Beta activity	26.9 pCi/g

034

Alpha activity	22.8 pCi/g
Beta activity	22.6 pCi/g
Chromium	42.3 mg/kg
Iron	30,700 mg/kg

006

Alpha activity	22.6 pCi/g
Beta activity	30.8 pCi/g
Thorium-234	7.2 pCi/g

004

Alpha activity	58 pCi/g
Beta activity	60.1 pCi/g
Thorium-234	14.8 pCi/g
Uranium	23.9 pCi/g
Uranium-234	7.21 pCi/g
Uranium-235	0.42 wt%
Uranium-238	16.2 pCi/g

007

Alpha activity	85 pCi/g
Beta activity	114 pCi/g
Neptunium-237	0.266 pCi/g
Thorium-234	88 pCi/g
Uranium	87.3 pCi/g
Uranium-234	30.1 pCi/g
Uranium-235	0.49 wt%
Uranium-238	55.5 pCi/g

003

Alpha activity	46 pCi/g
Beta activity	56 pCi/g
Thorium-234	37 pCi/g
Uranium	26.4 pCi/g
Uranium-234	6.59 pCi/g
Uranium-235	0.36 wt%
Uranium-238	19.3 pCi/g

Fig. 4.1. WAG 3-SWMU 4, contaminants in surface/sediment.

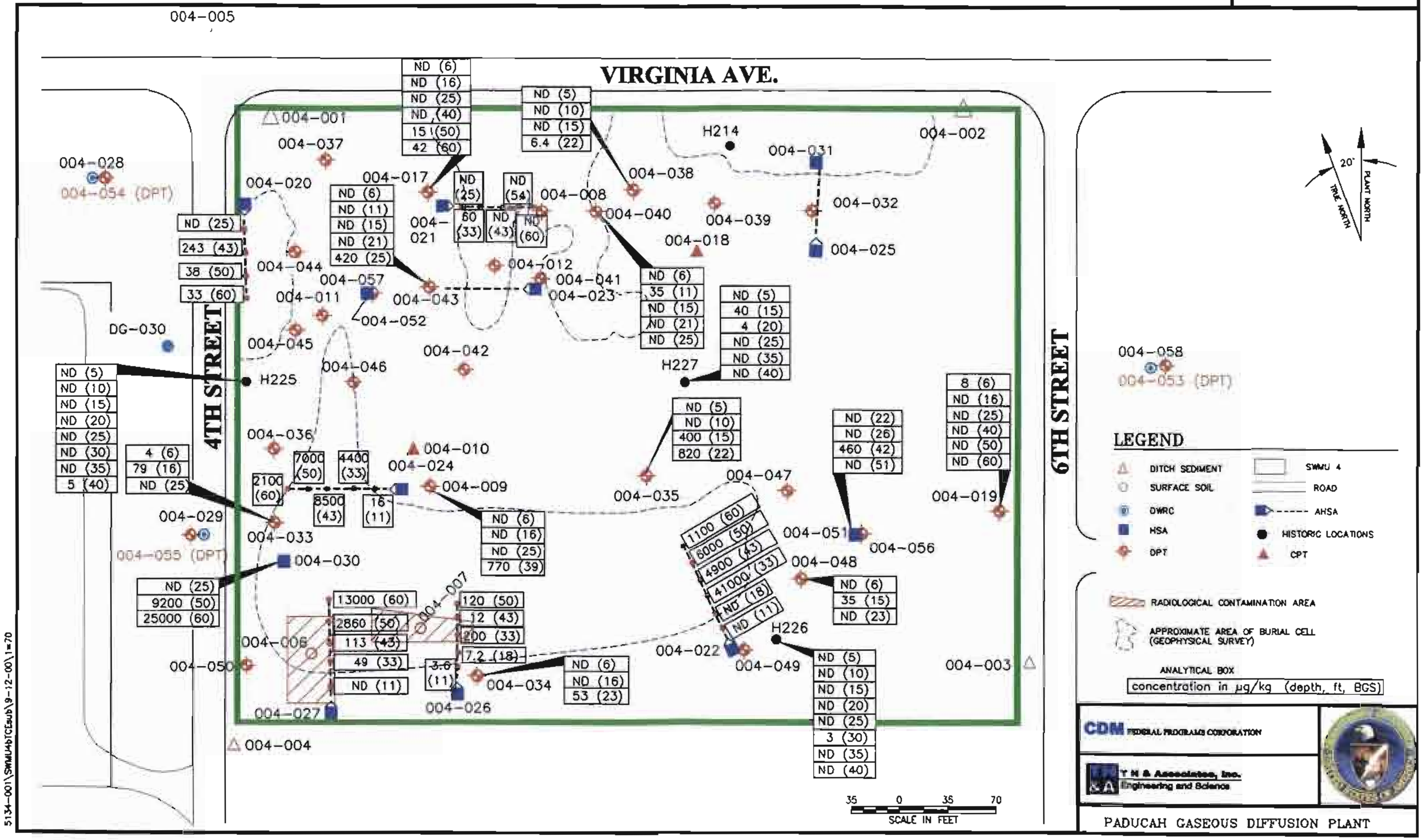


Fig. 4.2. WAG 3-SWMU 4, TCE in subsurface soil.

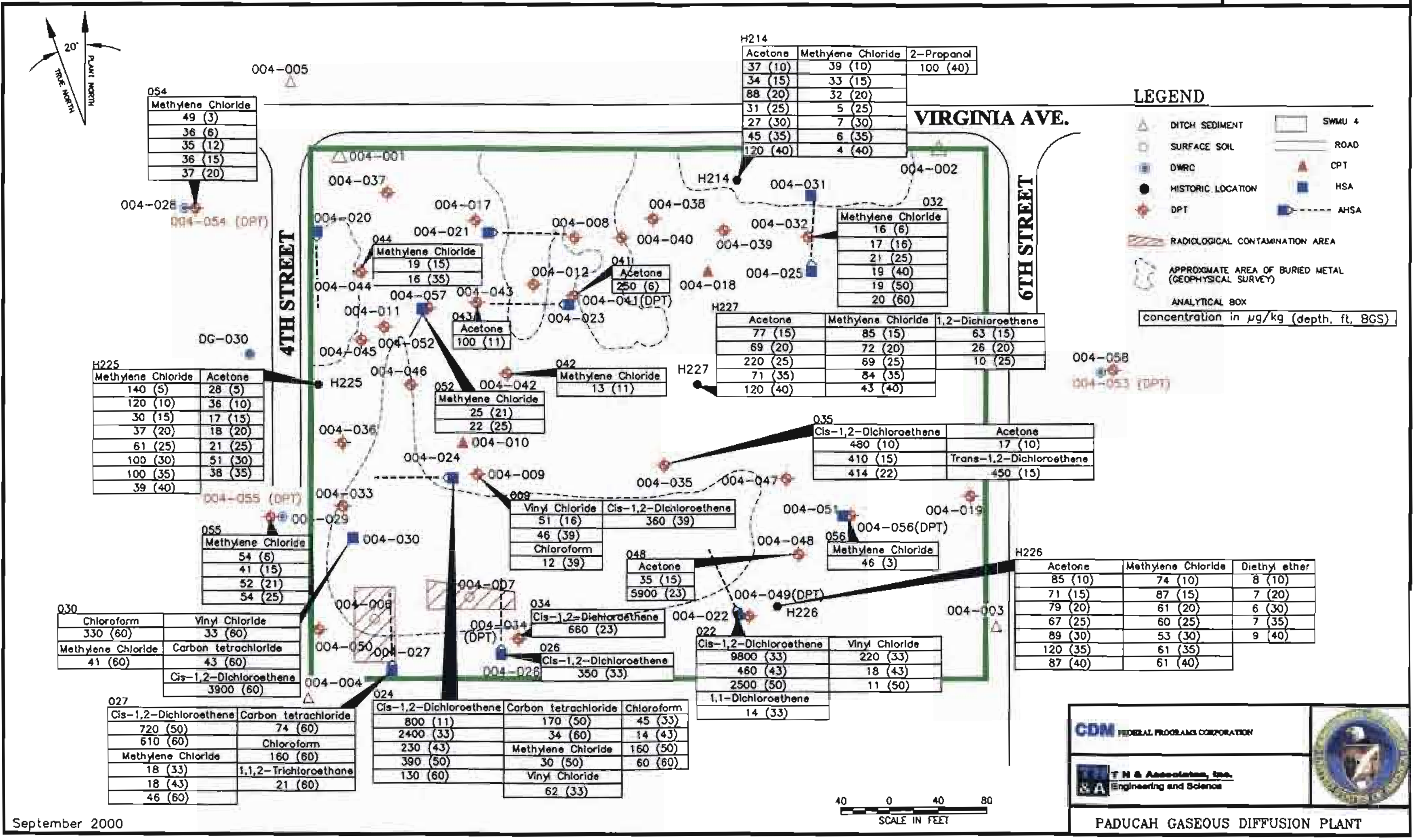


Fig. 4.3. WAG 3-SWMU 4, other VOA contaminants in subsurface soil.

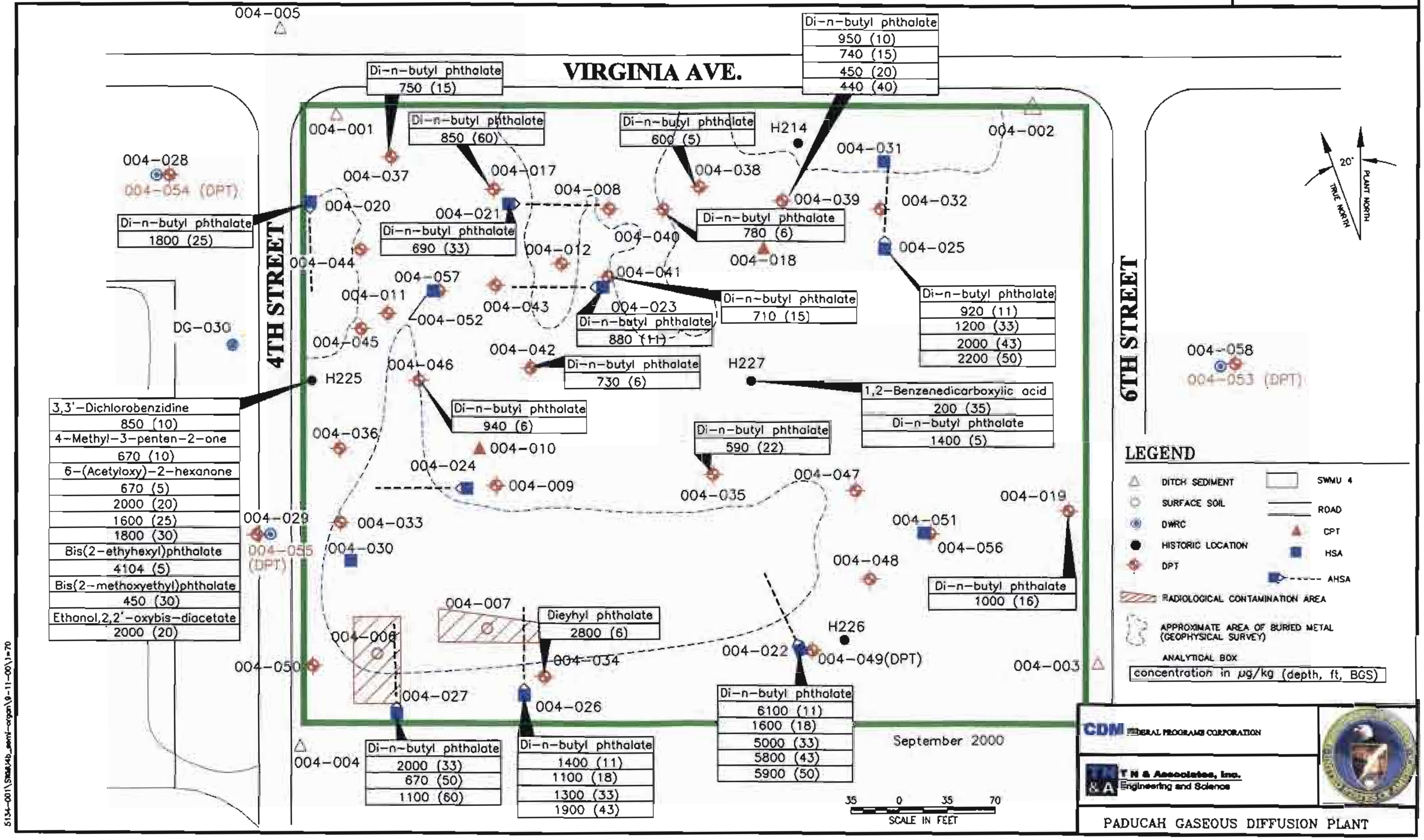


Fig. 4.4. WAG 3-SWMU 4, Semivolatile organics contaminants in subsurface soil.

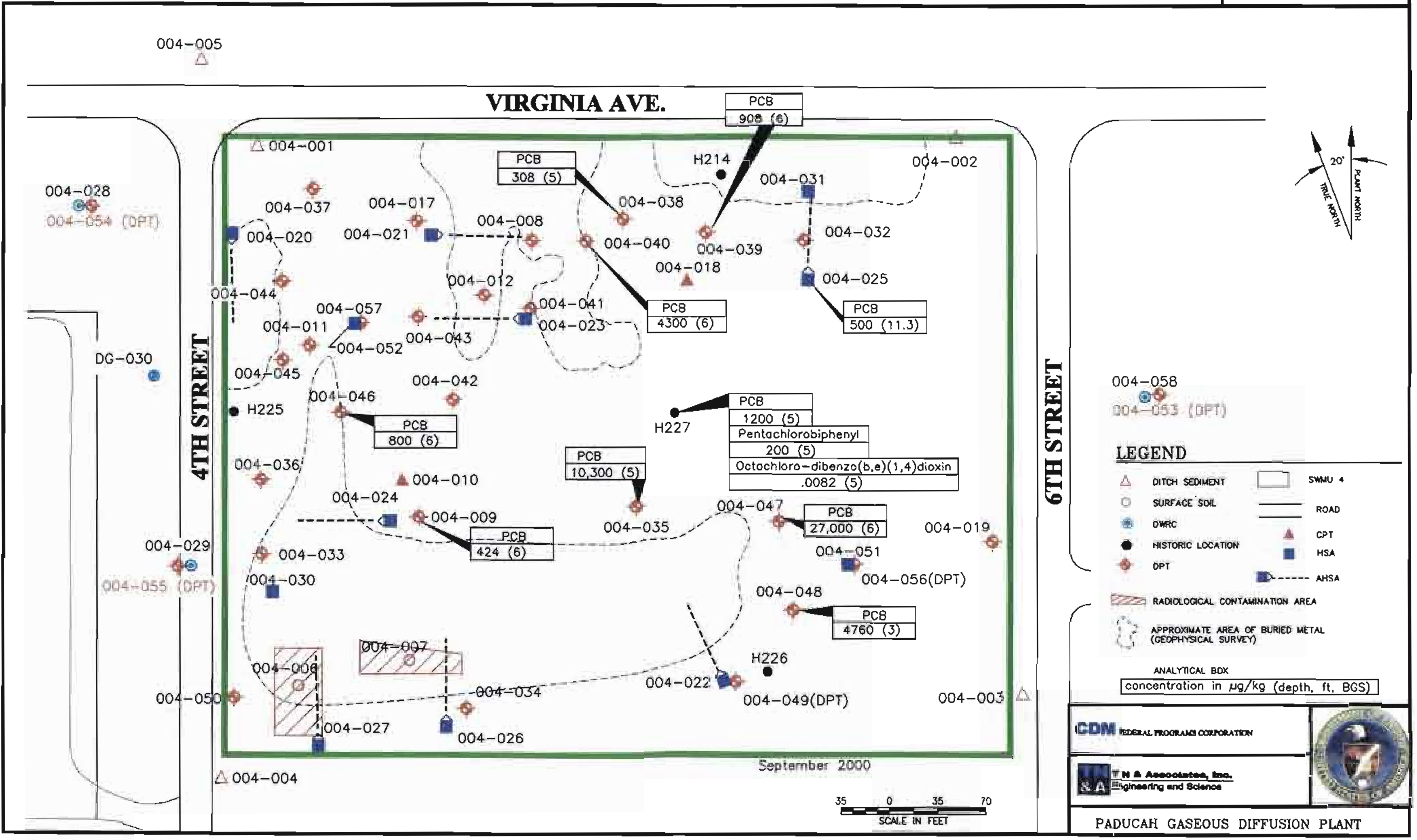


Fig. 4.5. WAG 3-SWMU 4, total PCBs in subsurface soil.

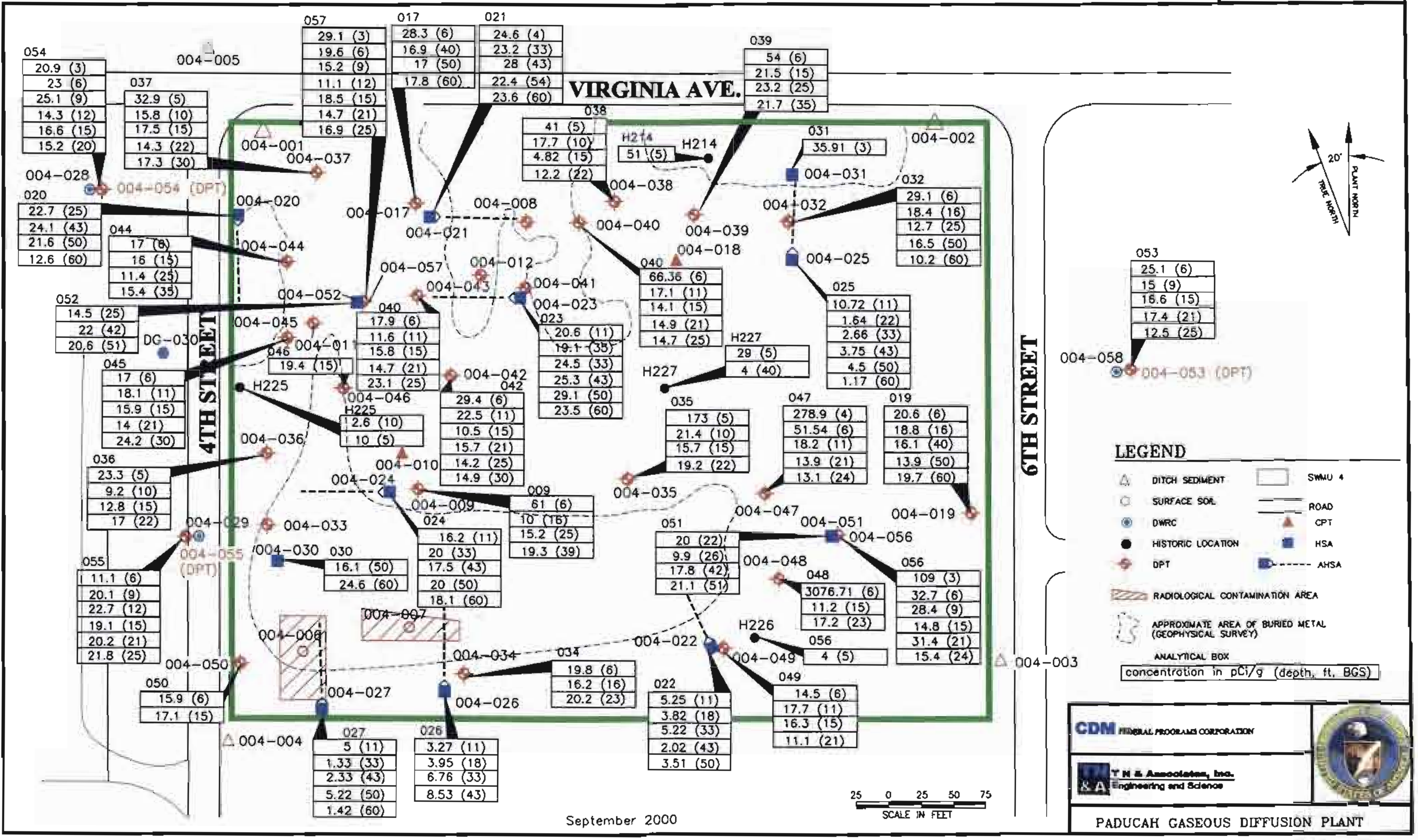


Fig. 4.6. WAG 3-SWMU 4, gross alpha activities in subsurface soil.

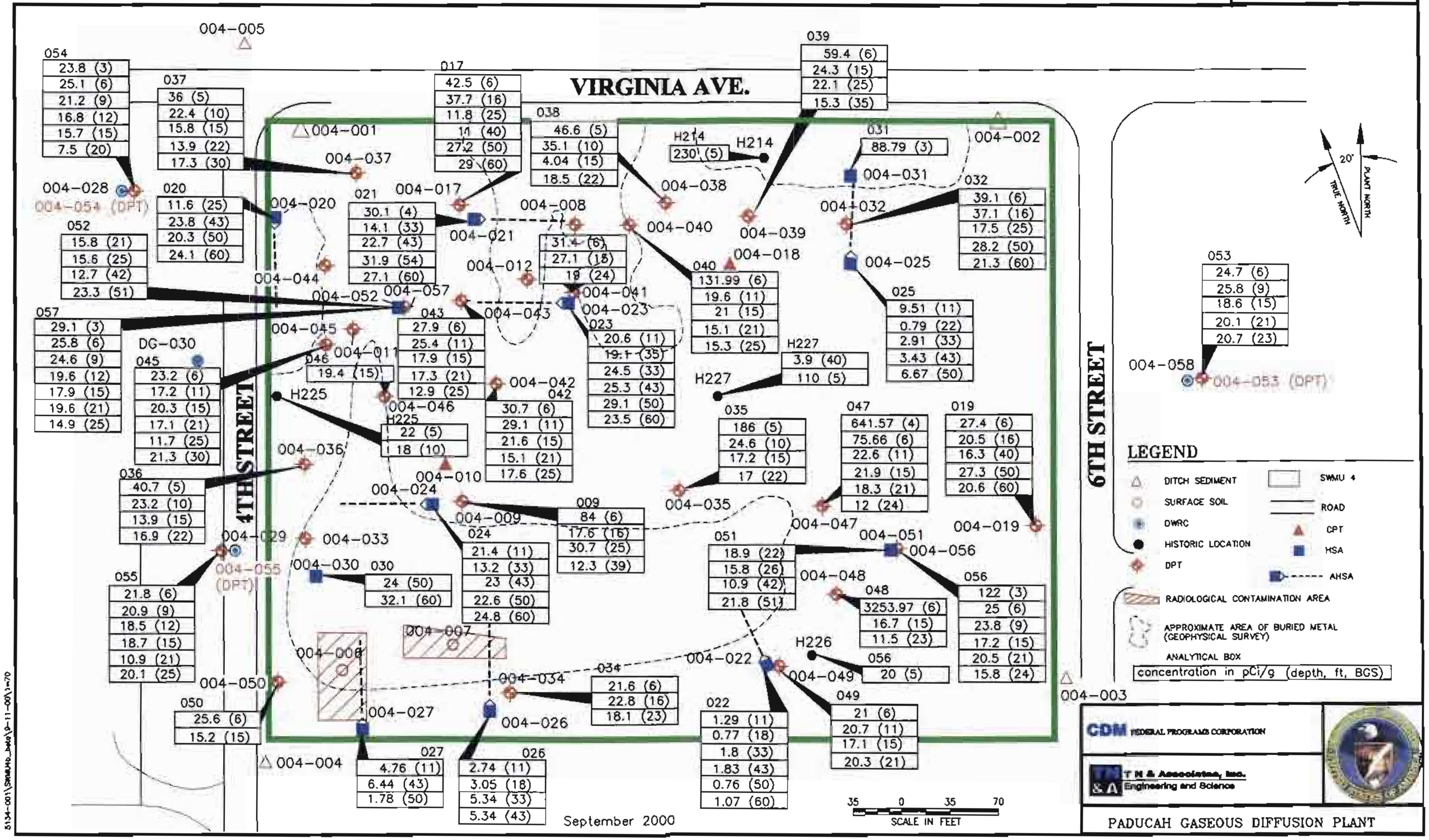


Fig. 4.7. WAG 3-SWMU 4, gross beta activities in subsurface soil.

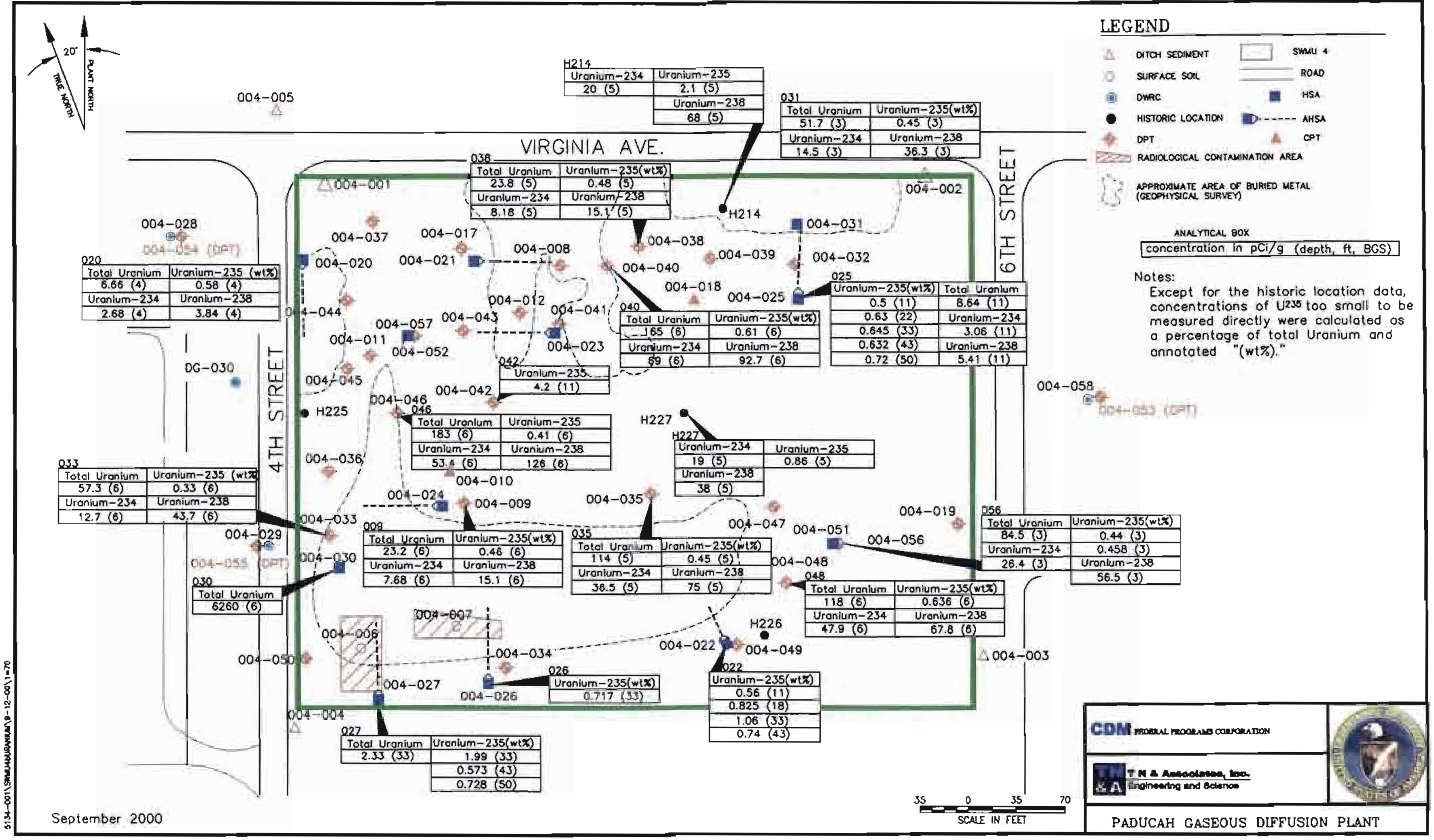


Fig. 4.8. WAG 3-SWMU 4, Uranium in subsurface soil.

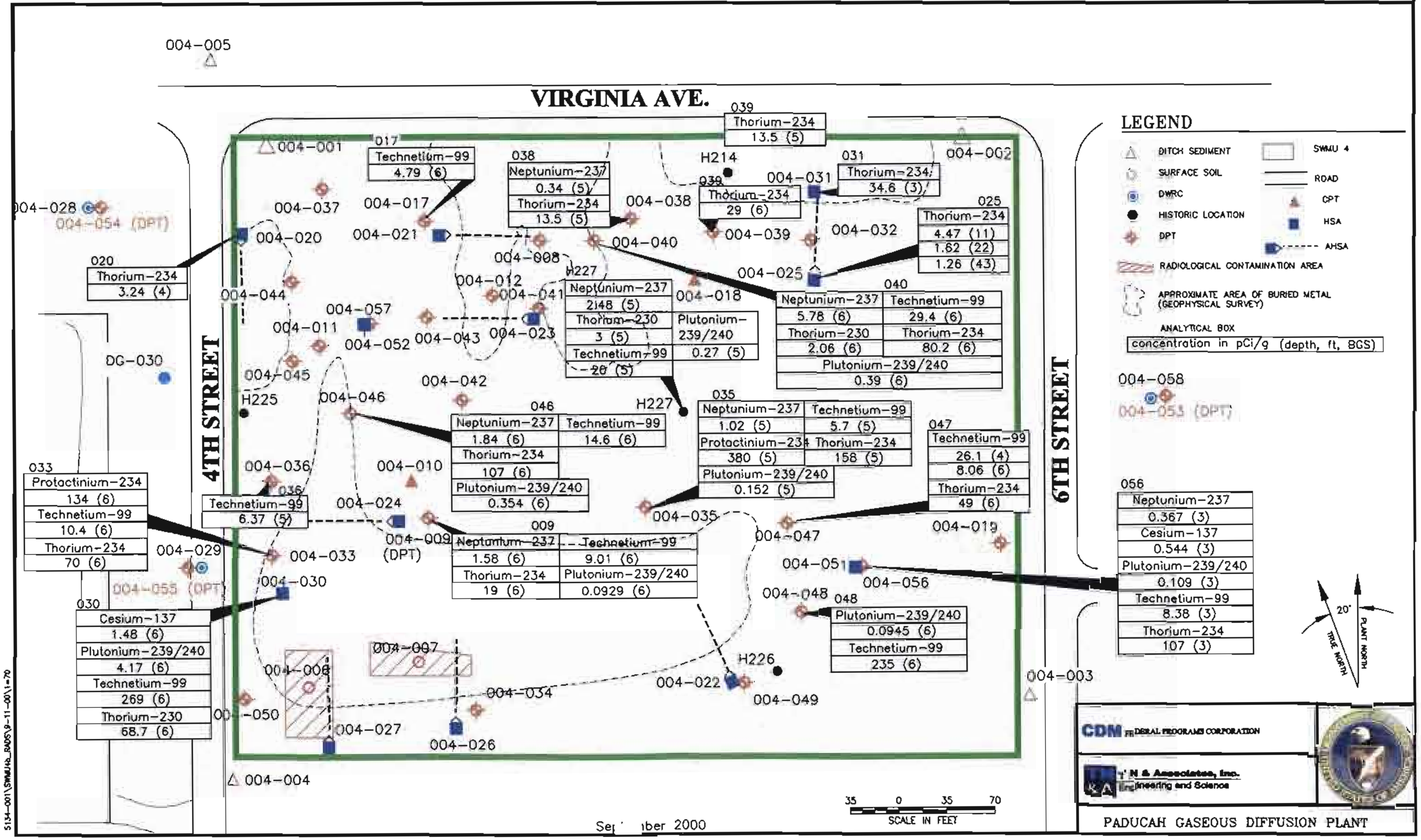


Fig. 4.9. WAG 3-SWMU 4, Radioisotopes in subsurface soil. (excluding alpha, beta, and uranium)

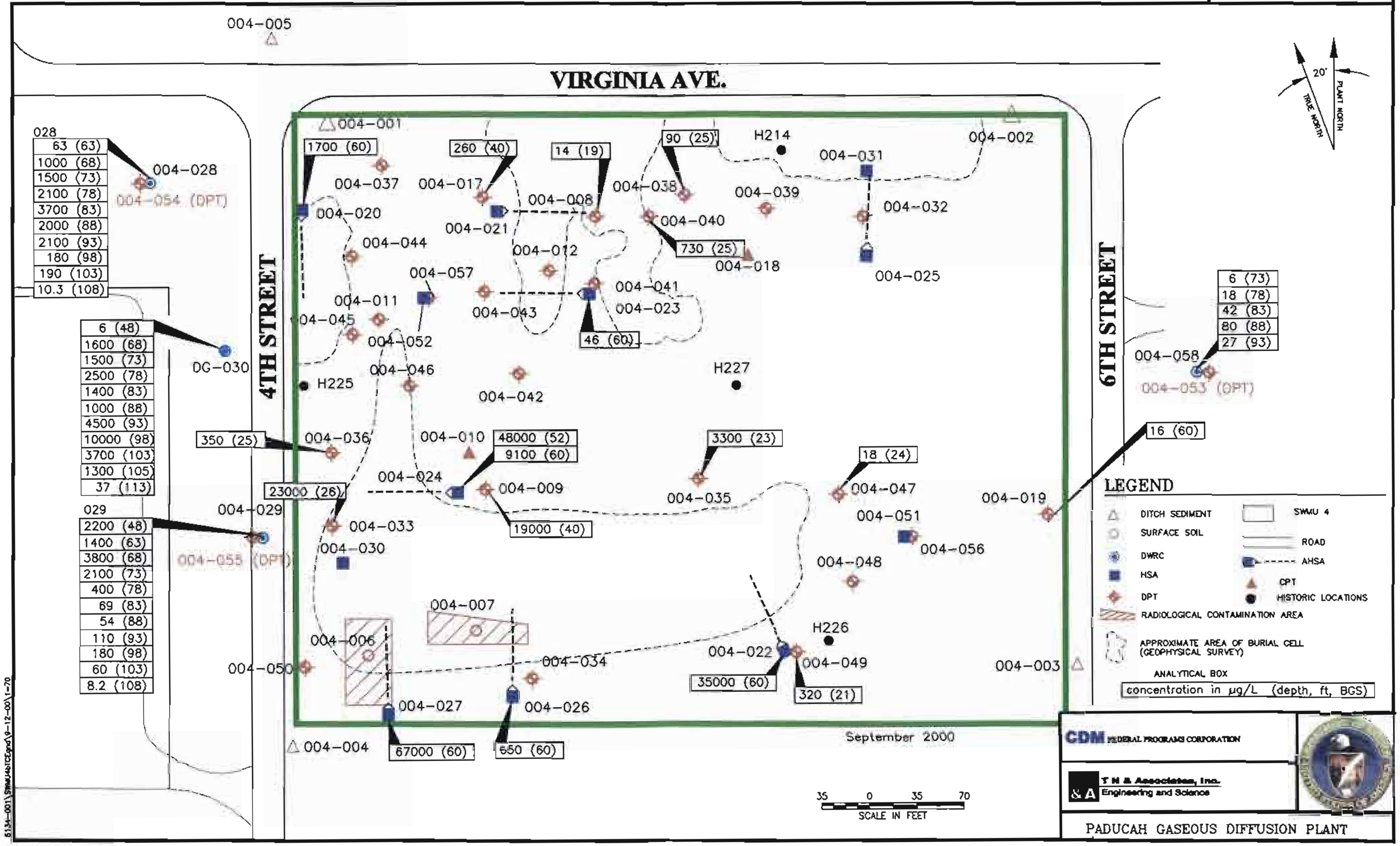


Fig.4.10. WAG 3-SWMU 4, TCE in groundwater.

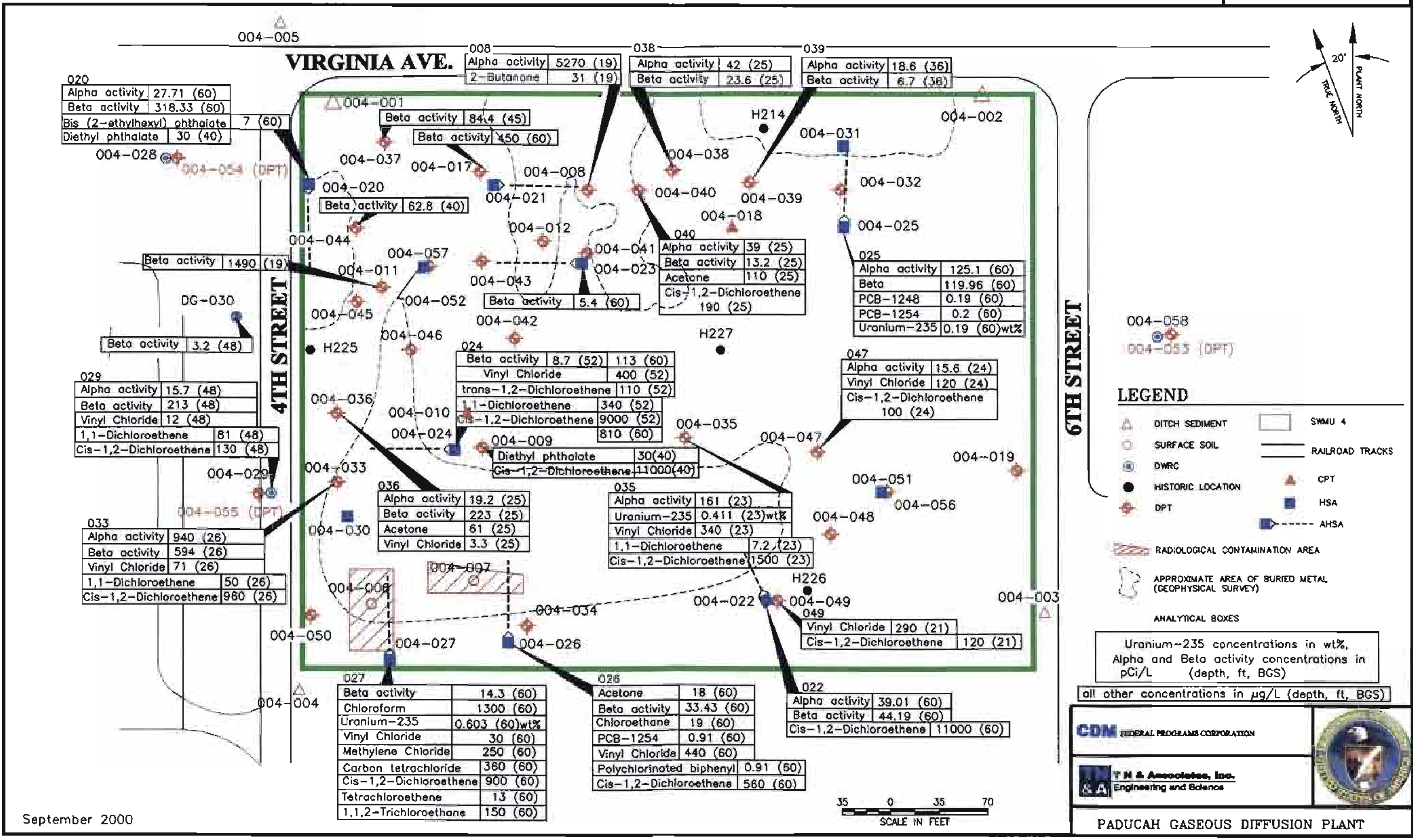


Fig. 4.11. WAG 3-SWMU 4, contaminants in UCRS groundwater (except TCE and Tc-99).

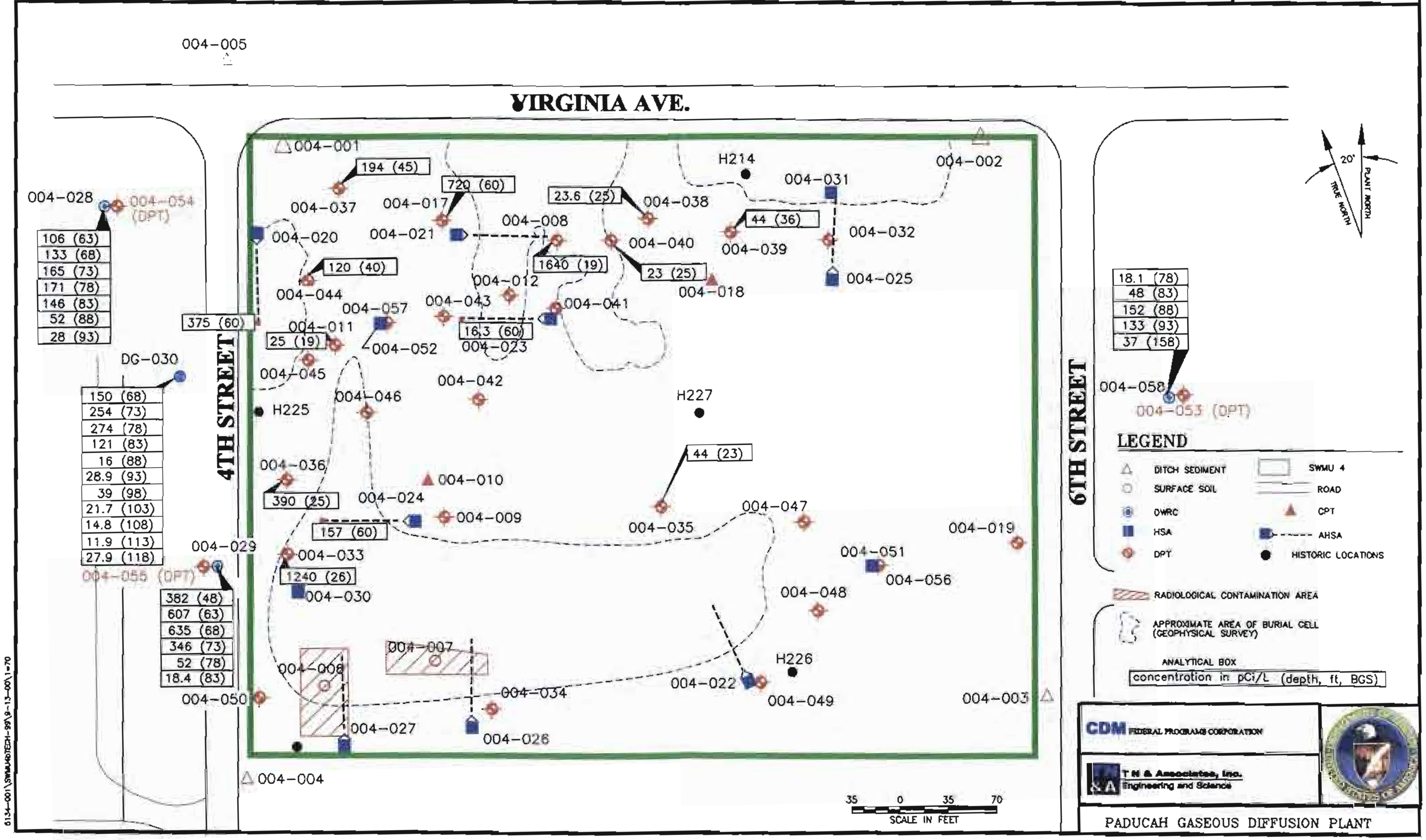


Fig. 4.12. WAG 3-SWMU 4, Technetium-99 in groundwater.

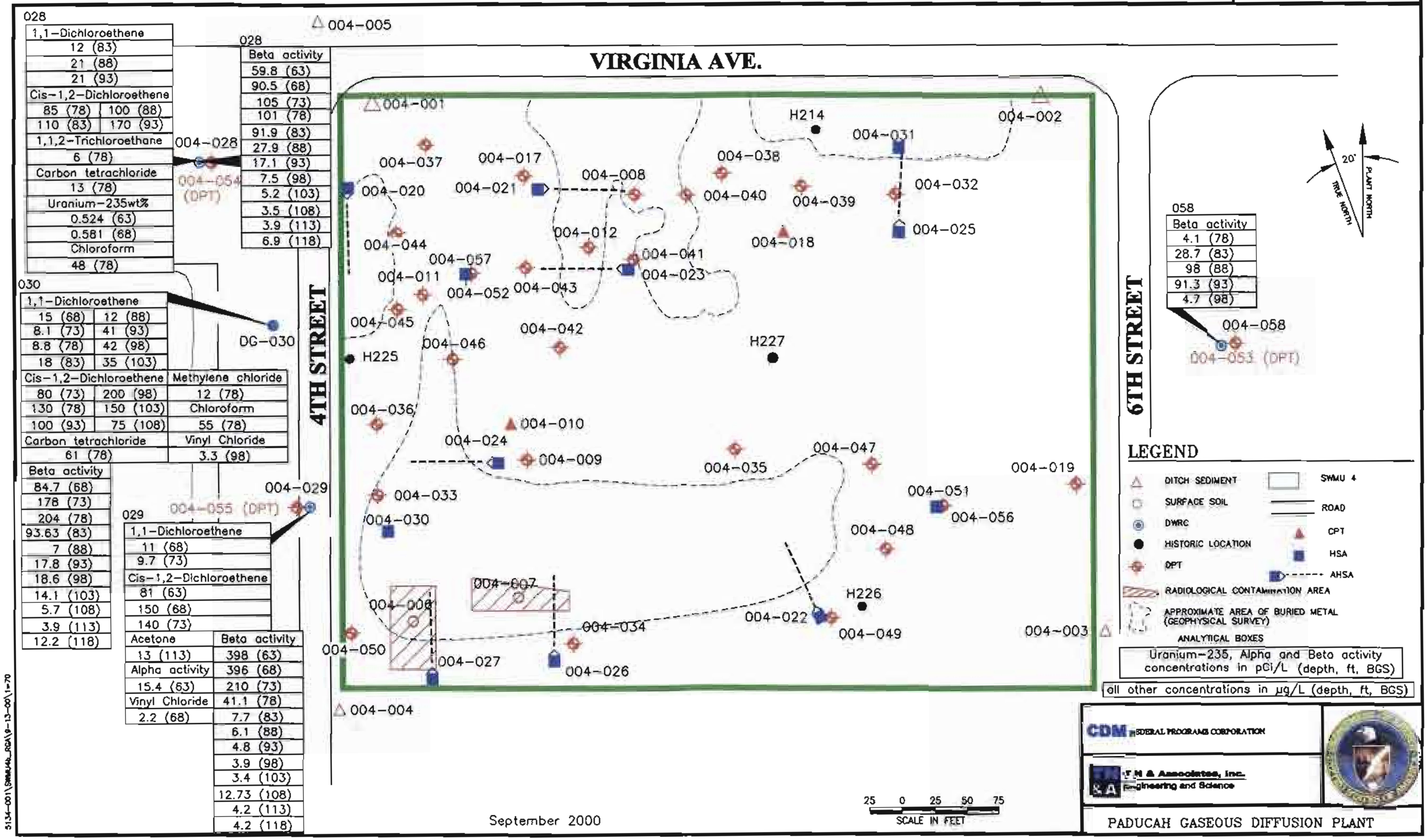


Fig. 4.13. WAG 3-SWMU 4, contaminants in RGA groundwater (except TCE, and Tc-99).

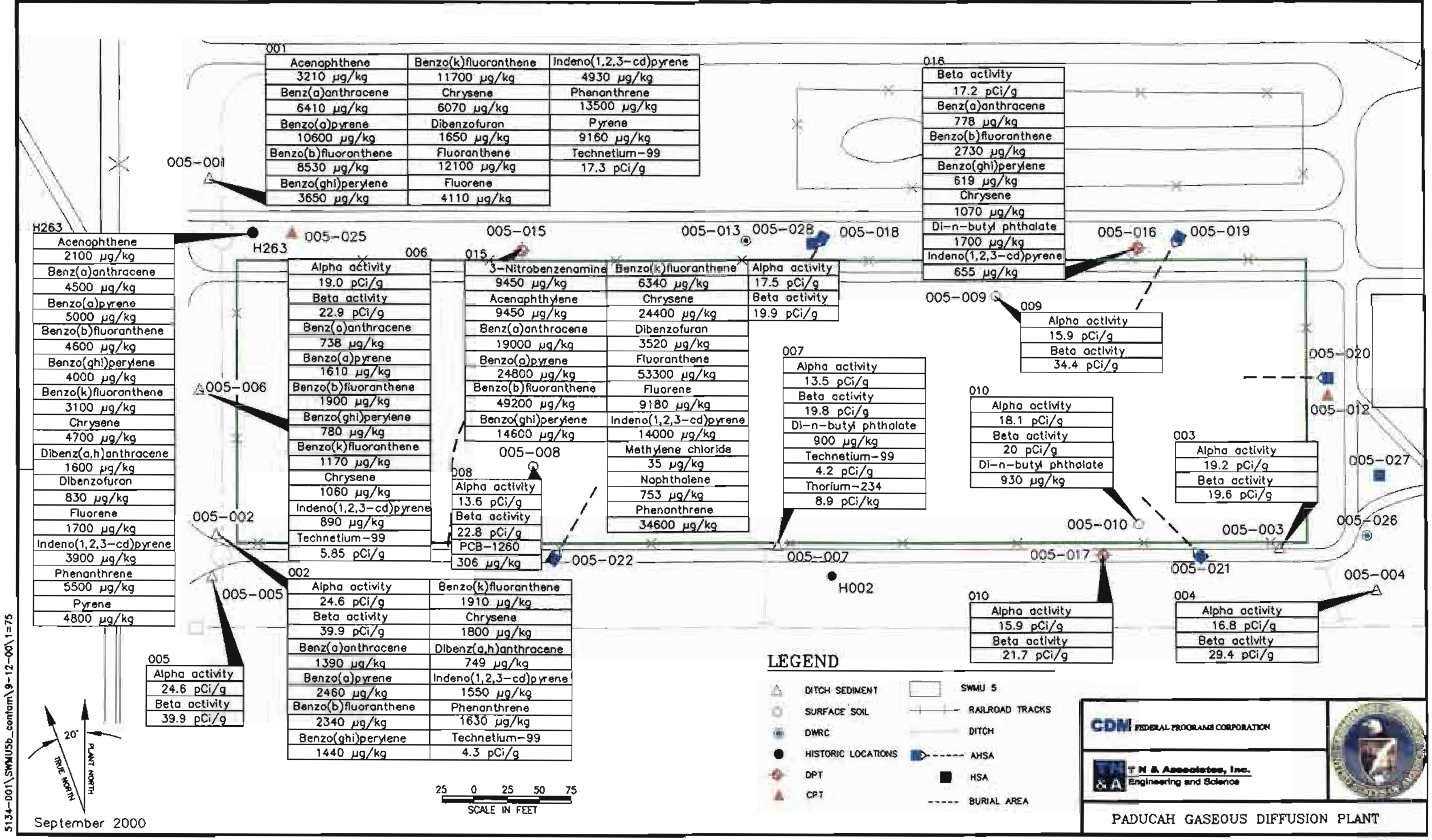


Fig. 4.15. WAG 3-SWMU 5, surface soil and sediment contaminants.

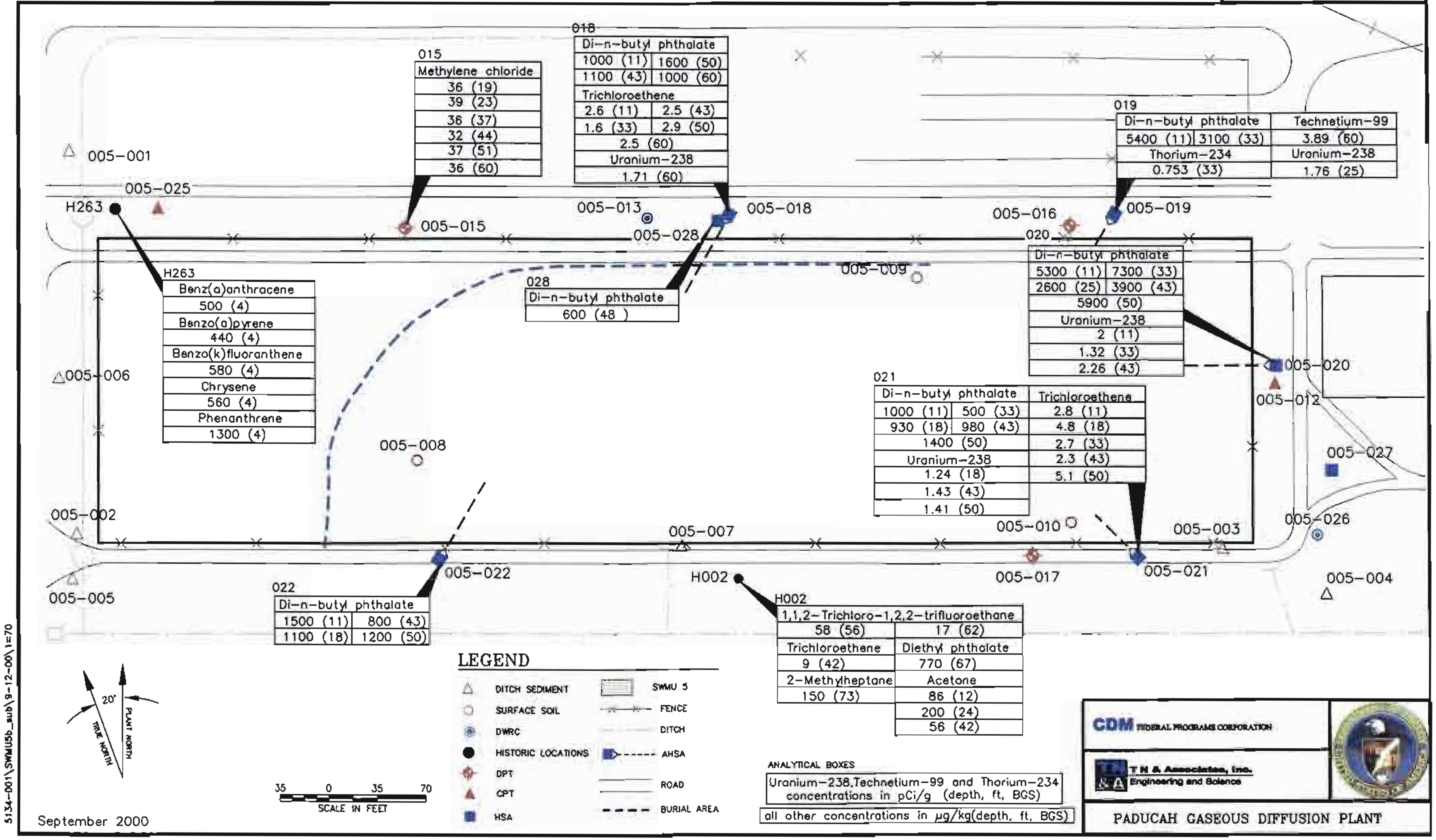


Fig. 4.16. WAG 3-SWMU 5, Contaminants in subsurface soil (excluding alpha and beta).

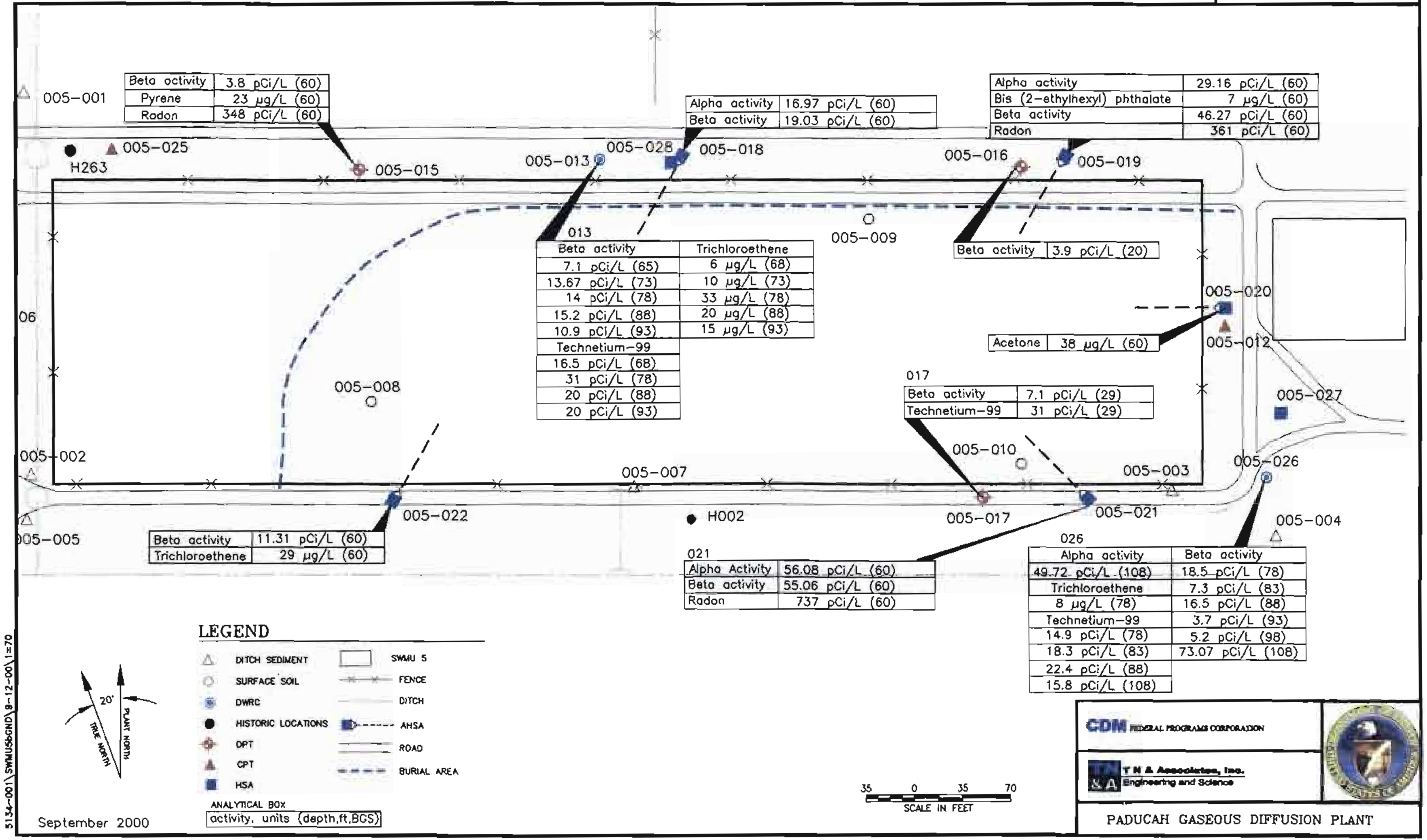
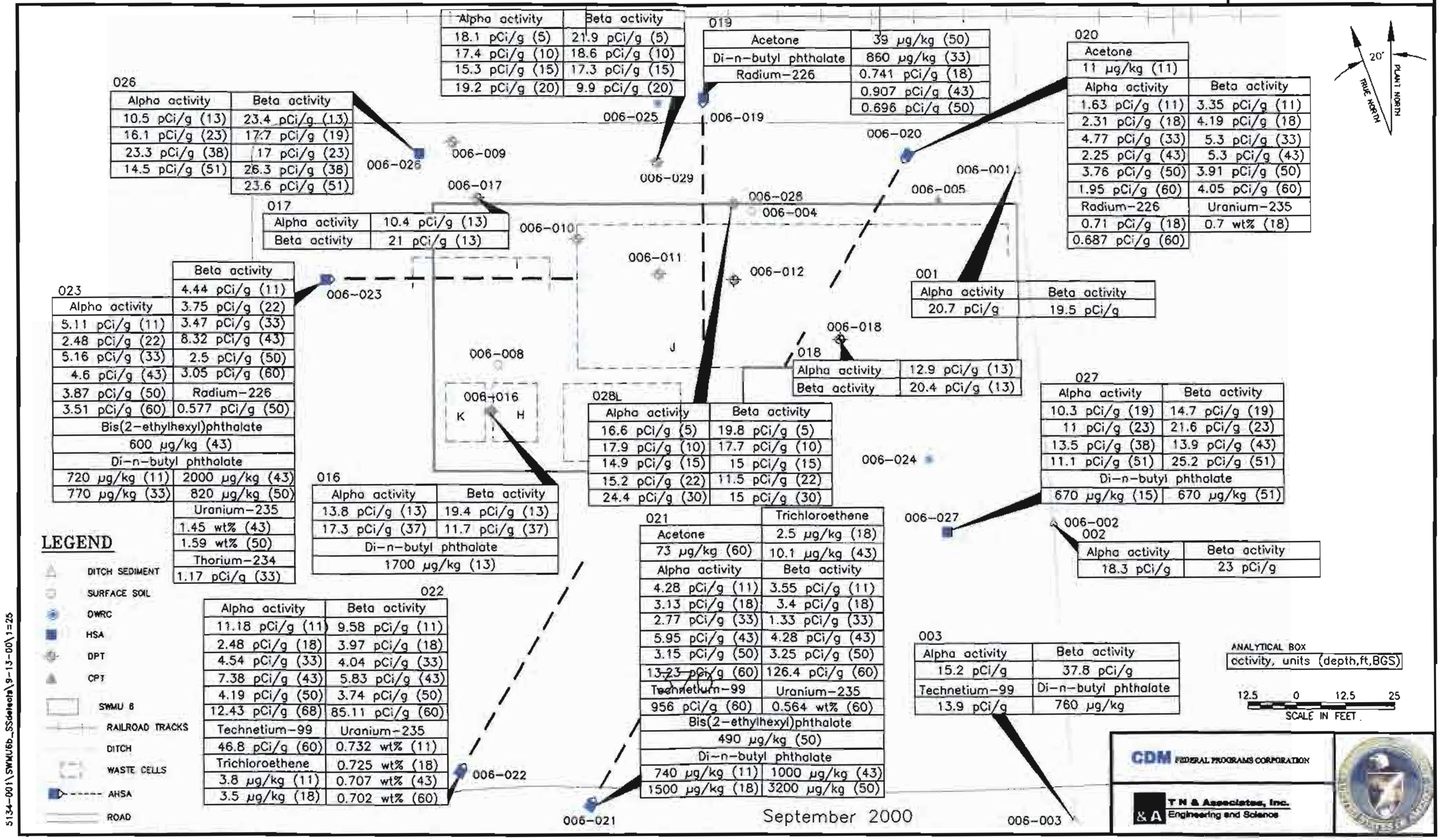


Fig. 4.17. WAG 3-SWMU 5, groundwater analytical results.



Alpha activity	Beta activity
18.1 pCi/g (5)	21.9 pCi/g (5)
17.4 pCi/g (10)	18.6 pCi/g (10)
15.3 pCi/g (15)	17.3 pCi/g (15)
19.2 pCi/g (20)	9.9 pCi/g (20)

019

Acetone	39 µg/kg (50)
Di-n-butyl phthalate	860 µg/kg (33)
Radium-226	0.741 pCi/g (18)
	0.907 pCi/g (43)
	0.696 pCi/g (50)

020

Acetone	
11 µg/kg (11)	
Alpha activity	Beta activity
1.63 pCi/g (11)	3.35 pCi/g (11)
2.31 pCi/g (18)	4.19 pCi/g (18)
4.77 pCi/g (33)	5.3 pCi/g (33)
2.25 pCi/g (43)	5.3 pCi/g (43)
3.76 pCi/g (50)	3.91 pCi/g (50)
1.95 pCi/g (60)	4.05 pCi/g (60)
Radium-226	Uranium-235
0.71 pCi/g (18)	0.7 wt% (18)
0.687 pCi/g (60)	

026

Alpha activity	Beta activity
10.5 pCi/g (13)	23.4 pCi/g (13)
16.1 pCi/g (23)	17.7 pCi/g (19)
23.3 pCi/g (38)	17 pCi/g (23)
14.5 pCi/g (51)	26.3 pCi/g (38)
	23.6 pCi/g (51)

017

Alpha activity	10.4 pCi/g (13)
Beta activity	21 pCi/g (13)

001

Alpha activity	Beta activity
20.7 pCi/g	19.5 pCi/g

023

	Beta activity
	4.44 pCi/g (11)
Alpha activity	3.75 pCi/g (22)
5.11 pCi/g (11)	3.47 pCi/g (33)
2.48 pCi/g (22)	8.32 pCi/g (43)
5.16 pCi/g (33)	2.5 pCi/g (50)
4.6 pCi/g (43)	3.05 pCi/g (60)
3.87 pCi/g (50)	Radium-226
3.51 pCi/g (60)	0.577 pCi/g (50)
Bis(2-ethylhexyl)phthalate	
600 µg/kg (43)	
Di-n-butyl phthalate	
720 µg/kg (11)	2000 µg/kg (43)
770 µg/kg (33)	820 µg/kg (50)
	Uranium-235
	1.45 wt% (43)
	1.59 wt% (50)
	Thorium-234
	1.17 pCi/g (33)

018

Alpha activity	12.9 pCi/g (13)
Beta activity	20.4 pCi/g (13)

028L

Alpha activity	Beta activity
16.6 pCi/g (5)	19.8 pCi/g (5)
17.9 pCi/g (10)	17.7 pCi/g (10)
14.9 pCi/g (15)	15 pCi/g (15)
15.2 pCi/g (22)	11.5 pCi/g (22)
24.4 pCi/g (30)	15 pCi/g (30)

027

Alpha activity	Beta activity
10.3 pCi/g (19)	14.7 pCi/g (19)
11 pCi/g (23)	21.6 pCi/g (23)
13.5 pCi/g (38)	13.9 pCi/g (43)
11.1 pCi/g (51)	25.2 pCi/g (51)
Di-n-butyl phthalate	
670 µg/kg (15)	670 µg/kg (51)

016

Alpha activity	Beta activity
13.8 pCi/g (13)	19.4 pCi/g (13)
17.3 pCi/g (37)	11.7 pCi/g (37)
Di-n-butyl phthalate	
1700 µg/kg (13)	

002

Alpha activity	Beta activity
18.3 pCi/g	23 pCi/g

021

	Trichloroethene
Acetone	2.5 µg/kg (18)
73 µg/kg (60)	10.1 µg/kg (43)
Alpha activity	Beta activity
4.28 pCi/g (11)	3.55 pCi/g (11)
3.13 pCi/g (18)	3.4 pCi/g (18)
2.77 pCi/g (33)	1.33 pCi/g (33)
5.95 pCi/g (43)	4.28 pCi/g (43)
3.15 pCi/g (50)	3.25 pCi/g (50)
~~13.23~~ pCi/g (60)	126.4 pCi/g (60)
Technetium-99	Uranium-235
956 pCi/g (60)	0.564 wt% (60)
Bis(2-ethylhexyl)phthalate	
490 µg/kg (50)	
Di-n-butyl phthalate	
740 µg/kg (11)	1000 µg/kg (43)
1500 µg/kg (18)	3200 µg/kg (50)

022

Alpha activity	Beta activity
11.18 pCi/g (11)	9.58 pCi/g (11)
2.48 pCi/g (18)	3.97 pCi/g (18)
4.54 pCi/g (33)	4.04 pCi/g (33)
7.38 pCi/g (43)	5.83 pCi/g (43)
4.19 pCi/g (50)	3.74 pCi/g (50)
12.43 pCi/g (68)	85.11 pCi/g (60)
Technetium-99	Uranium-235
46.8 pCi/g (60)	0.732 wt% (11)
Trichloroethene	0.725 wt% (18)
3.8 µg/kg (11)	0.707 wt% (43)
3.5 µg/kg (18)	0.702 wt% (60)

003

Alpha activity	Beta activity
15.2 pCi/g	37.8 pCi/g
Technetium-99	Di-n-butyl phthalate
13.9 pCi/g	760 µg/kg

September 2000

Fig. 4.18. WAG 3-SWMU 6, contaminants in sediment and subsurface soil.

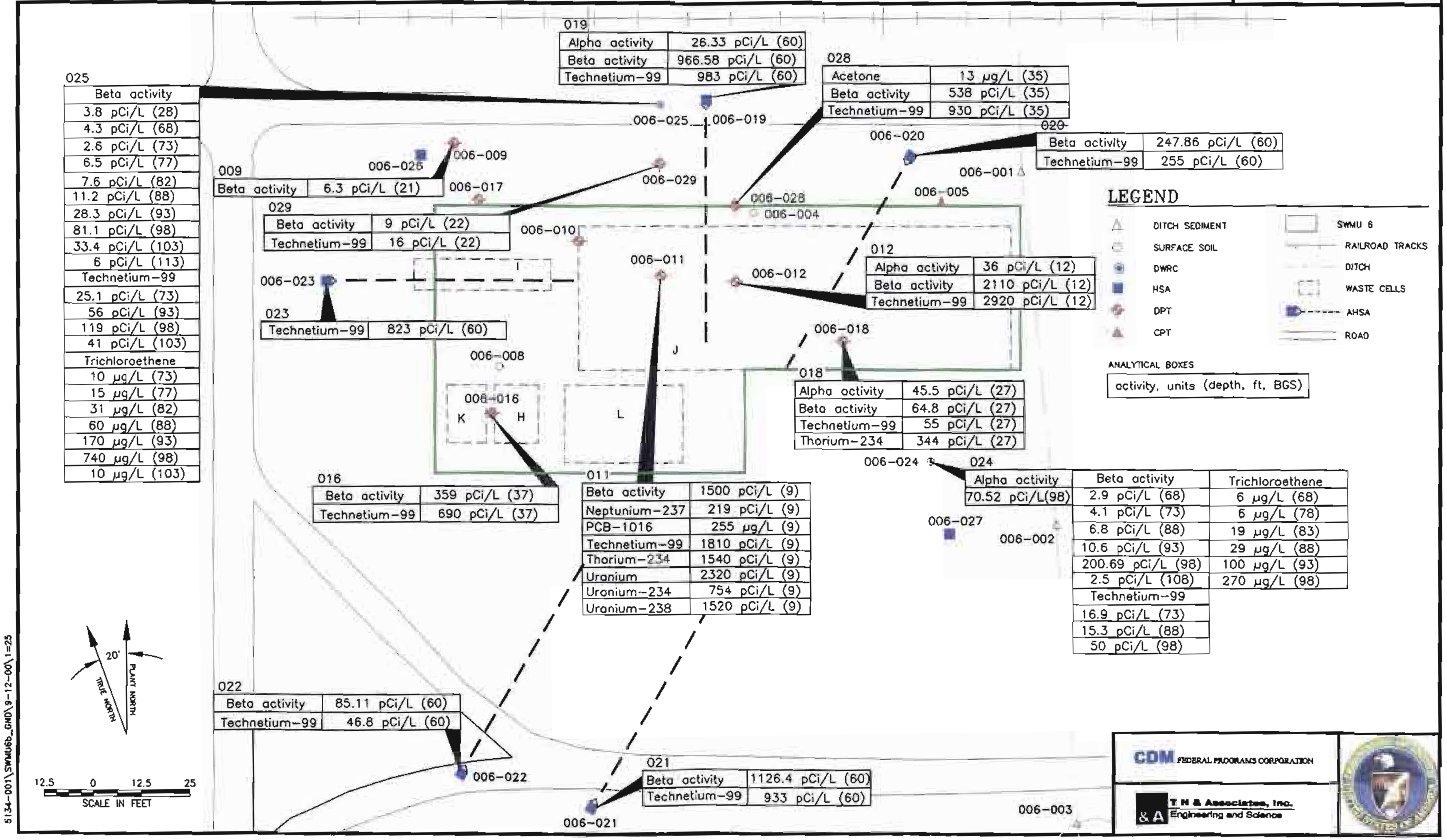


Fig. 4.19. WAG 3-SWMU 6, groundwater contamination.

Table 4.1. Metals background values

Analytical compound	Soil—Background data[a] (mg/kg) Near surface	 Subsurface
Aluminum	13,000	12,000
Antimony	0.21	0.21
Arsenic	12	7.9
Barium	200	170
Beryllium	0.67	0.69
Boron	NA	NA
Cadmium	0.21	0.21
Calcium	200,000	6,100
Chromium	16	43
Chromium, hexavalent	NA	NA
Cobalt	14	13
Copper	19	25
Cyanide	NA	NA
Iron	28,000	28,000
Lead	36	23
Lithium	NA	NA
Magnesium	7,700	2,100
Manganese	1,500	820
Mercury	0.2	0.13
Molybdenum	NA	NA
Nickel	21	22
Potassium	1,300	950
Selenium	0.8	0.7
Silica	NA	NA
Silver	2.3	2.7
Sodium	320	340
Strontium	NA	NA
Thallium	0.21	0.34
Vanadium	38	37
Zinc	65	60

[a] *Background Levels of Selected Radionuclides and Metals in Soils and Geologic Media at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 1997).

Table 4.2. Radioactive isotopes background values

Analytical compound	Soil—Background data[a] (pCi/g) Near surface	Soil—Background data[a] (pCi/g) Subsurface
Alpha activity	NA	NA
Americium-241	NA	NA
Beta activity	NA	NA
Cesium-137	0.49	0.28
Cobalt-60	NA	NA
Neptunium-237	0.1	NA
Plutonium-239	0.025	NA
Plutonium-239/240	NA	NA
Potassium-40	16	16
Protactinium-234m	NA	NA
Radium	NA	NA
Radium-226	1.5	1.5
Radon-222	NA	NA
Strontium-90	4.7	NA
Technetium-99	2.5	2.8
Thorium-230	1.5	1.4
Thorium-234	NA	NA
Uranium	NA	NA
Uranium (mg/kg or mg/L)	4.9	4.6
Uranium-234	2.5	2.4
Uranium-235	0.14	0.14
Uranium-238	1.2	1.2

[a] *Background Levels of Selected Radionuclides and Metals in Soils and Geologic Media at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 1997).

Table 4.3. EPA soil screening levels[a]

Analytical compound	Soil screening level (mg/kg)	Recommended dietary allowances for children (g/day)	
		RDA	1/5 RDA
	Inorganic compounds		
Alkalinity	NA	NA	NA
Aluminum	NA	NA	NA
Ammonia	NA	NA	NA
Antimony	5.4	NA	NA
Arsenic	200	NA	NA
Barium	1,600	NA	NA
Beryllium	63	NA	NA
Bicarbonate as $CaCO_3$	NA	NA	NA
Boron	210	NA	NA
Cadmium	7.5	NA	NA
Calcium	NA	800	160
Carbonate as $CaCO_3$	NA	NA	NA
Chemical Oxygen Demand (COD)	NA	NA	NA
Chloride	NA	600	120
Chromium	38	NA	NA
Chromium, hexavalent	42	NA	NA
Cobalt	NA	NA	NA
Copper	11,000	1.0–2.0	0.2
Cyanide	0.87	NA	NA
Fluoride	NA	1.5–2.5	0.3
Iron	NA	10	2
Lead	NA	NA	NA
Lithium	NA	NA	NA
Magnesium	NA	170	34
Manganese	2,200	NA	NA
Mercury	2.1	NA	NA
Molybdenum	74	0.05–0.15	0.01
Nickel	950	NA	NA
Nitrate as Nitrogen	NA	NA	NA
pH	NA	NA	NA
Phosphate as Phosphorous	NA	NA	NA
Potassium	NA	1,600	320
RedOx	NA	NA	NA
Selenium	300	0.03	0.006
Silica	NA	NA	NA
Silver	31	NA	NA
Sodium	NA	400	80
Strontium	15,000	NA	NA
Sulfate	NA	NA	NA
Sulfide	NA	NA	NA
Thallium	NA	NA	NA
Total Organic Carbon (TOC)	NA	NA	NA

Table 4.3 (continued)

Analytical compound	Soil screening level (mg/kg)	Recommended dietary allowances for children (g/day)	
		RDA	1/5 RDA
Total Phosphate as Phosphorous	NA	NA	NA
Vanadium	5,100	NA	NA
Zinc	14,000	NA	NA
	Organic compounds		
1,1,1-Trichloroethane	1.9	NA	NA
1,1,2,2-Tetrachloroethane	0.0033	NA	NA
1,1,2-Trichloroethane	0.018	NA	NA
1,1-Dichloroethane	21	NA	NA
1,1-Dichloroethene	0.058	NA	NA
1,2,4-Trichlorobenzene	5.3	NA	NA
1,2-Dichlorobenzene	17	NA	NA
1,2-Dichloroethane	0.024	NA	NA
1,2-Dichloroethene	NA	NA	NA
1,2-Dichloropropane	0.03	NA	NA
1,2-Dimethylbenzene	NA	NA	NA
1,3-Dichlorobenzene	NA	NA	NA
1,4-Dichlorobenzene	2.2	NA	NA
2,4,5-Trichlorophenol	250	NA	NA
2,4,6-Trichlorophenol	0.15	NA	NA
2,4-Dichlorophenol	1.1	NA	NA
2,4-Dimethylphenol	9	NA	NA
2,4-Dinitrophenol	0.29	NA	NA
2,4-Dinitrotoluene	0.00098	NA	NA
2,6-Dinitrotoluene	0.00085	NA	NA
2-Butanone	NA	NA	NA
2-Chloronaphthalene	270	NA	NA
2-Chlorophenol	3.6	NA	NA
2-Hexanone	NA	NA	NA
2-Methyl-4,6-dinitrophenol	NA	NA	NA
2-Methylnaphthalene	NA	NA	NA
2-Methylphenol	NA	NA	NA
2-Nitroaniline	NA	NA	NA
2-Nitrobenzenamine	NA	NA	NA
2-Nitrophenol	NA	NA	NA
3,3'-Dichlorobenzidine	0.0062	NA	NA
3-Nitroaniline	NA	NA	NA
3-Nitrobenzenamine	NA	NA	NA
4,4'-DDD	14	NA	NA
4,4'-DDE	45	NA	NA
4,4'-DDT	26	NA	NA
4,6'-Dinitro-2-methylphenol	NA	NA	NA
4-Bromophenyl phenyl ether	NA	NA	NA
4-Bromophenyl-phenylether	NA	NA	NA
4-Chloro-3-methylphenol	NA	NA	NA

Table 4.3 (continued)

Analytical compound	Soil screening level (mg/kg)	Recommended dietary allowances for children (g/day) RDA	1/5 RDA
4-Chloroaniline	0.97	NA	NA
4-Chlorobenzenamine	NA	NA	NA
4-Chlorophenyl phenyl ether	NA	NA	NA
4-Chlorophenyl-phenylether	NA	NA	NA
4-Methyl-2-pentanone	NA	NA	NA
4-Methylphenol	NA	NA	NA
4-Nitroaniline	NA	NA	NA
4-Nitrobenzenamine	NA	NA	NA
4-Nitrophenol	NA	NA	NA
Acenaphthene	630	NA	NA
Acenaphthylene	NA	NA	NA
Acetone	15	NA	NA
Aldrin	0.49	NA	NA
alpha-BHC	NA	NA	NA
alpha-Chlordane	NA	NA	NA
Anthracene	13,000	NA	NA
Benzene	0.034	NA	NA
Benzo(a)anthracene	NA	NA	NA
Benzo(a)pyrene	8.2	NA	NA
Benzo(b)fluoranthene	NA	NA	NA
Benzo(g,h,i)perylene	NA	NA	NA
Benzo(k)fluoranthene	NA	NA	NA
Benzoic acid	590	NA	NA
Benzyl alcohol	63	NA	NA
Benzyl butyl phthalate	17,000	NA	NA
beta-BHC	NA	NA	NA
bis(2-Chloroethoxy)methane	NA	NA	NA
bis(2-Chloroethyl)ether	0.00036	NA	NA
bis(2-Chloroisopropyl)ether	NA	NA	NA
bis(2-Ethylhexyl)phthalate	3,600	NA	NA
Bromodichloromethane	0.63	NA	NA
Bromoform	0.75	NA	NA
Bromomethane	0.25	NA	NA
Carbazole	0.59	NA	NA
Carbon disulfide	29	NA	NA
Carbon tetrachloride	0.066	NA	NA
Chlorobenzene	1.3	NA	NA
Chloroethane	NA	NA	NA
Chloroform	0.59	NA	NA
Chloromethane	0.04	NA	NA
Chrysene	NA	NA	NA
cis-1,2-Dichloroethene	0.4	NA	NA
cis-1,3-Dichloropropene	NA	NA	NA
delta-BHC	NA	NA	NA

Table 4.3 (continued)

Analytical compound	Soil screening level (mg/kg)	Recommended dietary allowances for children (g/day)	
		RDA	1/5 RDA
Di-n-butylphthalate	NA	NA	NA
Di-n-octylphthalate	NA	NA	NA
Dibenzo(a,h)anthracene	NA	NA	NA
Dibenzofuran	NA	NA	NA
Dibromochloromethane	0.39	NA	NA
Dichlorodifluoromethane	550	NA	NA
Dieldrin	0.0046	NA	NA
Diethylphthalate	450	NA	NA
Dimethylbenzene	NA	NA	NA
Dimethylphthalate	NA	NA	NA
Endosulfan I	20	NA	NA
Endosulfan II	20	NA	NA
Endosulfan sulfate	NA	NA	NA
Endrin	0.99	NA	NA
Endrin ketone	NA	NA	NA
Ethane	NA	NA	NA
Ethylbenzene	13	NA	NA
Ethylene	290	NA	NA
Fluoranthene	6,300	NA	NA
Fluorene	810	NA	NA
gamma-BHC (Lindane)	NA	NA	NA
gamma-Chlordane	NA	NA	NA
Heptachlor	23	NA	NA
Heptachlor epoxide	0.67	NA	NA
Hexachlorobenzene	2.2	NA	NA
Hexachlorobutadiene	2.4	NA	NA
Hexachlorocyclopentadiene	400	NA	NA
Hexachloroethane	0.46	NA	NA
Indeno(1,2,3-cd)pyrene	NA	NA	NA
Isophorone	0.53	NA	NA
m,p-Xylene	NA	NA	NA
Methoxychlor	160	NA	NA
Methylene chloride	0.023	NA	NA
N-Nitroso-di-n-propylamine	0.00006	NA	NA
N-Nitrosodiphenylamine	0.97	NA	NA
Naphthalene	61	NA	NA
Nitrobenzene	0.12	NA	NA
PCB-1016	0.056	NA	NA
PCB-1221	NA	NA	NA
PCB-1232	NA	NA	NA
PCB-1242	0.056	NA	NA
PCB-1248	NA	NA	NA
PCB-1254	0.34	NA	NA
PCB-1260	0.49	NA	NA

Table 4.3 (continued)

Analytical compound	Soil screening level (mg/kg)	Recommended dietary allowances for children (g/day)	
		RDA	1/5 RDA
PCB-1268	NA	NA	NA
Pentachlorophenol	0.028	NA	NA
Phenanthrene	NA	NA	NA
Phenol	110	NA	NA
Polychlorinated biphenyl	6.2	NA	NA
Pyrene	4,600	NA	NA
Pyridine	0.15	NA	NA
Styrene	3.5	NA	NA
Tetrachloroethene	0.058	NA	NA
Toluene	12	NA	NA
Total petroleum hydrocarbon	NA	NA	NA
Toxaphene	31	NA	NA
trans-1,2-Dichloroethene	0.68	NA	NA
trans-1,3-Dichloropropene	NA	NA	NA
Trichloroethene	0.057	NA	NA
Vinyl acetate	160	NA	NA
Vinyl chloride	0.013	NA	NA
Volatile organic qualitative scan	NA	NA	NA
Xylene	1,400	NA	NA
Radionuclides			
Alpha activity	NA	NA	NA
Americium-241	NA	NA	NA
Beta activity	NA	NA	NA
Cesium-137	NA	NA	NA
Cobalt-60	NA	NA	NA
Neptunium-237	NA	NA	NA
Plutonium-239	NA	NA	NA
Plutonium-239/240	NA	NA	NA
Potassium-40	NA	NA	NA
Protactinium-234m	NA	NA	NA
Radium	NA	NA	NA
Radium-226	NA	NA	NA
Radon-222	NA	NA	NA
Strontium-90	NA	NA	NA
Technetium-99	NA	NA	NA
Thorium-230	NA	NA	NA
Thorium-234	NA	NA	NA
Uranium	NA	NA	NA
Uranium (mg/kg or mg/L)	NA	NA	NA
Uranium-234	NA	NA	NA
Uranium-235	NA	NA	NA
Uranium-238	NA	NA	NA

[a] EPA's soil screening levels were calculated using EPA's soil screening level guidance available on the World Wide Web at *http://risk.lsd.ornl.gov/calc_start.htm.*

Table 4.4. Results of surface soil sampling and infiltrometer testing conducted at the C-747 Contaminated Burial Yard, historic locations

Sample	Soil description	Field screening
	Surface soil sampling	
H385	Lean clay (LC), moderate yellowish-brown (10 YR 5/4), light brown (5 YR 5/6), moist, crumbles	PID = 0 ppm Rad = 80 cpm
H384	Lean clay (CL), moderate brown (5 YR 4/4), moist	PID = 0 ppm Rad = 90 cpm
H383	Lean clay (CL), moderate brown (5 YR 3/4) , moist, light grey (N7) mottling	PID = 0 ppm Rad = 120 cpm
Location	**Average infiltration rate (cm/s)**	**Long-term infiltration rate (cm/s)**
	Infiltrometer testing	
DRI-7	$<3 \times 10^{-6}$	$<3 \times 10^{-6}$
DRI-8	—	5×10^{-6}
DRI-9	—	3×10^{-6}

Table 4.5. Maximum detected concentrations for soil at SWMU 4, historic locations

Analyte	Frequency of detects	Maximum result	Units	Station	Depth of maximum result
		Volatile organic compounds			
1,2-Dichloroethene	3/31	26	μg/kg	H227	15–20
2-Butanone	1/31	2 J	μg/kg	H214	35–40
Acetone	25/31	220	μg/kg	H227	20–25
Carbon disulfide	4/31	2 JB	μg/kg	H226	5–10
Methylene chloride	25/31	100 B	μg/kg	H225	25–30/30–35
Trichloroethene	9/31	7	μg/kg	H227	Unknown
		Semivolatile organic compounds			
bis-(2-Ethylhexyl)phthalate	21/32	4202 BJ	μg/kg	H225	5–10
Di-n-butylphthalate	14/32	1400	μg/kg	H227	0–5
Benzyl butyl phthalate	4/30	270 J	μg/kg	H225	10–15
Benzo(a)anthracene	2/30	58 J	μg/kg	H227	10–15
Fluoranthene	3/30	85 J	μg/kg	H227	10-15
Pentachlorophenol	1/32	210 DYJ	μg/kg	H227	10-15
Pyrene	2/30	300 JB	μg/kg	H227	10-15
		Metals			
Aluminum	29/30	15400	mg/kg	H225	0–5
Arsenic	29/30	9.8 N	mg/kg	H214	30–35
Barium	29/30	289	mg/kg	H227	10–15
Beryllium	29/30	0.9 B	mg/kg	H225	0–5
Cadmium	8/30	4.3	mg/kg	H225	30–35
Calcium	29/30	21200	mg/kg	H227	0–5

Table 4.5 (continued)

Analyte	Frequency of detects	Maximum result	Units	Station	Depth of maximum result
Chromium	29/30	77.3 N*	mg/kg	H214	25–30
Cobalt	23/30	14.2	mg/kg	H226	35–40
Copper	26/30	30.2*	mg/kg	H225	5–10
Iron	29/30	34100	mg/kg	H225	5–10
Lead	29/30	62.5 N*	mg/kg	H225	15–20
Magnesium	29/30	2560	mg/kg	H227	10–15
Manganese	29/30	2920 *	mg/kg	H225	0–5
Mercury	1/32	0.415	mg/kg	H227	0–5
Nickel	26/30	50.3	mg/kg	H227	0–5
Potassium	22/30	492 B	mg/kg	H225	0–5
Selenium	4/32	0.49 BNW	mg/kg	H226	15–20
Silver	6/32	2.3	mg/kg	H226	30–35
Sodium	27/30	320 B	mg/kg	H214	5–10
Vanadium	29/30	63.8 N*	mg/kg	H214	25–30
Zinc	3/31	26	mg/kg	H227	15–20
		Dioxin			
Octachlorodibenzo-p-dioxin	1/1	0.0082	µg/g	H227	0-5
		PCBs			
PCB-1254	1/18	1200	µg/kg	H227	0-5
		Radionuclides			
Neptunium-237	6-7	2.48	pCi/g	H227	SS
Plutonium-239	6/7	0.270	pCi/g	H227	SS
Technetium-99	6/6	20	pCi/g	H227	SS
Thorium-230	7/7	3	pCi/g	H227	SS
Uranium-234	7/7	20	pCi/g	H214	SS
Uranium-235	7/7	2.1	pCi/g	H214	SS
Uranium-238	7/7	68	pCi/g	H214	SS

B = ORG: Found in blank associated with sample; INORG: Value < required detection limit, > = IDL
N = ORG: TICs identified: INORG: spike recovery (SR) not within control limits; RAD: poor SR
W = INORG: Post-digestion spike for AA out of control limit
* = Duplicate analysis not within control limits
J = ORG: Estimated value (i.e., TIC or result < specified PQL but > 0)
D = Identified at secondary dilution

Table 4.6. Contamination detected in surface soil at SWMU 4

Chemical type	Analyte	Concentration	Data qualifier
Location 004-006			
Radionuclide	Alpha activity	22.6 ± 6.9 pCi/g	
	Beta activity	30.8 ± 4.3 pCi/g	
	Thorium-234	7.2 ± 5.1 pCi/g	
Location 004-007			
Radionuclide	Alpha activity	85 ± 13 pCi/g	
	Beta activity	114 ± 7.7 pCi/g	
	Neptunium-237	0.266 ± 0.0644 pCi/g	
	Thorium-234	88 ± 15 pCi/g	
	Uranium	87.3 ± 16.1 pCi/g	X
	Uranium-234	30.1 ± 5.55 pCi/g	
	Uranium-235	0.49 ± 0.04 wt %	
	Uranium-238	55.5 ± 3.45 pCi/g	
Location 004-009			
Radionuclide	Alpha activity	18.7 ± 7.4 pCi/g	
	Beta activity	26.9 ± 5.7 pCi/g	
Location 004-017			
Radionuclide	Alpha activity	14.1 ± 6.3 pCi/g	
	Beta activity	19.4 ± 5.4 pCi/g	
Location 004-019			
Radionuclide	Alpha activity	12.3 ± 6.7 pCi/g	
	Beta activity	25.8 ± 6.4 pCi/g	
Location 004-032			
VOA	Methylene Chloride	15 µg/kg	BJ
Radionuclide	Alpha activity	14.8 ± 6.6 pCi/g	
	Beta activity	22.8 ± 5.6 pCi/g	
Location 004-033			
Inorganic/Metal	Chromium	296 mg/kg	
Radionuclide	Alpha activity	14.1 ± 7.1 pCi/g	
	Beta activity	28.2 ± 6 pCi/g	
Location 004-034			
Inorganic/Metal	Chromium	42.3 mg/kg	
	Iron	30,700 mg/kg	*NW
Radionuclide	Alpha activity	22.8 ± 6.8 pCi/g	
	Beta activity	22.6 ± 5.3 pCi/g	
Location H214			
VOA	Acetone	34 µg/kg	B
SVOA	4-Methyl-3-penten-2-one	180 µg/kg	J
Radionuclide	Beta activity	21 ± 3 pCi/g	J
	Plutonium-239	0.026 ± 0.009 pCi/g	

Laboratory qualifiers

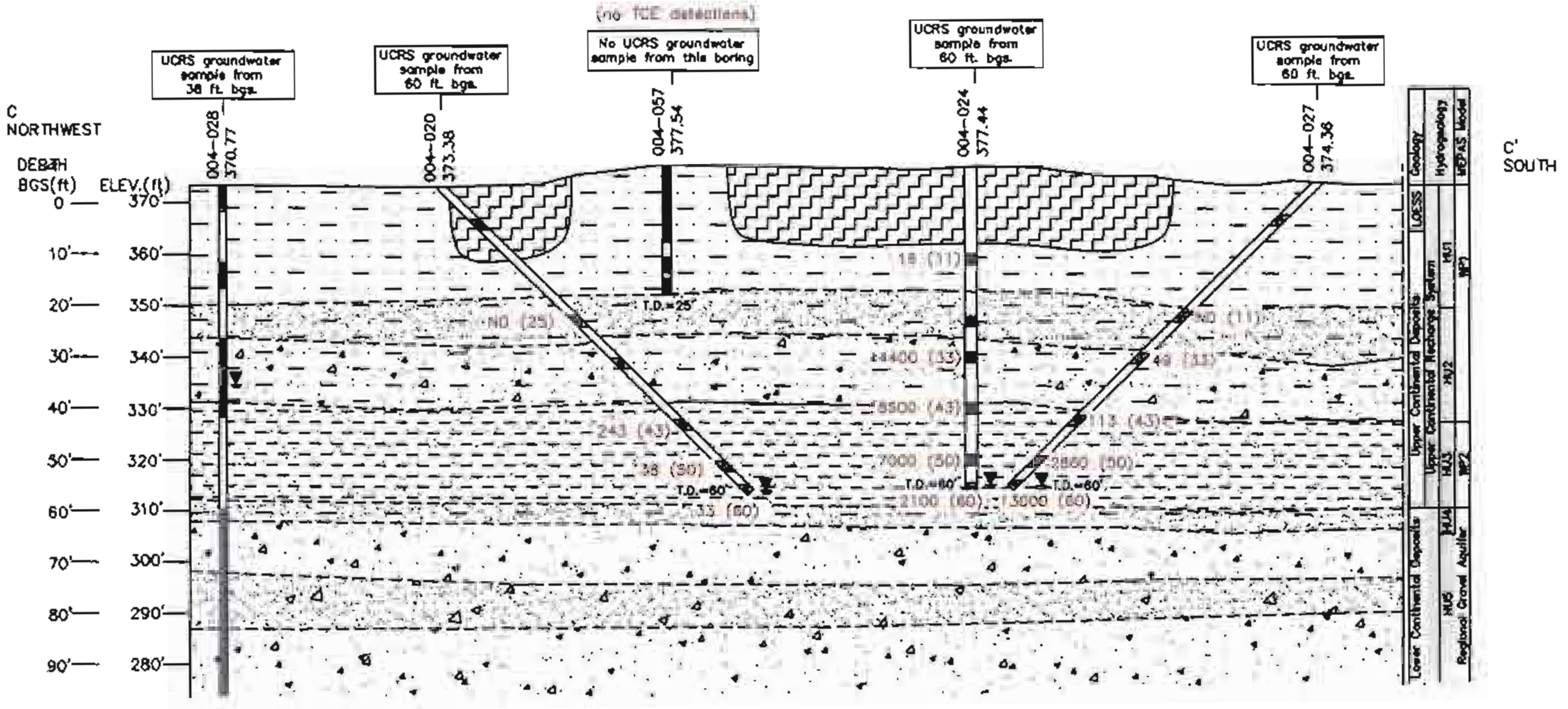
B = Found in the blank
J = Estimated
N = Tentatively identified
W = Laboratory-specific qualifier
X = Other specific flags may be required to properly define the results
* = Laboratory QC criteria not met

Table 4.7. Contamination detected in sediment at SWMU 4

Chemical type	Analyte	Concentration	Data qualifier
Location 004-001			
Radionuclide	Alpha activity	48 ± 9.6 pCi/g	
	Beta activity	67.5 ± 5.6 pCi/g	
	Plutonium-239/240	0.0644 ± 0.0229 pCi/g	
	Thorium-234	29 ± 23 pCi/g	
	Uranium	35.9 ± 7.94 pCi/g	
	Uranium-234	12.8 ± 2.83 pCi/g	
	Uranium-235	0.5 ± 0.04 wt %	
	Uranium-238	22.3 ± 2.56 pCi/g	
Location 004-002			
SVOA	Di-n-butyl phthalate	1,200 µg/kg	B
PCB	PCB-1260	115 µg/kg	
Radionuclide	Alpha activity	47 ± 9.3 pCi/g	
	Beta activity	53.4 ± 5.2 pCi/g	
	Thorium-234	24 ± 20 pCi/g	
	Uranium	25.8 ± 6.23 pCi/g	
	Uranium-234	7.88 ± 1.9 pCi/g	
	Uranium-235	0.43 ± 0.36 wt %	
	Uranium-238	17.5 ± 2.44 pCi/g	
Location 004-003			
Radionuclide	Alpha activity	46 ± 9 pCi/g	
	Beta activity	56 ± 4.8 pCi/g	
	Thorium-234	37 ± 21 pCi/g	
	Uranium	26.4 ± 6.6 pCi/g	
	Uranium-234	6.59 ± 1.65 pCi/g	
	Uranium-235	0.36 ± 0.03 wt %	
	Uranium-238	19.3 ± 2.72 pCi/g	
Location 004-004			
Radionuclide	Alpha activity	58 ± 11 pCi/g	
	Beta activity	60.1 ± 6.3 pCi/g	
	Thorium-234	14.8 ± 0.749 pCi/g	
	Uranium	23.9 ± 5.69 pCi/g	
	Uranium-234	7.21 ± 1.72 pCi/g	
	Uranium-235	0.42 ± 0.04 wt %	
	Uranium-238	16.2 ± 2.01 pCi/g	
Location 004-005			
PCB	PCB-1260	898 ug/kg	
Inorganic/Metal	Iron	41,900 mg/kg	*NW
Radionuclide	Alpha activity	123 ± 16 pCi/g	
	Americium-241	0.894 ± 0.428 pCi/g	X
	Beta activity	289 ± 11 pCi/g	
	Cesium-137	181 ± 17 pCi/g	
	Plutonium-239/240	27.1 ± 0.569 pCi/g	
	Technetium-99	39.3 ± 6.32 pCi/g	
	Thorium-234	19.9 ± 1.81 pCi/g	
	Uranium	34 ± 13.3 pCi/g	
	Uranium-234	11.7 ± 4.58 pCi/g	
	Uranium-235	0.48 ± 0.04 wt %	
	Uranium-238	21.6 ± 5.11 pCi/g	

Laboratory qualifiers

B = Found in the blank
N = Tentatively identified
W = Laboratory-specific qualifier
X = Other specific flags may be required to properly define the results
* = Laboratory QC criteria not met



LITHOLOGY

- ▤ SILT/CLAY
- ▨ WASTE CELL
- ⁘ GRAVEL
- ▒ SAND AND SILTY SAND AND/OR GRAVEL
- ▤ CLAY

HYDROLOGY

HU1 ······· HU1 – THE UPPER FLUVIAL/ALLUVIAL SILTY CLAYS RUST BROWN TO GREY-BROWN; PLEISTOCENE AGE.

HU2 ······· HU2 – LOESS, CLAYEY SILTY SAND TO SANDY SILT, SAND LENSES ARE DISCONTINUOUS BUT CORRELATABLE, RUST BROWN TO YELLOW-BROWN; PLEISTOCENE AGE.

HU3 ······· HU3 – CLAY TO SILTY CLAY, VERY IMPERMEABLE CLAY THAT ACTS AS A SEMICONFINING TO CONFINING LAYER, PRIMARY CONSTITUENT OF THE UPPER CONTINENTAL DEPOSITS; LOWER PLEISTOCENE AGE.

HU4 ······· HU4 – SAND WITH GRAVEL AND SILT, CONSIDERED THE UPPER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.

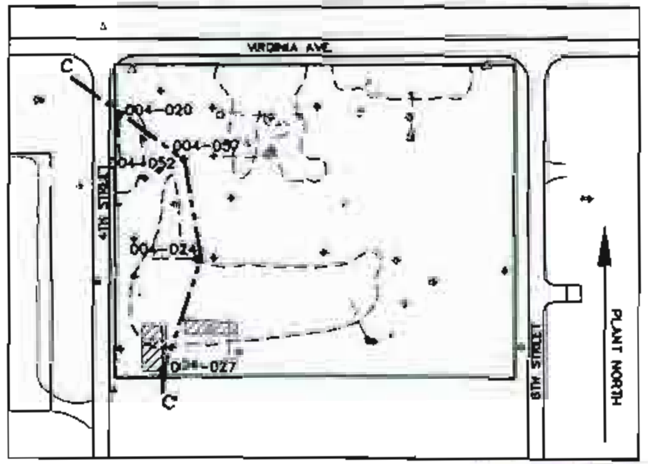
HU5 ······· HU5 – GRAVEL WITH SAND AND SILT, CONSIDERED THE LOWER PART OF THE RGA AS PART OF THE LOWER CONTINENTAL DEPOSITS; PLIOCENE AGE.

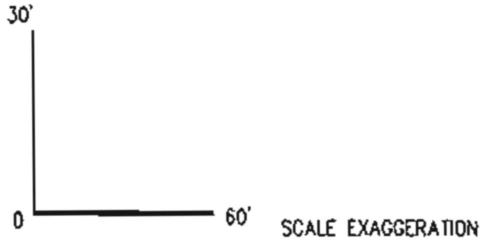
MCNAIRY FLOWSYSTEM ······· MCNAIRY FLOWSYSTEM – GREYISH WHITE TO DARK MICACEOUS CLAY, OFTEN SILTY, INTERBEDDED WITH LIGHT GREY TO YELLOW-BROWN VERY FINE SAND. CRETACEOUS AGE.

NOTE:

GRAY INSERTS IN WELLS ARE LOCATIONS WHERE SAMPLES FOR LITHOLOGIC CHARACTERIZATION WERE COLLECTED.

⧗ GROUNDWATER SAMPLE





Notes:

1. units in µg/kg (depth, ft, BGS)
2. ND = non-detect
3. Note that 004-020 bored under a burial cell (not shown due to perspective). 004-024 angled under a cell, but is shown straight on due to perspective.

5134-001\SWMU4_CC'_TCE\9-13-00

September 2000

CDM FEDERAL PROGRAMS CORPORATION

T N & Associates, Inc.
Engineering and Science

PADUCAH GASEOUS DIFFUSION PLANT

Fig. 4.14. WAG 3-SWMU 4,
TCE distribution in subsurface soil.

Table 4.8. Volatile organic analyte analyses of subsurface soil at SWMU 4

1,1-Dichloroethene (µg/kg)

Sample depth	004-022
11	ND
18	ND
25	NS
33	14
43	ND
50	ND
60	ND
	TD = 60 ft

1,1,2-Trichloroethane (µg/kg)

Sample depth	004-027
60	21 J
	TD = 60 ft

1,2-Dichloroethene (µg/kg)

Sample depth	H227
5	ND
15	63
20	26
25	10
35	ND
40	ND
	TD = 40 ft

2-Propanol (µg/kg)

Sample depth	H214
40	100 J
	TD = 40 ft

Acetone (µg/kg)

Sample depth	004-035	004-041	004-043	004-048	H214	H225	H226	H227
5	ND	NS	NS	NS	ND	28 B!	ND	ND
6	NS	250 J	ND	ND	NS	NS	NS	NS
10	17 J	NS	NS	NS	37 B	36 B!	85 B	NS
11	NS	NS	100 J	NS	NS	NS	NS	NS
15	ND	ND	ND	35 JX	34 B	17 B	71 B	77 B
20	NS	NS	NS	NS	88 B	18 B	79 B	69 B
21	NS	NS	ND	NS	NS	NS	NS	NS
22	ND	NS	NS	NS	NS	NS	NS	NS
23	NS	NS	NS	5900 EJ	NS	NS	NS	NS
24	*TD = 23 ft*	ND	NS	*TD = 23 ft*	NS	NS	NS	NS
25		*TD = 24 ft*	ND		31 B	21 B	67 B	220
30			*TD = 25 ft*		27 B	51 B	89 B	NS
35					45 B	38 B	120 B	71 B
40					120 B	BSV	87 B	120 B
					TD = 40 ft	*TD = 40 ft*	*TD = 40 ft*	*TD = 40 ft*

Carbon tetrachloride (µg/kg)

Sample depth	004-024	004-027	004-030
11	ND	NS	NS
25	NS	NS	ND
33	ND	ND	NS
43	ND	ND	NS
50	170 EJ	ND	ND
60	34 J	74 JY	43 J
80	*TD = 60 ft*	*TD = 60 ft*	NS
			TD = 80 ft

Chloroform (µg/kg)

Sample depth	004-009	004-024	004-027	004-030
16	ND	NS	NS	NS
33	NS	45 J	NS	NS
39	12 Y	NS	NS	NS
40	NS	NS	NS	NS
43	*TD = 40 ft*	14 J	NS	NS
50		160 EJ	NS	NS
60		60 J	160 EJ	330 EJ
80		*TD = 60 ft*	*TD = 60 ft*	NS
				TD = 80 ft

cis-1,2-Dichloroethene (µg/kg)

Sample depth	004-009	004-022	004-024	004-026	004-027	004-030	004-034	004-035
5	NS	NS	NS	NS	NS	NS	NS	ND
6	ND	NS	NS	NS	NS	NS	ND	NS
10	NS	NS	NS	NS	NS	NS	NS	480
11	NS	ND	800 J	ND	ND	NS	NS	NS
15	NS	NS	NS	NS	NS	NS	NS	410
16	ND	NS	NS	NS	NS	NS	ND	NS
18	NS	ND	NS	ND	NS	NS	NS	NS
22	NS	NS	NS	NS	NS	NS	NS	414
23	NS	NS	NS	NS	NS	NS	660	NS
25	ND	NS	NS	NS	NS	ND	NS	*TD = 23 ft*
26	NS	NS	NS	NS	NS	NS	NS	
33	NS	9800	2400	350	ND	NS	*TD = 26 ft*	
39	360 EJ	NS	NS	NS	NS	NS		
40	NS	NS	NS	NS	NS	NS		
43	*TD = 40 ft*	460	230 J	ND	ND	NS		
50		2500	390 EJ	ND	720	ND		
60		ND	130 J	NS	610	3900		
80		*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	NS		
						TD = 80 ft		

Diethyl ether (µg/kg)

Sample depth	H226
10	8 J
20	7 J
30	6 J
35	7 J
40	9 J
	TD = 40 ft

Methylene chloride (µg/kg)

Sample depth	004-024	004-027	004-030	004-032	004-042	004-044	004-052	004-054	004-055	004-056	H214	H225	H226	H227
3	NS	NS	NS	NS	NS	NS	NS	49 BJ	NS	46 BJ	NS	NS	NS	NS
5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	140 B!	ND	ND
6	NS	NS	NS	16 BJ	ND	ND	NS	36 BJ	54 BJ	ND	NS	NS	NS	NS
9	NS	NS	NS	NS	NS	NS	NS	ND	ND	ND	NS	NS	NS	NS
10	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	39 B	120 B!	74 B	NS
11	ND	NS	NS	NS	13 BJ	NS	NS	NS	NS	NS	NS	NS	NS	NS
12	NS	NS	NS	NS	NS	NS	NS	35 BJ	ND	NS	NS	NS	NS	NS
15	NS	NS	NS	NS	ND	19 BJ	NS	36 BJ	41 BJ	ND	33	30 B	87 B	85 B
16	NS	NS	NS	17 BJ	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
20	NS	NS	NS	NS	NS	NS	NS	37 BJ	NS	NS	32 B	37 B	61 B	72 B
21	NS	NS	NS	NS	ND	NS	25 BJ	*TD = 20 ft*	52 BJ	ND	NS	NS	NS	NS
24	NS	NS	NS	NS	NS	NS	NS		NS	ND	NS	NS	NS	NS
25	NS	NS	ND	21 BJ	ND	ND	22 BJ		54 BJ	*TD = 24 ft*	5 JB	61 B	60 B	69 B
30	NS	NS	NS	NS	ND	NS	NS		*TD = 25 ft*		7 B	100 B	53 B	NS
33	ND	18 B	NS	NS	NS	NS	NS				NS	NS	NS	NS
35	NS	NS	NS	NS	*TD = 33 ft*	16 BJ	NS				6 B	100 B	61 B	84 B
40	NS	NS	NS	19 BJ		NS	NS				4 JB	39 B	61 B	43 B
42	NS	NS	NS	NS		*TD = 40 ft*	ND				*TD = 40 ft*	*TD = 40 ft*	*TD = 40 ft*	*TD = 40 ft*
43	ND	18 BJ	NS	NS			NS							
50	30 BJ	ND	ND	19 BJ			NS							
51	NS	NS	NS	NS			ND							
60	ND	46 BJ	41 BJ	20 BJ			*TD = 51 ft*							
80	*TD = 60 ft*	*TD = 60 ft*	NS	*TD = 60 ft*										
			TD = 80 ft											

trans-1,2-Dichloroethene (µg/kg)

Sample depth	004-035
5	ND
10	ND
15	450
22	ND
23	NS
	TD = 23 ft

Table 4.8 (continued)

Trichloroethene (TCE) (µg/kg)

Sample depth	004-009	004-017	004-019	004-020	004-021	004-022	004-024	004-026	004-027	004-030	004-033	004-034	004-035	004-038	004-040	004-043	004-048	004-051	H225	H226	H227
5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	NS	NS	NS	NS	ND	ND	ND
6	ND	ND	8	NS	NS	NS	NS	NS	NS	NS	4	ND	NS	NS	ND	ND	ND	NS	NS	NS	NS
10	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	NS	NS	NS	NS	ND	ND	NS
11	NS	NS	NS	NS	NS	ND	16	3.6	ND	NS	NS	NS	NS	NS	35	ND	NS	NS	NS	NS	NS
15	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	400	ND	ND	ND	35	NS	ND	ND	40
16	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	79 J	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS
18	NS	NS	NS	NS	NS	ND	NS	7.2	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
20	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	4
21	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	NS	NS	NS	NS	NS
22	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	820	6.4	NS	NS	NS	ND	NS	NS	NS
23	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	53	NS	NS	NS	NS	ND	NS	NS	NS	NS
25	ND	ND	ND	ND	ND	NS	NS	NS	NS	ND	ND	NS	*TD = 23 ft*	NS	ND	420	*TD = 23 ft*	NS	ND	ND	ND
26	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		*TD = 25 ft*	*TD = 25 ft*	*TD = 25 ft*		ND	NS	NS	NS
28	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*TD = 26 ft*						NS	NS	NS	NS
30	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*TD = 28 ft*							NS	ND	3	NS
33	NS	NS	NS	NS	60 J	41,000	4400	200	49	NS								NS	NS	NS	NS
35	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS								NS	ND	ND	ND
39	770	NS	NS	NS	NS	NS	NS	NS	NS	NS								NS	NS	NS	NS
40	NS	ND	ND	NS	NS	NS	NS	NS	NS	NS								NS	5	ND	ND
42	*TD = 40 ft*	NS	NS	NS	NS	NS	NS	NS	NS	NS								460	*TD = 40 ft*	*TD = 40 ft*	*TD = 40 ft*
43		NS	NS	243	ND	4900	8500	12	113	NS								NS			
48		NS	NS	NS	NS	NS	NS	NS	NS	NS								NS			
50		15 Y	ND	38	NS	6000	7000	120	2860	9200								NS			
51		NS	NS	NS	NS	NS	NS	NS	NS	NS								ND			
54		NS	NS	NS	ND	NS	NS	NS	NS	NS								*TD = 51 ft*			
60		42	ND	33	ND	1100	2100	NS	13,000	25,000											
80		*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	NS											
										TD = 80 ft											

Vinyl chloride (µg/kg)

Sample depth	004-009	004-022	004-024	004-030
6	ND	NS	NS	NS
11	NS	ND	ND	NS
16	51 J	NS	NS	NS
18	NS	ND	NS	NS
25	ND	NS	NS	ND
33	NS	220 EJ	62 JY	NS
39	46 JY	NS	NS	NS
40	NS	NS	NS	NS
43	*TD = 40 ft*	18	ND	NS
50		11	ND	ND
60		ND	ND	33 JY
80		*TD = 60 ft*	*TD = 60 ft*	NS
				TD = 80 ft

Notes:

BSV = Below screening value
ND = Below detection limit
NS = Not sampled
TD = Total depth

Laboratory qualifiers

B = Found in the blank
E = Result exceeds calibration range
J = Estimated

X = Other specific flags may be required to properly define the results
Y = MS/MSD recovery and/or RPD failed acceptance criteria
! = Less than quantity

Table 4.9. Semivolatile organic analyte analyses of subsurface soil at SWMU 4

1,2-Benzenedicarboxylic acid (μg/kg)

Sample depth	H227
35	200 J
40	NS
	TD = 40 ft

3,3'-Dichlorobenzidine (μg/kg)

Sample depth	H225
10	850 !
20	NS
30	NS
40	NS
	TD = 40 ft

4-Methyl-3-penten-2-one (μg/kg)

Sample depth	H225
10	670 J
20	NS
30	NS
40	NS
	TD = 40 ft

6-(Acetyloxy)-2-hexanone (μg/kg)

Sample depth	H225
5	670 J
20	2000 JN
25	1600 J
30	1800 J
40	NS
	TD = 40 ft

Bis(2-ethylhexyl)phthalate (μg/kg)

Sample depth	H225
5	4104 BJ!
10	NS
20	NS
30	NS
40	NS
	TD = 40 ft

Bis(2-methoxyethyl)phthalate (μg/kg)

Sample depth	H225
30	450 J
40	NS
	TD = 40 ft

Diethyl phthalate (μg/kg)

Sample depth	004-034
6	2800
16	ND
26	NS
	TD = 26 ft

Di-n-butyl phthalate (μg/kg)

Sample depth	004-017	004-019	004-020	004-021	004-022	004-023	004-025	004-026	004-027	004-035	004-037	004-038	004-040	004-041	004-042	004-046	H214	H227
5	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	600 X	NS	NS	NS	NS	ND	1400
6	ND	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	780 X	ND	730 X	940 X	NS	NS
10	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	ND	NS	NS	NS	NS	950	NS
11	NS	NS	NS	NS	6100 B	880 B	920 B	1400 B	NS	NS	NS	NS	ND	NS	ND	NS	NS	NS
15	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	750 X	ND	ND	710 X	ND	ND	740	ND
16	ND	1000 B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
18	NS	NS	NS	NS	1600 B	NS	NS	1100 B	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
20	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	450	ND
22	NS	NS	NS	NS	NS	NS	NS	NS	NS	590 X	ND	NS	NS	NS	NS	NS	NS	NS
23	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
24	NS	NS	NS	NS	NS	NS	NS	NS	NS	*TD = 23 ft*	NS	NS	NS	NS	NS	NS	NS	NS
25	ND	ND	1800 BJ	NS	NS	NS	NS	NS	NS		NS	NS	NS	*TD = 24 ft*	NS	*TD = 24 ft*	ND	ND
33	NS	NS	NS	690 B	5000 B	ND	1200 B	1300 B	2000 B		NS	*TD = 25 ft*	*TD = 25 ft*		ND		NS	NS
40	ND	ND	NS	NS	NS	NS	NS	NS	NS		NS				*TD = 33 ft*		440	ND
43	NS	NS	ND	ND	5800 B	ND	2000 B	1900 B	ND		NS						*TD = 40 ft*	*TD = 40 ft*
45	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS							
50	ND	ND	ND	NS	5900 B	NS	2200 B	NS	670 B		*TD = 45 ft*							
60	850 B	ND	NS	NS	NS	NS	NS	NS	1100 B									
	TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*									

Ethanol,2,2'-oxybis-diacetate (μg/kg)

Sample depth	H225
20	2,000 JN
30	NS
40	NS
	TD = 40 ft

Notes:

ND = Below detection limit
NS = Not sampled
TD = Total depth

Laboratory qualifiers

B = Found in the blank
J = Estimated
N = Tentatively identified

X = Other specific flags may be required to properly define the results
! = Less than quantity

Table 4.10. PCB analyses of subsurface soil at SWMU 4

PCB-1016/1248/1254/1260 (µg/kg)

Sample depth	004-009	004-025	004-035	004-038	004-039	004-040	004-046	004-047	004-056	H227
3	NS	NS	NS	NS	NS	NS	NS	NS	4760^{c} ND^{a,b,d}	NS
5	NS	NS	10,300^{c} ND^{a,d}	308^{c} ND^{a,b,d}	NS	NS	NS	NS	NS	1200^{c} ND^{a,b,d}
6	424^{a} ND^{b,c,d}	NS	NS	NS	908^{c} ND^{a,b,d}	2500^{d} 1300^{c} 500^{a} 4300^{e} ND^{b}	800^{b} 800^{e} ND^{a,c,d}	27,000^{c} ND^{a,b,d}	ND^{a,b,c,d}	NS
9	NS	NS	NS	NS	NS	NS	NS	NS	ND^{b,c,d}	NS
10	NS	NS	ND ND^{b,c,d}	ND ND^{b,c,d}	NS	NS	NS	NS	NS	NS
11.3	NS	300^{b} 200^{c} 500^{e} ND^{a,d}	NS	NS	NS	ND^{a,b,c,d}	NS	ND^{a,b,c,d}	NS	NS
15	NS	NS	ND^{b,c,d}	ND^{b,c,d}	ND ND^{b,c,d}	ND^{b,c,d}	ND^{b,c,d}	ND^{b,c,d}	ND^{b,c,d}	NS
16	ND^{b,c,d}	NS	NS	NS	NS	NS	NS	NS	NS	NS
21	NS	NS	NS	NS	NS	ND^{b,c,d}	NS	ND^{b,c,d}	ND ND^{b,c,d}	NS
22	NS	NS	ND^{b,c,d}	ND^{b,c,d}	NS	NS	NS	NS	NS	NS
23	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
24	NS	NS	*TD = 23 ft*	NS	NS	NS	NS	ND^{b,c,d}	NS	NS
25	ND^{b,c,d}	NS		NS	NS	ND^{b,c,d}	ND^{b,c,d}	*TD = 24 ft*	*TD = 24 ft*	NS
33	NS	ND ND^{b,c,d}		*TD = 25 ft*	NS	*TD = 25 ft*	*TD = 25 ft*			NS
35	NS	NS			ND^{b,c,d}					NS
36	NS	NS			NS					NS
39	ND^{b,c,d}	NS			*TD = 36 ft*					NS
40	NS	NS								NS
43	*TD = 40 ft*	ND ND^{b,c,d}								*TD = 40 ft*
50		ND ND^{b,c,d}								
60		NS								
		TD = 60 ft								

Pentachlorobiphenyl (µg/kg)

Sample depth	H227
5	200 J
10	NS
20	NS
30	NS
40	NS
	TD = 40 ft

Octachloro-dibenzo(b,e)(1,4)dioxin (ng/kg)

Sample depth	H227
5	8.2
10	NS
20	NS
30	NS
40	NS
	TD = 40 ft

Notes:

Where a superscript is not shown for a contaminant as either a result or nondetect, the contaminant was not sampled (NS).

ND = Below detection limit
NS = Not sampled
TD = Total depth
^{a}PCB-1260
^{b}PCB-1248
^{c}PCB-1254
^{d}PCB-1016
^{e}Total PCB

Laboratory qualifier
J = Estimated

Table 4.11. Inorganic analyses of subsurface soil at SWMU 4

Aluminum (mg/kg)

Sample depth	004-017	004-021	004-022	004-023	004-025	004-030	004-032	004-035	004-036	004-037	004-040	004-043	004-044	004-047	H225
5	NS	NS	NS	NS	NS	NS	NS	12,900 NW	BSV	16,300 *NW	NS	NS	NS	NS	15,400
6	12,600 *NW	NS	NS	NS	NS	NS	13,000 NW	NS	NS	NS	BSV	BSV	14,800 *NW	16,000 *NW	NS
10	NS	NS	NS	NS	NS	NS	NS	14,600 NW	19,000 NW	BSV	NS	NS	NS	NS	BSV
11	NS	NS	BSV	BSV	BSV	NS	NS	NS	NS	NS	12,600 *NW	BSV	NS	BSV	NS
15	NS	NS	NS	NS	NS	NS	NS	15,800 NW	BSV	BSV	BSV	BSV	BSV	BSV	BSV
21	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	BSV	12,800 NW	NS	BSV	NS
23	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
24	NS	NS	NS	NS	NS	NS	NS	*TD = 23 ft*	NS	NS	NS	NS	NS	BSV	NS
25	BSV	NS	NS	NS	NS	NS	BSV		NS	NS	NS	BSV	NS	*TD = 24 ft*	BSV
33	NS	14,000 *NW	14,600 NW	BSV	BSV	NS	NS		*TD = 25 ft*	NS	*TD = 25 ft*	*TD = 25 ft*	NS		NS
40	BSV	NS	NS	NS	NS	NS	BSV			NS			NS		BSV
43	NS	13,400 *NW	BSV	13,400 *NW	13,700 NW	NS	NS			NS			*TD = 40 ft*		*TD = 40 ft*
45	NS	NS	NS	NS	NS	NS	NS			NS					
50	BSV	NS	BSV	BSV	17,500 NW	13,200 NW	14,300 NW			*TD = 45 ft*					
54	NS	12,800 *NW	NS	NS	NS	NS	NS								
60	BSV	BSV	NS	NS	NS	NS	BSV								
	TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	NS	*TD = 60 ft*								
						NS									
						TD = 80 ft									

Chromium (mg/kg)

Sample depth	004-035	H214
5	BSV	BSV
10	BSV	BSV
15	BSV	BSV
20	NS	BSV
22	60.8	NS
23	NS	NS
25	*TD = 23 ft*	BSV
30		77.3 N*
35		BSV
40		NS
		TD = 40 ft

Cobalt (mg/kg)

Sample depth	004-025	004-030	004-032	004-035	004-036	004-037
5	NS	NS	NS	NS	13.5	BSV
6	BSV	NS	NS	NS	NS	NS
10	NS	NS	NS	NS	ND	BSV
11	NS	NS	17.6	BSV	NS	NS
15	NS	NS	NS	14.8	ND	BSV
16	BSV	NS	NS	NS	NS	NS
20	NS	NS	NS	NS	ND	BSV
21	NS	NS	NS	BSV	NS	NS
24	NS	NS	NS	NS	NS	NS
25	BSV	31.6	NS	*TD = 24 ft*	BSV	BSV
30	NS	NS	NS		ND	NS
33	NS	NS	BSV		NS	NS
35	NS	NS	NS		ND	BSV
40	BSV	NS	NS		ND	14.2
43	NS	BSV	BSV		*TD = 40 ft*	*TD = 40 ft*
50	15.6	BSV	18.2 *N			
60	BSV	NS	NS			
	TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*			

Table 4.11 (continued)

Iron (mg/kg)

Sample depth	004-019	004-021	004-023	004-030	004-035	H225
5	NS	NS	NS	NS	30,200 *NX	BSV
6	BSV	NS	NS	NS	N	NS
10	NS	NS	NS	NS	BSV	34,100
11	NS	NS	BSV	NS	NS	NS
15	NS	NS	NS	NS	BSV	BSV
16	BSV	NS	NS	NS	NS	NS
20	NS	NS	NS	NS	NS	BSV
22	NS	NS	NS	NS	BSV	NS
23	NS	NS	NS	NS	NS	NS
25	BSV	NS	NS	NS	*TD = 23 ft*	BSV
30	NS	NS	NS	NS		BSV
33	NS	31,800 *NW	BSV	NS		NS
35	NS	NS	NS	NS		BSV
40	34,500 *N	NS	NS	NS		BSV
43	NS	BSV	28,600 *NW	NS		*TD = 40 ft*
50	BSV	NS	28,900 *NW	33,400 *N		
54	NS	28,900 *NW	NS	NS		
60	BSV	BSV	NS	NS		
	TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	NS		
				NS		
				TD = 80 ft		

Lead (mg/kg)

Sample depth	004-027	004-037	H225
5	NS	30.2 N	BSV
10	NS	ND	BSV
15	NS	ND	BSV
20	NS	NS	62.5 N*
22	NS	ND	NS
25	NS	NS	BSV
30	NS	ND	50 N*
33	23.7	NS	NS
35	NS	NS	BSV
40	NS	NS	BSV
43	ND	NS	*TD = 40 ft*
45	NS	NS	
50	ND	*TD = 45 ft*	
60	ND		
	TD = 60 ft		

Manganese (mg/kg)

Sample depth	004-009	H225
5	NS	2920 *
6	BSV	NS
10	NS	BSV
15	NS	BSV
16	2700 *N	NS
20	NS	BSV
25	BSV	BSV
30	NS	BSV
35	NS	BSV
39	BSV	NS
40	NS	BSV
	TD = 40 ft	*TD = 40 ft*

Notes:

BSV = Below screening value
ND = Below detectin limit
NS = Not sampled
TD = Total depth

Laboratory qualifiers
N = Tentatively identified
W = Laboratory-specific qualifier
X = Other specific flags may be required to properly define the results
* = Laboratory QC criteria not met

Table 4.12. Alpha activities in subsurface soil at SWMU 4

Alpha activity (pCi/g)

Sample depth	004-009	004-017	004-019	004-020	004-021	004-022	004-023	004-024	004-025	004-026	004-027	004-030	004-031	004-032
3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	35.91 ± 2	NS
4	NS	NS	NS	NS	24.6 ± 7.4	NS	NS	NS	NS	NS	NS	NS	*TD = 3 ft*	NS
5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
6	61 ± 12	28.3 ± 8.5	20.6 ± 7.5	NS	NS	NS	NS	NS	NS	NS	NS	NS		29.1 ± 8.3
9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
10	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
11	NS	NS	NS	NS	NS	5.25 ± 3.16	20.6 ± 6.3	16.2 ± 6	10.72 ± 4.8	3.27 ± 2.67	5 ± 1.41	NS		NS
12	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
15	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
16	10 ± 6.1	ND	18.8 ± 7.5	NS	NS	NS	NS	NS	NS	NS	NS	NS		18.4 ± 7.3
18	NS	NS	NS	NS	NS	3.82 ± 2.7	NS	NS	NS	3.95 ± 2.98	NS	NS		NS
19	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
20	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
21	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
22	NS	NS	NS	NS	NS	NS	NS	NS	ND	NS	NS	NS		NS
23	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
24	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
25	15.2 ± 7.5	15 ± 6.4	NS	22.7 ± 7	NS	NS	19.1 ± 7.8	NS	NS	NS	NS	NS		12.7 ± 6.2
26	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
28	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
30	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
33	NS	NS	NS	NS	23.2 ± 7	5.22 ± 3.15	24.5 ± 7.3	20 ± 6.7	2.66 ± 2.37	6.76 ± 3.9	ND	NS		NS
35	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
36	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
39	19.3 ± 7.3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
40	*TD = 40 ft*	16.9 ± 7	16.1 ± 6.8	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
42		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
43		NS	NS	24.1 ± 7.3	28 ± 7.6	2.02 ± 1.43	25.3 ± 7.6	17.5 ± 6.8	3.75 ± 2.83	8.53 ± 4.4	2.33 ± 1.76	NS		NS
45		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
50		17 ± 7.9	13.9 ± 7.4	21.6 ± 7.1	NS	3.51 ± 2.03	29.1 ± 8.3	20 ± 6.7	4.5 ± 2.49	ND	5.22 ± 3.15	16.1 ± 7.1		16.5 ± 7.5
51		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
54		NS	NS	NS	22.4 ± 7.4	NS	NS	NS	NS	NS	NS	NS		NS
60		17.8 ± 8.4	19.7 ± 7.2	12.6 ± 5.6	23.6 ± 7.1	ND	23.5 ± 7.8	18.1 ± 6.4	ND	NS	ND	24.6 ± 7.5		10.2 ± 5.9
70		*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	NS		*TD = 60 ft*
80												NS		
												TD = 80 ft		

Table 4.12 (continued)

Alpha activity (pCi/g)

Sample depth	004-033	004-034	004-035	004-036	004-037	004-038	004-039	004-040	004-041	004-042	004-043	004-044	004-045	004-046
3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
5	NS	NS	173 ± 17	23.3 ± 7.7	32.9 ± 8	41 ± 10	NS	NS	NS	NS	NS	NS	NS	NS
6	87 ± 12	19.8 ± 6.5	NS	NS	NS	NS	54 ± 10	66.36 ± 3.11	21.6 ± 7.3	29.4 ± 8	17.9 ± 6.9	17 ± 7.3	17 ± 6.9	NS
9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
10	NS	NS	21.4 ± 6.5	9.2 ± 5.4	15.8 ± 6.8	17.7 ± 7	NS	NS	NS	NS	NS	NS	NS	NS
11	NS	NS	NS	NS	NS	NS	NS	17.1 ± 6.5	NS	22.5 ± 7.5	11.6 ± 5.8	NS	18.1 ± 6.6	NS
12	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
15	NS	NS	15.7 ± 5.8	12.8 ± 5.5	17.5 ± 7.8	4.82 ± 0.85	21.5 ± 7.2	14.1 ± 6.5	13.5 ± 7.3	10.5 ± 5.7	15.8 ± 6.5	16 ± 6.6	15.9 ± 6.5	19.4 ± 6.8
16	10.6 ± 5.4	16.2 ± 6.3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
18	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
19	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
20	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
21	NS	NS	NS	NS	NS	NS	NS	14.9 ± 6.3	NS	15.7 ± 6.4	14.7 ± 6	NS	14 ± 6.7	NS
22	NS	NS	19.2 ± 6.5	17 ± 6.9	14.3 ± 6.7	12.2 ± 5.4	NS	NS	NS	NS	NS	NS	NS	NS
23	NS	20.2 ± 6.8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
24	NS	NS	*TD = 23 ft*	NS	NS	NS	NS	NS	22.1 ± 7.7	NS	NS	NS	NS	NS
25	22.5 ± 7.2	NS		NS	NS	NS	23.2 ± 8.1	14.7 ± 6.2	*TD = 24 ft*	14.2 ± 7.8	23.1 ± 6.9	11.4 ± 6	ND	ND
26	NS	NS		*TD = 25 ft*	NS	*TD = 25 ft*	NS	*TD = 25 ft*		NS	*TD = 25 ft*	NS	NS	*TD = 25 ft*
28	NS	*TD = 26 ft*			NS		NS			NS		NS	NS	
30	*TD = 28 ft*				17.3 ± 6.7		NS			14.9 ± 7.3		NS	24.2 ± 9.4	
33					NS		NS			NS		NS	*TD = 30 ft*	
35					NS		21.7 ± 7.6			*TD = 33 ft*		15.4 ± 6.6		
36					NS		NS					NS		
39					NS		*TD = 36 ft*					NS		
40					NS							NS		
42					NS							*TD = 40 ft*		
43					NS									
45					NS									
50					*TD = 45 ft*									
51														
54														
60														
70														
80														

Table 4.12 (continued)

Alpha activity (pCi/g)

Sample depth	004-047	004-048	004-049	004-050	004-051	004-052	004-053	004-054	004-055	004-056	004-057	H214	H225	H227
3	NS	NS	NS	NS	NS	NS	NS	20.9 ± 6.6	NS	109 ± 13	29.1 ± 7.4	NS	NS	NS
4	278.9 ± 6.56	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	51 ± 8 J	10 ± 4 J	29 ± 6 J
6	51.54 ± 2.91	3076.71 ± 51.08	14.5 ± 7.1	15.9 ± 6.9	NS	NS	25.1 ± 7.3	23 ± 7.1	11.1 ± 5.9	32.7 ± 7.7	19.6 ± 6.7	NS	NS	NS
9	NS	NS	NS	NS	NS	NS	15 ± 6.3	25.1 ± 7	20.1 ± 6.6	28.4 ± 7.6	15.2 ± 6	NS	NS	NS
10	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	2.6 ± 2.3 J	NS
11	18.2 ± 6.8	NS	17.7 ± 6.9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12	NS	NS	NS	NS	NS	NS	NS	14.3 ± 5.9	22.7 ± 6.6	NS	11.1 ± 5.2	NS	NS	NS
15	ND	11.2 ± 6.3	16.3 ± 6.6	17.1 ± 6.6	NS	NS	16.6 ± 6.2	16.6 ± 6.1	19.1 ± 6.6	14.8 ± 5.9	18.5 ± 6.4	NS	NS	NS
16	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
18	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
19	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
20	NS	NS	NS	*TD = 19 ft*	NS	NS	NS	15.2 ± 5.6	NS	NS	NS	NS	NS	NS
21	13.9 ± 6.8	NS	11.1 ± 5.7		NS	ND	17.4 ± 5.8	*TD = 20 ft*	20.2 ± 6.2	31.4 ± 7.2	14.7 ± 5.8	NS	NS	NS
22	NS	NS	*TD = 21 ft*		20 ± 6.7	NS	NS		NS	NS	NS	NS	NS	NS
23	NS	17.2 ± 6.4			NS	NS	NS		NS	NS	NS	NS	NS	NS
24	13.1 ± 6.3	*TD = 23 ft*			NS	NS	NS		NS	15.4 ± 5.9	NS	NS	NS	NS
25	*TD = 24 ft*				NS	14.5 ± 6.9	12.5 ± 6.1		21.8 ± 7.1	*TD = 24 ft*	16.9 ± 6.2	NS	NS	NS
26					9.9 ± 5.6	NS	*TD = 25 ft*		*TD = 25 ft*		*TD = 25 ft*	NS	NS	NS
28					NS	NS						NS	NS	NS
30					NS	NS						NS	NS	NS
33					NS	NS						NS	NS	NS
35					NS	NS						NS	NS	NS
36					NS	NS						NS	NS	NS
39					NS	NS						NS	NS	NS
40					NS	NS						NS	NS	ND
42					17.8 ± 5.9	22 ± 7.3						*TD = 40 ft*	*TD = 40 ft*	*TD = 40 ft*
43					NS	NS								
45					NS	NS								
50					NS	NS								
51					21.1 ± 7	20.6 ± 8.2								
54					*TD = 51 ft*	*TD = 51 ft*								
60														
70														
80														

Notes:
ND = Below detection limit
NS = Not sampled
TD = Total depth

Laboratory qualifiers
J = Estimated

Table 4.13. Beta activities in subsurface soil at SWMU 4

Beta activity (pCi/g)

Sample depth	004-009	004-017	004-019	004-020	004-021	004-022	004-023	004-024	004-025	004-026	004-027	004-030	004-031	004-032
3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	88.79 +/- 2.22	NS
4	NS	NS	NS	NS	30.1 ± 4	NS	NS	NS	NS	NS	NS	NS	*TD = 3 ft*	NS
5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
6	84 ± 8.3	42.5 ± 6.1	27.4 ± 5.4	NS	NS	NS	NS	NS	NS	NS	NS	NS		39.1 ± 5.7
9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
10	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
11	NS	NS	NS	NS	NS	1.29 ± 0.67	21.7 ± 3.5	21.4 ± 3.8	9.51 ± 2.9	2.74 ± 1.41	4.76 ± 0.79	NS		NS
12	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
15	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
16	17.6 ± 4.5	37.7 ± 6.4	20.5 ± 5.6	NS	NS	NS	NS	NS	NS	NS	NS	NS		37.1 ± 6.7
18	NS	NS	NS	NS	NS	0.77 ± 0.43	NS	NS	NS	3.05 ± 1.44	NS	NS		NS
19	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
20	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
21	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
22	NS	NS	NS	NS	NS	NS	NS	NS	0.79 ± 0.5	NS	NS	NS		NS
23	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
24	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
25	30.7 ± 6.8	11.8 ± 4.7	NS	11.6 ± 4.3	NS	NS	19.1 ± 4.9	NS	NS	NS	NS	NS		17.5 ± 5.7
26	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
28	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
30	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
33	NS	NS	NS	NS	14.1 ± 4.2	1.8 ± 0.88	17.5 ± 4	13.2 ± 3.9	2.91 ± 1.37	5.34 ± 2.05	ND	NS		NS
35	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
36	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
39	12.3 ± 5.1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
40	NS	11 ± 5.2	16.3 ± 5.5	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
42	*TD = 40 ft*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
43		NS	NS	23.8 ± 4.9	22.7 ± 4.6	1.83 ± 0.75	23.4 ± 4.8	23 ± 3.8	3.43 ± 1.54	5.34 ± 2.05	6.44 ± 1.99	NS		NS
45		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
50		27.2 ± 7.7	27.3 ± 7.4	20.3 ± 4.8	NS	0.76 ± 0.37	23.5 ± 4.9	22.6 ± 3.8	6.67 ± 2.14	ND	1.78 ± 0.84	24 ± 5.4		28.2 ± 7.3
51		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS
54		NS	NS	NS	31.9 ± 5	NS	NS	NS	NS	NS	NS	NS		NS
60		29 ± 7.6	20.6 ± 5.9	24.1 ± 4.2	27.1 ± 4.7	1.07 ± 0.49	26.4 ± 4.5	24.8 ± 4.1	ND	NS	ND	32.1 ± 4.7		21.3 ± 6.1
70		*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	NS		*TD = 60 ft*
80												NS		
												TD = 80 ft		

Table 4.13 (continued)

Beta activity (pCi/g)

Sample depth	004-033	004-034	004-035	004-036	004-037	004-038	004-039	004-040	004-041	004-042	004-043	004-044	004-045	004-046
3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
4	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
5	NS	NS	186 ± 8.6	40.7 ± 6	36 ± 4.7	46.6 ± 7.2	NS	NS	NS	NS	NS	NS	NS	NS
6	114 ± 8.5	21.6 ± 4.4	NS	NS	NS	NS	59.4 ± 5.7	131.99 ± 2.72	31.4 ± 5.3	30.7 ± 4.8	27.9 ± 4.5	27.5 ± 6	23.2 ± 4.6	NS
9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
10	NS	NS	24.6 ± 3.8	23.2 ± 4.2	22.4 ± 4.6	35.1 ± 5	NS	NS	NS	NS	NS	NS	NS	NS
11	NS	NS	NS	NS	NS	NS	NS	19.6 ± 4.1	NS	29.1 ± 4.9	25.4 ± 4.7	NS	17.2 ± 4.7	NS
12	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
15	NS	NS	17.2 ± 3.3	13.9 ± 3.2	15.8 ± 5.8	4.04 ± 0.42	24.3 ± 4.2	21 ± 4.9	27.1 ± 6.8	21.6 ± 5.2	17.9 ± 4.8	18.3 ± 3.8	20.3 ± 4.6	30.7 ± 4.3
16	17.3 ± 5.7	22.8 ± 5.6	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
18	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
19	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
20	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
21	NS	NS	NS	NS	NS	NS	NS	15.1 ± 4	NS	15.1 ± 3.9	17.3 ± 4.8	NS	17.1 ± 5.3	NS
22	NS	NS	17 ± 3.7	16.9 ± 5.7	13.9 ± 4.2	18.5 ± 3.7	NS	NS	NS	NS	NS	NS	NS	NS
23	NS	18.1 ± 5.7	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
24	NS	NS	*TD = 23 ft*	NS	NS	NS	NS	NS	19 ± 5.6	NS	NS	NS	NS	NS
25	13.6 ± 5.1	NS		NS	NS	NS	22.1 ± 5.2	15.3 ± 4.1	*TD = 24 ft*	17.6 ± 6.6	12.9 ± 4	11 ± 3.8	11.7 ± 5.4	19.7 ± 5.8
26	NS	NS		*TD = 25 ft*	NS	*TD = 25 ft*	NS	*TD = 25 ft*		NS	*TD = 25 ft*	NS	NS	*TD = 25 ft*
28	NS	*TD = 26 ft*			NS		NS			NS		NS	NS	
30	*TD = 28 ft*				17.3 ± 4.5		NS			ND		NS	21.3 ± 6.8	
33					NS		NS			NS		NS	*TD = 30 ft*	
35					NS		15.3 ± 4.7			*TD = 33 ft*		14.8 ± 3.9		
36					NS		NS					NS		
39					NS		*TD = 36 ft*					NS		
40					NS							NS		
42					NS							*TD = 40 ft*		
43					NS									
45					NS									
50					*TD = 45 ft*									
51														
54														
60														
70														
80														

Table 4.13 (continued)

Beta activity (pCi/g)

Sample depth	004-047	004-048	004-049	004-050	004-051	004-052	004-053	004-054	004-055	004-056	004-057	H214	H225	H226	H227
3	NS	NS	NS	NS	NS	NS	NS	23.8 ± 3.7	NS	122 ± 6.8	29.1 ± 4.2	NS	NS	NS	NS
4	641.57 ± 6.23	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	230 ± 10 J	22 ± 3 J	20 ± 3 J	110 ± 10 J
6	75.66 ± 2.12	3253.97 ± 31.37	21 ± 4.7	25.6 ± 5.6	NS	NS	24.7 ± 4.4	25.1 ± 5	21.8 ± 4.8	25 ± 4.2	25.8 ± 3.9	NS	NS	NS	NS
9	NS	NS	NS	NS	NS	NS	25.8 ± 4.8	21.2 ± 3.9	20.9 ± 3.8	23.8 ± 4.1	24.6 ± 4.4	NS	NS	NS	NS
10	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	18 ± 3 J	NS	NS
11	22.6 ± 4.9	NS	20.7 ± 4.9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12	NS	NS	NS	NS	NS	NS	NS	16.8 ± 3.5	18.5 ± 3.7	NS	19.6 ± 4	NS	NS	NS	NS
15	21.9 ± 4.7	16.7 ± 5.5	17.1 ± 4.4	15.2 ± 4.2	NS	NS	18.6 ± 3.7	15.7 ± 3.5	18.7 ± 3.8	17.2 ± 3.9	17.9 ± 4.8	NS	NS	NS	NS
16	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
18	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
19	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
20	NS	NS	NS	*TD = 19 ft*	NS	NS	NS	7.5 ± 3.3	NS	NS	NS	NS	NS	NS	NS
21	18.3 ± 4.9	NS	20.3 ± 4.2		NS	15.8 ± 5.8	20.1 ± 3.4	*TD = 20 ft*	10.9 ± 3.5	20.5 ± 3.5	19.6 ± 3.8	NS	NS	NS	NS
22	NS	NS	*TD = 21 ft*		18.9 ± 4.3	NS	NS		NS	NS	NS	NS	NS	NS	NS
23	NS	11.5 ± 3.7			NS	NS	NS		NS	NS	NS	NS	NS	NS	NS
24	12 ± 4.6	*TD = 23 ft*			NS	NS	NS		NS	15.8 ± 3.4	NS	NS	NS	NS	NS
25	*TD = 24 ft*				NS	15.6 ± 5	20.7 ± 4.2		20.1 ± 4.4	*TD = 24 ft*	14.9 ± 4	NS	NS	NS	NS
26					15.8 ± 4	NS	*TD = 25 ft*		*TD = 25 ft*		*TD = 25 ft*	NS	NS	NS	NS
28					NS	NS						NS	NS	NS	NS
30					NS	NS						NS	NS	NS	NS
33					NS	NS						NS	NS	NS	NS
35					NS	NS						NS	NS	NS	NS
36					NS	NS						NS	NS	NS	NS
39					NS	NS						NS	NS	NS	NS
40					NS	NS						NS	NS	NS	3.9 ± 1.7 J
42					10.9 ± 3.3	12.7 ± 3.9						*TD = 40 ft*	*TD = 40 ft*	*TD = 40 ft*	*TD = 40 ft*
43					NS	NS									
45					NS	NS									
50					NS	NS									
51					21.8 ± 5.1	23.3 ± 5.9									
54					*TD = 51 ft*	*TD = 51 ft*									
60															
70															
80															

Notes:
ND = Below detection limit
NS = Not sampled
TD = Total depth

Laboratory qualifier
J = Estimated

Table 4.14. Radioisotopic analyses of subsurface soil at SWMU 4

Cesium-137 (pCi/g)

Sample depth	004-030	004-056
3	NS	0.544 ± 0.0785 X
5	NS	NS
6	1.48 ± 0.34	ND
9	NS	ND
10	NS	NS
15	NS	ND
21	NS	ND
22	NS	NS
24	NS	ND
30	NS	*TD = 24 ft*
45	NS	
50	ND	
60	ND	
80	NS	
	TD = 80 ft	

Neptunium-237 (pCi/g)

Sample depth	004-009	004-035	004-038	004-040	004-046	004-056	H227
3	NS	NS	NS	NS	NS	0.367 ± 0.0882	NS
5	NS	1.02 ± 0.102	0.34 ± 0.0697	NS	NS	NS	2.48 ± 0.25
6	1.58 ± 0.117	NS	NS	5.78 ± 0.266	1.84 ± 0.136	NS	NS
23	NS	NS	NS	NS	NS	NS	NS
24	NS	*TD = 23 ft*	NS	NS	NS	NS	NS
25	NS		NS	NS	NS	*TD = 24 ft*	NS
28	NS		*TD = 25 ft*	*TD = 25 ft*	*TD = 25 ft*		NS
40	NS						BSV
	TD = 40 ft						*TD = 40 ft*

Plutonium-239/240 (pCi/g)

Sample depth	004-009	004-030	004-035	004-040	004-046	004-048	004-056	H227
3	NS	NS	NS	NS	NS	NS	0.109 ± 0.039	NS
5	NS	NS	0.152 ± 0.0428	NS	NS	NS	NS	0.27 ± 0.13 R
6	0.0929 ± 0.0332	4.17 ± 0.301	NS	0.39 ± 0.0635	0.354 ± 0.0631	0.0945 ± 0.036	NS	NS
10	NS	NS	NS	NS	NS	NS	NS	NS
23	NS	NS	NS	NS	NS	NS	NS	NS
24	NS	NS	*TD = 23 ft*	NS	NS	*TD = 23 ft*	NS	NS
25	NS	NS		NS	NS		*TD = 24 ft*	NS
40	NS	NS		*TD = 25 ft*	*TD = 25 ft*			BSV
80	*TD = 40 ft*	NS						*TD = 40 ft*
		TD = 80 ft						

Protactinium-234m (pCi/g)

Sample depth	004-033	004-035
5	NS	380 +/- 313
6	134 +/- 67	NS
10	NS	ND
15	NS	ND
16	ND	NS
22	NS	ND
23	NS	NS
25	ND	*TD = 23 ft*
28	NS	
30	*TD = 28 ft*	
45		

Technetium-99 (pCi/g)

Sample depth	004-009	004-017	004-030	004-033	004-035	004-036	004-040	004-046	004-047	004-048	004-056	H227
3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	8.38 ± 3.42	NS
4	NS	NS	NS	NS	NS	NS	NS	NS	26.1 ± 4.02	NS	NS	NS
5	NS	NS	NS	NS	5.7 ± 3.37	6.37 ± 3.32	NS	NS	NS	NS	NS	20 ± 2
6	9.01 ± 3.39	4.79 ± 3.14	269 ± 10.5	10.4 ± 3.56	NS	NS	29.4 ± 4.33	14.6 ± 4.93	8.06 ± 3.25	235 ± 9.51	ND	NS
9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	NS
10	NS	NS	NS	NS	ND	ND	NS	NS	NS	NS	NS	NS
11	NS	NS	NS	NS	NS	NS	ND	NS	ND	NS	NS	NS
15	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	NS
16	ND	ND	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS
21	NS	NS	NS	NS	NS	NS	ND	NS	ND	NS	ND	NS
22	NS	NS	NS	NS	ND	ND	NS	NS	NS	NS	NS	NS
23	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
24	NS	NS	NS	NS	*TD = 23 ft*	NS	NS	NS	ND	*TD = 23 ft*	NS	NS
25	NS	ND	ND	NS		NS	ND	ND	*TD = 24 ft*		*TD = 24 ft*	NS
28	NS	NS	NS	NS		*TD = 25 ft*	*TD = 25 ft*	*TD = 25 ft*				NS
39	ND	NS	NS	*TD = 28 ft*								NS
40	NS	ND	NS									BSV
50	*TD = 40 ft*	ND	ND									*TD = 40 ft*
60		NS	ND									
70		*TD = 60 ft*	NS									
80			NS									
			TD = 80 ft									

Table 4.14 (continued)

Thorium-230 (pCi/g)

Sample depth	004-030	004-040	H227
5	NS	NS	3 ± 0.1 J
6	68.7 ± 1.81	2.06 ± 0.245	NS
25	NS	NS	NS
40	NS	*TD = 25 ft*	BSV
80	NS		*TD = 40 ft*
	TD = 80 ft		

Thorium-234 (pCi/g)

Sample depth	004-009	004-020	004-022	004-025	004-033	004-035	004-038	004-039	004-040	004-046	004-047	004-056
3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	107 ± 33
4	NS	3.24 ± 0.594	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
5	NS	NS	NS	NS	NS	158 ± 45	13.5 ± 1.02	NS	NS	NS	NS	NS
6	19 ± 11	NS	NS	NS	70 ± 12	NS	NS	79 ± 34	80.2 ± 2.22	107 ± 1.98	49 ± 34	ND
9	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND
10	NS	NS	NS	NS	NS	ND	ND	NS	NS	NS	NS	NS
11	NS	NS	ND	4.47 ± 2.07	NS	NS	NS	NS	ND	NS	ND	NS
15	NS	NS	NS	NS	NS	ND	NS	ND	ND	ND	ND	ND
16	ND	NS	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS
18	NS	NS	ND	NS	NS	NS	NS	NS	NS	NS	NS	NS
21	NS	NS	NS	NS	NS	NS	NS	NS	ND	NS	ND	ND
22	NS	NS	NS	1.62 ± 0.258	NS	ND	ND	NS	NS	NS	NS	NS
23	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
24	NS	NS	NS	NS	NS	*TD = 23 ft*	NS	NS	NS	NS	ND	ND
25	ND	ND	NS	NS	ND		NS	ND	ND	ND	*TD = 24 ft*	*TD = 24 ft*
28	NS	NS	NS	NS	NS		*TD = 25 ft*	NS	*TD = 25 ft*	*TD = 25 ft*		
30	NS	NS	NS	NS	*TD = 28 ft*			NS				
33	NS	NS	ND	ND				NS				
35	NS	NS	NS	NS				ND				
36	NS	NS	NS	NS				NS				
39	ND	NS	NS	NS				*TD = 36 ft*				
40	NS	NS	NS	NS								
43	*TD = 40 ft*	ND	0.939 ± 0.252	1.26 ± 0.36								
45		NS	NS	NS								
50		ND	ND	ND								
60		ND	NS	ND								
		TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*								

Table 4.14 (continued)

Total uranium (pCi/g)

Sample depth	004-009	004-020	004-025	004-027	004-030	004-031	004-033	004-035	004-038	004-040	004-046	004-048	004-056
3	NS	NS	NS	NS	NS	51.7 ± 10.2	NS	NS	NS	NS	NS	NS	84.5 ± 15.5
4	NS	6.66 ± 3.65	NS	NS	NS	*TD = 3 ft*	NS	NS	NS	NS	NS	NS	NS
5	NS	NS	NS	NS	NS		NS	114 ± 20.1	23.8 ± 6.35	NS	NS	NS	NS
6	23.2 ± 5.96	NS	NS	NS	6260 ± 1040		57.3 ± 11.3	NS	NS	165 ± 30.5	183 ± 32	118 ± 21	NS
11	NS	NS	8.64 ± 6.36	NS	NS		NS	NS	NS	NS	NS	NS	NS
18	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS
22	NS	NS	ND	NS	NS		NS	NS	NS	NS	NS	NS	NS
23	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS
24	NS	NS	NS	NS	NS		NS	*TD = 23 ft*	NS	NS	NS	*TD = 23 ft*	NS
25	NS	NS	NS	NS	NS		NS		NS	NS	NS		*TD = 24 ft*
28	NS	NS	NS	NS	NS		NS		*TD = 25 ft*	*TD = 25 ft*	*TD = 25 ft*		
33	NS	NS	ND	2.33 ± 1.66	NS		*TD = 28 ft*						
40	NS	NS	NS	NS	NS								
43	*TD = 40 ft*	NS	ND	ND	NS								
50		NS	ND	ND	NS								
60		NS	ND	ND	NS								
80		*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	NS								
					TD = 80 ft								

Uranium-234 (pCi/g)

Sample depth	004-009	004-020	004-025	004-031	004-033	004-035	004-038	004-040	004-046	004-048	004-056	H214	H227
3	NS	NS	NS	14.5 ± 2.85	NS	NS	NS	NS	NS	NS	26.4 ± 4.86	NS	NS
4	NS	2.68 ± 1.47	NS	*TD = 3 ft*	NS	NS	NS	NS	NS	NS	NS	NS	NS
5	NS	NS	NS		NS	36.5 ± 6.45	8.18 ± 2.19	NS	NS	NS	NS	20 ± 1 J	19 ± 1 R
6	7.68 ± 1.97	NS	NS		12.7 ± 2.51	NS	NS	69 ± 12.7	53.4 ± 9.33	47.9 ± 8.48	NS	NS	NS
11	NS	NS	3.06 ± 2.26		NS	NS	NS	NS	NS	NS	NS	NS	NS
23	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS
24	NS	NS	NS		NS	*TD = 23 ft*	NS	NS	NS	*TD = 23 ft*	NS	NS	NS
25	NS	NS	BSV		NS		NS	NS	NS		*TD = 24 ft*	NS	NS
28	NS	NS	NS		*TD = 28 ft*		*TD = 25 ft*	*TD = 25 ft*	*TD = 25 ft*			NS	NS
33	NS	NS	BSV									NS	NS
40	NS	NS	NS									NS	BSV
43	*TD = 40 ft*	NS	BSV									*TD = 40 ft*	*TD = 40 ft*
50		NS	ND										
60		NS	ND										
		TD = 60 ft	*TD = 60 ft*										

Table 4.14 (continued)

Uranium-235 (pCi/g)

Sample depth	004-009	004-020	004-022	004-025	004-026	004-027	004-031	004-033	004-035	004-038	004-040	004-046	004-048	004-056	H214	H227
3	NS	NS	NS	NS	NS	NS	0.45 ± 0.04	NS	NS	NS	NS	NS	NS	0.458	NS	NS
4	NS	0.58 ± 0.13	NS	NS	NS	NS	*TD = 3 ft*	ND	NS	NS	NS	NS	NS	NS	NS	NS
5	NS	NS	NS	NS	NS	NS		NS	0.45 ± 0.04	0.48 ± 0.04	NS	NS	NS	NS	2.1 ± 0.1	0.86 ± 0.23 R
6	0.46 ± 0.04	NS	NS	NS	NS	NS		0.33 ± 0.03	NS	NS	0.61 ± 0.05	0.41 ± 0.03	0.636	ND	NS	NS
9	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	ND	NS	NS
10	NS	NS	NS	NS	NS	NS		NS	ND	ND	NS	NS	NS	NS	NS	NS
11	NS	NS	0.56 ± 0.38	0.5 ± 0.15	ND	NS		ND	NS	NS	ND	NS	NS	NS	NS	NS
15	NS	NS	NS	NS	NS	NS		NS	ND	NS	ND	ND	ND	ND	NS	NS
16	ND	NS	NS	NS	NS	NS		ND	NS	NS	NS	NS	NS	NS	NS	NS
18	NS	NS	0.825	NS	ND	NS		ND	NS	NS	NS	NS	NS	NS	NS	NS
21	NS	NS	NS	NS	NS	NS		NS	NS	NS	ND	NS	NS	ND	NS	NS
22	NS	NS	NS	0.63 ± 0.43	NS	NS		NS	ND	ND	NS	NS	NS	NS	NS	NS
23	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	ND	NS	NS	NS
24	NS	NS	NS	NS	NS	NS		NS	*TD = 23 ft*	NS	NS	NS	*TD = 23 ft*	ND	NS	NS
25	ND	ND	NS	NS	NS	NS		ND		NS	ND	ND		*TD = 24 ft*	NS	NS
28	NS	NS	NS	NS	NS	NS		NS		*TD = 25 ft*	*TD = 25 ft*	*TD = 25 ft*			NS	NS
30	NS	NS	NS	NS	NS	NS		*TD = 28 ft*							NS	NS
33	NS	NS	1.06 ± 0.72	0.645	0.717	1.99 ± 0									NS	NS
39	ND	NS	NS	NS	NS	NS									NS	NS
40	NS	NS	NS	NS	NS	NS									NS	BSV
43	*TD = 40 ft*	ND	0.74	0.632	ND	0.573									*TD = 40 ft*	*TD = 40 ft*
45		NS	NS	NS	NS	NS										
50		ND	ND	0.72 ± 0.49	ND	0.728										
60		ND	NS	ND	NS	ND										
		TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*										

Uranium-238 (pCi/g)

Sample depth	004-009	004-020	004-025	004-031	004-033	004-035	004-038	004-040	004-046	004-048	004-056	H214	H227
3	NS	NS	NS	36.3 ± 2.78	NS	NS	NS	NS	NS	NS	56.5 ± 3.58	NS	NS
4	NS	3.84 ± 0.666	NS	*TD = 3 ft*	NS	NS	NS	NS	NS	NS	NS	NS	NS
5	NS	NS	NS		NS	75 ± 3.24	15.1 ± 2.5	NS	NS	NS	NS	68 ± 1	38 ± 1 R
6	15.1 ± 2.41	NS	NS		43.7 ± 3.34	NS	NS	92.7 ± 6.25	126 ± 5.76	67.8 ± 3.44	NS	NS	NS
11	NS	NS	5.41 ± 1.93		NS	NS	NS	NS	NS	NS	NS	NS	NS
22	NS	NS	ND		NS	NS	NS	NS	NS	NS	NS	NS	NS
23	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS
24	NS	NS	NS		NS	*TD = 23 ft*	NS	NS	NS	*TD = 23 ft*	NS	NS	NS
25	NS	NS	NS		NS		NS	NS	NS		*TD = 24 ft*	NS	NS
28	NS	NS	NS		NS		*TD = 25 ft*	*TD = 25 ft*	*TD = 25 ft*			NS	NS
33	NS	NS	ND		*TD = 28 ft*							NS	NS
40	NS	NS	NS									NS	BSV
43	*TD = 40 ft*	NS	ND									*TD = 40 ft*	*TD = 40 ft*
50		NS	ND										
60		NS	ND										
		TD = 60 ft	*TD = 60 ft*										

Notes:

BSV = Below screening value
ND = Below detection limit
NS = Not sampled
TD = Total depth

Laboratory qualifiers

A = Indicates that a tentatively identified compound is suspected aldol-condensation product
J = Estimated
R = QC indicates that data are not usable. Resampling and reanalysis are necessary for verification
X = Other specific flags may be required to properly define the results

Table 4.15. Volatile organic analyte analyses of groundwater at SWMU 4

Trichloroethene (TCE) (µg/L)

Sample depth	004-008	004-009	004-017	004-019	004-020	004-022	004-023	004-024	004-026	004-027	004-028	004-029	004-033	004-035	004-036	004-038	004-040	004-047	004-049	004-058	DG-030
19	14	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
21	*TD = 19 ft*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	320	NS	NS
23		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	3300	NS	NS	NS	NS	*TD = 21 ft*	NS	NS
24		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*TD = 23 ft*	NS	NS	NS	18		NS	NS
25		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		350	90	730	*TD = 24 ft*		NS	NS
26		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	23,000		*TD = 25 ft*	*TD = 25 ft*	*TD = 25 ft*			NS	NS
28		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS							NS	NS
40		19,000	260	NS	NS	NS	NS	NS	NS	NS	NS	NS	*TD = 28 ft*							NS	NS
48		*TD = 40 ft*	NS	NS	NS	NS	NS	NS	NS	NS	ND	2200								NS	6
52			NS	NS	NS	NS	NS	48,000	NS	NS	NS	NS								NS	NS
60			NS	16	1700	35,000	46	9100	650 DX	67,000 DX	NS	NS								NS	NS
63			*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	63	1400								NS	NS
68											1000	3800								ND	1600
73											1500	2100								6	1500
78											2100	400								18	2500 XY
83											3700	69								42	1400
88											2000	54								80	1000
93											2100	110								27 J	4500
98											180	180								ND	10,000
103											190	60								NS	3700
108											10.3	8.2								NS	1300
113											ND	ND								NS	37
118											ND	ND								NS	BSV
158											ND	NS								ND	NS
											TD = 158 ft	*TD = 158 ft*								*TD = 158 ft*	*TD = 158 ft*

2-Butanone (µg/L)

Sample depth	004-008
19	31
	TD = 19 ft

Chloroethane (µg/L)

Sample depth	004-026
60	19
	TD = 60 ft

cis-1,2-Dichloroethene (µg/L)

Sample depth	004-009	004-022	004-024	004-026	004-027	004-028	004-029	004-033	004-035	004-040	004-047	004-049	DG-030
21	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	120	NS
23	NS	NS	NS	NS	NS	NS	NS	NS	1500	NS	NS	*TD = 21 ft*	NS
24	NS	NS	NS	NS	NS	NS	NS	NS	*TD = 23 ft*	NS	100		NS
25	NS	NS	NS	NS	NS	NS	NS	NS		190	*TD = 24 ft*		NS
26	NS	NS	NS	NS	NS	NS	NS	960		*TD = 25 ft*			NS
28	NS	NS	NS	NS	NS	NS	NS	NS					NS
40	11,000	NS	NS	NS	NS	NS	NS	*TD = 28 ft*					NS
48	*TD = 40 ft*	NS	NS	NS	NS	ND	130						ND
52		NS	9000	NS	NS	NS	NS						NS
60		11,000	810	560 DX	900 EX	NS	NS						NS
63		*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	BSV	81						NS
68						BSV	150						BSV
73						BSV	140						80
78						85	BSV						130 E
83						110	BSV						BSV
88						100	ND						BSV
93						170	ND						100
98						BSV	BSV						200
103						BSV	BSV						150
108						ND	ND						75
113						ND	ND						ND
118						ND	ND						ND
158						ND	NS						NS
						TD = 158 ft	*TD = 158 ft*						*TD = 158 ft*

Table 4.15 (continued)

1,1-Dichloroethene (µg/L)

Sample depth	004-024	004-028	004-029	004-033	004-035	DG-030
23	NS	NS	NS	NS	7.2	NS
26	NS	NS	NS	50	*TD = 23 ft*	NS
28	NS	NS	NS	NS		NS
48	NS	ND	81	*TD = 28 ft*		ND
52	340	NS	NS			NS
60	ND	NS	NS			NS
68	*TD = 60 ft*	ND	11			15
73		ND	9.7			8.1
78		ND	BSV			8.8
83		12	ND			18
88		21	ND			12
93		21	ND			41
98		BSV	BSV			42
103		BSV	BSV			35
108		ND	ND			BSV
113		ND	ND			ND
118		ND	ND			ND
158		ND	NS			NS
		TD = 158 ft	*TD = 158 ft*			*TD = 158 ft*

Vinyl chloride (µg/L)

Sample depth	004-024	004-026	004-027	004-029	004-033	004-035	004-036	004-047	004-049	DG-030
21	NS	NS	NS	NS	NS	NS	NS	NS	290	NS
23	NS	NS	NS	NS	NS	340	NS	NS	*TD = 21 ft*	NS
24	NS	NS	NS	NS	NS	*TD = 23 ft*	NS	120		NS
25	NS	NS	NS	NS	NS		3.3	*TD = 24 ft*		NS
26	NS	NS	NS	NS	71		*TD = 25 ft*			NS
28	NS	NS	NS	NS	NS					NS
48	NS	NS	NS	12	*TD = 28 ft*					ND
52	400	NS	NS	NS						NS
60	ND	440 DX	30	NS						NS
68	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	2.2						ND
98				ND						3.3
103				ND						BSV
108				ND						ND
113				ND						ND
118				ND						ND
158				NS						NS
				TD = 158 ft						*TD = 158 ft*

Carbon tetrachloride (µg/L)

Sample depth	004-027	004-028	DG-030
60	360 EX	NS	NS
78	*TD = 60 ft*	13	61
83		NS	NS
88		NS	NS
93		NS	NS
98		NS	NS
103		NS	NS
108		NS	NS
113		NS	NS
118		NS	NS
158		NS	NS
		TD = 158 ft	*TD = 158 ft*

Methylene chloride (µg/L)

Sample depth	004-027	DG-030
60	250 EX	NS
78	*TD = 60 ft*	12 J
83		NS
88		NS
93		NS
98		NS
103		NS
108		NS
113		NS
118		NS
158		NS
		TD = 158 ft

Chloroform (µg/L)

Sample depth	004-027	004-028	DG-030
60	1300 EX	NS	NS
78	*TD = 60 ft*	48	55
83		NS	NS
88		NS	NS
93		NS	NS
98		NS	NS
103		NS	NS
108		NS	NS
113		NS	NS
118		NS	NS
158		NS	NS
		TD = 158 ft	*TD = 158 ft*

Table 4.15 (continued)

1,1,2-Trichloroethane (µg/L)

Sample depth	004-027	004-028
60	150 EX	NS
78	*TD = 60 ft*	6
83		NS
88		NS
93		NS
98		NS
103		NS
108		NS
113		NS
118		NS
158		NS
		TD = 158 ft

Acetone (µg/L)

Sample depth	004-026	004-029	004-036	004-040
25	NS	NS	61	110
60	18	NS	*TD = 25 ft*	*TD = 25 ft*
63	*TD = 60 ft*	NS		
68		NS		
73		NS		
78		NS		
83		NS		
88		NS		
93		NS		
98		NS		
103		NS		
108		NS		
113		13 X		
118		NS		
158		NS		
		TD = 158 ft		

Tetrachloroethene (µg/L)

Sample depth	004-027
60	13
	TD = 60 ft

trans-1,2-Dichloroethene (µg/L)

Sample depth	004-024
52	110
60	ND
	TD = 60 ft

Notes:

BSV = Below screening value
ND = Below detection limit
NS = Not sampled
TD = Total depth

Laboratory qualifiers

D = Compounds identified in a reanalysis at a secondary dilution factor
E = Result exceeds calibration range
J = Estimated
X = Other specific flags may be required to properly define the results
Y = MS/MSD recovery and/or RPD failed acceptance criteria

Table 4.16. Semivolatile organic analyte analyses of groundwater at SWMU 4

Bis(2-ethylhexyl)phthalate (μg/L)

Sample depth	004-020
60	7 J

TD = 60 ft

Diethyl phthalate (μg/L)

Sample depth	004-020
40	30

TD = 40 ft

Note:
TD = Total depth

Laboratory qualifier
J = Estimated

Table 4.17. PCBs analyses of groundwater at SWMU 4

PCB-1016/1248/1254/1260 (μg/L)

Sample depth	004-025	004-026
60	0.19[a] 0.2[b] ND[c,d]	0.91 X[b] 0.91[e]X ND[a,c,d]

TD = 60 ft *TD = 60 ft*

Notes:
ND = Below detection limit
TD = Total depth

[a] PCB-1248

[b] PCB-1254

[c] PCB-1260

[d] PCB-1016

[e] Total PCB

Laboratory qualifier
X = Other specific flags may be required to properly define the results

Table 4.18. Inorganic analyses of groundwater at SWMU 4

Aluminum (mg/L)

Sample depth	004-021	004-028
60	0.97	NS
63	*TD = 60 ft*	0.57
68		ND
73		ND
78		ND
83		ND
88		ND
93		ND
98		ND
103		ND
108		ND
113		ND
118		ND
158		ND
		TD = 158 ft

Arsenic (mg/L)

Sample depth	004-021	004-022	004-023	004-027
60	0.311 W	0.052	0.203 W	0.086 N
	TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*

Beryllium (mg/L)

Sample depth	004-028
48	ND
63	0.016 B
68	ND
73	ND
78	ND
83	ND
88	ND
93	ND
98	ND
103	ND
108	ND
113	ND
118	ND
158	ND
	TD = 158 ft

Cadmium (mg/L)

Sample depth	004-021
60	0.012
	TD = 60 ft

Cobalt (mg/L)

Sample depth	004-020	004-021	004-022	004-023	004-024	004-026	004-027	004-028	004-029	004-037	004-038	004-058	DG-030
25	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.012	NS	NS
45	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.019	*TD = 25 ft*	NS	NS
48	NS	NS	NS	NS	NS	NS	NS	0.028	0.041	*TD = 45 ft*		NS	ND
60	0.058	0.015	0.027	0.04	0.054	0.058	0.052	NS	NS			NS	NS
63	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	0.088	0.016			NS	NS
68								0.014	0.031			0.024	0.014
73								ND	0.012			ND	0.043
78								0.013	0.015			0.013	0.02
83								ND	0.012			0.012	0.042
88								0.028	0.015			ND	0.066
93								0.012	0.026			ND	0.022
98								0.03	0.022			ND	ND
103								0.022	0.025			NS	0.028
108								ND	ND			NS	0.03
113								ND	ND			NS	ND
118								ND	0.016			NS	ND
158								ND	NS			NS	NS
								TD = 158 ft	*TD = 158 ft*			*TD = 158 ft*	*TD = 158 ft*

Iron (mg/L)

Sample depth	004-020	004-021	004-022	004-024	004-026	004-027	004-028	004-029	004-037	004-058	DG-030
45	NS	NS	NS	NS	NS	NS	NS	NS	1.74	NS	NS
60	0.694	11.5	4.75	0.224	7.35 N	26.7 N	NS	NS	*TD = 45 ft*	NS	NS
68	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	0.559 B	0.224 B		0.574 B	ND
73							0.394 B	ND		0.315 B	0.246
78							0.665	1.38		1.86	1.69
83							1.18	1.16		ND	ND
88							ND	ND		1.3	5.16
93							1.1	0.93		ND	ND
98							ND	0.313		3.01 B	0.776 B
103							1.62	0.224 B		NS	0.697 B
108							1.11	ND		NS	ND
113							0.583 B	ND		NS	3.37
118							ND	0.273 B		NS	ND
158							0.24 B	NS		NS	NS
							TD = 158 ft	*TD = 158 ft*		*TD = 158 ft*	*TD = 158 ft*

Table 4.18 (continued)

Manganese (mg/L)

Sample depth	004-020	004-021	004-022	004-023	004-024	004-026	004-027	004-028	004-029	004-037	004-038	004-058	DG-030
25	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	4.47	NS	NS
45	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.819	NS	NS	NS
48	NS	NS	NS	NS	NS	NS	NS	1.06	2.24	*TD = 45 ft*	*TD = 45 ft*	NS	0.414
60	1.17	0.737 N	8.66	1.72 N	2.24 N	8.28 N	3.25 N	NS	NS			NS	NS
63	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	3.08	0.927			NS	NS
68								0.829	0.654			2.72	3.4
73								0.378	1.05			0.632	1.75
78								2.03	0.578			0.582	0.816
83								0.462	0.447			3.33	1.27
88								4.58	0.6			1.8	1.87
93								0.451	0.64			1.08	0.742
98								0.939	0.933			0.935	0.187
103								0.591	1.19			NS	0.647
108								0.174	0.655			NS	0.802
113								0.913	0.682			NS	1.25
118								0.698	2.77			NS	0.92
158								0.33	NS			NS	NS
								TD = 158 ft	*TD = 158 ft*			*TD = 158 ft*	*TD = 158 ft*

Strontium (mg/L)

Sample depth	DG-030
48	ND
63	NS
68	ND
73	ND
78	ND
83	ND
88	0.074
93	0.051
98	0.052
103	ND
108	ND
113	0.111
118	0.156
158	NS
	TD = 158 ft

Zinc (mg/L)

Sample depth	004-021	004-022	004-026	004-027	004-028
60	1.63	0.635	0.222	0.23	NS
63	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	0.202 N
68					ND
73					ND
78					ND
83					ND
88					ND
93					ND
98					ND
103					ND
108					ND
113					ND
118					ND
158					ND
					TD = 158 ft

Notes:
ND = Below detection limit
NS = Not sampled
TD = Total depth

Laboratory qualifiers
B = Found in the blank
N = Sample spike recovery not within control limits
W = Post-digestion spike recovery out of control limits

Table 4.19. Alpha activities in groundwater at SWMU 4

Alpha activity (pCi/L)

Sample depth	004-008	004-020	004-022	004-025	004-029	004-033	004-035	004-036	004-038	004-039	004-040	004-047
19	5,270 ± 45	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
23	*TD = 19 ft*	NS	NS	NS	NS	NS	161 ± 14	NS	NS	NS	NS	NS
24		NS	NS	NS	NS	NS	*TD = 23 ft*	NS	NS	NS	NS	15.6 ± 8.6
25		NS	NS	NS	NS	NS		19.2 ± 6	42 ± 11	NS	39 ± 9.2	*TD = 24 ft*
26		NS	NS	NS	NS	940 ± 42		*TD = 25 ft*	*TD = 25 ft*	NS	*TD = 25 ft*	
28		NS	NS	NS	NS	NS				NS		
36		NS	NS	NS	NS	*TD = 28 ft*				18.6 ± 3.8		
48		NS	NS	NS	15.7 ± 6.1					*TD = 36 ft*		
60		27.71 ± 5.24	39.01 ± 11.05	125.1 ± 24.07	NS							
63		*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	15.4 ± 5.1							
68					BSV							
73					BSV							
78					ND							
83					BSV							
88					BSV							
93					BSV							
98					BSV							
103					BSV							
108					ND							
113					BSV							
118					BSV							
158					NS							
					TD = 158 ft							

Notes:
BSV = Below screening value
ND = Below detection limit
NS = Not sampled
TD = Total depth

Table 4.20. Beta activities in groundwater at SWMU 4

Beta activity (pCi/L)

Sample depth	004-011	004-017	004-020	004-022	004-023	004-024	004-025	004-026	004-027	004-028	004-029	004-033	004-036	004-037	004-038	004-039	004-040	004-044	004-058	DG-030
19	1,490 ± 55	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
25	*TD = 19 ft*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	223 ± 5.7	NS	23.6 ± 6.4	NS	13.2 ± 4.8	NS	NS	NS
26		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	594 ± 17	*TD = 25 ft*	NS	*TD = 25 ft*	NS	*TD = 25 ft*	NS	NS	NS
28		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS		NS		NS	NS	NS
36		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*TD = 28 ft*		NS		6.7 ± 1.7		NS	NS	NS
40		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS			NS		*TD = 36 ft*		62.8 ± 3.1	NS	NS
45		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS			84.4 ± 3.6				*TD = 40 ft*	NS	NS
48		NS	NS	NS	NS	NS	NS	NS	NS	ND	213 ± 6			*TD = 45 ft*					NS	3.2 ± 1.4
52		NS	NS	NS	NS	8.7 ± 5	NS	NS	NS	NS	NS								NS	NS
60		450 ± 5.9	318.33 ± 15.31	44.19 ± 7.34	5.4 ± 2.1	113 ± 4.4	119.96 ± 13.76	33.43 ± 5.78	14.3 ± 2.82	NS	NS								NS	NS
63		*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	59.8 ± 3.4	398 ± 7.9								NS	NS
68										90.5 ± 3.8	396 ± 7.9								ND	84.7 ± 3.6
73										105 ± 4.2	210 ± 5.8								ND	178 ± 4.9
78										101 ± 4.1	41.1 ± 2.8								4.1 ± 1.7	204 ± 5.3
83										91.9 ± 3.9	7.7 ± 1.9								28.7 ± 2.5	93.63 ± 6.98
88										27.9 ± 2.6	6.1 ± 1.8								98 ± 4.1	7 ± 1.6
93										17.1 ± 2.1	4.8 ± 1.6								91.3 ± 4	17.8 ± 2
98										7.5 ± 1.8	3.9 ± 1.5								4.7 ± 1.6	18.6 ± 2
103										5.2 ± 1.7	3.4 ± 1.6								NS	14.1 ± 1.9
108										3.5 ± 1.7	12.73 ± 2.06								NS	5.7 ± 1.5
113										3.9 ± 1.5	4.2 ± 1.6								NS	3.9 ± 1.5
118										6.9 ± 1.8	4.2 ± 1.6								NS	12.2 ± 1.8
158										6.3 ± 1.7	NS								24.7 ± 5.4	NS
										TD = 158 ft	*TD = 158 ft*								*TD = 158 ft*	*TD = 158 ft*

Notes:
ND = Below detection limit
NS = Not sampled
TD = Total depth

Table 4.21. Radioisotopic analyses of groundwater at SWMU 4

Technetium-99 (pCi/L)

Sample depth	004-008	004-011	004-017	004-020	004-023	004-024	004-028	004-029	004-033	004-035	004-036	004-037	004-038	004-039	004-040	004-044	004-058	DG-030
19	1640 ± 37	25 ± 9.5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
23	*TD = 19 ft*	*TD = 19 ft*	NS	NS	NS	NS	NS	NS	NS	44 ± 11	NS	NS	NS	NS	NS	NS	NS	NS
25			NS	NS	NS	NS	NS	NS	NS	*TD = 23 ft*	390 ± 21	NS	23.6 ± 9.2	NS	23 ± 9.6	NS	NS	NS
26			NS	NS	NS	NS	NS	NS	1240 ± 33		*TD = 25 ft*	NS	*TD = 25 ft*	NS	*TD = 25 ft*	NS	NS	NS
28			NS	NS	NS	NS	NS	NS	NS			NS		NS		NS	NS	NS
36			NS	NS	NS	NS	NS	NS	*TD = 28 ft*			NS		44 ± 9.9		NS	NS	NS
40			NS	NS	NS	NS	NS	NS				NS		*TD = 36 ft*		120 ± 12	NS	NS
45			NS	NS	NS	NS	NS	NS				194 ± 12				*TD = 40 ft*	NS	NS
48			NS	NS	NS	NS	ND	382 ± 18				*TD = 45 ft*					NS	ND
60			720 ± 18	375 ± 18	16.3 ± 8.7	157 ± 13	NS	NS									NS	NS
63			*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	106 ± 12	607 ± 21									NS	NS
68							133 ± 13	635 ± 21									ND	150 ± 11
73							165 ± 13	346 ± 17									ND	254 ± 13
78							171 ± 14	52 ± 9.6									18.1 ± 8.7	274 ± 14
83							146 ± 13	18.4 ± 8.5									48 ± 9.9	121 ± 11
88							52 ± 10	ND									152 ± 13	16 ± 7.8
93							28 ± 9.7	ND									133 ± 13	28.9 ± 8.2
98							ND	ND									ND	39 ± 8.5
103							ND	ND									NS	21.7 ± 6.6
108							ND	ND									NS	14.8 ± 6.4
113							ND	ND									NS	11.9 ± 6.3
118							ND	ND									NS	27.9 ± 7.8
158							ND	NS									37 ± 10	NS
							TD = 158 ft	*TD = 158 ft*									*TD = 158 ft*	*TD = 158 ft*

Uranium-235 (wt %)

Sample depth	004-025	004-027	004-028	004-035
23	NS	NS	NS	0.411
60	0.586	0.603	NS	*TD = 23 ft*
63	*TD = 60 ft*	*TD = 60 ft*	0.524	
68			0.581	
73			ND	
78			ND	
83			ND	
88			NS	
93			NS	
98			NS	
103			NS	
108			NS	
113			NS	
118			NS	
158			NS	
			TD = 158 ft	

Notes:
ND = Below detection limit
NS = Not sampled
TD = Total depth

Table 4.22. Comparison of filtered and unfiltered groundwater samples in SWMU 4

Analyte	Not filtered			0.45 Micron			5 Micron		
(mg/L)	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Aluminum	213.11	1.86	1270	0.58	0.2	0.97	1.06	0.2	8.09
Antimony	1.10	0.2	2	0.20	0.2	0.2			
Arsenic	0.05	0.005	0.254	0.06	0.005	0.311	0.06	0.005	0.282
Barium	1.89	0.075	13.6	0.19	0.05	1.67	0.16	0.05	0.624
Beryllium	0.06	0.005	0.15	0.01	0.005	0.016	0.01	0.005	0.01
Cadmium	0.04	0.01	0.101	0.01	0.01	0.012	0.01	0.01	0.011
Calcium	61.40	12.1	226	33.63	10	198	27.54	8.87	130
Chromium	1.04	0.05	5.11	0.05	0.05	0.05	0.05	0.05	0.05
Cobalt	0.36	0.01	3.58	0.03	0.01	0.088	0.03	0.01	0.056
Copper	0.54	0.05	1.55	0.07	0.05	0.089	0.05	0.05	0.05
Iron	657.37	11.5	2560	2.74	0.2	26.7	2.00	0.2	26.8
Lead	0.74	0.2	2.15	0.20	0.2	0.2	0.20	0.2	0.2
Magnesium	32.04	6.01	149	11.69	3.95	64.4	10.53	3.05	34
Manganese	11.62	0.325	118	1.79	0.174	8.66	1.69	0.065	9.24
Mercury	0.00	0.0002	0.0082	0.00	0.0002	0.0002	0.00	0.0002	0.0002
Nickel	0.36	0.05	1.26	0.05	0.05	0.05	0.05	0.05	0.057
Potassium	22.67	2	90.8	2.71	2	4.09	2.84	2	4.59
Selenium	0.01	0.005	0.015	0.01	0.005	0.005	0.01	0.005	0.005
Silver	0.28	0.05	0.5	0.05	0.05	0.05			
Sodium	37.29	10.1	312	36.72	12.4	247	37.10	11.6	213
Thallium	1.10	0.2	2	0.20	0.2	0.2			
Vanadium	1.74	0.1	6.94	0.08	0.05	0.1	0.08	0.05	0.1
Zinc	2.22	0.2	9.67	0.48	0.2	1.63	0.31	0.2	0.635

Table 4.23. Maximum detected concentrations for soil at SWMU 5, historic locations

Analyte	Frequency of detects	Maximum result	Units	Station	Depth
Volatile organic compounds					
Acetone	6/22	200	µg/kg	H002	18–24
Methylene chloride	2/22	54 B	µg/kg	MW 190	5–10
Toluene	1/22	7	µg/kg	H002	36–42
Trichloroethene	2/22	9	µg/kg	H002	36–42
Semivolatile organic compounds					
Acenaphthene	1/22	160 J	µg/kg	MW 190	5–10
Anthracene	1/22	240 J	µg/kg	MW 190	5–10
Benzo(a)anthracene	1/22	430	µg/kg	MW 190	5–10
Benzo(a)pyrene	1/22	410 J	µg/kg	MW 190	5–10
Benzo(b)fluoranthene	1/22	540	µg/kg	MW 190	5–10
Benzo(g,h,i)perylene	1/22	260 J	µg/kg	MW 190	5–10
Benzo(k)fluoranthene	1/22	180 J	µg/kg	MW 190	5–10
bis(2-ethylhexyl)phthalate	10/22	1600	µg/kg	H002	0–6
Dibenzo(a,h)anthracene	1/22	56 J	µg/kg	MW 190	5–10
Dibenzofuran	1/22	84 J	µg/kg	MW 190	5–10
Di-n-octylphthalate	1/22	140 J	µg/kg	H002	42–48
Diethylphthalate	1/22	770	µg/kg	H002	63–47
Fluoranthene	1/22	1200	µg/kg	MW 190	5–10
Fluorene	1/22	140 J	µg/kg	MW 190	5–10
Indeno(1,2,3-cd)pyrene	1/22	270 J	µg/kg	MW 190	5–10
Phenanthrene	1/22	1100	µg/kg	MW 190	5–10
Pyrene	1/22	900	µg/kg	MW 190	5–10
Metals					
Aluminum	16/22	12400 *	mg/kg	H002	0–6
Arsenic	16/22	4.4 NJ	mg/kg	H002/MW190	0–6/5–10
Barium	16/22	202	mg/kg	MW 190	5–10
Beryllium	11/22	1.4	mg/kg	H002	42–48
Cadmium	5/22	2.3	mg/kg	H002	24–30
Calcium	16/22	3720	mg/kg	H002	0–6
Chromium	16/22	161 *	mg/kg	H002	63–67
Cobalt	14/22	19.2	mg/kg	H002	42–48
Copper	16/22	37.1*	mg/kg	MW 190	12–20
Iron	16/22	23100	mg/kg	H002	53–67
Lead	16/22	16.1 N*	mg/kg	MW 190	5–10
Magnesium	16/22	1720	mg/kg	H002	0–6
Manganese	16/22	1120	mg/kg	MW 190	5–10
Mercury	2/22	0.062 B	mg/kg	MW 190	15–20
Potassium	9/22	755.6	mg/kg	H002	42–48
Silver	2/22	2.5	mg/kg	H002	40–43
Sodium	11/22	383 B	mg/kg	MW 190	5–10
Thallium	2/22	0.25 BWJ	mg/kg	H002	56–62
Vanadium	16/22	37.6	mg/kg	H002	24–30
Zinc	14/22	43.2	mg/kg	H002	0–6

Table 4.23 (continued)

Analyte	Frequency of detects	Maximum result	Units	Station	Depth
		Radionuclides			
Plutonium-239	2/2	0.017	pCi/g	H264	0–1
Technetium-99	1/2	7.7	pCi/g	H264	0–1
Thorium-230	2/2	0.76	pCi/g	H264	0–1
Uranium-234	2/2	2.9	pCi/g	H264	0–1
Uranium-235	2/2	0.0582	pCi/g	H264	0–1
Uranium-238	2/2	6.5	pCi/g	H264	0–1

B – ORG: Found in blank associated with sample; INORG: Value < required detection limit, ≥ IDL.
N – ORG: TICs identified; INORG: Spike recovery (SR) not within control limits; RAD: poor SR.
W – INORG: Post-digestion spike for AA out of control limit.
* – Duplicate analysis not within control limits.
J – ORG: Estimated value (i.e., TIC or result < specified PQL but > 0).

Table 4.24. Maximum detected concentrations for groundwater at SWMU 5, historic locations

Analyte/unit	RGA Frequency of detects	RGA Maximum results	RGA Station	UCRS Frequency of detects	UCRS Maximum results	UCRS Station
Volatile organic compounds						
1,2-Dichloroethane (μg/L)	1/7	3 J	MW 53	–	–	–
2-Butanone (μg/L)	1/6	8 J	MW 53	–	–	–
Carbon disulfide (μg/L)	1/6	2 J	MW 54	–	–	–
Toluene (μg/L)	1/36	3 J	MW 53	–	–	–
Trichloroethene (μg/L)	13/45	2	MW 54	3/8	6	MW 190
Semivolatile organic compounds						
bis(2-Ethylhexyl)phthalate (μg/L)	2/7	63	MW 53	1/1	31	MW 190
Other						
Nitrate as nitrogen (mg/L)	3/33	9.9	MW 54	1/2	1.7	MW 190
Oil and grease (mg/L)	1/1	2.6	MW 52	–	–	–
Sulfate (mg/L)	33/35	22.8	MW 52	2/2	8	MW 190
Sulfide (mg/L)	2/5	9.6	MW 52	–	–	–
Total petroleum hydrocarbons (μg/L)	12/29	800	MW 52	–	–	–
Inorganics						
Aluminum (mg/L)	5/6	0.899	MW 53	3/3	8.08	MW 190
Antimony (mg/L)	2/6	0.0191 B	MW 54	1/3	0.0173 B	MW 190
Arsenic (mg/L)	3/5	0.0041 B	MW 52	1/3	0.0079 B	MW 190
Barium (mg/L)	6/6	0.08649 B	MW 53	3/3	0.249	MW 190
Beryllium (mg/L)	1/6	0.002 B	MW 53	1/3	0.0003 B	MW 190
Calcium (mg/L)	14/14	43.5 BJ	MW 53	3/3	41.4	MW 190
Chloride (mg/L)	11/11	12	MW 52	2/2	206	MW 190
Chromium (mg/L)	6/36	0.016	MW 54	1/3	0.0829	MW 190
Cobalt (mg/L)	1/6	0.0038 B	MW 54	1/3	0.0044 B	MW 190
Copper (mg/L)	8/35	0.0392 *	MW 53	1/3	0.0133 B	MW 190
Fluoride (mg/L)	22/30	0.22	MW 54	2/2	0.16	MW 190
Iron (mg/L)	50/50	61.2 J	MW 53	3/3	6.66	MW 190
Lead (mg/L)	8/50	0.0263 NJ	MW 54	1/1	0.0061	MW 190
Magnesium (mg/L)	14/14	9.83	MW 54	3/3	21.5	MW 190
Manganese (mg/L)	22/22	0.789 NJ	MW 52	3/3	0.428	MW 190
Nickel (mg/L)	1/36	0.0348 B	MW 52	1/3	0.043	MW 190
Potassium (mg/L)	4/8	2.76 B	MW 53	1/3	0.988 B	MW 190
Selenium (mg/L)	2/21	0.476	MW 53	–	–	–
Sodium (mg/L)	19/19	20.3 BJ	MW 53	3/3	156 E	MW 190
Uranium (mg/L)	2/31	0.001	MW 52/ MW 54	–	–	–
Vanadium (mg/L)	3/6	0.0109 B	MW 52	3/3	0.188	MW 190
Zinc (mg/L)	31/36	0.176 J	MW 53	3/3	0.0467 E	MW 190

Table 4.24 (continued)

Analyte/unit	RGA			UCRS		
	Frequency of detects	Maximum results	Station	Frequency of detects	Maximum results	Station
Radionuclides						
Americium-241 (pCi/L)	4/15	3.5	MW 54	–	–	–
Cesium-137 (pCi/L)	4/15	1.4	MW 53	–	–	–
Cobalt-60 (pCi/L)	8/14	2.3	MW 54	–	–	–
Neptunium-237 (pCi/L)	2/2	0.31	MW 53	1/2	0.01	MW 190
Plutonium-239 (pCi/L)	4/4	29	MW 53	2/3	0.17	MW 190
Radon-222 (pCi/L)	1/1	394	MW 53	–	–	–
Radium-226 (pCi/L)	13/16	4	MW 54	–	–	–
Technetium-99 (pCi/L)	28/44	27	MW 52	7/9	22	MW 190
Thorium-230 (pCi/L)	2/2	5.5	MW 53	2/2	0.46	MW 190
Uranium-234 (pCi/L)	2/2	3.3	MW 54	2/2	0.24	MW 190
Uranium-235 (pCi/L)	1/1	0.05	MW 54	2/2	0.02	MW 190
Uranium-238 (pCi/L)	2/2	20	MW 54	2/2	0.45	MW 190

B – ORG: Found in blank associated with sample; INORG: Value < required detection limit, ≥ IDL.
N – ORG: TICs identified; INORG: Spike recovery (SR) not within control limits; RAD: poor SR.
W – INORG: Post-digestion spike for AA out of control limit.
* – Duplicate analysis not within control limits.
J – ORG: Estimated value (i.e., TIC or result < specified PQL but > 0).

Table 4.25. Contamination detected in surface soil at SWMU 5

Chemical type	Analyte	Concentration	Data qualifier
Location 005-008			
PCB	PCB-1260	306 µg/kg	
Radionuclide	Alpha activity	13.6 ± 6.2 pCi/g	
	Beta activity	22.8 ± 4.4 pCi/g	
Location 005-009			
Radionuclide	Alpha activity	15.9 ± 7.2 pCi/g	
	Beta activity	34.4 ± 6.0 pCi/g	
Location 005-010			
SVOA	Di-n-butyl-phthalate	930 µg/kg	*NW
Inorganic/Metal	Aluminum	13,800 mg/kg	
Radionuclide	Alpha activity	18.1 ± 6.9 pCi/g	
	Beta activity	20.0 ± 4.5 pCi/g	
Location 005-015			
VOA	Methylene chloride	35 µg/kg	
SVOA	3-Nitrobenzenamine	9450 µg/kg	*N
	Acenaphthylene	9450 µg/kg	
	Benz(a)anthracene	19000 µg/kg	
	Benzo(a)pyrene	24800 µg/kg	
	Benzo(b)fluoranthene	49200 µg/kg	*N
	Benzo(ghi)perylene	14600 µg/kg	*N
	Benzo(k)fluoranthene	6340 µg/kg	J
	Chrysene	24400 µg/kg	
	Dibenzofuran	3520 µg/kg	*NW
	Fluoranthene	53300 µg/kg	
	Fluorene	9180 µg/kg	
	Indeno(1,2,3-cd)pyrene	14000 µg/kg	
	Naphthalene	753 µg/kg	
	Phenanthrene	34600 µg/kg	
Radionuclide	Alpha activity	17.5 ± 6.4 pCi/g	
	Beta activity	19.9 ± 4.4 pCi/g	
Location 005-016			
SVOA	Benz(a)anthracene	778 µg/kg	
	Benzo(b)fluoranthene	2730 µg/kg	*N
	Benzo(ghi)perylene	619 µg/kg	*NW
	Chrysene	1070 µg/kg	
	Di-n-butyl phthalate	1700 µg/kg	
	Indeno(1,2,3-cd)pyrene	655 µg/kg	
Radionuclide	Beta activity	17.2 ± 5.2 pCi/g	
Location 005-017			
Radionuclide	Alpha activity	15.9 ± 4.9 pCi/g	
	Beta activity	21.7 ± 3.3 pCi/g	
Location H263			
SVOA	Acenaphthene	2100 µg/kg	
	Benz(a)anthracene	4500 µg/kg	
	Benzo(a)pyrene	5000 µg/kg	
	Benzo(b)fluoranthene	4600 µg/kg	
	Benzo(ghi)perylene	4000 µg/kg	

Table 4.25 (continued)

Chemical type	Analyte	Concentration	Data qualifier
	Benzo(k)fluoranthene	3100 µg/kg	
	Chrysene	4700 µg/kg	
	Dibenz(a,h)anthracene	1600 µg/kg	
	Dibenzofuran	830 µg/kg	
	Fluorene	1700 µg/kg	
	Indeno(1,2,3-cd)pyrene	3900 µg/kg	
	Phenanthrene	5500 µg/kg	
	Pyrene	4800 µg/kg	

Laboratory qualifiers
J = Estimated
N = Tentatively identified
W = Laboratory-specific qualifier
* = Laboratory QC criteria not met

Table 4.26. Contamination detected in sediment at SWMU 5

Chemical type	Analyte	Concentration	Data qualifier
Location 005-001			
SVOA	Acenaphthene	3210 µg/kg	
	Benz(a)anthracene	6410 µg/kg	
	Benzo(a)pyrene	10600 µg/kg	
	Benzo(b)fluoranthene	8530 µg/kg	
	Benzo(ghi)perylene	3650 µg/kg	
	Benzo(k)fluoranthene	11700 µg/kg	
	Chrysene	6070 µg/kg	
	Dibenzofuran	1650 µg/kg	J
	Fluoranthene	12100 µg/kg	
	Fluorene	4110 µg/kg	
	Indeno (1,2,3-cd)pyrene	4930 µg/kg	
	Phenanthrene	13500 µg/kg	
	Pyrene	9160 µg/kg	
Radionuclide	Technetium-99	17.3 ± 3.74 pCi/g	
Location 005-002			
SVOA	Benz(a)anthracene	1390 µg/kg	
	Benzo(a)pyrene	2460 µg/kg	
	Benzo(b)fluoranthene	2340 µg/kg	
	Benzo(ghi)perylene	1440 µg/kg	
	Benzo(k)fluoranthene	1910 µg/kg	
	Chrysene	1800 µg/kg	
	Dibenz(a,h)anthracene	749 µg/kg	
	Indeno(1,2,3-cd)pyrene	1550 µg/kg	
	Phenanthrene	1630 µg/kg	
Radionuclide	Alpha activity	31.2 ± 7.9 pCi/g	
	Beta activity	36.4 ± 4.5 pCi/g	
	Technetium-99	4.3 ± 3.08 pCi/g	
Location 005-003			
Radionuclide	Alpha activity	19.2 ± 6.1 pCi/g	W
	Beta activity	19.6 ± 3.6 pCi/g	
Location 005-004			
Radionuclide	Alpha activity	16.8 ± 6.6 pCi/g	W
	Beta activity	29.4 ± 5.2 pCi/g	A
Location 005-005			
Radionuclide	Alpha activity	24.6 ± 8.1 pCi/g	A
	Beta activity	39.9 ± 5.7 pCi/g	
Location 005-006			
SVOA	Benz(a)anthracene	738 µg/kg	
	Benzo(a)pyrene	1610 µg/kg	
	Benzo(b)fluoranthene	1900 µg/kg	
	Benzo(ghi)perylene	780 µg/kg	
	Benzo(k)fluoranthene	1170 µg/kg	
	Chrysene	1060 µg/kg	
	Indeno(1,2,3-cd)pyrene	890 µg/kg	
Inorganic/Metal	Aluminum	13,600 mg/kg	

Table 4.26 (continued)

Chemical type	Analyte	Concentration	Data qualifier
Radionuclide	Alpha activity	19.0 ± 6.8 pCi/g	
	Beta activity	22.9 ± 4.3 pCi/g	
	Technetium-99	5.85 ± 3.26 pCi/g	
Location 005-007			
SVOA	Di-n-butyl phthalate	900 µg/kg	B
Radionuclide	Alpha activity	13.5 ± 6.3 pCi/g	
	Beta activity	19.8 ± 4.4 pCi/g	
	Technetium-99	4.2 ± 3.04 pCi/g	
	Thorium-234	8.9 ± 7.3 pCi/g	

Laboratory qualifiers

A = Indicates that a tentatively identified compound is suspected aldol-condensation product
B = Found in the blank
J = Estimated
W = Laboratory-specific qualifier

Table 4.27. Volatile organic analyte analyses of subsurface soil at SWMU 5

Acetone (µg/kg)

Sample depth	H002
12	86
24	200
42	56
	TD = 73 ft

Methylene chloride (µg/kg)

Sample depth	005-015
19	36 BJ
23	39 BJ
37	36 BJ
44	32 BJ
51	37 BJ
60	36 BJ
	TD = 60 ft

Note: These samples were analyzed outside the holding time.

Trichloroethene (µg/kg)

Sample depth	005-018	005-021	H002
11	2.6	2.8	NS
18	NS	4.8	NS
33	1.6 W	2.7	NS
42	NS	NS	9
43	2.5 W	2.3	NS
50	2.9	5.1	NS
60	2.5	NS	NS
	TD = 60 ft	*TD = 60 ft*	*TD = 73 ft*

1,1,2-Trichloro-1,2,2-trifluoroethane (µg/kg)

Sample depth	H002
56	58
62	17
	TD = 73 ft

Notes:
NS = Not sampled
TD = Total depth

Laboratory qualifiers
B = Found in the blank
J = Estimated
W = Laboratory-specific qualifier

Table 4.28. Semivolatile organic analyte analyses of subsurface soil at SWMU 5

Benz(a)anthracene (µg/kg)

Sample depth	H263
4	500
	TD = 6 ft

Benzo(a)pyrene (µg/kg)

Sample depth	H263
4	440
	TD = 6 ft

Benzo(k)fluoranthene (µg/kg)

Sample depth	H263
4	580
	TD = 6 ft

Chrysene (µg/kg)

Sample depth	H263
4	560
	TD = 6 ft

Diethyl phthalate (µg/kg)

Sample depth	H002
67	770
	TD = 73 ft

Di-n-butyl phthalate (µg/kg)

Sample depth	005-018	005-019	005-020	005-021	005-022	005-028
11	1000[a]	5400[b]	5300[b]	1000[c]	1500[e]	NS
18	NS	NS	NS	930[d]	1100[e]	NS
25	NS	NS	2600[b]	NS	NS	NS
33	NS	3100[b]	7300 U[b]	500[d]	ND	NS
36	NS	NS	NS	NS	NS	NS
43	1100[a]	NS	3900[b]	980[d]	800[e]	NS
48	NS	NS	NS	NS	NS	600[f]
50	1600[a]	NS	5900[b]	1400[d]	1200[e]	NS
60	1000[a]	NS	NS	NS	NS	NS
	TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 51 ft*

2-Methylheptane (µg/kg)

Sample depth	H002
73	150
	TD = 73 ft

Phenanthrene (µg/kg)

Sample depth	H263
4	1300
	TD = 6 ft

Notes:

[a] Di-n-butyl phthalate was detected in the method blank at a concentration of 990 µg/kg.

[b] Di-n-butyl phthalate was detected in the method blank at a concentration of 7900 µg/kg.

[c] Di-n-butyl phthalate was detected in the method blank at a concentration of 840 µg/kg.

[d] Di-n-butyl phthalate was detected in the method blank at a concentration of 1000 µg/kg.

[e] Di-n-butyl phthalate was detected in the method blank at a concentration of 930 µg/kg.

[f] Di-n-butyl phthalate was detected in the method blank at a concentration of 660 µg/kg.

NS = Not sampled
TD = Total depth

Table 4.29. Inorganic analyses of subsurface soil at SWMU 5

Aluminum (mg/kg)

Sample depth	005-020	005-021	005-022	005-027	H002
6	NS	NS	NS	NS	12400
43	13608	16400	15600	NS	NS
51	NS	NS	NS	12500	NS
60	NS	NS	NS	*TD = 51 ft*	NS
73	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*		NS
					TD = 73 ft

Chromium (mg/kg)

Sample depth	005-017	005-027	H002
23	296	NS	NS
37	ND	NS	NS
26	*TD = 37 ft*	83.9	NS
38		BSV	NS
51		ND	NS
67		*TD = 51 ft*	161
73			89.8
			TD = 73 ft

Cobalt (mg/kg)

Sample depth	H263	H002	005-015	005-018
4	24.7	NS	NS	NS
42	*TD = 6 ft*	19.2	NS	NS
46		NS	19.4 W	ND
48		NS	NS	ND
51		NS	15.2 W	NS
60		NS	BSV	15.3
63		NS	*TD = 60 ft*	*TD = 60 ft*
66		NS		
69		NS		
		TD = 73 ft		

Iron (mg/kg)

Sample depth	005-017	005-022	005-027	005-028	H263
4	NS	NS	NS	NS	33,100
6	NS	NS	NS	NS	31,800
23	29,200	NS	NS	NS	*TD = 6 ft*
25	*TD=37 ft*	NS	NS	32,900	
51		NS	31,900	BSV	
60		29,400	*TD = 51 ft*	*TD = 51 ft*	
		TD = 60 ft			

Notes:
BSV = Below screening value
ND = Below detection limit
NS = Not sampled
TD = Total depth

Laboratory qualifier
W = Laboratory-specific qualifier

Table 4.30. Radionuclide analyses of subsurface soil at SWMU 5

Alpha Activity (pCi/g)

Sample depth	005-015	005-016	005-017	005-018	005-019	005-020	005-021	005-022	005-027	005-028	H002
11	NS	NS	NS	3.61 ± 0.81	5.13 ± 0.94	3.26 ± 0.62	3.18 ± 0.61	2.87 ± 0.69	NS	NS	NS
18	NS	NS	NS	NS	NS	NS	3.15 ± 0.6	4.17 ± 0.83	NS	NS	3.1 ± 1.5
19	18.9 ± 7.1	11.3 ± 5.8	22 ± 7.5	NS	NS	NS	NS	NS	NS	NS	NS
21	NS	*TD = 20 ft*	NS	NS	NS	NS	NS	NS	NS	13.6 ± 5.8	NS
23	21 *N ± 7.6		21 ± 7	NS	2.93 ± 0.7	NS	NS	NS	NS	NS	NS
25	NS		NS	NS	NS	1.42 ± 0.03	NS	NS	NS	18.3 ± 6.7	NS
26	NS		NS	NS	NS	NS	NS	NS	23.8 ± 7.4	NS	NS
30	NS		NS	NS	NS	NS	NS	NS	NS	NS	6.2 ± 1.9
33	NS		NS	5.64 ± 1.03	6.5 ± 1.06	2.31 ± 0.52	4.76 ± 0.7	4.59 ± 0.88	NS	NS	NS
36	NS		NS	NS	NS	NS	NS	NS	NS	NS	2.2 ± 1.4
37	19.6 *N ± 4.4		10.4 ± 4.3	NS	NS	NS	NS	NS	NS	NS	NS
38	NS		*TD = 37 ft*	NS	NS	NS	NS	NS	22.3 ± 7.5	20.2 ± 7.4	NS
42	NS			NS	3.84 ± 0.81	NS	NS	NS	NS	NS	1.6 ± 1
43	NS			8.3 ± 1.24	NS	3.85 ± 0.86	4.92 ± 0.78	5.45 ± 0.96	NS	NS	NS
44	15.2 ± 7.6			NS	NS	NS	NS	NS	NS	NS	NS
48	NS			NS	NS	NS	NS	NS	NS	NS	2.1 ± 0.9
50	NS			4.51 ± 0.9	0.78 ± 0.25	4.15 ± 0.7	4.16 ± 0.7	4.19 ± 0.84	NS	NS	NS
51	15.1 ± 7.1			NS	NS	NS	NS	NS	16 ± 7.2	15.7 U ± 7.3	NS
54	NS			NS	NS	NS	NS	NS	*TD = 51 ft*	*TD = 51 ft*	1.4 ± 0.8
60	19.6 *N ± 7.2			5.83 ± 1.02	1.94 ± 0.41	NS	NS	NS			0.8 ± 0.7
63	*TD = 60 ft*			*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*			2.8 ± 1.4
											TD = 73 ft

Beta Activity (pCi/g)

Sample depth	005-015	005-016	005-017	005-018	005-019	005-020	005-021	005-022	005-027	005-028	H002
11	NS	NS	NS	4.05 ± 0.51	2.63 ± 0.39	3.18 ± 0.43	3.85 ± 0.46	3.85 ± 0.48	NS	NS	NS
18	NS	NS	NS	NS	NS	NS	4.12 ± 0.48	3.7 ± 0.47	NS	NS	NS
19	ND	17.8 ± 4.8	20.5 ± 5.9	NS	NS	NS	NS	NS	NS	NS	NS
21	NS	*TD = 20 ft*	NS	NS	NS	NS	NS	NS	18.3 ± 4.5	12.6 ± 3.9	NS
23	13.4 N ± 5.2		15 ± 4.9	NS	NS	NS	NS	NS	NS	NS	NS
25	NS		NS	NS	2.04 ± 0.35	2.75 ± 0.04	NS	NS	NS	16.5 ± 3.7	NS
26	NS		NS	NS	NS	NS	NS	NS	12.1 ± 3.9	NS	NS
30	NS		NS	NS	NS	NS	NS	NS	NS	NS	6.4 ± 1.3
33	NS		NS	3.08 ± 0.45	2.63 ± 0.39	4.92 ± 0.66	4.12 ± 0.48	3.85 ± 0.48	NS	NS	NS
36	NS		NS	NS	NS	NS	NS	NS	NS	NS	8 ± 1.4
37	17.4 *N ± 4.4		9.1 ± 2.9	NS	NS	NS	NS	NS	NS	NS	NS
38	NS		*TD = 37 ft*	NS	NS	NS	NS	NS	12 ± 4.2	15.3 ± 4.4	NS
42	NS			NS	2.04 ± 0.35	NS	NS	NS	NS	NS	2.4 ± 1.1
43	NS			6.65 ± 0.67	NS	3.9 ± 0.48	2.47 ± 0.37	4.14 ± 0.5	NS	NS	NS
44	23.2 W ± 6.1			NS	NS	NS	NS	NS	NS	NS	NS
48	NS			NS	NS	NS	NS	NS	NS	NS	7.7 ± 1.3
50	NS			5.02 ± 0.57	2.13 ± 0.32	4.05 ± 0.48	4.12 ± 0.48	3.25 ± 0.044	NS	NS	NS
51	23.1 *N ± 5.1			NS	NS	NS	NS	NS	23.6 ± 5.2	27.6 ± 5.5	NS
54	NS			NS	NS	NS	NS	NS	*TD = 51 ft*	*TD = 51 ft*	5.9 ± 1.2
60	24.6 W ± 4.6			6.97 ± 0.67	1.19 ± 0.24	NS	NS	NS			NS
63	*TD = 60 ft*			*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*			NS
66											6.2 ± 1.2
67											3.8 ± 1.1
72											5.3 ± 1.2
73											2.4 ± 1
											TD = 73 ft

Table 4.30 (continued)

Technetium-99 (pCi/g)

Sample depth	005-019
60	3.89 ± 2.71

TD = 60 ft

Thorium-234 (pCi/g)

Sample depth	005-019
11	ND
18	NS
25	ND
33	0.753 ± 0.33
43	NS
50	NS
60	ND

TD = 60 ft

Uranium-238 (pCi/g)

Sample depth	005-018	005-019	005-020	005-021
11	NS	NS	2 ± 0.722	NS
18	NS	NS	NS	1.24 ± 1.1
25	NS	1.76 ± 0.754	NS	NS
33	NS	NS	1.32 ± 0.393	NS
43	NS	NS	2.26 ± 0.93	1.43 ± 0.443
50	NS	NS	NS	1.41 ± 0.632
60	1.71 ± 0.717	NS	NS	NS
	TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*

Notes:
ND = Below detectin limit
NS = Not sampled
TD = Total depth

Laboratory qualifiers
N = Tentatively identified
U = Non-detect
W = Laboratory-specific qualifier
* = Laboratory QC criteria not met

Table 4.31. Inorganic analyses of groundwater at SWMU 5

Cobalt (mg/L)

Sample depth	005-013	005-018	005-019	005-021	005-022	005-026
60	NS	0.017	0.075	0.014 J	0.023	NS
63	0.017	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	ND
68	0.038					ND
73	0.024					0.013
78	ND					ND
93	ND					0.011
98	0.011					ND
	TD = 158 ft					***TD = 158 ft***

Iron (mg/L)

Sample depth	005-013	005-019	005-022	005-026
60	NS	3.3	2.75	NS
63	0.794	*TD = 60 ft*	*TD = 60 ft*	ND
68	1.23			ND
73	ND			0.897 N
78	1.59			0.387
88	0.569			0.235 *NW
93	ND			0.385 *NW
98	5.63			0.201 *N
108	NS			0.294 B
	TD = 158 ft			***TD = 158 ft***

Manganese (mg/L)

Sample depth	005-013	005-015	005-018	005-019	005-021	005-022	005-026
60	NS	0.404	1.03	4.69	0.953	1.18 *J	NS
63	0.781	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	0.689 BU
68	2.43 A						1.27
73	3.37 B						1.43 J
78	1.06						0.995
83	NS						0.985
88	1.15						1.61
93	0.323						2.54
98	0.982						0.232
108	NS						0.445
	TD = 158 ft						***TD = 158 ft***

Zinc (mg/L)

Sample depth	005-019
60	0.271 J
	TD = 60 ft

Notes:
ND = Below detection limit
NS = Not sampled
TD = Total depth

<u>Laboratory qualifier</u>
B = Found in the blank
J = Estimated
N = Sample spike recovery not within control limits
W = Post-digestion spike recovery out of control limits
* = Duplicate analysis not within control limits

Table 4.32. Radionuclide analyses of groundwater at SWMU 5

Alpha Activity (pCi/L)

Sample depth	**005-018**	**005-019**	**005-021**	**005-026**
60	16.97 ± 4.49	29.16 ± 7.41 J	56.08 ± 10.5 J	NS
108	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	49.72 ± 7.91
				TD = 158 ft

Beta Activity (pCi/L)

Sample depth	**005-013**	**005-015**	**005-016**	**005-017**	**005-018**	**005-019**	**005-021**	**005-022**	**005-026**
20	NS	NS	3.9 ± 1.4 J	NS	NS	NS	NS	NS	NS
29	NS	NS	NS	7.1 ± 3.1 J	NS	NS	NS	NS	NS
60	NS	3.8 ± 1.5 J	NS	NS	19.03 ± 3.03	46.27 ± 5.81	55.06 ± 6.43	11.31 ± 2.14	NS
68	7.1 ± 1.7	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	ND
73	13.67 ± 2.09 J								ND
78	14 ± 2								18.5 ± 2.2
83	NS								7.3 ± 1.7
88	15.2 ± 2 J								16.5 ± 2.2
93	10.9 ± 2								3.7 ± 1.5
98	ND								5.2 ± 1.6
108	ND								73.07 ± 6.93
	TD = 158 ft								*TD = 158 ft*

Radon (pCi/L)

Sample depth	**005-015**	**005-019**	**005-021**
60	348 ± 85.9	361 ± 77.2	737 ± 170 *N
	TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*

Technetium-99 (pCi/L)

Sample depth	**005-013**	**005-017**	**005-026**
29	NS	31 ± 9.4 B	NS
68	16.5 ± 9.3	*TD = 37 ft*	ND
78	31 ± 11		14.9 ± 8.6
83	NS		18.3 ± 8.7
88	20 ± 10 A		22.4 ± 8.9
93	20 ± 10		ND
108	ND		15.8 ± 9.2
	TD = 158 ft		*TD = 158 ft*

Table 4.32 (continued)

Notes:
ND = Below detection limit
NS = Not sampled
TD = Total depth

Laboratory qualifiers
A = Indicates that a tentatively identified compound is suspected aldol-condensation product
B = Found in the blank
J = Estimated
N = Sample spike recovery not within control limits
* = Duplicate analysis not within control limits

Table 4.33. Volatile organic analyte analyses of groundwater at SWMU 5

Acetone (μg/L)

Sample depth	005-020
60	38

TD = 60 ft

Trichloroethene (μg/L)

Sample depth	005-013	005-022	005-026
60	NS	29	NS
68	6	*TD = 60 ft*	ND
73	10		ND
78	33		8
88	20		BSV
93	15		ND
98	ND		ND
108	ND		NS

TD = 158 ft (005-013)

TD = 158 ft (005-026)

Notes:
BSV = Below screening value
ND = Below detection limit
NS = Not sampled
TD = Total depth

Table 4.34. Semivolatile organic analyte analyses of groundwater at SWMU 5

Bis(2-ethylhexyl)phthalate (μg/L)

Sample depth	005-019
60	7

TD = 60 ft

Pyrene (μg/L)

Sample depth	005-015
60	23 B

TD = 60 ft

Notes:
TD = Total depth

Laboratory qualifier
B = Found in the blank

Table 4.35. Comparison of filtered and unfiltered groundwater samples in SWMU 5

Analyte (mg/L)	Not filtered			0.45 micron			5 micron		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Aluminum	119.34	1.58	591	0.20	0.2	0.2	1.45	0.2	3.67
Antimony	1.10	0.2	2						
Arsenic	0.01	0.005	0.014	0.01	0.005	0.005	0.01	0.005	0.005
Barium	1.90	0.087	10.5	0.13	0.05	0.283	0.14	0.05	0.259
Beryllium	0.03	0.005	0.144	0.01	0.005	0.01	0.01	0.005	0.01
Cadmium	0.04	0.01	0.1	0.01	0.01	0.01	0.01	0.01	0.01
Calcium	42.20	10.8	202	18.60	8.1	48.9	18.87	9	47.7
Chromium	1.16	0.05	6.47	0.05	0.05	0.05	0.05	0.05	0.05
Cobalt	0.18	0.01	1.82	0.03	0.01	0.075	0.03	0.01	0.082
Copper	0.56	0.05	1.81	0.05	0.05	0.05	0.05	0.05	0.05
Iron	465.04	14.6	2160	1.34	0.2	5.63	1.91	0.2	11.3
Lead	0.44	0.2	0.816	0.20	0.2	0.2	0.20	0.2	0.2
Magnesium	21.32	4.65	88.6	7.47	3.7	19.2	7.49	4.06	18.9
Manganese	10.75	0.312	54.8	1.44	0.225	4.69	1.29	0.216	4.75
Mercury	0.00	0.0002	0.003	0.00	0.0002	0.0002	0.00	0.0002	0.0002
Nickel	0.28	0.05	1.37	0.05	0.05	0.05	0.05	0.05	0.05
Potassium	15.52	2	39.2	2.28	2	2.86	2.38	2	3.08
Selenium	0.01	0.005	0.005				0.01	0.005	0.005
Silver	0.28	0.05	0.5						
Sodium	18.42	7.97	48.7	20.03	10.4	56.9	20.20	9.91	56.1
Thallium	1.10	0.2	2						
Vanadium	0.71	0.05	2.62	0.08	0.05	0.1	0.08	0.05	0.1
Zinc	1.52	0.2	6.77	0.24	0.2	0.271	0.24	0.2	0.269

Table 4.36. Contamination detected above screening levels in sediment at SWMU 6

Chemical type	Analyte	Concentration	Data qualifier
Location 006-001			
Radionuclide	Alpha activity	20.7 ± 7.3 pCi/g	
	Beta activity	19.5 ± 5.5 pCi/g	
Location 006-002			
Radionuclide	Alpha activity	18.3 ± 6.6 pCi/g	
	Beta activity	23.0 ± 3.8 pCi/g	
Location 006-003			
SVOA	Di-n-butyl phthalate	760 µg/kg	B
Radionuclide	Alpha activity	15.2 ± 7.9 pCi/g	
	Beta activity	37.8 ± 5.5 pCi/g	
	Technetium-99	13.9 ± 4.28 pCi/g	

Laboratory qualifier

B = Found in the blank

Table 4.37. Volatile organic analyte analyses of subsurface soil at SWMU 6

Acetone (µg/kg)

Sample depth	006-019	006-020	006-021
11	ND	11 J	ND
22	NS	NS	ND
50	39 BJ	ND	ND
60	NS	ND	73 J
	TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*

Trichloroethene (µg/kg)

Sample depth	006-021	006-022
11	ND	3.8
18	2.5	3.5
43	10.1	ND
60	ND	ND
	TD = 60 ft	*TD = 60 ft*

Notes:
ND = Below detection limit
NS = Not sampled
TD = Total depth

Laboratory qualifier
B = Found in the blank
J = Estimated

Table 4.38. Semivolatile organic analyte analyses of subsurface soil at SWMU 6

Bis(2-ethylhexyl)phthalate (µg/kg)

Sample depth	006-021	006-023
43	ND	600 B
50	490 B	ND
60	ND	NS
	TD = 60 ft	*TD = 60 ft*

Di-n-butyl phthalate (µg/kg)

Sample depth	006-016	006-019	006-021	006-023	006-027
11	NS	ND	740 B	720 B	NS
13	1700 B	NS	NS	NS	NS
15	NS	NS	NS	NS	670 B
18	NS	NS	1500 B	NS	NS
33	NS	860	NS	770 B	NS
37	NS	NS	NS	NS	NS
43	*TD = 37 ft*	ND	1000 B	2000 B	NS
50		NS	3200 B	820 B	NS
51		NS	NS	NS	670 B
60		NS	ND	NS	*TD = 51 ft*
		TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	

Notes:
ND = Below detection limit
NS = Not sampled
TD = Total depth

Laboratory qualifier
B = Found in the blank

Table 4.39. Inorganic analyses of subsurface soil at SWMU 6

Aluminum (mg/kg)

Sample depth	006-016	006-017	006-018	006-020	006-021	006-022	006-023	006-026	006-027	006-028	006-029
5	NS	NS	NS	NS	NS	NS	NS	NS	NS	8240 *NW	8970 *NW
10	NS	NS	NS	NS	NS	NS	NS	NS	NS	6120 *NW	9760 *NW
11	NS	NS	NS	9900 *NW	9330 N	9720 N	10500 N	NS	NS	NS	NS
13	7430 NW	8620 NW	10400 NW	NS	NS	NS	NS	9630 *NW	NS	NS	NS
15	NS	NS	NS	NS	NS	NS	NS	NS	NS	7520 *NW	8140 *NW
18	NS	NS	NS	5560 *NW	9590 N	6070 N	NS	NS	NS	NS	NS
19	NS	NS	NS	NS	NS	NS	NS	4660 *NW	4370 *NW	NS	NS
22	NS	5080 NW	NS	NS	NS	NS	8730 N	NS	NS	NS	NS
23	3630 NW	*TD = 22 ft*	5420 NW	NS	NS	NS	NS	3510 *NW	10300 *NW	NS	NS
27	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS
30	NS		*TD = 27 ft*	NS	NS	NS	NS	NS	NS	4260 *NW	NS
33	NS			11300 *NW	NS	NS	4060 N	NS	NS	NS	NS
35	NS			NS	NS	NS	NS	NS	NS	NS	*TD = 33 ft*
37	3600 NW			NS	NS	NS	NS	NS	NS	*TD = 35 ft*	
38	*TD = 37 ft*			NS	NS	NS	NS	7460 *NW	3910 *NW		
43				22500 *NW	13100 N	11100 N	13100 N	NS	NS		
50				11300 *NW	4960 N	NS	10300 N	NS	NS		
51				NS	NS	NS	NS	12100 *NW	10000 *NW		
60				NS	2230 N	8750 N	NS	*TD = 51 ft*	*TD = 51 ft*		
				TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*				

Arsenic (mg/kg)

Sample depth	006-016	006-021	006-022	006-029
5	NS	NS	NS	5.76 W
23	5.5 W	NS	NS	NS
33	NS	NS	NS	NS
37	ND	NS	NS	*TD = 33 ft*
60	*TD = 37 ft*	0.006 NW	0.013 NW	
		TD = 60 ft	*TD = 60 ft*	

Table 4.39 (continued)

Barium (mg/kg)

Sample depth	006-016	006-017	006-018	006-020	006-021	006-022	006-023	006-026	006-027	006-028	006-029
5	NS	NS	NS	NS	NS	NS	NS	NS	NS	77.8	86.3
10	NS	NS	NS	NS	NS	NS	NS	NS	NS	67.6	98.6
11	NS	NS	NS	84.9	63	65.9	83.5	NS	NS	NS	NS
13	75.5 N	76.6 N	74.2 N	NS	NS	NS	NS	88.6 *N	NS	NS	NS
15	NS	NS	NS	NS	NS	NS	NS	NS	NS	33.4	50.1
18	NS	NS	NS	28.2	35.9	25.8	NS	NS	NS	NS	NS
19	NS	NS	NS	NS	NS	NS	NS	17.6 *N	19.5	NS	NS
22	NS	20.7 N	NS	NS	NS	NS	40.6	NS	NS	NS	NS
23	17.3 N	*TD = 22 ft*	37.8 N	NS	NS	NS	NS	14.1 *N	32.9 *N	NS	NS
27	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS
30	NS		*TD = 27 ft*	NS	NS	NS	NS	NS	NS	16.3	NS
33	NS			29.4	NS	NS	17	NS	NS	NS	NS
35	NS			NS	NS	NS	NS	NS	NS	NS	*TD = 33 ft*
37	10.9 N			NS	NS	NS	NS	NS	NS	*TD = 35 ft*	
38	*TD = 37 ft*			NS	NS	NS	NS	15.3 *N	13.1 *N		
43				114	69.4	65.4	104	NS	NS		
50				59.1	48.6	NS	55.2	NS	NS		
51				NS	NS	NS	NS	108 *N	50.6		
60				NS	32.8	51.1	NS	*TD = 51 ft*	*TD = 51 ft*		
				TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*				

Table 4.39 (continued)

Beryllium (mg/kg)

Sample depth	006-016	006-017	006-018	006-019	006-020	006-021	006-022	006-023	006-026	006-027	006-028	006-029
5	NS	NS	NS	NS	ND	ND	NS	NS	NS	NS	2.62	ND
10	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.64	0.59
11	NS	NS	NS	ND	NS	NS	BSV	0.56	NS	NS	NS	NS
13	NS	ND	13.32	NS	NS	NS	NS	NS	0.59	NS	NS	NS
15	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	0.7
18	NS	NS	NS	NS	ND	0.52	0.67	NS	NS	NS	NS	NS
22	NS	1.51	NS	NS	NS	NS	NS	0.59	NS	NS	NS	NS
23	0.74	*TD = 22 ft*	1.17	NS	NS	NS	NS	NS	1	ND	NS	NS
27	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
30	NS		*TD = 27 ft*	NS	NS	NS	NS	NS	NS	NS	0.6	NS
33	NS			0.81	0.88	NS	NS	ND	NS	NS	NS	NS
35	NS			NS	NS	NS	NS	NS	NS	NS	NS	*TD = 33 ft*
37	NS			NS	NS	NS	NS	NS	NS	NS	*TD = 35 ft*	
38	*TD = 37 ft*			NS	NS	NS	NS	NS	ND	1.7		
43				1.59	1.93	2.16	1.54	1.49	NS	NS		
50				NS	1.66	ND	NS	1.15	NS	NS		
51				NS	NS	NS	NS	NS	2.01	3.07		
60				NS	NS	ND	0.67	NS	*TD = 51 ft*	*TD = 51 ft*		
				TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*				

Table 4.39 (continued)

Chromium (mg/kg)

Sample depth	006-016	006-017	006-018	006-020	006-021	006-022	006-023	006-026	006-027	006-028	006-029
5	NS	NS	NS	NS	NS	NS	NS	NS	NS	17.5	9.06
10	NS	NS	NS	NS	NS	NS	NS	NS	NS	8.17	12.8
11	NS	NS	NS	13	13	13.3	15.5	NS	NS	NS	NS
13	12.2	12	20.5	NS	NS	NS	NS	15.3	NS	NS	NS
15	NS	NS	NS	NS	NS	NS	NS	NS	NS	4.93	10.2
18	NS	NS	NS	19.5	11.8	12.7	NS	NS	NS	NS	NS
19	NS	NS	NS	NS	NS	NS	NS	6.43	4.32	NS	NS
22	NS	46.8	NS	NS	NS	NS	8.85	NS	NS	NS	NS
23	43.2	*TD = 22 ft*	55.9	NS	NS	NS	NS	56.8	12.8	NS	NS
27	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS
30	NS		*TD = 27 ft*	NS	NS	NS	NS	NS	NS	9.48	NS
33	NS			13.7	NS	NS	6.5	NS	NS	NS	NS
35	NS			NS	NS	NS	NS	NS	NS	NS	*TD = 33 ft*
37	3.38			NS	NS	NS	NS	NS	NS	*TD = 35 ft*	
38	*TD = 37 ft*			NS	NS	NS	NS	5.58	112		
43				21.3	22.6	19.8	14.4	NS	NS		
50				18.1	6.74	NS	13.5	NS	NS		
51				NS	NS	NS	NS	18.1	23.1		
60				NS	6.72	30.9	NS	*TD = 51 ft*	*TD = 51 ft*		
				TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*				

Table 4.39 (continued)

Cobalt (mg/kg)

Sample depth	006-016	006-017	006-018	006-020	006-021	006-022	006-023	006-026	006-027	006-028	006-029
5	NS	NS	NS	NS	NS	NS	NS	NS	NS	6.81	4.57
10	NS	NS	NS	NS	NS	NS	NS	NS	NS	2.27	2.93
11	NS	NS	NS	4.16 N	2.73	3.02	2.7	NS	NS	NS	NS
13	2.87	4.14	10.8	NS	NS	NS	NS	2.35	NS	NS	NS
15	NS	NS	NS	NS	NS	NS	NS	NS	NS	4.07	7.75
18	NS	NS	NS	4.5 N	3.63	ND	NS	NS	NS	NS	NS
19	NS	NS	NS	NS	NS	NS	NS	1.98	2.02	NS	NS
22	NS	7.53	NS	NS	NS	NS	10.1	NS	NS	NS	NS
23	2.86	*TD = 22 ft*	8.47	NS	NS	NS	NS	4.48	1.96	NS	NS
27	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS
30	NS		*TD = 27 ft*	NS	NS	NS	NS	NS	NS	1.94	NS
33	NS			6.56 N	NS	NS	2.44	NS	NS	NS	NS
35	NS			NS	NS	NS	NS	NS	NS	NS	*TD = 33 ft*
37	2.13			NS	NS	NS	NS	NS	NS	*TD = 35 ft*	
38	*TD = 37 ft*			NS	NS	NS	NS	1.3	8.05		
43				156 N	2.76	2.45	19.8	NS	NS		
50				5.26 N	2.47	NS	11.5	NS	NS		
51				NS	NS	NS	NS	18.5	3.43		
60				NS	2.8	2.02	NS	*TD = 51 ft*	*TD = 51 ft*		
				TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*				

Table 4.39 (continued)

Copper (mg/kg)

Sample depth	006-016	006-017	006-018	006-020	006-021	006-022	006-023	006-026	006-027	006-028	006-029
5	NS	NS	NS	NS	NS	NS	NS	NS	NS	19.2	7.45
10	NS	NS	NS	NS	NS	NS	NS	NS	NS	5.63	7.61
11	NS	NS	NS	7.13	6.53	6.41	20.9	NS	NS	NS	NS
13	5.49	4.97	7.81	NS	NS	NS	NS	5.77	NS	NS	NS
15	NS	NS	NS	NS	NS	NS	NS	NS	NS	2.64	4.34
18	NS	NS	NS	3.92	6.74	5.25	NS	NS	NS	NS	NS
19	NS	NS	NS	NS	NS	NS	NS	ND	2.02	NS	NS
23	4.43	*TD = 22 ft*	3.96	NS	NS	NS	NS	3.39	3.53	NS	NS
27	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS
30	NS		*TD = 27 ft*	NS	NS	NS	NS	NS	NS	3.36	NS
33	NS			5.42	NS	NS	4.43	NS	NS	NS	NS
35	NS			NS	NS	NS	NS	NS	NS	NS	*TD = 33 ft*
37	ND			NS	NS	NS	NS	NS	NS	*TD = 35 ft*	
38	*TD = 37 ft*			NS	NS	NS	NS	2.51	2.46		
43				10.8	13.8	11.7	9.78	NS	NS		
50				7.57	3.42	NS	8.12	NS	NS		
51				NS	NS	NS	NS	9.7	9.76		
60				NS	2.8	6.15	NS	*TD = 51 ft*	*TD = 51 ft*		
				TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*				

Table 4.39 (continued)

Iron (mg/kg)

Sample depth	006-016	006-017	006-018	006-020	006-021	006-022	006-023	006-026	006-027	006-028	006-029
5	NS	NS	NS	NS	NS	NS	NS	NS	NS	54200 NW	10700 NW
10	NS	NS	NS	NS	NS	NS	NS	NS	NS	10700 NW	11800 NW
11	NS	NS	NS	10700 NW	9210 *NW	9140 *NW	9880 *NW	NS	NS	NS	NS
13	10500 NW	9280 NW	35300 *NW	NS	NS	NS	NS	10800 *NW	NS	NS	NS
15	NS	NS	NS	NS	NS	NS	NS	NS	NS	7690 NW	11600 NW
18	NS	NS	NS	7520 NW	10000 *NW	11500 *NW	NS	NS	NS	NS	NS
19	NS	NS	NS	NS	NS	NS	NS	6270 *NW	4160 NW	NS	NS
22	NS	58700 *N	NS	NS	NS	NS	11500 *NW	NS	NS	NS	NS
23	24800 *N	*TD = 22 ft*	33700 *NW	NS	NS	NS	NS	20200 *NW	9200 *NW	NS	NS
27	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS
30	NS		*TD = 27 ft*	NS	NS	NS	NS	NS	NS	16800 NW	NS
33	NS			17300 NW	NS	NS	7460 *NW	NS	NS	NS	NS
35	NS			NS	NS	NS	NS	NS	NS	NS	*TD = 33 ft*
37	3720 NW			NS	NS	NS	NS	NS	NS	*TD = 35 ft*	
38	*TD = 37 ft*			NS	NS	NS	NS	5170 *NW	22200 *NW		
43				26700 NW	29900 *NW	23000 *NW	20100 *NW	NS	NS		
50				22200 NW	5010 *NW	NS	17300 *NW	NS	NS		
51				NS	NS	NS	NS	32900 *NW	36900 NW		
60				NS	5140 *NW	1180 *NW	NS	*TD = 51 ft*	*TD = 51 ft*		
				TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*				

Lead (mg/kg)

Sample depth	006-023	006-028
5	NS	35.4
35	NS	NS
43	25.2	*TD = 35 ft*
60	NS	
	TD = 60 ft	

Table 4.39 (continued)

Manganese (mg/kg)

Sample depth	006-016	006-017	006-018	006-020	006-021	006-022	006-023	006-026	006-027	006-028	006-029
5	NS	NS	NS	NS	NS	NS	NS	NS	NS	353 N	349 N
10	NS	NS	NS	NS	NS	NS	NS	NS	NS	79.3 N	143 N
11	NS	NS	NS	230 N	164 *N	222 *N	165 *N	NS	NS	NS	NS
13	106 N	207 N	411 N	NS	NS	NS	NS	93.4 *NW	NS	NS	NS
15	NS	NS	NS	NS	NS	NS	NS	NS	NS	157 N	174 N
18	NS	NS	NS	184 N	100 *N	81 *N	NS	NS	NS	NS	NS
19	NS	NS	NS	NS	NS	NS	NS	92.1 *NW	108 N	NS	NS
22	NS	*TD = 22 ft*	NS	NS	NS	NS	NS	NS	NS	NS	NS
23	167 N		333 N	NS	NS	NS	NS	117 *NW	62.4 *NW	NS	NS
27	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS
30	NS		*TD = 27 ft*	NS	NS	NS	NS	NS	NS	63.2 N	NS
33	NS			119 N	NS	NS	59.7 *N	NS	NS	NS	NS
35	NS			NS	NS	NS	NS	NS	NS	NS	*TD = 33 ft*
37	39.7 N			NS	NS	NS	NS	NS	NS	*TD = 35 ft*	
38	*TD = 37 ft*			NS	NS	NS	NS	22.7 *NW	60.1 *NW		
43				602 N	162 *N	96 *N	398 *N	NS	NS		
50				102 N	144 *N	NS	130 *N	NS	NS		
51				NS	NS	NS	NS	442 *NW	64.3 N		
60				NS	183 *N	66.4 *N	NS	*TD = 51 ft*	*TD = 51 ft*		
				TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*				

Table 4.39 (continued)

Nickel (mg/kg)

Sample depth	006-016	006-017	006-019	006-021	006-022	006-023	006-026	006-027	006-029
10	NS	NS	NS	NS	NS	NS	NS	NS	7.71
11	NS	NS	11.2	7.21	7.2	15.4	NS	NS	NS
13	7.35	9.61	NS	NS	NS	NS	30	NS	NS
19	NS	NS	NS	NS	NS	NS	14.3	ND	NS
22	NS	ND	NS	NS	NS	ND	NS	NS	NS
23	7.38	*TD = 22 ft*	NS	NS	NS	NS	40.7	21.4	NS
33	NS		NS	NS	NS	NS	NS	NS	NS
37	NS		NS	NS	NS	NS	NS	NS	*TD = 33 ft*
38	*TD = 37 ft*		NS	NS	NS	NS	13.7	48.3	
43			15.1	8.64	13.6	NS	NS	NS	
50			NS	NS	NS	5.74	NS	NS	
51			NS	NS	NS	NS	68.6	17.2	
60			NS	0.38	5.77	NS	*TD = 51 ft*	*TD = 51 ft*	
			TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*			

Table 4.39 (continued)

Vanadium (mg/kg)

Sample depth	006-016	006-017	006-018	006-019	006-020	006-021	006-022	006-023	006-026	006-027	006-028	006-029
5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	65.6	17.9
10	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	25	24.4
11	NS	NS	NS	19.8 *N	22.6 *N	18.1	18.9	23.8	NS	NS	NS	NS
13	22.5 N	19.1 N	52.7	NS	NS	NS	NS	NS	21.6	NS	NS	NS
15	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	15.5	25
18	NS	NS	NS	NS	17.8 *N	20.2	29.1	NS	NS	NS	NS	NS
19	NS	NS	NS	NS	NS	NS	NS	NS	11.4	11.9	NS	NS
22	NS	79.1 N	NS	NS	NS	NS	NS	20.1	NS	NS	NS	NS
23	46.6 N	*TD = 22 ft*	64.7	NS	NS	NS	NS	NS	49.4	16.6	NS	NS
27	NS		*TD = 27 ft*	NS	NS	NS	NS	NS	NS	NS	NS	NS
30	NS			NS	NS	NS	NS	NS	NS	NS	31.6	NS
33	NS			33 *N	32.9 *N	NS	NS	13.9	NS	NS	NS	NS
35	NS			NS	NS	NS	NS	NS	NS	NS	NS	*TD = 33 ft*
37	10.7 N			NS	NS	NS	NS	NS	NS	NS	*TD = 35 ft*	
38	*TD = 37 ft*			NS	NS	NS	NS	NS	10	71.1		
43				23.1 *N	42.8 *N	33.6	23.4	19.2	NS	NS		
50				NS	27.3 *N	6.26	NS	18.8	NS	NS		
51				NS	NS	NS	NS	NS	30.6	42.5		
60				NS	NS	5.42	13.4	NS	*TD = 51 ft*	*TD = 51 ft*		
				TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*				

Table 4.39 (continued)

Zinc (mg/kg)

Sample depth	006-016	006-017	006-018	006-019	006-020	006-021	006-022	006-023	006-026	006-027	006-028	006-029
5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	35.7	28.1
10	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	17.8	34.7
11	NS	NS	NS	36	40.7	32.5	48.3	27.4	NS	NS	NS	NS
13	27.1	34.2	36.7	NS	NS	NS	NS	NS	27.1	NS	NS	NS
15	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	17.4
22	NS	21.1	NS	NS	NS	NS	NS	ND	NS	NS	NS	NS
23	16.8	*TD = 22 ft*	24.5	NS	NS	NS	NS	NS	17.3	19.8	NS	NS
27	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
33	NS		*TD = 27 ft*	NS	ND	NS	NS	ND	NS	NS	NS	NS
35	NS			NS	NS	NS	NS	NS	NS	NS	NS	*TD = 33 ft*
37	ND			NS	NS	NS	NS	NS	NS	NS	*TD = 35 ft*	
38	*TD = 37 ft*			NS	NS	NS	NS	NS	ND	20.9		
43				65	68.6	68.8	72.8	54.8	NS	NS		
50				NS	54.5	22.4	NS	48.9	NS	NS		
51				NS	NS	NS	NS	NS	69.7	58.4		
60				NS	NS	0.611 N	44.2	NS	*TD = 51 ft*	*TD = 51 ft*		
				TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*				

Notes:
ND = Below detection limit
NS = Not sampled
TD = Total depth

<u>Laboratory qualifiers</u>
N = Sample spike recovery not within control limits
W = Laboratory-specific qualifier
* = Duplicate analysis not within control limits

Table 4.40. Radionuclide analyses of subsurface soil at SWMU 6

Alpha activity (pCi/g)

Sample depth	006-016	006-017	006-018	006-020	006-021	006-022	006-023	006-026	006-027	006-028	006-029
5	NS	NS	NS	NS	NS	NS	NS	NS	NS	16.6 ± 6.4	18.1 ± 6.4
10	NS	NS	NS	NS	NS	NS	NS	NS	NS	17.9 ± 6.5	17.4 ± 6.3
11	NS	NS	NS	1.63 ± 0.46	4.28 ± 0.96	11.18 ± 1.29	5.11 ± 0.81	NS	NS	NS	NS
13	13.8 ± 5.7	10.4 ± 5.2	12.9 ± 6.2	NS	NS	NS	NS	10.5 ± 6.6	NS	NS	NS
15	NS	NS	NS	NS	NS	NS	NS	NS	NS	14.9 ± 6.4	15.3 ± 6.2
18	NS	NS	NS	2.31 ± 0.55	3.13 ± 0.81	2.48 ± 0.59	NS	NS	NS	NS	NS
19	NS	NS	NS	NS	NS	NS	NS	BSV	10.3 ± 5.8	NS	NS
20	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	19.2 ± 6.4
22	NS	NS	NS	NS	NS	NS	2.48 ± 0.56	NS	NS	15.2 ± 6.5	NS
23	NS	*TD = 22 ft*	NS	NS	NS	NS	NS	16.1 ± 6.5	11 ± 6.3	NS	NS
27	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS
30	NS		*TD = 27 ft*	NS	NS	NS	NS	NS	NS	24.4 ± 7.3	NS
33	NS			4.77 ± 0.81	2.77 ± 0.78	4.54 ± 0.8 X	5.16 ± 0.82	NS	NS	NS	NS
35	NS			NS	NS	NS	NS	NS	NS	NS	*TD = 33 ft*
37	17.3 ± 6.2			NS	NS	NS	NS	NS	NS	*TD = 35 ft*	
38	*TD = 37 ft*			NS	NS	NS	NS	23.3 ± 7.6	13.5 ± 6.8		
43				2.25 ± 0.54	5.95 ± 1.13	7.38 ± 1.02 X	4.6 ± 0.75	NS	NS		
50				3.76 ± 0.72	3.15 ± 0.81	4.19 ± 0.76 X	3.87 ± 0.71	NS	NS		
51				NS	NS	NS	NS	14.5 ± 7.4	11.1 ± 7.1		
60				1.95 ± 0.5	13.23 ± 2.63	12.43 ± 4.14	3.51 ± 0.67	*TD = 51 ft*	*TD = 51 ft*		
				TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*				

Table 4.40 (continued)

Beta activity (pCi/g)

Sample depth	006-016	006-017	006-018	006-020	006-021	006-022	006-023	006-026	006-027	006-028	006-029
5	NS	NS	NS	NS	NS	NS	NS	NS	NS	19.8 ± 4	21.9 ± 3.8
10	NS	NS	NS	NS	NS	NS	NS	NS	NS	17.7 ± 3.9	18.6 ± 3.7
11	NS	NS	NS	3.35 ± 0.43	3.55 ± 0.46	9.58 ± 0.72	4.44 ± 0.5	NS	NS	NS	NS
13	19.4 ± 4	21 ± 4.2	20.4 ± 4.6	NS	NS	NS	NS	23.4 ± 5.6	NS	NS	NS
15	NS	NS	NS	NS	NS	NS	NS	NS	NS	15 ± 3.8	17.3 ± 4.2
18	NS	NS	NS	4.19 ± 0.48	3.4 ± 0.45	3.97 ± 0.47	NS	NS	NS	NS	NS
19	NS	NS	NS	NS	NS	NS	NS	17.7 ± 4.6	14.7 ± 3.6	NS	NS
20	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	9.9 ± 3.6
22	NS	NS	NS	NS	NS	NS	3.75 ± 0.46	NS	NS	11.5 ± 3.8	NS
23	NS	*TD = 22 ft*	NS	NS	NS	NS	NS	17 ± 4.5	21.6 ± 5.1	NS	NS
27	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS
30	NS		*TD = 27 ft*	NS	NS	NS	NS	NS	NS	15 ± 4.2	NS
33	NS			5.3 ± 0.54	1.33 ± 0.28	4.04 ± 0.49	3.47 ± 0.44	NS	NS	NS	NS
35	NS			NS	NS	NS	NS	NS	NS	NS	*TD = 33 ft*
37	11.7 ± 3.8			NS	NS	NS	NS	NS	NS	*TD = 35 ft*	
38	*TD = 37 ft*			NS	NS	NS	NS	26.3 ± 4.9	13.9 ± 4.1		
43				5.3 ± 0.54	4.28 ± 0.5	5.83 ± 0.59	8.32 ± 0.68	NS	NS		
50				3.91 ± 0.47	3.25 ± 0.44	3.74 ± 0.47	2.5 ± 0.37	NS	NS		
51				NS	NS	NS	NS	23.6 ± 6.3	25.2 ± 5		
60				4.05 ± 0.48	1126.4 ± 33.12	85.11 ± 8.23	3.05 ± 0.41	*TD = 51 ft*	*TD = 51 ft*		
				TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*				

Table 4.40 (continued)

Radium-226 (pCi/g)

Sample depth	006-019	006-020	006-023
11	ND	ND	ND
18	0.741 ± 0.068	0.71 ± 0.0644	NS
33	ND	ND	ND
43	0.907 ± 0.0823	ND	ND
50	0.696 ± 0.0549	ND	0.577 ± 0.064
60	NS	0.687 ± 0.0611	ND
	TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*

Technetium-99 (pCi/g)

Sample depth	006-021	006-022
60	956 ± 31.7	46.8 ± 13.8
	TD = 60 ft	*TD = 60 ft*

Thorium-234 (pCi/g)

Sample depth	006-023
11	ND
18	NS
33	1.17 ± 0.397
43	ND
50	ND
60	BSV
	TD = 60 ft

Uranium-235 (wt %)

Sample depth	006-020	006-021	006-022
11	NS	NS	0.732
18	0.7 ± 0.48	NS	0.725
33	NS	NS	NS
43	NS	NS	0.707
50	NS	NS	NS
60	NS	0.564	0.702
	TD = 60 ft	*TD = 60 ft*	*TD = 60 ft*

Notes:

BSV = Below screening value
ND = Below detection limit
NS = Not sampled
TD = Total depth

Table 4.41. Volatile organic analyte analyses of groundwater at SWMU 6

Acetone (µg/L)

Sample depth	006-028
35	13
	TD = 35 ft

Trichloroethene (µg/L)

Sample depth	006-024	006-025
68	6	NS
73	BSV	10
77	NS	15
78	6	NS
82	NS	31
83	19	NS
88	29	60
93	100	170
98	270	740
103	NS	10
108	BSV	NS
158	NS	NS
	TD = 158 ft	*TD = 158 ft*

Notes:
BSV = Below screening value
NS = Not sampled
TD = Total depth

Table 4.42. PCB analyses of groundwater at SWMU 6

PCB-1016 (µg/L)

Sample depth	006-028
9	255
	TD = 9 ft

Table 4.43. Inorganic analyses of groundwater at SWMU 6

Aluminum (mg/L)

Sample depth	006-011	006-012	006-025	006-029
9	4.68	NS	NS	NS
12	*TD = 9 ft*	4.43	NS	NS
22		*TD = 12 ft*	NS	0.259
28			0.21	NS
33			NS	NS
68			ND	*TD = 33 ft*
98			ND	
158			NS	
			TD = 158 ft	

Cobalt (mg/L)

Sample depth	006-016	006-019	006-020	006-022	006-023	006-024	006-025	006-029
22	NS	NS	NS	NS	NS	NS	NS	0.011
33	NS	NS	NS	NS	NS	NS	NS	NS
37	0.033	NS	NS	NS	NS	NS	NS	*TD = 33 ft*
60	*TD = 37 ft*	0.027	0.026	0.047	0.02	NS	NS	
68		*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	0.011	ND	
73						0.02	ND	
77						NS	0.018	
108						ND	NS	
158						NS	NS	
						TD = 158 ft	*TD = 158 ft*	

Table 4.43 (continued)

Iron (mg/L)

Sample depth	006-016	006-019	006-020	006-021	006-022	006-023	006-024	006-025
37	0.477 N	NS	NS	NS	NS	NS	NS	NS
60	*TD = 37 ft*	5.53 N	2.9 N	11.7	389 N	1.39	NS	NS
68		*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	ND	0.284
73							ND	1.44
77							NS	0.514
82							NS	1.81
88							ND	3.61
93							ND	3.4
98							0.286	1.69
108							1.53	NS
158							NS	NS
							TD = 158 ft	*TD = 158 ft*

Table 4.43 (continued)

Manganese (mg/L)

Sample depth	006-016	006-018	006-019	006-020	006-021	006-022	006-023	006-024	006-025	006-029
22	NS	NS	NS	NS	NS	NS	NS	NS	NS	3.09
27	NS	1.54	NS	NS	NS	NS	NS	NS	NS	NS
28	NS	*TD = 27 ft*	NS	NS	NS	NS	NS	NS	0.413	NS
33	NS		NS	NS	NS	NS	NS	NS	NS	NS
37	1.07		NS	NS	NS	NS	NS	NS	NS	*TD = 33 ft*
60	*TD = 37 ft*		1.33	0.844	0.705	0.956	0.914	NS	NS	
68			*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	1.39	1.06	
73								2.96	0.638	
77								NS	2.16	
78								1.61	NS	
82								NS	1.06	
83								1.61 N	NS	
88								2.51 N	1.42	
93								0.956 N	0.742	
98								0.273 N	0.944	
103								NS	0.459	
108								0.305 N	NS	
113								NS	0.369	
158								NS	NS	
								TD = 158 ft	*TD = 158 ft*	

Zinc (mg/L)

Sample depth	006-019	006-021
60	0.205	0.202 B
	TD = 60 ft	*TD = 60 ft*

Notes:

ND = Below detection limit
NS = Not sampled
TD = Total depth

<u>Laboratory qualifiers</u>

B = Found in the blank
N = Sample spike recovery not within control limits

Table 4.44. Radionuclide analyses of groundwater at SWMU 6

Alpha activity (pCi/L)

Sample depth	006-012	006-018	006-019	006-024
12	36 ± 17	NS	NS	NS
27	*TD = 12 ft*	45.5 ± 6.6	NS	NS
60		*TD = 27 ft*	26.33 ± 4.26	NS
98			*TD = 60 ft*	70.52 ± 7.62
108				BSV
158				NS
				TD = 158 ft

Beta activity (pCi/L)

Sample depth	006-009	006-011	006-012	006-016	006-018	006-019	006-020	006-021	006-024	006-025	006-028	006-029
9	NS	1500 ± 13	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12	NS	*TD = 9 ft*	2110 ± 27	NS	NS	NS	NS	NS	NS	NS	NS	NS
21	6.3 ± 1.5		*TD = 12 ft*	NS	NS	NS	NS	NS	NS	NS	NS	NS
22	*TD = 21 ft*			NS	NS	NS	NS	NS	NS	NS	NS	9 ± 1.9
27				NS	64.8 ± 4	NS	NS	NS	NS	NS	NS	NS
28				NS	*TD = 27 ft*	NS	NS	NS	NS	3.8 ± 1.6	NS	NS
33				NS		NS	NS	NS	NS	NS	NS	NS
35				NS		NS	NS	NS	NS	NS	538 ± 40	*TD = 33 ft*
37				359 ± 7.1		NS	NS	NS	NS	NS	*TD = 35 ft*	
60				*TD = 37 ft*		966.58 ± 30.64	247.86 ± 14.18	1126.4 ± 33.12	NS	NS		
68						*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	2.9 ± 1.5	4.3 ± 1.6		
73									4.1+/-2.4	2.6 ± 1.4		
77									NS	6.5 ± 1.7		
82									NS	7.6 ± 1.8		
88									6.8 ± 1.7	11.2 ± 1.9		
93									10.6 ± 1.8	28.3 ± 2.5		
98									200.69 ± 10.24	81.1 ± 3.7		
103									NS	33.4 ± 2.6		
108									2.5 ± 1.5	NS		
113									NS	6 ± 1.6		
158									NS	NS		
									TD = 158 ft	*TD = 158 ft*		

Table 4.44 (continued)

Neptunium237 (pCi/L)

Sample depth	006-019
9	219
	TD = 9 ft

Technetium-99 (pCi/L)

Sample depth	006-011	006-012	006-016	006-018	006-019	006-020	006-023	006-024	006-025	006-028	006-029
9	1810 ± 32	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
12	*TD = 9ft*	2920 ± 41	NS	NS	NS	NS	NS	NS	NS	NS	NS
22		*TD = 12 ft*	NS	NS	NS	NS	NS	NS	NS	NS	16 ± 8.8
27			NS	55 ± 9.1	NS	NS	NS	NS	NS	NS	NS
33			NS	*TD = 27 ft*	NS	NS	NS	NS	NS	NS	NS
35			NS		NS	NS	NS	NS	NS	930 ± 49	*TD = 33 ft*
37			690 ± 20		NS	NS	NS	NS	NS	*TD = 35 ft*	
60			*TD = 37 ft*		983 ± 32.1	255 ± 19.4	823 ± 29.8	NS	NS		
73					*TD = 60 ft*	*TD = 60 ft*	*TD = 60 ft*	16.9 ± 8.7	25.1 ± 9.1		
88								15.3 ± 8.7	ND		
93								ND	56 ± 11		
98								50 ± 10	119 ± 12		
103								ND	41 ± 10		
108								ND	NS		
158								NS	NS		
								TD = 158 ft	*TD = 158 ft*		

Uranium (pCi/L)

Sample depth	006-011
9	2320 ± 2140
	TD = 9 ft

Uranium-234 (pCi/L)

Sample depth	006-011
9	754 ± 697
	TD = 9 ft

Uranium-238 (pCi/L)

Sample depth	006-011
9	1520 ± 980
	TD = 9 ft

Notes:

BSV = Below screening value
ND = Below detection limit
NS = Not sampled
TD = Total depth

Table 4.45. Comparison of filtered and unfiltered groundwater samples at SWMU 6

Analyte (mg/L)	Not filtered			0.45-micron			5-micron		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Aluminum	120.07	0.202	1650	1.96	0.2	4.68	1.91	0.2	6.86
Antimony	1.10	0.2	2						
Arsenic	0.01	0.005	0.035	0.01	0.005	0.005	0.01	0.005	0.005
Barium	1.13	0.076	9.59	0.14	0.05	0.351	0.14	0.05	0.365
Beryllium	0.03	0.005	0.09	0.01	0.005	0.005	0.01	0.005	0.005
Cadmium	0.02	0.01	0.039	0.01	0.01	0.01	0.01	0.01	0.01
Calcium	85.45	10.9	892	26.00	2.38	95.7	30.71	2.78	100
Chromium	0.58	0.05	3	0.05	0.05	0.05	0.05	0.05	0.05
Cobalt	0.15	0.01	1.2	0.02	0.01	0.033	0.02	0.01	0.035
Copper	0.30	0.05	0.9	0.05	0.05	0.05	0.05	0.05	0.05
Iron	291.06	0.869	2640	1.71	0.2	5.53	1.75	0.2	6.19
Lead	0.72	0.2	2.03	0.20	0.2	0.2	0.20	0.2	0.2
Magnesium	23.24	2.81	190	9.94	0.088	31.4	11.85	0.239	31.8
Manganese	8.86	0.367	93	1.10	0.05	3.09	1.07	0.05	3.85
Mercury	0.00	0.0002	0.003	0.00	0.0002	0.0002	0.00	0.0002	0.0002
Nickel	0.22	0.05	0.5	0.05	0.05	0.05	0.05	0.005	0.005
Potassium	11.77	2	40	9.02	2	29	11.76	2	30.4
Selenium	0.01	0.005	0.005						
Silver	0.28	0.05	0.5						
Sodium	39.62	6.78	165	38.39	9.76	186	48.01	12.4	194
Thallium	1.10	0.2	2						
Vanadium	0.74	0.068	3.34	0.08	0.05	0.1	0.08	0.05	0.1
Zinc	0.78	0.2	4.16	0.20	0.2	0.205	0.20	0.2	0.2

5. CONTAMINANT FATE AND TRANSPORT

5.1 INTRODUCTION

This chapter provides an overview of the release mechanisms, potential migration pathways, mechanisms for transport, and the behavior of radiological and chemical substances reported in the WAG 3 sites (i.e., SWMUs 4, 5, and 6). The data derived from the sampling and analysis described in Chap. 2 and evaluated in Chap. 4 have been carried forward in this chapter to determine the fate of the contamination in the environment from the WAG 3 SWMUs, and to evaluate the transport mechanisms to determine when and where these contaminants will exit DOE property. Computer-based contaminant fate and transport modeling (leachability analysis) was performed for the sites using all chemical data available. These models simulated vertical transport from the UCRS to the RGA and horizontal transport within the RGA to predict the likely future maximum concentration of source-related COPCs at downgradient site boundaries. The ultimate objectives of these analyses were to evaluate potential future impacts to human health and the environment and to provide a basis for evaluating the effectiveness of proposed remedial alternatives in the feasibility study. Although some vertical migration of low concentrations of contaminants from the RGA to the McNairy Formation occurs, vertical transport within the McNairy is insignificant compared to that in the RGA. Therefore, vertical contaminant transport to the McNairy and horizontal transport within the McNairy are not addressed in the fate and transport modeling.

Physical, chemical, and biological processes affect the nature and distribution of chemicals in the environment. Although, in many instances, the specific chemicals, sources, and concentrations differ across the three sites, physio-chemical and hydrogeologic conditions that affect the migration and fate of contaminants are similar. Therefore, migration is addressed for the entire WAG 3 area.

A summary of the principles of contaminant fate and transport analysis and the results of the modeling activities are included in the following sections. Section 5.2 discusses the conceptual site model and potential contaminant migration pathways at WAG 3. This discussion considers site topography, geology, hydrology, and site-related chemicals. Section 5.3 presents a discussion of the persistence of the contaminants in the environment and the physical and chemical properties of the site-related chemicals that were used in the fate and transport modeling. Contaminant release mechanisms and transport media are also described in this section. Chemical migration rates for the WAG 3 COPCs are presented in Sect. 5.4.

5.2 CONCEPTUAL SITE MODEL

The conceptual site model developed for WAG 3 is a representation of known site conditions that serve as the framework for quantitative modeling. Site conditions described by the conceptual site model include waste source information, the surrounding geologic and hydrologic conditions, site-related chemicals, and current spatial distribution of the site-related chemicals. This information is combined to identify the likely chemical migration pathways.

Potential sources at the WAG 3 sites include burial areas where potentially contaminated trash and scrap were buried. Releases from these sources could directly impact soils below or adjacent to the source and/or sediments and surface water in nearby drainages. Continuing transport processes may also result in secondary releases that could impact larger areas or affect additional environmental media. Transport processes that could be active at the WAG 3 sites include volatilization, mobilization of dust particles, soil erosion and surface runoff, vertical infiltration in soil, and lateral and vertical migration in groundwater.

The air pathway is not considered a probable exposure route for contaminants from the WAG 3 sites. For the groundwater OU, some simple air modeling calculations were made for TCE and vinyl chloride to assess the possible impact of the air exposure pathway (DOE 2000b). Existing soil concentrations near the C-400 building were used with SESOIL to calculate the concentration in the soil vapor. Then, the assumption was made that the entire land surface was available for contact with the soil vapor. Atmospheric dispersion equations based on Fick's law were used to predict atmospheric concentrations of TCE and vinyl chloride downwind. The results showed that for the very high soil concentrations near the C-400 building, EPA atmospheric standards were exceeded directly at the point of release into the atmosphere, but that just 200 m downwind the standards were met. Since all of the ground surface is not commonly available for release due to buildings, pavement, caps, or ground cover, the same analysis was conducted assuming that only 50% of the surface area was available for transport. Under this assumption, the EPA atmospheric standards were met at the point of entry into the atmosphere from the source. These results, combined with the fact that TCE and vinyl chloride concentrations at WAG 3 are lower than at the C-400 building, make the air an unlikely exposure pathway and is therefore not considered in this analysis.

The surface water pathway is also not considered a likely off-site exposure route from WAG 3 source areas. Surface water at the site is controlled by a series of ditches and outfalls. Flow in the ditches that intersect the WAG 3 SWMUs is intermittent, based on seasonal rainfall. Any runoff from the WAG 3 SWMUs drains into the ditches and discharges to either Outfall 015 for SWMU 4 or Outfall 001 for SWMUs 5 and 6. These outfalls are monitored under a separate unit, the Surface Water Operable Unit, and will therefore be considered as a part of any action for that unit.

Data were collected during the RI to characterize potential exposure pathways for site-related chemicals in groundwater and surface and subsurface soil. Where data on source characteristics were lacking, sampling was also performed to evaluate the nature of the source. Based on this evaluation, a fate and transport model was developed and used to simulate vertical transport of contaminants from the source areas to the UCRS and RGA. The model then calculated predicted contaminant concentrations in groundwater after migration to two downgradient receptor points within the RGA (the PGDP security fence and the DOE property boundary) (see Sect. 5.4).

5.2.1 Contaminant Sources

Based on historical process knowledge and the findings of the sampling and analyses performed at WAG 3, the following contaminant sources have been identified.

5.2.1.1 SWMU 4

The C-747 Contaminated Burial Yard and C-748-B Burial Area (SWMU 4) are located immediately south of Virginia Avenue, between 4th and 6th Streets on the western side of the plant. Pits were excavated to a depth of about 15 ft, where contaminated and uncontaminated trash, some of which was burned, was buried and covered with 2 to 3 ft of soil. The trash reportedly included scrap equipment (steel, Monel, etc.) from the enrichment process. The WAG 3 investigation identified metals, VOAs, and radionuclides in the subsurface at SWMU 4.

5.2.1.2 SWMU 5

The C-746-F Classified Burial Yard (SWMU 5) is located in the northwest area of the plant site. SWMU 5 was used as a burial ground for the disposal of contaminated and uncontaminated classified scrap. The scrap was covered with 2 to 3 ft of soil.

During the WAG 3 RI, only a few metals, organics, and radionuclides were identified above screening levels.

5.2.1.3 SWMU 6

The C-747-B Burial Ground (SWMU 6) is located in the northwest area of the plant site. Reportedly, the site consisted of five separate burial plots, each used for specific waste types: magnesium scrap, laboratory exhaust fans contaminated with perchloric acid fumes, contaminated aluminum scrap, and a single contaminated UF_6 condenser.

The results of the RI indicated that metals, PCBs, and radionuclides are present in the subsurface at concentrations in excess of screening levels.

5.2.2 Hydrologic Properties and Water Balance

A description of the site hydrogeology and hydrology is provided in Chap. 3. Storm water runoff from WAG 3 is captured by ditches, which flow from the SWMUs predominantly westward to Outfalls 001 and 015. These outfalls discharge into Bayou Creek to the west of PGDP.

Three hydrogeologic units underlie PGDP and control the flow of groundwater and thus contaminant migration. These are, in descending order:

- UCRS: approximately 60 ft of silt and clay with discontinuous lenses of sand and gravel beneath an overlying loess deposit
- RGA: approximately 40 ft of gravel, sand, and silt deposits that overlie the McNairy Formation
- McNairy Formation: approximately 225 ft of a sandy, silty confining clay

For modeling purposes, it was assumed that the UCRS is not perennially saturated. Instead, it was assumed that groundwater infiltrates and migrates downward to recharge the RGA. This is a conservative assumption because, if saturated conditions in the UCRS were assumed, contaminant transport through it would have been further attenuated.

A water balance is a means of quantitatively accounting for all components of the hydrologic cycle at a site. The components of a simple steady-state water balance model include precipitation (P), evapotranspiration (ET), surface runoff (Sr), and groundwater recharge or deep percolation (Gr). The simple steady-state model is defined as follows:

$$P = ET + Sr + Gr$$

$$P\text{-}ET = Sr + Gr$$

The amount of rainfall that enters the surface runoff and groundwater recharge components (Sr + Gr) is the amount available to promote chemical migration away from a waste source.

The annual average water balance estimates for WAG 3, based on the Geotrans (1992) model for PGDP, are summarized below:

- evapotranspiration = 54% of total rainfall
- surface runoff = 38% of total rainfall
- groundwater recharge (percolation) = 8% of total rainfall; a small amount of which (7% of the recharged water) flows laterally through the top portion of the surface soil and is discharged to the surface water drainage system prior to reaching the saturated zone.

A past study (Geotrans 1992) has suggested that as much as 93% of the recharge to the UCRS may flow downward to recharge the RGA.

5.2.3 Site-Related Chemicals, Release Mechanisms, Migration Pathways, and Chemical Properties

Site-related chemicals for WAG 3 are discussed in Chap. 4. All waste-source chemicals that passed screening criteria and which were not considered laboratory contaminants are addressed in the quantitative fate and transport modeling. The following are site-related chemicals identified for fate and transport modeling during the WAG 3 RI:

- VOAs, including TCE and its degradation products (cis-1,2-dichloroethene, 1,2-dichloroethene and vinyl chloride), 1,1-dichloroethene, 2-butanone, 2-propanol, carbon tetrachloride, diethyl ether, and toluene.
- SVOAs, including 2-methylheptane, 2-methylnaphthalene, 3-nitrobenzenamine, 4-methyl-3-penten-2-one, 6-(acetyloxy)-2-hexanone, acenaphthylene, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, bis(2-methylhexyl)phythalate, bis(2-methoxyethyl)phthalate, dibenzofuran, ethanol, 2,2'-oxybis-, diacetate, pentachlorophenol, and phenanthrene.
- PCBs, including the Aroclors 1016, 1248, 1254, and 1260, in addition to total.
- Ten metals: aluminum, chromium, cobalt, copper, iron, lead, lithium, manganese, nickel, and strontium.
- Technetium-99, cesium-137, neptunium-237, plutonium-239, radium-226, thorium-230, and uranium and its decay products uranium-234, uranium-235, and uranium-238.

Detections of these chemicals in soil and/or groundwater confirm the potential for multimedia chemical transport. The migration pathways considered to be the most viable exposure routes for each of the WAG 3 sites are discussed here and include the potential for leaching of contaminants through soil to groundwater and migration of groundwater to downgradient receptors.

The fate and transport of organic compounds, metals, and radionuclides are functions of both site characteristics and the physical and chemical interactions between the contaminants and the environmental media with which they come into contact. The physical and chemical properties of the contaminants that influence these interactions include, but are not limited to (1) their solubility in water, (2) their tendency to transform or degrade (usually described by a half-life or an environmental half-life in a given medium), and (3) their chemical affinity for solids or organic matter (usually described by a partitioning coefficient K_d, K_{oc}, or K_{ow}). For purposes of conducting transport analyses in the vertical direction through the UCRS (i.e., migration from the site sources to the RGA) and for lateral transport in the RGA, default K_d values from the MEPAS modeling program were used for the soil type specified. Tables 5.1-5.3 list primary chemicals reported at WAG 3 and the media in which they were found.

5.2.3.1 Organic compounds

The organic constituents detected at WAG 3 include VOAs and SVOAs. These contaminants may be degraded in the environment by various processes including hydrolysis, oxidation/reduction, photolysis, or biodegradation. Degradation may reduce the toxicity of a chemical or, as in the case of TCE, may result in more toxic daughter products. The environmental half-lives of organic compounds in various media, defined as the time necessary for half of the chemical concentration to react, can vary from minutes to years, depending on the chemical and environmental conditions. Organic chemicals with differing chemical structures will biodegrade at different rates. Primary biodegradation consists of any biologically induced structural change in an organic chemical, while complete biodegradation is the biologically mediated degradation of an organic compound into carbon dioxide, water, oxygen, and other metabolic inorganic products (Dragun 1988). The biodegradation rate of an organic chemical is generally dependent on the presence and population size of soil microorganisms capable of degrading the chemical.

The mobility of an organic compound is affected by its volatility, its partitioning behavior between solids and water, water solubility, and concentration. The Henry's Law constant value (K_H) for a compound is the ratio of the compound's vapor pressure to its aqueous solubility. The K_H value can be used to make general predictions about the compound's tendency to volatilize from water. Substances with K_H values less than 1×10^{-7} atm/m^3/mol will generally volatilize slowly while compounds with K_H greater than 1×10^{-3} atm/m^3/mol will volatilize rapidly (Lyman et al. 1983). Vapor pressure is a measure of the pressure at which a compound and its vapor are in equilibrium. The value can be used to determine the extent to which a compound would travel in air, as well as the rate of volatilization from soils and solution. In general, compounds with vapor pressures lower than 1×10^{-7} mm mercury will not be present in the atmosphere, soil, or air in significant amounts, while compounds with vapor pressures higher than 1×10^{-2} mm mercury will exist primarily in the air (Dragun 1988).

Water solubility and the tendency to adsorb to particles or organic matter can correlate with retardation in groundwater transport. In general organic chemicals with high solubilities are more mobile in water than those that sorb more strongly to soils. The following properties must be measured when identifying a compound's mobility within a specific medium.

- K_{oc}, the soil organic carbon partition coefficient, is a measure of the tendency for organic compounds to be adsorbed to the organic matter of soil and sediments. K_{oc} is expressed as the ratio of the amount of chemical adsorbed per unit weight of organic carbon to the chemical concentration in solution at equilibrium.

- K_{ow}, the octanol-water partition coefficient, is an indicator of hydrophobicity (the tendency of a chemical to avoid the aqueous phase) and is correlated with potential adsorption to soils. It is also used to estimate the potential for bioconcentration of chemicals into tissues.

- K_d, the soil/water partition coefficient, is a measure of the tendency of a chemical to adsorb to soil or sediment particles. For organic compounds, this coefficient is calculated as the product of the K_{oc} value and the fraction of organic carbon in the soils. In general, chemicals with higher K_d values sorb more strongly to soil/sediment particles and are less mobile than those with lower K_d values.

Because the chemical and physical properties do not vary significantly within a given class of organic compounds, the fate and transport mechanisms can be discussed separately for each class of compound. Table 5.1 displays the VOAs and SVOAs present in WAG 3.

5.2.3.2 PAHs

PAHs are common components of fuel oils and tar mixtures. Fuel use, vehicular traffic, and asphalt surfaces can contribute to detected levels of polycyclic aromatic hydrocarbon (PAHs). PAHs are relatively persistent and represent a broad class of compounds ranging from low molecular weight components (such as naphthalene) to high molecular weight compounds [such as dibenzo(a,h)anthracene]. Solubility, volatility, biodegradability, and toxicity vary widely across this class of compounds.

Volatility, as indicated by the Henry's Law constant, decreases as the molecular weight of PAHs increases. Particulate emissions to ambient air can result from adsorption onto soot particles that can be carried on wind currents and then returned to the surface (dry deposition). High molecular weight PAHs are more likely to be transported via particulate emissions, whereas low molecular weight PAHs have a higher tendency to volatilize.

The behavior of PAHs in tar and oil waste mixtures is determined to a large extent by the mobility and behavior of the waste itself. For example, as tar waste weathers, volatilization, degradation, and leaching of the more mobile constituents occur. The overall loss rate decreases exponentially over time, and the material left behind becomes richer in more viscous and persistent components. Therefore, low molecular weight PAHs can migrate from spills and continuous releases of tars and oils; however, as weathering occurs, the rate of release decreases. Higher molecular weight PAHs would persist in the vicinity of the original release.

Lower molecular weight PAHs have higher water solubilities and are more likely to be released into groundwater than higher molecular weight PAH compounds. The higher molecular weight PAHs have relatively high K_{oc} values, indicating an increased tendency for adsorption to soil or other organic matter. A primary fate and transport mechanism is the migration of adsorbed PAHs with mobile soil and sediment. The erosion of soil and movement of suspended sediments may result in PAH migration to surface water. However, the low solubility of adsorbed PAHs indicates that they would not partition significantly to water. Most PAHs in aquatic environments are associated with particulate materials. Only about 33% are present in dissolved form (SAIC 1998).

Photolysis, oxidation, and biodegradation are common attenuation mechanisms for PAH compounds. Although all PAHs transform in the presence of light via photolysis, their transformation rates are highly variable. Photolysis may reduce the concentrations of these chemicals in surface waters or surface soils but is not relevant for subsurface soils. Biodegradation rates of PAHs in soils are also extremely variable across the chemical class. Generally, the dicyclic and tricyclic PAHs biodegrade more readily than the higher molecular weight PAHs. Factors that affect the rate of biodegradation in soils include the types of microorganisms present, the availability of nutrients, the presence of oxygen, and the chemical concentration. The extent to which chemicals may biodegrade also can be affected by their presence in mixtures. Some PAHs are more degradable than others. If both stable and mobile PAHs are present in a mixture, the less degradable materials may be co-metabolized at rates similar to or greater than the rates of the more degradable compounds.

In general, PAHs are not mobile in soil or groundwater. Model simulations of solute transport of PAHs in soil (Clausen 1996) and their physical properties indicate limited migration potential.

The distribution of PAHs above screening levels at the WAG 3 sites is not widespread. In the soil these compounds are limited to surface samples at SWMU 5 and shallow soil in historical data from the SWMU. No groundwater samples contained detectable concentrations of PAHs.

5.2.3.3 PCBs

PCBs were widely used at PGDP as hydraulic fluid and as dielectric fluids in electrical transformers and capacitors. Like many chlorinated organic compounds, PCBs in liquid form are DNAPLs. However, many times the PCBs were mixed with oils and, in such cases, may take on the properties of light, nonaqueous-phase liquids.

Like PAHs, PCBs have relatively high K_{oc} values, indicating an increased tendency for adsorption to soil or other organic matter. A primary fate and transport mechanism is the migration of adsorbed PCBs with mobile soil and sediment. The erosion of soil and movement of suspended sediments may result in PCB migration to surface water. However, the low solubility of adsorbed PCBs indicates that they would not partition significantly to water.

In general, PCBs are not mobile in soil and are rarely seen in groundwater. Typically, as the number of chlorine atoms present in the PCB congener increases, the water solubility decreases. Model simulations of transport of PCBs in soil indicate no migration potential.

The distribution of PCBs above screening levels at the WAG 3 sites is not widespread. In the soil these compounds are limited to surface samples at SWMU 5 and shallow soil at SWMUs 4 and 6. Groundwater samples contained detectable concentrations of PCBs in the waste cells at SWMU 6. Two RGA samples from SWMU 4 also contained detectable concentrations of PCBs.

5.2.3.4 Chlorinated VOAs

Chlorinated VOAs were detected above screening levels in soils above the RGA only at SWMU 4, and in only two historical RGA soil samples from one location in SWMU 5 (1,1,2-trichloro-1,2,2-trifluoroethane). Compounds detected at SWMU 4 include the following: carbon tetrachloride and TCE and its degradation products [cis-1,2-dichloroethene, 1,2-dichloroethene (total), and vinyl chloride].

TCE and various degradation products [cis-1,2-dichloroethene, 1,2-dichloroethene (total), and vinyl chloride] were detected in UCRS and RGA groundwater at SWMU 4. TCE and the degradation products [cis-1,2-dichloroethene and 1,2-dichloroethene (total)] were also detected in McNairy groundwater samples at SWMU 4. Additionally, carbon tetrachloride, chloroethane, and chloroform were detected above screening levels in RGA groundwater samples at SWMU 4.

At SWMUs 5 and 6, only TCE was detected above screening levels in the RGA groundwater. TCE was also detected in groundwater samples from the McNairy at SWMU 6.

These chemicals have high vapor pressures and Henry's Law constants, indicating a potential for volatilization. Therefore, they are not expected to persist in surface soils. The rate of loss from volatilization depends on the compound, temperature, soil gas permeability, and chemical-specific vapor pressure.

Release and transport mechanisms include vertical advective migration through unsaturated soils toward the water table as well as gravity driven migration as a DNAPL. The range of K_{oc} values indicates that chlorinated VOAs are mobile through soils as dissolved constituents and tend not to partition significantly from water to soil. However, some of these compounds are retained in pore spaces in the form of DNAPLs. A DNAPL migrates principally under the influence of gravity, not advection. Thus, a DNAPL will migrate vertically, fingering out among available pore space and continue downward. If a DNAPL is present in sufficient quantity it may spread out laterally along lower permeability zones it encounters and even pool there if a sufficiently large zone exists. This type of migration allows a DNAPL to take a highly variable path and exist in areas that are almost impossible to characterize where the geology is as spatially variable as it is in the UCRS.

Biodegradation and chemical degradation are important considerations in evaluating chlorinated solvents because of the potential formation of COPCs and/or losses of COPCs. The redox conditions in the RGA appear to be somewhat variable; however, the groundwater chemistry indicates that only limited anaerobic degradation is occurring. Anaerobic degradation primarily occurs in the soils above the aquifer.

Aerobic and anaerobic biodegradation are important transformation processes for chlorinated aliphatic compounds in natural water systems and soil, and considerable research has been done on the degradation mechanisms and pathways for this class of compounds. Although several degradation pathways could occur for these constituents, the patterns described below have been identified for degradation under anaerobic conditions. The anaerobic degradation pathway is as follows:

TCE → Dichloroethene → Vinyl Chloride or Chloroethane

The anaerobic biodegradation of TCE, which initially forms cis-1,2-dichloroethene, occurs under reducing conditions where sulfide- and/or methane-producing conditions exist. Such conditions occur primarily in the presence of other natural or anthropogenic carbon sources.

Total organic carbon (TOC) levels in soil at the PGDP were measured during the WAG 3 RI for surface soils and UCRS soils. All TOC values for UCRS soils were less than the laboratory detection limit of 300 mg/kg in SWMUs 5 and 6. Only one TOC sample measured above the detection limit in SWMU 4; its result was 400 mg/kg. The relatively low TOC content of site soils does not promote the anaerobic biodegradation of TCE.

Dichloroethene is an indicator for this degradation pathway, because it is not used as a pure product but is found solely as a degradation product. 1,2-Dichloroethene may further degrade anaerobically to vinyl chloride, but the rate is slower and the process may require stronger reducing conditions than those required for reduction of trichloromethene or TCE.

TCE generally would be expected to persist under aerobic or denitrifying conditions. Denitrifying conditions are indicated when nitrates are present in groundwater, but no oxygen is present.

Aerobic biodegradation of TCE may occur under certain conditions. For example, specialized microorganisms have been identified that aerobically degrade some of these solvents in the presence of ammonia, methane, and toluene. Lower molecular weight chlorinated hydrocarbons, such as dichloroethene, undergo anaerobic degradation less readily than the higher molecular weight chlorinated hydrocarbons such as TCE, but undergo aerobic degradation more readily.

In summary, TCE, dichloroethene, and vinyl chloride were reported both in groundwater and soils at concentrations exceeding screening levels at SWMU 4. Therefore, SWMU 4 appears to contain source(s) for TCE in the groundwater at PGDP.

Additionally, carbon tetrachloride was detected above screening levels in soils at SWMU 4 and also in an RGA groundwater sample from a previous investigation. Therefore, SWMU 4 appears to contain a source for carbon tetrachloride in the groundwater at PGDP.

Chloroethane and chloroform were detected above screening levels in RGA groundwater samples at SWMU 4, but were not found in soil samples. Therefore, the source of the two compounds is probably upgradient of SWMU 4.

5.2.3.5 Metals

Inorganic chemicals released to unsaturated soil become dissolved in soil moisture or adsorbed onto soil particles. Dissolved inorganic analytes detected at WAG 3 include the metals listed in Table 5.2. These dissolved metals are subject to movement with vadose zone water. Aqueous transport mechanics may result in metal migration through the vadose zone to groundwater. Metals, unlike organic compounds, cannot be degraded. However, metals migration can be attenuated by retarding reactions such as adsorption, surface complexation, co-precipitation, and ion-exchange reactions with the soils with which they come into contact. Such reactions are affected by pH; oxidation-reduction conditions; and the type and amount of organic matter, clay, and hydrous oxides present. These reactions are typically reversible, resulting in dynamic metal solubility in immature or poorly developed soils. Some metals, such as arsenic and chromium, can be transformed to other oxidation states in soil. Such transformations can reduce the metals' toxicities and/or affect their mobilities by affecting the way in which they react with soil particles or other solid surfaces by ion exchange, adsorption, precipitation, or complexation.

The oxidation state and chemical speciation of inorganic chemicals control solubility and thus, to a great extent, mobility in the environment. The mobility of both metals and radionuclides can be significantly enhanced by the formation of organometallic and/or anionic complexes. Chemical speciation may be an important process in determining the chemical form present in the soil. However, speciation is very complex and difficult to distinguish in routine laboratory analysis;

therefore, its impact may not be measurable or predictable. In soil, metals are typically found in the following states:

- Dissolved in interstitial fluids
- Occupying exchange sites on inorganic soil constituents
- Adsorbed on inorganic soil constituents
- Associated with insoluble soil organic matter
- Precipitated as pure or mixed solids
- Present in the structure of secondary minerals
- Present in the structure of primary minerals

In situations where metals have been introduced into the environment through human activities, metals are typically associated with the first five conditions. The dissolved aqueous fraction and its equilibrium solid fraction are of primary importance when considering the migration potential of metals associated with soils. The unfilterable inorganics represent the dissolved fraction, which is the more mobile fraction. Of the compounds that are most likely to form in soils, chlorides, nitrates, and nitrites are the most soluble. Sulfates, carbonates, and hydroxides have low to moderate solubility. In general, soluble compounds are transported in aqueous forms that are subject to retardation, whereas insoluble compounds remain as precipitates and limit the overall dissolution of metals.

Adsorption depends on the surface charge, the dissolved ion and its charge, and the pH of the soils. Positively charged metal ions (such as trivalent chromium, cadmium, lead, iron, manganese, and zinc) tend to be adsorbed, and the transport of these species is slower than the groundwater or pore water velocity. The retardation factor (R_f) describes numerically the extent to which the velocity of the contaminant migration is decreased and is largely derived from the partition coefficient (K_d). The K_d values of metals vary widely in the same soil type and may vary by orders of magnitude among samples from the same site.

Contaminant persistence is a function of physical, chemical, and biological processes that affect the chemical as it moves through air, soil, and water. Some inorganic contaminants may undergo chemical species transformation after being released to the environment. An important example of one such transformation is the change of the charge state from Cr^{+6} to Cr^{+3}. Organometallic compounds can undergo a variety of chemical reactions that may transform one compound into another, change the state of the compound, or cause a compound to combine with other chemicals; however, the metallic portion of the organometallic compounds only changes oxidation states. With the exception of changing oxidation states or possibly exchanging metallic species, inorganic contaminants are much more stable than organic contaminants.

The mobility of metals is directly related to their solubility in water or other fluids and to pH and redox conditions. In the absence of fluids to mobilize and transport metals, virtually no transport is possible. Even if fluids are present, metals become more mobile only under favorable pH and redox conditions. Movement of metals is also controlled by the solubility (pH- and Eh-dependent), adsorption, and redox state of the metal. With the exceptions of hexavalent chromium, barium, and selenium, the solubility of other metals of concern is inversely proportional to pH. However, iron, manganese, and aluminum oxides, plus carbonates, hydroxides, and organic materials, may cause metals to precipitate or be adsorbed onto soil particles. Based on WAG 27 data (DOE 1999b), the pH of the RGA water samples ranged from a low of 5.75 (at SWMU 001) to a high of 8.28 (at SWMU 091), with an average of 6.24. Water samples collected from the RGA during the WAG 3 investigation ranged in pH from 6.02 to 6.52.

Chemical distributions in both soil and water are more difficult to predict for metals than for organic compounds. A direct relationship between the measured total metal concentration in soil and the extractable aqueous concentration cannot be assumed. The metal may be fixed in the interior of the soil and unavailable for exchange or release to water, or exchangeable metal may be present at the surface of the particles.

Published K_d values generally represent the potential relationship between water and exchangeable metal at the surface of the soil, which is as follows:

$$C_{total} = C_{fixed} + C_{adsorbed}$$

$$K_d = C_{adsorbed}/C_{water}$$

where

C_{total} = total concentration of metal (fixed plus adsorbed),
C_{fixed} = fixed concentration of metal (contained within the chemical structure of the minerals),
$C_{adsorbed}$ = adsorbed concentration of metal,
K_d = chemical-specific distribution coefficient (cc/g),
C_{water} = concentration of metal in water.

This relationship is useful in determining retardation (the tendency for the metal to sorb to the surface of the soil), but it does not relate the total metal concentration in the solid to a dissolved concentration.

At the three sites investigated during the WAG 3 RI, eight metals (aluminum, chromium, cobalt, copper, iron, lead, manganese, and nickel) were detected in soils at levels that exceeded screening values. All of these metals exceeded screening values in less than 10% of the WAG 3 soil samples analyzed for metals.

5.2.3.6 Radionuclides

Radionuclides represent a special case of inorganic species. Although radionuclides behave chemically as metals, the radioactive nuclides undergo spontaneous transformations that involve the emission of particles and radiant energy. Most important for WAG 3 are the emission of alpha and beta particles and the emission of gamma energy. The resulting daughters (i.e., product nuclides) may be radioactive themselves (in which case they too will undergo spontaneous decay) or may be stable nuclides. The decay process can occur by various spontaneous mechanisms.

Two of the more important decay modes are alpha decay and beta decay, the latter being differentiated into electron and positron decay. As with inorganic and organic chemical species that do not undergo nuclear transformations, the persistence of radionuclide contaminants at WAG 3 is related largely to their geochemical mobility in the environment.

Natural uranium consists of three primary isotopes: uranium-234, uranium-235, and uranium-238. The decay products of uranium isotopes are also radioactive and form decay chains.

Uranium hexafluoride is the sole raw material used in the enrichment process at PGDP. Some of the uranium feed material that was handled at PGDP has been reclaimed or recycled from reprocessed, spent reactor fuel. The chemical processes by which recycled uranium is purified leave trace amounts of transuranic elements (neptunium and plutonium) and fission products (mainly technetium-99). Technetium-99 (in the +7 oxidation state) is highly soluble in groundwater and is very mobile (its K_d is similar to that of TCE). The groundwater plumes of TCE and technetium-99 at PGDP are similar in size and geometry.

On an activity basis, the principal radionuclides expected to pass through chemical processing and contaminate the recycled uranium are the transuranic radionuclides produced in highest abundance and with moderate half-lives: neptunium-237, plutonium-238, plutonium-239, plutonium-240, and americium-241. However, characterization studies (DOE 1998c, SAIC 1998) have generally shown that these radioisotopes are usually present in activities that are less than 1% of the uranium activity unless treatment processes have collected and concentrated them in sludges or trap material. Of the transuranic radionuclides, neptunium fluoride is believed to have been the most mobile in the gaseous phase and to have migrated further in the process system before being deposited. The others are believed to have been present in the feed in lower concentrations and to have been more persistent in the heel of the feed cylinders.

In addition, certain fission and activation products may form volatile compounds in the fluorination process: zirconium-95, niobium-95, technetium-99, ruthenium-106, cesium-134, and cesium-137. However, zirconium-95, niobium-95, ruthenium-106, and cesium-134 have short half-lives (65 days, 55 days, 368 days, and 2.1 years, respectively) compared to the 15-plus years since recycled uranium was last introduced; as a result, they are unlikely to be present in significant quantities today. Because cesium-137 has a half-life of 30 years, it is the most likely fission product (except for technetium-99) still to be present at the site.

Several soil and groundwater samples from the WAG 3 sites contained activities of radionuclides above screening levels, the majority coming from SWMU 4. The most frequently detected radionuclide in groundwater samples was technetium-99. This is not unexpected, as the paths of the northwest and southwest plumes fall close to the WAG 3 sites (Bechtel Jacobs Company 2000). Radionuclides present are shown in Table 5.3.

Buildup of Uranium Daughter Products

Uranium, uranium-234, and uranium-238 were detected in 32% to 34% of soil samples collected during the WAG 3 RI. Uranium, uranium-234, uranium-235, and uranium-238 were not detected in RGA and McNairy groundwater samples during the WAG 3 RI.

Uranium-238 and uranium-235 have very long half-lives; however, secular equilibrium is attained quickly and daughter activity increases rapidly. Secular equilibrium is the term applied to a closed system that has been left undisturbed for a long time compared to the half-life of any of the parent or daughter radionuclides in the system. At this point, the rate of decay of each daughter radionuclide is equal to its rate of production from its parent radionuclide. Upon reaching secular equilibrium, the rate of decay of the daughter products is equal to that of the parents. When release of the parent radionuclide species occurs (i.e., when uranium-238 and uranium-235 are first introduced into a closed system), daughter product activity is at a low background level. Because secular equilibrium is attained quickly for a closed system with uranium-238 and uranium-235 as the parent species, this implies that there will be a rapid increase of daughter product activity until secular equilibrium is attained, at which point both parent (i.e., uranium-238 and uranium-235) and daughter product activities will be equal.

5.3 CHEMICAL MIGRATION RATES AND PATHWAYS

Most chemicals in soil or groundwater migrate at a velocity slower than that of water, which is the transport medium. The retardation factor, R_f, is the relative chemical migration velocity, which is calculated as follows:

$$R_f = 1 + (K_d \rho) / \eta$$

where

R_f = chemical-specific retardation factor (dimensionless),
K_d = chemical-specific distribution coefficient (cc/g),
ρ = bulk mass density of dry aquifer system skeleton (g/cc)
[1.67 g/cc (based on soil samples collected during the WAG 27 RI)],
η = total porosity (dimensionless)
(0.37 value from literature).

The distribution coefficient K_d for organic constituents is estimated as follows:

$$K_d = K_{oc} * foc$$

where

K_d = chemical-specific distribution coefficient (cc/g),
K_{oc} = chemical-specific organic carbon partition coefficient,
foc = fraction of organic carbon
[0.00801 (based on soil samples collected during the WAG 27 RI)].

In general, metals are persistent in the environment. Metals are not typically volatile, so any emissions to ambient air would be in the form of particulate emissions.

5.3.1 Soil to Groundwater Pathway—UCRS

Contaminants present in surface and subsurface soils may leach to the underlying aquifer. Several factors influence the dissolution of COPCs in soils and the rate of contaminant movement through soils. These factors include the physical/chemical properties of the contaminants (e.g., solubility, density, viscosity, mineralogy, and K_d) and the physical/chemical properties of the environment (e.g., rainfall, percolation rate, soil permeability, porosity, particle size, and amount of organic carbon). Contaminants migrate to groundwater through infiltration, leaching, and the movement of subsurface water within the capillary fringe.

Generally, groundwater is relatively deep at WAG 3, and many of the potential source areas have been present for a long time. Therefore, leaching potential is indicated by the observed groundwater concentrations. The amount of water available for infiltration is based on an average rainfall recharge rate of 4 in./year. The interstitial groundwater velocity (in./year) is estimated by dividing the average rainfall recharge rate by the volumetric moisture content of the unsaturated zone. Thus, assuming a water-filled porosity of 0.37, the interstitial groundwater velocity is about 11 in. per year. The depth to the water table in many areas is approximately 55–60 ft, suggesting an average travel time from the surface to the water table of 60 years. Actual contaminant travel times to the RGA groundwater integrator unit will vary depending upon many factors including local subsurface conditions, the depth of a waste unit, whether or not DNAPL may be present which may facilitate transport of certain other contaminants, and the actual amount of vertical infiltration flowing through a particular waste site. In areas beneath low-permeability zones (such as a paved area or a clay cap), less infiltration would occur. Adjacent to these low-permeability areas, higher rates of recharge may occur as runoff increases the infiltration in localized areas. While vertical migration rates may vary spatially according to the local geology and infiltration rates, the overall migration pathway for contaminants entering the UCRS is ultimately downward toward the RGA.

Vertical migration rates for dissolved constituents are influenced largely by advection and dispersion. Within high permeability zones advection may be dominant, while dispersion may dominate in lower permeability zones. Overall, however, advection is the primary mechanism for transport vertically through the UCRS.

Chemicals also can attenuate in the vadose zone. Chemicals that strongly sorb to soils, including most PAH and PCB compounds, tend to remain in or near the point of release. The R_fs for these constituents indicate that they would be expected to migrate much more slowly than water in some instances. In addition to their strong tendency to adsorb, these compounds biodegrade during the slow transport, limiting the impacted area. Other constituents such as VOAs tend to volatilize in the unsaturated zone, decreasing their persistence in that medium.

Further, the UCRS is divided into three hydrologic units at the WAG 3 sites. The first hydrologic unit (HU1) is made up of the overlying loess that blankets the entire site. The second unit (HU2) is similar to the HU1, but has a lesser clay content and lacks the coarser-grained lenses of HU1. The third unit (HU3) is fairly hard, dense, and slightly damp clay to clay with silt. Previous investigations at the Paducah site of the shallow groundwater determined that the flow is primarily vertical, although there may be some hydraulic lateral interconnectivity between the sand and gravel lenses that are in close proximity to one another. Perched water tables are present where the downward flow has been terminated because of an impermeable layer (such as the HU3 unit). A more detailed description of the geology and hydrogeology of the WAG 3 sites can be found in Chap. 3.

5.3.2 Groundwater Contaminant Migration—RGA

The primary COCs reported in RGA groundwater include TCE and the associated daughter products cis-1,2-dichloroethene, 1,2-dichloroethene (total), and vinyl chloride, technetium-99, and several metals. VOAs were detected above screening values at all three SWMUs in WAG 3; the highest VOA concentration reported was for TCE at 67,000 µg/L at SWMU 4. Technetium-99 was also detected above screening values in RGA groundwater at all three SWMUs; reported activities for technetium-99 ranged from 720 pCi/L (004017WA040) to 14.9 pCi/L. RGA groundwater containing elevated metals concentrations was also detected at all three SWMUs.

Once in the groundwater, the COCs generally move through the RGA via advection. Using the hydraulic properties of the RGA as a conservative estimate of advective transport, the seepage velocity (advection velocity) is estimated at 2 ft/day. [The advection (seepage) velocity, $v = ki/n$, where k is the hydraulic conductivity (1500 ft/day), i is the hydraulic gradient (0.0004), and n is the effective porosity (30%).] Therefore, based on advection alone, it is estimated that contaminants could migrate as far as 730 ft each year.

COCs spread both horizontally and vertically due to the process of dispersion, while adsorption retards the movement of chemicals in groundwater. Dispersion generally causes chemicals to migrate from 10% to 20% farther than migration caused by advection alone. Adsorption, which retards the movement of chemicals, counteracts the advection and dispersion processes. Adsorption is generally described by a chemical's distribution coefficient (K_d). The migration potential for one year was calculated for COCs in accordance with the groundwater flow velocities at that location. These calculations were based on the following equation:

$$V_c = V / R_f$$

where

V_c = chemical horizontal migration velocity in feet per year (ft/year),
V = site-specific groundwater flow velocity (ft/year),
R_f = chemical-specific retardation factor (dimensionless).

Calculated horizontal migration velocities are based on advection, retardation, and dispersion but not on the effects of biodegradation. Of the COCs identified in Tables 5.1-5.3, the most mobile constituents include the chlorinated VOAs and technetium-99. Other constituents, such as metals, are not readily transported in groundwater.

5.4 FATE AND TRANSPORT MODELING

Contaminant fate and transport modeling was conducted for SWMUs 4, 5, and 6 using the MEPAS model (Battelle 1995). The MEPAS model is a fate and transport and risk computation code that combines source term, transport, and exposure type models. The MEPAS model was selected for use at the PGDP as a screening tool for RIs and risk assessments. By using a simplistic one-dimensional analytical model with conservative transport parameters, MEPAS results allow contaminants to be dropped for further consideration during the risk assessment phase. At the PGDP a series of modeling levels are used throughout the RI/feasibility study (FS) process at various phases and are categorized roughly as screening level, far-field, transport and predictive. To maximize the efficiency of modeling efforts, each level is designed to fulfill specific needs throughout the RI/FS process. During the RI phase, screening level modeling is intended to filter out contaminants from an initial set of analytical data by making conservative assumptions. Contaminants which do not pose a problem from model results can be confidently dropped from further consideration. At each successive level of the modeling hierarchy, the models employed become more rigorous, data intensive, and time intensive. The levels range from the most simplistic screening level models to sophisticated three-dimensional numerical models which have been rigorously calibrated. Model selection was based on the premise of using less time-consuming models to screen out those contaminants which can be easily shown not to pose a threat even under the most conservative assumptions. More rigorous models are then used for those contaminants which continue to appear to pose a problem. The modeling steering committee at the site recommended MEPAS as an ideal tool for this task due to its ease of use, ability to simulate depleting source terms, ability to simulate multiple pathways, and ability to perform risk computations. For purposes of this analysis, only the groundwater pollutant transport portion of the model was used. For the groundwater pathway, the MEPAS code calculates groundwater concentrations using the one-dimensional advective and three-dimensional dispersive equations for solute flow, accounting for degradation and decay:

$$\left(\frac{\partial c}{\partial t}\right) + \left(\frac{u}{R_f}\right)\left(\frac{\partial c}{\partial x}\right) = \left(\frac{D_x}{R_f}\right)\left(\frac{\partial^2 c}{\partial x^2}\right) + \left(\frac{D_y}{R_f}\right)\left(\frac{\partial^2 c}{\partial y^2}\right) + \left(\frac{D_z}{R_f}\right)\left(\frac{\partial^2 c}{\partial z^2}\right) - \lambda c$$

in which

$$R_f = 1 + \frac{\beta K_d}{n_e} \text{ (saturated zone)}$$

$$R_f = 1 + \frac{\beta K_d}{\theta} \text{ (vadose zone)}$$

$$\theta = n\left[\frac{(K(\theta))}{K_s}\right]^b$$

and where

c = dissolved concentration (g/mL or Ci/mL)
u = pore-water velocity (cm/s)
D_x, D_y, D_z = the dispersion coefficients in the X, Y, and Z directions, respectively (cm^2/s)
λ = degradation/decay rate (L/s)
β = bulk density of soil (g/cm^3)
K_d = distribution coefficient (mL/g)
n_e = effective porosity (dimensionless)
n = total porosity (dimensionless)
θ = moisture content of the soil (dimensionless)
$K(\theta)$ = unsaturated hydraulic conductivity (cm/s)
K_s = saturated hydraulic conductivity (cm/s)
b = empirically based value that is a function of the soil property
K_s = retardation factor

Because the MEPAS algorithm does account for degradation/decay, the model is especially useful for such screening level groundwater modeling. Additional information regarding the MEPAS model and the mathematical formulas on which the calculations are based may be found in Vols. I and III of the report, *Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance* (Battelle 1995).

Concentrations were modeled to two receptor points: the PGDP security fence and the DOE property boundary to determine if WAG 3 sites contribute to off-site plumes. The output tables (Tables 5.4 through 5.6) list the maximum concentrations for each source constituent and the corresponding times at which these concentrations reach each receptor point. For all three SWMUs, the saturated layer includes the RGA and extends from an average depth of 60 to 100 ft bgs (55 to

100 ft bgs for SWMU 4). The direction of groundwater flow was assumed to be to the north (Davis et al.1973).

The following sections provide a general overview of the results of the modeling for each area in WAG 3. More details concerning contaminant screening, development of the contaminant source terms, and the specific parameter values entered into the model are provided in Vol. 4, Appendix B. The results of the MEPAS modeling are compared to risk-based values in Vol. 4 to assist in the evaluation of risks to future residential groundwater users.

The residual radioactivity (RESRAD) model was used to estimate potential future concentrations of selected radionuclides in RGA groundwater below each SWMU in WAG 3. Land uses and exposure routes assessed using RESRAD for each SWMU were as follows:

- Industrial worker exposure to surface soil—ingestion of soil, inhalation of particulates emitted from soil, and external exposure to ionizing radiation emitted from soil
- Excavation worker exposure to surface and subsurface soil—ingestion of soil, inhalation of particulates emitted from soil, and external exposure to ionizing radiation emitted from soil
- Residential exposure to RGA groundwater—ingestion of RGA groundwater

5.4.1 SWMU 4

Based on soil boring logs, two model layers (one partially saturated and one saturated) were delineated at SWMU 4. These layers correspond to the UCRS (1–55 ft bgs) and the RGA (55–100 ft bgs). Figures 3.3, 3.4, and 3.5 present a cross-section delineating the layers modeled at the unit. The travel distances from the source to each downgradient exposure point were 890 ft to the PGDP security fence and 2895 ft to the DOE property boundary, based on a west to northwestward groundwater flow direction.

This WAG 3 RI, the SI (CH2M HILL 1991, 1992), and the Data Gaps Investigation Report (DOE 2000a) provided surface and subsurface soil data used to develop the source terms. Source terms for surface soils were delineated for the most part along drainage pathways. Discrete subsurface source areas were defined for each contaminant present in the partially saturated layer. Individual waste cells within SWMU 4 were not discretized; with the exception of total uranium sampled from one waste cell, the levels of which other samples in the SWMU did not match. No background values are available for lithium and strontium at PGDP, so all detected values were used to develop their source volumes. Because lithium and strontium were widespread across the unit, their source areas were assumed to be equal to the total SWMU area. Additionally, source terms developed for modeling of SWMU 4 were conservative. For radiological parameters, in most cases, the entire boundary of the SWMU was used as the source term. The result of these conservative source terms is relatively high maximum concentrations/activities.

Table 5.4 provides the results of MEPAS modeling for SWMU 4. This table lists the maximum concentrations of each source contaminant (and, in the case of the radionuclides, their daughter products) expected to reach the two receptor locations. Results indicate that chromium and PCBs in the surface soil and aluminum, barium, chromium, lead, zinc, PCBs, and pentachlorophenol in the UCRS contribute no or negligible contaminants to the groundwater in the RGA. The maximum potential cobalt concentration, as indicated by modeling, is 3.29 mg/L at the PGDP fence in 787.5 years and 0.646 mg/L at the DOE boundary in 961.3 years.

The maximum potential copper concentration is 7.32 mg/L at the PGDP fence in 7992 years from contributions made by contaminants in the UCRS. The maximum potential concentration is above the current MCL of 1.3 mg/L. The maximum potential concentration at the DOE boundary is 1.46 mg/L in 9539 years.

Volatile contaminants in the UCRS will contribute significantly to the groundwater in the RGA. Most significantly,

- 1,1-Dichloroethene will reach 72.58 µg/L at the PGDP fence, 63 years from the time of its presence in the environment at present and 53.8 µg/L in 69 years at the DOE boundary. The MCL for 1,1-dichloroethene is 7 µg/L.

- TCE will reach 22,600 µg/L at the PGDP fence, 101 years from the time of its presence in the environment at present and 4700 µg/L in 111 years at the DOE boundary. The MCL for TCE is 5 µg/L.

- Vinyl chloride will reach 331 µg/L at the PGDP fence, 56 years from the time of its presence in the environment at present and 69 µg/L in 62 years at the DOE boundary. The MCL for vinyl chloride is 2 µg/L.

Contributions from radionuclide contaminants in the surface soil to the groundwater in the RGA are negligible. Radionuclide contaminants in the UCRS contribute the following to the groundwater in the RGA:

- Neptunium-237 will reach 488 pCi/L at the PGDP fence, 316.4 years from the time of its presence in the environment at present and 98.3 pCi/L in 380.4 years at the DOE boundary.

- Technetium-99 will reach 6340 pCi/L at the PGDP fence, 111.4 years from the time of its presence in the environment at present and 1320 pCi/L in 112.7 years at the DOE boundary.

- Uranium-234 will reach 4510 pCi/L at the PGDP fence, 4329 years from the time of its presence in the environment at present and 8940 pCi/L in 5140 years at the DOE boundary.

- Uranium-238 will reach 833 pCi/L at the PGDP fence, 4330 years from the time of its presence in the environment at present and 166 pCi/L in 5141 years at the DOE boundary.

- Total uranium will reach 6460 pCi/L at the PGDP fence, 4330 years from the time of its presence in the environment at present and 2130 pCi/L in 5141 years at the DOE boundary.

5.4.2 SWMU 5

Three model layers, two partially saturated and one saturated, were delineated at SWMU 5. The partially saturated layer includes the loess deposits making up HU1, the permeable but discontinuous sand and gravel lenses of the UCRS, and a silty clay aquitard HU3 (1–60 ft bgs). The saturated layer consists of the RGA and extends from 60 to 100 ft bgs.

A cross-section showing the depths of these layers at the unit is presented in Figs. 3.8, 3.9, and 3.10. The travel distance from the source to each downgradient exposure point is 890 ft to the PGDP security fence and 2780 ft to the DOE property boundary.

Surface and subsurface soil data provided by the WAG 3 RI and the SI (CH2M HILL 1991, 1992) were used to develop the source terms and inventories for the site contaminants. Metals, organic compounds, and radionuclides were identified as present above screening levels in surface soils at SWMU 5.

The results of the MEPAS modeling for SWMU 5 are presented in Table 5.5. These results indicate contributions from constituents in surface soil to groundwater in the RGA are negligible with the exception of technetium-99, which is predicted to reach a maximum activity of 57.8 pCi/L at the PGDP security fence in 109.5 years.

Iron is projected to contribute to the RGA from three distinct sources. Results from the sources to the PGDP fence are 49.8 mg/L in 1411 years, 18.8 mg/L in 1591 years, and 464 mg/L in 1873 years. To the DOE boundary, concentrations from these sources are 18.4 mg/L in 1602 years, 6.61 mg/L in 1871 years, and 82.7 mg/L in 2069 years. Technetium-99 is projected to contribute to the RGA resulting in 229 pCi/L at the PGDP fence in 130.1 years and 99.6 pCi/L in 138.6 years. Contributions to the RGA from other constituents are minor.

5.4.3 SWMU 6

Three model layers (two partially saturated and one saturated) were delineated at SWMU 6 (see Figs. 3.12 and 3.13). The first partially saturated layer extends to a depth of 40 ft bgs and includes the loess deposits making up HU1 and the HU2; the second partially saturated layer extends to a depth of 60 ft bgs and includes the silty clay aquitard, the HU3. The saturated layer includes the RGA and extends from an average depth of 60 to 100 ft bgs.

The travel distances from the source to each downgradient exposure point are 920 ft to the PGDP security fence and 2820 ft to the DOE property boundary. The direction of groundwater flow in the RGA was assumed to be north, based on potentiometric maps of the area.

The WAG 3 RI soil data were used to develop the source terms and inventories for the SWMU 6 site contaminants. The results of the MEPAS modeling conducted for SWMU 6 are presented in Table 5.6. These results indicate contributions from constituents in surface soil to groundwater in the RGA are negligible.

Iron is contributing to the RGA from three distinct sources. Results from the sources to the PGDP fence are 60.1 mg/L in 1966 years, 32.8 mg/L in 1787 years, and 7.77 mg/L in 1787 years. To the DOE boundary, concentrations from these sources are 21.2 mg/L in 2171 years, 11.9 mg/L in 2076 years, and 2.56 mg/L in 2076 years. Technetium-99 contamination from the SWMU 6 waste cell is predicted by the model to reach a maximum activity of 91.5 pCi/L at the PGDP security fence in 118.6 years and 31.8 pCi/L at the DOE property boundary in 120.1 years. Contributions to the RGA from other constituents are minor.

5.4.4 RESRAD Modeling

In summary, there are five radionuclides with chemical-specific excess lifetime cancer risks (ELCRs) that exceed 1.0E-06. These chemicals and their sources are as follows:

- SWMU 4 surface soil (industrial and residential use)—thorium-230, uranium-238
- SWMU 4 UCRS soil (excavator)—thorium-230
- SWMU 4 waste cell (excavator)—total uranium (modeled as uranium-238)
- SWMU 5 surface soil (residential use only)—radium-226
- SWMU 5 UCRS soil (excavator)—uranium-238
- SWMU 6 RGA surface soil (residential use only)—technetium-99
- SWMU 6 UCRS soil (excavator)—uranium-238
- SWMU 6 waste cell—neptunium-237

Table 5.1. VOAs and SVOAs reported at WAG 3

Site-related analytes	SWMU 4			SWMU 5			SWMU 6		
	SS	SB	GW	SS	SB	GW	SS	SB	GW
VOAs									
1,1-Dichloroethene			×						
1,1,2-Trichloro-1,2,2-trifluoroethane					×				
1,1,2-Trichloroethane		×							
1,2-Dichloroethene		×							
2-Butanone		×	×						
2-Propanol		×							
Acetone			×						
Carbon tetrachloride		×	×						
cis-1,2-Dichloroethene		×	×						
Chloroethane			×						
Chloroform			×						
Diethyl ether		×							
Toluene					×				
Trichloroethene		×	×			×			×
Vinyl chloride		×	×						
SVOAs									
2-Methylheptane					×				
2-Methylnaphthalene				×					
3-Nitrobenzenamine				×					
4-Methyl-3-penten-2-one	×	×							
6-(Acetyloxy)-2-hexanone		×							
Acenaphthylene				×					
Benz(a)anthracene				×					
Benzo(a)pyrene				×					
Benzo(b)fluoranthene				×					
Benzo(g,h,i)perylene				×	×		×		
Bis(2-ethylhexyl)phthalate			×						
Bis(2-methoxyethyl)phthalate		×							
Dibenzofuran				×	×				
Ethanol, 2,2'-oxybis-, diacetate		×							
Pentachlorophenol		×		×					
Phenanthrene				×	×		×		

× – Indicates constituent detected above screening values
SS – Surface soil
SB – Subsurface soil
GW – Groundwater

Table 5.2. Inorganic chemicals to be modeled later at WAG 3 sites

	SWMU 4			SWMU 5			SWMU 6		
Site-related analytes	**SS**	**SB**	**GW**	**SS**	**SB**	**GW**	**SS**	**SB**	**GW**
Aluminum		X		X	X			X	
Chromium	X	X			X			X	
Cobalt		X			X			X	
Copper	X	X					X	X	
Iron	X	X			X			X	
Lead		X						X	
Lithium			X						
Manganese		X			X			X	
Nickel	X	X							
Strontium			X						

X - Indicates constituent detected above screening values
SS - Surface soil
SB - Subsurface soil
GW - Groundwater

Table 5.3. Radionuclide chemicals to be modeled later at WAG 3 sites

	SWMU 4			SWMU 5			SWMU 6		
Site-related radionuclides	**SS**	**SB**	**GW**	**SS**	**SB**	**GW**	**SS**	**SB**	**GW**
Cesium-137		X							
Neptunium-237	X	X						X	X
Plutonium-239/240	X	X							
Protactinium-234m		X							
Radium-226		X			X				
Radon						X			
Technetium-99		X		X	X		X	X	X
Thorium-230		X							
Thorium-234	X	X		X	X			X	X
Uranium	X	X			X			X	X
Uranium-233/234	X	X							
Uranium-235		X							
Uranium-238	X	X			X			X	X

X - Indicates constituent detected above screening values
SS - Surface soil
SB - Subsurface soil
GW - Groundwater

Table 5.4. MEPAS results for SWMU 4

		PGDP security fence		DOE property boundary	
Source	Constituent (daughter products are denoted with an asterisk)	Potential maximum concentration (mg/L or pCi/L)	Time (years)	Potential maximum concentration (mg/L or pCi/L)	Time (years)
Surface Soil	Chromium	2.81E-40	10,000	1.95E-52	10,000
	Copper	4.40E-04	8039	1.40E-04	9585
	Iron	1.97E+00	1337	6.41E-01	1525
	Nickel	2.53E-03	5044	8.45E-04	6107
	PCB-1260	0	10,000	0	10,000
	Neptunium-237	5.33E-02	275.5	1.64E-02	314.6
	Protactinium-233*	5.33E-02	275.5	1.64E-02	314.6
	Uranium-233*	6.39E-05	275.5	2.35E-05	336.5
	Thorium-229*	8.24E-07	275.5	3.69E-07	336.5
	Radium-225*	8.24E-07	275.5	3.69E-07	336.5
	Actinium-225*	8.23E-07	275.5	3.69E-07	336.5
	Plutonium-239	4.16E-04	8717	1.44E-04	10,260
	Uranium-234	1.37E+00	4355	4.16E-01	5166
	Thorium-230*	5.32E-02	4355	1.90E-02	5166
	Radium-226*	2.99E-02	4605	1.16E-02	5414
	Uranium-238	2.67E+00	4356	8.08E-01	5167
	Thorium234*	2.67E+00	4356	8.08E-01	5167
	Uranium-234*	3.28E-02	4356	1.18E-02	5167
	Thorium-230*	6.63E-04	4606	2.79E-04	5415
	Radium-226*	2.87E-04	4606	1.33E-04	5415
	Radon-222*	2.87E-04	4606	1.33E-04	5415
	Lead-210*	2.82E-04	4606	1.31E-04	5415
	Bismuth-210*	2.82E-04	4606	1.31E-04	5415
	Polonium-210*	2.82E-04	4606	1.31E-04	5415
UCRS—WP1	Aluminum	0	10,000	0	10,000
	Arsenic	1.86E-01	1853	3.54E-02	2241
	Barium	0	10,000	0	10,000
	Chromium	1.15E-37	10,000	9.22E-53	10,000
	Cobalt	3.29E+00	787.5	6.46E-01	961.3
	Copper	7.32E+00	7992	1.46E+00	9539
	Iron	1.16E+03	1738	2.41E+02	2055
	Lead	8.45E-42	10,000	7.54E-53	10,000
	Lithium	1.76E-03	29.91	5.06E-04	36.29
	Manganese	5.13E+01	2248	9.46E+00	2566
	Nickel	1.45E-01	5019	4.29E-02	6081
	Strontium	2.54E-05	8661	7.44E-06	10,450
	Vanadium	5.53E-02	9411	1.06E-02	11,180
	Zinc	0	10,000	0	10,000
	1,1-Dichloroethene	2.58E-01	62.86	5.38E-02	68.83
	1,2-Dichloroethene	2.24E-03	18.18	6.64E-04	20.75
	Carbon Tetrachloride	5.94E-04	300.6	1.85E-04	307.2
	PCB-1016	0	10,000	0	10,000
	PCB-1248	0	10,000	0	10,000
	PCB-1254	0	10,000	0	10,000
	PCB-1260	0	10,000	0	10,000
	PCBs	0	10,000	0	10,000
	Pentachlorophenol	3.35E-18	10,790	6.06E-19	12,910

Table 5.4 (continued)

		PGDP security fence		DOE property boundary	
Source	Constituent (daughter products are denoted with an asterisk)	Potential maximum concentration (mg/L or pCi/L)	Time (years)	Potential maximum concentration (mg/L or pCi/L)	Time (years)
UCRS—WP1 (cont.)	Trichloroethene	2.26E+01	101.6	4.70E+00	110.7
	Vinyl Chloride	3.31E-01	56.6	6.90E-02	61.96
	Cesium-137	0	12,920	0	12,920
	Neptunium-237	4.88E+02	316.4	9.83E+01	380.4
	Protactinium-233*	4.88E+02	316.4	9.83E+01	380.4
	Uranium-233*	6.74E-01	337.5	1.63E-01	380.4
	Thorium-229*	1.06E-02	337.5	2.89E-03	380.4
	Radium-225*	1.06E-02	337.5	2.89E-03	380.4
	Actinium-225*	1.06E-02	337.5	2.89E-03	380.4
	Plutonium-239	1.09E+01	8665	2.05E+00	10,210
	Radium-226	2.21E-01	8208	2.16E-02	9765
	Technetium-99	6.34E+04	111.4	1.32E+04	112.7
	Thorium-230	3.56E-28	10,000	1.30E-43	10,000
	Radium-226*	3.58E-28	10,000	1.31E-43	10,000
	Uranium-234	4.51E+03	4329	8.94E+02	5140
	Thorium-230*	1.74E+02	4329	4.09E+01	5388
	Radium-226*	9.72E+01	4579	2.52E+01	5388
	Uranium-235	4.75E+01	4330	9.45E+00	5141
	Thorium-231*	4.75E+01	4330	9.45E+00	5141
	Protactinium-231*	4.14E+00	4330	9.71E-01	5389
	Actinium-227*	4.11E+00	4330	9.65E-01	5389
	Thorium-227*	4.11E+00	4330	9.65E-01	5389
	Radium-223*	4.11E+00	4330	9.65E-01	5389
	Uranium-238	8.33E+02	4330	1.66E+02	5141
	Thorium-234*	8.33E+02	4330	1.66E+02	5141
	Uranium-234*	1.02E+01	4330	2.41E+00	5389
	Thorium-230*	2.05E-01	4580	5.77E-02	5389
	Radium-226*	8.83E-02	4580	2.75E-02	5389
	Radon-222*	8.83E-02	4580	2.75E-02	5389
	Lead-210*	8.67E-02	4580	2.71E-02	5389
	Bismuth-210*	8.67E-02	4580	2.71E-02	5389
	Polonium-210*	8.67E-02	4580	2.71E-02	5389
	Total Uranium[a]	6.46E+03	4330	2.13E+03	5141
	Thorium-234*	6.46E+03	4330	2.13E+03	5141
	Uranium-234*	7.94E+01	4580	3.09E+01	5141
	Thorium-230*	1.62E+00	4580	7.38E-01	5389
	Radium-226*	6.99E-01	4580	3.52E-01	5389
	Radon-222*	6.99E-01	4580	3.52E-01	5389
	Lead-210*	6.87E-01	4580	3.46E-01	5389
	Bismuth-210*	6.87E-01	4580	3.46E-01	5389
	Polonium-210*	6.86E-01	4580	3.46E-01	5389

[a] Total uranium was analyzed as an activity for the WAG 3 investigation and not as a concentration. MEPAS does not contain a provision for total uranium as an activity in its chemical database, so total uranium activities were modeled as uranium-238.

Table 5.5. MEPAS results for SWMU 5

		PGDP security fence		DOE property boundary	
Source	Constituent (daughter products are denoted with an asterisk)	Potential maximum concentration (mg/L or pCi/L)	Time (years)	Potential maximum concentration (mg/L or pCi/L)	Time (years)
Surface Soil	Aluminum	0	10,000	0	10,000
	PCB-1260	0	20,000	0	20,000
	2-Methylnaphthalene	3.88E-05	4650	7.00E-06	4659
	Acenaphthylene	4.35E-03	2620	8.05E-04	2658
	Benz(a)anthracene	0	20,000	0	20,000
	Benzo(a)pyrene	0	20,000	0	20,000
	Benzo(b)fluoranthene	0	20,000	0	20,000
	Pentachlorophenol	1.08E-27	20,650	1.25E-28	22,420
	Phenanthrene	2.62E-03	13,600	3.69E-04	13,600
	Technetium-99	5.78E+01	109.5	9.65E+00	110.7
UCRS—First Partially Saturated Zone	Aluminum	0	10,000	0	10,000
	Chromium	0	10,000	0	10,000
	Cobalt	2.51E-05	14,940	7.61E-06	14,940
	Iron	4.98E+01	1411	1.84E+01	1602
	Iron (at H263)	1.88E+01	1591	6.61E+00	1871
	Manganese	2.32E-01	3870	8.44E-02	4245
	Phenanthrene	6.09E-05	13,600	1.64E-05	13,600
	Radium-226	5.59E-03	12,380	1.13E-03	13,130
	Uranium-238	5.14E-19	19,830	2.13E-19	20,590
	Thorium-234*	5.14E-19	19,830	2.13E-19	20,590
	Uranium-234*	2.81E-20	19,830	1.21E-20	20,590
	Thorium-230*	2.40E-21	20,080	1.07E-21	20,590
	Radium-226*	1.93E-21	20,080	8.61E-22	20,590
	Radon-222*	1.93E-21	20,080	8.61E-22	20,590
	Lead-210*	1.92E-21	20,080	8.58E-22	20,590
	Bismuth-210*	1.92E-21	20,080	8.58E-22	20,590
	Polonium-210*	1.92E-21	20,080	8.58E-22	20,590
UCRS—Second Partially Saturated Zone	Aluminum	0	20,000	0	20,000
	Cobalt	1.89E-03	14,940	2.81E-04	14,940
	Iron	4.64E+02	1873	8.27E+01	2069
	Manganese	1.56E+01	4097	2.76E+00	4481
	Toluene	2.78E-05	321.2	1.19E-05	344.4
	Technetium-99	2.29E+02	130.1	9.96E+01	138.6
	Radium-226	5.33E-03	12,380	1.04E-03	13,130

Table 5.6. MEPAS results for SWMU 6

Source	Constituent (Daughter products are denoted with an asterisk)	PGDP security fence		DOE property boundary	
		Potential maximum concentration (mg/L or pCi/L)	Time (years)	Potential maximum concentration (mg/L or pCi/L)	Time (years)
Surface Soil	Copper	2.56E-12	17920	2.11E-14	17920
	Phenanthrene	9.78E-07	13470	2.71E-07	13470
	Technetium-99	9.71E+00	105.1	3.15E+00	113.2
UCRS—Waste Cells	Aluminum	0	20000	0	20000
	PCB-1016	0	20000	0	20000
	Technetium-99	9.15E+01	118.6	3.18E+01	120.1
	Neptunium-237	1.68E-01	330.2	5.53E-02	387.1
	Protactinium-233*	1.68E-01	330.2	5.53E-02	387.1
	Uranium-233*	2.45E-04	348.9	9.33E-05	387.1
	Thorium-229*	3.99E-06	348.9	1.69E-06	387.1
	Radium-225*	3.99E-06	348.9	1.68E-06	387.1
	Actinium-225*	3.99E-06	348.9	1.68E-06	387.1
	Uranium-238	4.80E-19	20040	1.42E-19	20790
	Thorium-234*	4.80E-19	20040	1.42E-19	20790
	Uranium-234*	2.66E-20	20040	8.12E-21	20790
	Thorium-230*	2.28E-21	20040	7.22E-22	20790
	Radium-226*	1.83E-21	20040	5.84E-22	20790
	Radon-222*	1.83E-21	20040	5.84E-22	20790
	Lead-210*	1.82E-21	20040	5.82E-22	20790
	Bismuth-210*	1.82E-21	20040	5.82E-22	20790
	Polonium-210*	1.82E-21	20040	5.82E-22	20790
UCRS—First Partially Saturated Zone	Chromium	0	20000	0	20000
	Cobalt	8.06E-05	14720	2.33E-05	14720
	Copper	3.13E-11	17920	2.44E-13	17920
	Iron	6.01E+01	1966	2.12E+01	2171
	Lead	0	20,000	0	20,000
	Manganese	4.08E-01	3690	1.41E-01	4057
	Technetium-99	1.16E+01	118.6	3.86E+00	120.1
	Neptunium-237	5.97E-02	330.2	1.95E-02	387.1
	Protactinium-233*	5.9E-02	330.2	1.95E-02	387.1
	Uranium-233*	9.02E-05	348.9	3.29E-05	387.1
	Thorium-229*	1.47E-06	348.9	5.95E-07	387
	Radium-225*	1.47E-06	348.9	5.95E-07	387
	Actinium-225*	1.47E-06	348.9	5.95E-07	387
	Uranium-238	3.49E-19	20040	1.00E-19	20790
	Thorium-234*	3.49E-19	20040	1.00E-19	20790
	Uranium-234*	1.93E-20	20040	5.75E-21	20790
	Thorium-230*	1.66E-21	20040	5.11E-22	20790
	Radium-226*	1.33E-21	20040	4.13E-22	20790
	Radon-222*	1.33E-21	20040	4.13E-22	20790
	Lead-210*	1.33E-21	20040	4.12E-22	20790
	Bismuth-210*	1.33E-21	20040	4.12E-22	20790
	Polonium-210*	1.33E-21	20040	4.12E-22	20790
UCRS—Second Partially Saturated Zone	Aluminum	0	20000	0	20000
	Cobalt	1.66E-03	14720	4.96E-04	14720
	Iron	3.28E+01	1787	1.19E+01	2076
	Iron (from 006-027)	7.77E+00	1787	2.56E+00	2076
	Lead	0	20,000	0	20,000

6. RESULTS OF BASELINE RISK ASSESSMENT

This baseline risk assessment utilizes information collected during the recently completed RI of WAG 3 and the results of previous risk assessments for SWMUs in WAG 3 to characterize the baseline risks posed to human health and the environment from contact with contaminants in soil and groundwater. In addition, the baseline risk assessment uses results of fate and transport modeling to estimate the baseline risks posed to human health through contact with receiving media impacted by contaminants migrating off-site from the various sources in WAG 3. The ecological assessment focuses on exposure to contaminants in surface soil. Evaluation of off-site streams is deferred to the surface water OU investigation. Baseline risks are those that may be present now or in the future in the absence of corrective or remedial actions. Methods used for fate and transport modeling are presented in Chap. 5 of Vol. 1, Appendix B of Vol. 4 (MEPAS), and Appendix C (RESRAD) of Vol. 4.

To facilitate data aggregation and to focus results on specific areas, this baseline risk assessment derives hazard and risk estimates for the following SWMUs:

- SWMU 4—C-747 Contaminated Burial Yard
- SWMU 5—C-746-F Classified Burial Yard
- SWMU 6—C-747-B Burial Ground

Consistent with regulatory guidance and agreements contained in the approved human health risk assessment methods document (DOE 1996), the baseline human health risk assessment (BHHRA) evaluates land use scenarios that encompass current use and several hypothetical future uses of the WAG 3 SWMUs and the areas to which contaminants may migrate. The following land use scenarios and exposure routes are assessed:

Current industrial worker

- Incidental ingestion of soil
- Dermal contact with soil
- Inhalation of vapors and particulates emitted from soil
- External exposure to ionizing radiation emitted from soil

Future industrial worker

- Incidental ingestion of soil
- Dermal contact with soil
- Inhalation of vapors and particulates emitted from soil
- External exposure to ionizing radiation emitted from soil
- Ingestion of groundwater
- Dermal contact with groundwater while showering
- Inhalation of vapors emitted by groundwater while showering

Future excavation worker

- Incidental ingestion of soil (soil and waste)
- Dermal contact with soil (soil and waste)
- Inhalation of vapors and particulates emitted from soil (soil and waste)
- External exposure to ionizing radiation emitted from soil (soil and waste)

Future recreational user

- Ingestion of venison grazing on vegetation grown in contaminated soil
- Ingestion of rabbit grazing on vegetation grown in contaminated soil
- Ingestion of quail grazing on vegetation grown in contaminated soil

Future on-site rural resident

- Incidental ingestion of soil
- Dermal contact with soil
- Inhalation of vapors and particulates emitted from soil
- External exposure to ionizing radiation emitted from soil
- Ingestion of groundwater
- Dermal contact with groundwater while showering
- Inhalation of vapors emitted by groundwater during household use
- Inhalation of vapors emitted by groundwater while showering
- Ingestion of vegetables grown in contaminated soil

Off-site rural resident (at PGDP security fence)

- Ingestion of groundwater
- Dermal contact with groundwater while showering
- Inhalation of vapors emitted by groundwater during household use
- Inhalation of vapors emitted by groundwater while showering

Also consistent with regulatory guidance and the strategy for ecological risk assessment of source units (DOE 1993, EPA 1998), the baseline ecological risk assessment (BERA) evaluates risks under both current and potential future conditions to several ecological receptors that may come into contact with contaminated media at or migrating from sources in WAG 3. The land uses and media assessed for risks to human health and ecological receptors for each SWMU in WAG 3 are presented in Table 6.1.

Major conclusions and observations of the BHHRA and BERA are presented in the following sections.

6.1 BHHRA—PRINCIPAL FINDINGS

For all SWMUs in WAG 3, the cumulative human health systemic toxicity and ELCR exceed the accepted standards of KDEP and EPA for one or more land use scenarios when assessed using default exposure parameters. The land use scenarios for which risks exceed *de minimis* levels [i.e., for KDEP, a cumulative hazard index (HI) of 1 or a cumulative ELCR of 1.0E-06, and for EPA, an

HI of 1 and a range of 1.0E-04–1.0E-06 for ELCR] are summarized in Table 6.2. This information is derived from the risk summary tables (Tables 6.3–6.5), which present the cumulative risk values for each land use scenario, the COCs, and the pathways of concern (POCs).

6.1.1 Lead

A striking feature of the results of the BHHRA are the exceedingly high HIs that have been computed for land use scenarios, SWMUs, and media in which lead was detected (HIs of up to 2,390,000). This finding may be attributed to the use of a very conservative (1.0E-07 mg/kg-day) reference dose (RfD) value provided by KDEP. Where lead was detected, it was the overwhelming risk driver. To accommodate any uncertainty associated with this finding, the systemic toxicity associated with contaminants at WAG 3 has been assessed throughout this BHHRA by both including and excluding lead as a COPC. This strategy allows the identification of other contaminants contributing to significant levels of systemic toxicity and highlights HIs that exceed the *de minimus* level (i.e., HI > 1) in the absence of lead.

In an effort to reduce the uncertainty surrounding assessment of systemic toxicity at WAG 3 SWMUs where lead is present, two further analytical approaches are included in this risk assessment. Risks to exposed children were estimated using EPA's Integrated Exposure Uptake Biokinetic (IEUBK) model, and the reasonable maximum exposure (RME) concentrations of lead in soil and groundwater samples were compared to KDEP and EPA screening values.

Applying the biokinetic model for lead indicates that the concentrations in RGA groundwater at SWMUs 4, 5 and 6 (159, 195, and 227 μg/L, respectively) and McNairy groundwater at the same locations (2150, 708, and 698 μg/L, respectively) result in unacceptable blood level concentrations in a child (66.92, 75.59, and 81.13 percent probability, respectively, for RGA groundwater at SWMUs 4, 5, and 6 and 99.97, 98.67, and 98.67 percent probability, respectively, for McNairy groundwater at the same locations). These findings are consistent with the respective lead-driven HIs of 71,100, 218,000, and 253,000, respectively, at SWMUs 4, 5, and 6 applicable to a future child rural resident exposed to RGA groundwater and HIs of 2,390,000, 789,000, and 778,000, respectively, for the child exposed to McNairy groundwater.

The RME lead concentrations in RGA and McNairy groundwater at the subject locations are also greater than the KDEP and EPA screening level concentrations for this element (4 and 15 μg/L, respectively). Therefore, when these findings are considered together, there is qualitative agreement on the potential hazards of prevailing lead concentrations in the groundwater at these SWMUs.

Where lead was detected in subsurface soil, lead-driven HIs of greater than 1000 for the future excavator contrast markedly with very low probabilities (<0.02%) of children having blood lead levels greater than 10 μg/dL, as determined by the IEUBK model. Furthermore, lead concentrations in subsurface soil at SWMUs 4 and 6 do not exceed the soil screening values specified by either agency. These findings point to a dichotomy between the findings of the IEUBK model for the metal in soil and the determinations of lead-driven systemic toxicity as indicated by the pathway-specific HIs.

Because the risks calculated using the provisional lead RfD are so uncertain, all observations presented in Tables 6.3–6.5 exclude the quantitative contribution from lead.

6.1.2 Exposure Routes

Dermal contact with soil has been a driving exposure pathway in previous BHHRAs at PGDP, with most of this risk arising from contact with metals. This is a direct result of using dermal absorption factors (ABS values) that exceed gastrointestinal absorption values and may be overly conservative. In such circumstances, risk estimates from the dermal exposure route may be unrealistic and exceed the real risk posed by this route of exposure. Although chemical-specific ABS values were used when available, default ABS values were used for most chemicals because chemical-specific values are lacking. Chemical-specific ABS values are available for PCBs and cadmium and were used in this BHHRA. Remedial decisions based on the dermal contact with soil exposure route should be carefully considered because of the uncertainty associated with risk from this exposure route.

While the dermal pathway may represent an important route of contaminant uptake for persons exposed to soil at WAG 3, ingestion of groundwater appears to represent the most important mechanism of uptake of contaminants from the RGA aquifer and McNairy Formation, with ingestion of groundwater-irrigated vegetables also representing a significant pathway for the hypothetical on-site resident.

6.1.3 Land Use Scenario Hazards/Risks/COCs

6.1.3.1 Current and future industrial worker

Soil hazards (total HIs) for the current industrial worker exceed *de minimis* levels (HI >1 or ELCR >1.0E-06) at only one SWMU, SWMU 4 (HI = 3.62). The contaminants at SWMU 4 contributing more than 10% to total HI are chromium, iron, and vanadium, with dermal contact as the driving exposure route. Soil cancer risks (total ELCRs) for the current industrial worker exceed *de minimis* levels at SWMUs 4, 5, and 6 (ELCRs > 1.0E-04). The major contaminant in surface soils at all SWMUs is beryllium, with significant contributions from PAHs at SWMUs 5 and 6. For all SWMUs, dermal contact is the driving exposure route.

The future industrial land use scenario is identical to the current industrial land use scenario except that the future industrial land use scenario also evaluates use of groundwater. Groundwater HIs for the future industrial worker exceed *de minimis* levels at all SWMUs (16,000–216,000); however, these hazards are markedly reduced by excluding lead as a COPC (19.1–75.9). Iron, manganese, vanadium, and trichloroethene contribute more than 10% to total HIs, with ingestion as the driving exposure route. Iron is both widespread and predominant as a COC, contributing 61–80% to HI, depending on location. Groundwater ELCRs for the future industrial worker exceed *de minimis* levels at all SWMUs (> 1.0E-04). Arsenic, beryllium, trichloroethene, and radium-226 contribute more than 10% to ELCR, with ingestion as the driving exposure route.

6.1.3.2 Future excavation worker

Total soil and waste HIs for the future excavation worker exceed *de minimis* levels at all SWMUs (2.16–1750) but fall below 3 when lead is excluded as a COPC. Chromium, iron, manganese, and vanadium are the contaminants contributing more than 10% to HI, with dermal contact as the driving exposure route. Total soil and waste ELCRs for the future excavator exceed *de minimis* levels at all SWMUs (> 1.0E-04). Total uranium is the major contributor to ELCR at SWMU 4 (83%), with external exposure as the driving exposure route. Beryllium and total PAHs contribute 10% or more to ELCR at SWMU 5, with dermal contact as the driving exposure route. Beryllium is the major contributor to ELCR at SWMU 6, with dermal contact as the driving exposure route.

6.1.3.3 Future rural resident

Soil HIs for the future rural resident exceed *de minimis* levels at all SWMUs but are less than 100 when lead is excluded as a COPC. Aluminum, arsenic, chromium, iron, and nickel contribute more than 10% to total HIs, with dermal contact with soil and ingestion of vegetables raised in soil as the driving exposure routes. The uncertainty associated with the dermal pathway has been previously discussed. Exclusion of the vegetable pathway would reduce soil HIs for the rural resident by as much as 87%. Soil ELCRs for the future rural resident exceed *de minimis* levels at all SWMUs (> 1.0E-03). Beryllium and uranium-238 contribute 10% or more to ELCR at SWMU 4, with ingestion of vegetables as the driving exposure route. Arsenic and total PAHs contribute 10% or more to ELCR, with ingestion of vegetables as the driving exposure route. Beryllium and total PAHs contribute 10% or more to ELCR at SWMU 6, with ingestion of vegetables as the driving exposure route. Exclusion of the vegetable pathway would reduce soil ELCRs for the rural resident by as much as 90%.

Groundwater HIs for the future rural resident exceed *de minimis* levels at all SWMUs (218,000–2,390,000) but are reduced by several orders of magnitude with lead excluded as a COPC (223–798). Iron, manganese, vanadium, carbon tetrachloride, and trichloroethene contribute more than 10% to total HI, with ingestion of water and ingestion of vegetables irrigated with water as the driving exposure routes. As for the future industrial worker land use scenario, iron is both widespread and predominant as a COC, contributing 49–77% to HI, depending on location. Exclusion of the vegetable pathway would reduce groundwater HIs for the rural resident by as much as 40%. Groundwater ELCRs for the future rural resident exceed *de minimis* levels at all SWMUs (> 1.0E-03). Arsenic, beryllium, 1,1-dichloroethane, trichloroethane, radium-226, and technetium-99 contribute more than 10% to ELCR, with ingestion of water and ingestion of vegetables irrigated with water as the driving exposure pathways. Exclusion of the vegetable pathway would reduce groundwater ELCRs for the rural resident by as much as 46%.

6.1.3.4 Future recreational user

The future recreational user scenario is not of concern regarding total soil HI at any WAG 3 SWMU. In terms of cancer risks, total soil ELCR exceeds *de minimis* levels only at SWMU 5 (1.0E-05), where PAHs contribute 96% to risk, with ingestion of rabbit as the driving exposure route.

6.1.4 Modeled On-site and Off-site COCs

As noted previously, this baseline risk assessment uses results of fate and transport modeling (MEPAS) to estimate the baseline risks posed to human health through contact with media impacted by contaminants migrating off-site from the various sources in WAG 3. The following chemicals are "priority COCs" for MEPAS-modeled off-site use of groundwater (i.e., rural residential use in the home). The following chemicals are COCs that may migrate from a source at a SWMU in WAG 3 to an off-site location and present a chemical-specific HI or ELCR to the rural resident that is greater than 0.1 or 1.0E-06, respectively:

- SWMU 4 arsenic, cobalt, copper, iron, manganese, nickel, vanadium, 1,1-dichloroethene, 1,2-dichloroethene, carbon tetrachloride, trichloroethene, vinyl chloride, neptunium-237, plutonium-239, technetium-99, total uranium (assessed as uranium-238), and uranium-238

- SWMU 5 iron and manganese

- SWMU 6 iron and manganese

The RESRAD model was used to model both dose and excess cancer risk for radionuclides, accounting for in-growth of decay products. The following chemicals are "priority COCs" for modeled on-site soil use (i.e., industrial and excavator) and on-site groundwater use (i.e., rural residential use in the home). These chemicals are radionuclides that, through in-growth of decay products, present a chemical-specific ELCR that exceeds 1.0E-06 from exposure to surface and subsurface soil and waste at SWMUs in WAG 3 and radionuclides that may migrate from a source at a SWMU in WAG 3 to on-site RGA groundwater and present a chemical-specific ELCR to the rural resident that is greater than 1.0E-06:

- SWMU 4 thorium-230, total uranium (modeled as uranium-238), and uranium-238
- SWMU 5 radium-226 and uranium-238
- SWMU 6 neptunium-237, technetium-99, and uranium-238

6.1.5 Further Observations

The effects of the use of the conservative provisional RfD for lead and conservative ABS values have been noted. In addition, the following observations should be examined when considering remedial alternatives for WAG 3 SWMUs.

- As discussed in *Background Levels of Selected Radionuclides and Metals in Soils and Geologic Media at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 1997), several metals and radionuclides exist in surface and subsurface soils at WAG 3 SWMUs at background concentrations that are higher than their industrial and residential risk-based concentrations (RBCs). These metals and radionuclides are aluminum, arsenic, beryllium, iron, lead, manganese, vanadium, and radium-226.

- A particular case in point is iron. A substantial portion of the total systemic toxicity associated with both soil and groundwater for several land use scenarios at WAG 3 is due to iron. Similar to lead, iron has a provisional RfD that is very conservative. Unlike lead, iron is an essential human nutrient. The RDA for iron is 10 mg/day, below which a person could be expected to be deficient.

  To be retained as a COPC for quantitative evaluation in the BHHRA, certain threshold concentrations must be exceeded, thus the maximum detected concentration of an analyte (per medium) is compared to various screening values (e.g., background concentration, RBC, and one-fifth the RDA). For example, the maximum detected concentration of iron in SWMU 4 surface soil is 30,700 mg/kg. This concentration is just slightly above the background level of 28,000 mg/kg, yet the residential use RBC for iron in surface soil (calculated using the conservative RfD) is 310 mg/kg, three orders of magnitude lower than background. The maximum detected concentration of iron in SWMU 4 surface soil yields a child intake of

6.14 mg/day, which exceeds one-fifth the RDA (2.0 mg/day) used as a screening value. Having exceeded all these screening values, iron was retained as a COPC. Using the actual representative concentration (95% upper confidence limit of the mean) of iron in SWMU 4 surface soil (17,800 mg/kg) yields a child daily intake of 3.56 mg/day, clearly less than the RDA, yet because of the conservative RfD, this dose results in a hazard quotient of 59 for iron alone, which contributes 60% to the total site HI (98).

- The identification of total PAHs as risk drivers in soil at some SWMUs in WAG 3 agrees with previous risk assessments; however, the significance of this finding should be considered along with the sources previously and currently identified at PGDP. Generally, before taking action to address PAH contamination in soil at WAG 3 SWMUs, it may be prudent to consider the widespread nature of PAH contamination at PGDP, the continuing sources of contamination (e.g., motorized vehicles, asphalt paving, etc.), and the level of PAH contamination at areas outside PGDP.

- Subsurface soil and waste were treated as one medium in this BHHRA for excavator exposures; however, waste cells were sampled in SWMUs 4 and 6. The hazards and risks associated with subsurface samples that were collected from the waste cells, and thereby considered to be composed primarily of waste, were compared to subsurface soil samples collected from the periphery of the pits and thereby considered to consist largely of soil. Hazards and risks associated with the putative waste material in SWMUs 4 and 6 were considerably lower than those of the surrounding areas of soil and waste combined (default condition). For example, the ELCR for a future excavation worker exposed to soil at SWMU 4 was greater than that of an excavation worker exposed to buried waste at SWMU 4 (2.72E-03 vs. 2.15E-04). This unexpected result implies that the content of the pits may not necessarily be the drivers for the SWMU-specific risks for these burial pits. However, the overall contribution to uncertainty of this heterogeneity is small.

  Another perspective on the heterogeneity associated with subsurface soil samples taken in and around the area of the pits is available when hazards and risks are calculated for individual sampling locations at SWMUs 4 and 6 and compared to those for the SWMUs as a whole. For example, in SWMU 6, there is considerable disparity between the location-specific risk associated with one location versus another. Thus, the risks associated with sampling location 006-010 are several orders of magnitude greater than others at the same SWMU. Sampling location 006-010 may therefore, in comparison to the ELCR applicable to the SWMU as a whole, be considered a risk driver ("hot spot") for this particular exposure pathway at this site.

- In this BHHRA, all analyte concentrations in water are from the analyses of unfiltered or total samples. The use of data from analyses of total samples is consistent with current EPA guidance (EPA 1989) but introduces an additional uncertainty to the BHHRA for some water-use pathways. The magnitude of the effect of this uncertainty upon the risk estimates is difficult to determine because the extent to which the quality of water (in terms of total solids) from a residential well could differ from the quality of water collected during the recent sampling effort is unknown. Because the groundwater samples used in this BHHRA were from boreholes, some samples had high solid content.

The HI estimates calculated using unfiltered water from RGA and McNairy groundwater at WAG 3 SWMUs differed from those HIs calculated using *only* filtered samples by more than one order of magnitude in almost every case and, in some cases, up to three orders of magnitude. By contrast, the available ELCRs for filtered and unfiltered groundwater (RGA at SWMU 4) suggest only a small contribution to uncertainty. These results are consistent with the concept that the bulk of the turbid material removed from groundwater during filtering will be those inorganic components contributing most to the calculated systemic toxicity. In summary, the effect of this uncertainty on the ELCR determination is small, but medium-to-large for the HI determinations.

- Another factor in the risk assessment that makes a large contribution to uncertainty is the use of KDEP defaults versus site-specific estimates for the exposure duration and frequency at which a current industrial worker will be exposed to contamination at the subject SWMUs. Discrepancies in the computed ELCRs of close to three orders of magnitude may be an underestimation of the "true" differences between these pathway-specific risks because the actual exposure duration and frequency of a PGDP worker to surface soil at SWMUs 4, 5, and 6 is likely to be even less than the site-specific estimates used for this comparison.

6.2 BERA—PRINCIPAL FINDINGS

The three SWMUs comprising WAG 3 provide a small area of grassy habitat suitable for ecological receptors. The ecological risk assessment evaluates risks from current and potential future exposure of terrestrial plants, soil invertebrates, and terrestrial wildlife to chemicals in WAG 3 surface soil.

Chemical and radionuclide contaminants were evaluated for surface soils from SWMUs 4, 5, and 6. Table 6.6 summarizes chemicals of potential ecological concern (COPECs) that were identified based on the results of screening contaminant concentrations against ecological benchmarks. Maximum concentrations of a number of analytes were near background levels or exceeded background levels or benchmarks at only a couple of stations.

Eleven nonradionuclide COPECs exceeded background levels and benchmarks for at least one receptor group at one or more SWMUs. The inorganics are aluminum, arsenic, chromium, copper, nickel, vanadium, and zinc; the organics are fluoranthene, phenanthrene, dibutylphthalate, and total PCBs. The list of 11 analytes is misleading because a number of analytes that exceeded a benchmark appear unlikely to pose a significant risk to terrestrial receptor populations. Aluminum and arsenic were within background in SWMUs 4 and 6 and had maximum concentrations of only 1.06× and 1.02× background, respectively, in SWMU 5. Neither is likely to pose a significant risk. With the exception of one station in SWMU 4, chromium was within or near background levels. Copper exceeded a benchmark at only one station in SWMU 4 and was otherwise below benchmarks and within background. Vanadium was detected above background at only one station. Fluoranthene and phenanthrene were above benchmarks at only one station, 005-015. Dibutylphthalate and PCBs were detected infrequently at concentrations resulting in exposures below lowest observed adverse effect levels (LOAELs) for wildlife. Chromium, nickel, and zinc appear to be the only potential ecological concerns for terrestrial receptors at relatively few stations at WAG 3.

Radionuclides in surface soil do not present a risk to terrestrial receptors at any of the SMWUs. Estimated doses from exposure to radionuclides in soil were below recommended dose rate limits for all receptors at all SWMUs.

The purpose of this assessment was to evaluate the likelihood that adverse ecological effects may occur or are occurring as a result of exposures at WAG 3. Analytes that are retained as COPECs may require further study to determine whether adverse ecological effects are likely if decisions for remedial actions are based on ecological concerns. Uncertainty concerning the future condition, the bioavailability or form of metals (e.g., arsenic, chromium), and use of only one line of evidence (comparison of exposures to single-chemical toxicity values) may lead to an overestimate of potential ecological risks.

A summary of analytes of potential concern and receptors potentially at risk is presented below by SWMU and in Table 6.6.

- **SWMU 4**—Risks to terrestrial receptors at this SWMU are limited in extent. While chromium is generally below background levels and not a concern across the entire SWMU, the high concentration at Station 004-033 is a potential concern for plants, soil invertebrates, and wildlife. Nickel is also a potential concern for plants at Station 004-033 but not at other stations across the SWMU. Vanadium and zinc exceeded benchmarks for plants at one station each, but concentrations were within 1.3× background and are unlikely to be a real concern. PCBs slightly exceeded the no observed adverse effect level (NOAEL) for short-tailed shrews, but the exceedance was low and resulted in doses below LOAELs. Estimated doses from exposure to radionuclides in soil were below recommended dose rate limits for all receptors.

- **SWMU 5**—Risks to terrestrial receptors at this SWMU are limited in extent. Nickel poses a potential risk to plants at Station 005-009 but was within background at all other stations. Zinc is a potential concern to plants, soil invertebrates, and terrestrial wildlife (woodcock) primarily as a result of the elevated concentrations at Stations 005-007 and 005-002. However, even the maximum zinc concentration is within 2.5× background, and hazard quotients were low. Aluminum, arsenic, and chromium exceeded benchmarks, but all were within background at nearly all stations and none exceeded background levels by more than 1.3×. PCBs and dibutylphthalate resulted in dose estimates above NOAELs for shrews and woodcock, respectively, but neither exceeded a LOAEL. Estimated doses from exposure to radionuclides in soil were below recommended dose rate limits for all receptors.

- **SWMU 6**—Risks to terrestrial receptors are not expected from current or future exposures at this SMWU. Nickel and zinc exceeded benchmarks for plants, soil invertebrates, or wildlife, but both were within background at all stations except Station 006-001. Both were within 2.6× background at Station 006-001. Dibutylphthalate resulted in a dose estimate above the NOAEL for the woodcock but below the LOAEL. Estimated doses from exposure to radionuclides in soil were below recommended dose rate limits for all receptors.

Table 6.1. Land uses and media assessed at WAG 3 SWMUs

Land use scenario	Site SWMU 4	 SWMU 5	 SWMU 6
Current industrial worker			
Surface soil	×	×	×
Current terrestrial biota	×	×	×
Future industrial worker			
Surface soil	×	×	×
RGA groundwater	×	×	×
McNairy groundwater	×	×	×
Future excavation worker			
Surface and subsurface soil/waste	×	×	×
Future recreational user			
Soil (game)	×	×	×
Future on-site rural resident			
Surface soil	×	×	×
RGA groundwater	×	×	×
McNairy groundwater	×	×	×
Off-site rural resident			
Groundwater	×	×	×
Future terrestrial biota	×	×	×

Notes: Land use scenarios that were assessed in this baseline risk assessment are marked with an "X."

Table 6.2. Land use scenarios for which human health risk exceeds *de minimis* levels

Land use scenario	Site SWMU 4	 SWMU 5	 SWMU 6
	Systemic toxicity[a]		
Current industrial worker			
Exposure to soil	×[b]	—	—
Future industrial worker			
Exposure to soil	×[b]	—	—
Exposure to RGA groundwater	×[c]	×[c]	×[c]
Exposure to McNairy groundwater	×[c]	×[c]	×[c]
Future on-site rural resident[a]			
Exposure to soil	×[b]	×[b]	×[b]
Exposure to RGA groundwater	×[c]	×[c]	×[c]
Exposure to McNairy groundwater	×[c]	×[c]	×[c]
Off-site rural resident			
Exposure to groundwater[d]	×	×	×
Future recreational user[a]			
Exposure to soil	—	—	—

Table 6.2 (continued)

Land use scenario	Site SWMU 4	 SWMU 5	 SWMU 6
Future excavation worker			
Exposure to soil and waste	X[c]	X[b]	X[c]
Excess lifetime cancer risk			
Current industrial worker			
Exposure to soil	X	X	X
Future industrial worker			
Exposure to soil	X	X	X
Exposure to RGA groundwater	X	X	X
Exposure to McNairy groundwater	X	X	X
Future on-site rural resident[d]			
Exposure to soil	X	X	X
Exposure to RGA groundwater	X	X	X
Exposure to McNairy groundwater	X	X	X
Off-site rural resident[e]			
Exposure to groundwater	X[e]	—	—
Future recreational user[d]			
Exposure to soil	—	X	—
Future excavation worker			
Exposure to soil and waste	X	X	X

Notes:
Land use scenarios where risk exceeded the benchmark levels (HI of 1/ELCR of 1.0E-06) are marked with an "X."
Land use scenarios where risk did not exceed a benchmark level are marked with a "—."

[a] Results for a child are presented for systemic toxicity for the future recreational user and the future on-site rural resident.

[b] These land use scenarios are of concern even though lead was not detected.

[c] Lead is present, and the land use scenario is of concern whether or not the element is included in the assessment.

[d] Values for excess lifetime cancer risk for the future recreational user and the future on-site rural resident are for lifetime exposure.

[e] Based on the results of contaminant transport modeling, "X" indicates that the location contains a source of unacceptable off-site contamination.

Table 6.3. Summary of human health risk characterization for SWMU 4 without lead as a COPC

Receptor	Total ELCR	COCs	% Total ELCR	POCs	% Total ELCR	Total HI	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil)	5.4E-04	Beryllium Uranium-238	97 2	Dermal contact External exposure	97 2	3.62	Beryllium Chromium Iron Vanadium Barium	5 45 24 24 2	Dermal contact	99
Future industrial worker at current concentrations (soil)	5.4E-04	Beryllium Uranium-238	97 2	Dermal contact External exposure	97 2	3.62	Beryllium Chromium Iron Vanadium Barium	5 45 24 24 2	Dermal contact	99
Future industrial worker at current concentrations (RGA groundwater)	4.7E-04	Arsenic Beryllium 1,1-Dichloroethene Carbon tetrachloride Chloroform Trichloroethene Vinyl chloride	15 48 8 7 2 20 2	Incidental ingestion Dermal contact Inhalation while showering	72 18 10	32.6	Aluminum Arsenic Cadmium Chromium Iron Manganese Vanadium Carbon tetrachloride Trichloroethene	4 1 1 1 66 5 2 4 14	Ingestion Dermal contact Inhalation while showering	88 6 6
Future industrial worker at current concentrations (McNairy groundwater)	3.1E-03	Arsenic Beryllium	18 82	Ingestion Dermal contact	78 22	75.9	Aluminum Arsenic Barium Beryllium Cadmium Chromium Iron Manganese Vanadium	4 5 1 1 1 3 63 8 14	Ingestion Dermal contact	93 7
Future child rural resident at current concentrations (soil)	NA	NA	NA	NA	NA	98.2	Barium Beryllium Cadmium Chromium Iron Nickel Vanadium	2 2 2 24 60 2 9	Ingestion Dermal contact Ingestion of vegetables	1 21 78

Table 6.3 (continued)

Receptor	Total ELCR	COCs	% Total ELCR	POCs	% Total ELCR	Total HI	COCs	% Total HI	POCs	% Total HI
Future child rural resident at current concentrations (RGA groundwater)	NA	NA	NA	NA	NA	487	Aluminum Arsenic Boron Chromium Iron Manganese Vanadium Carbon tetrachloride Chloroform Trichloroethene *cis*-1,2-Dichloroethene	3 1 1 1 49 3 1 10 1 29 1	Ingestion Dermal contact Inhalation while showering/household Ingestion of vegetables	40 1 30 29
Future child rural resident at current concentrations (McNairy groundwater)	NA	NA	NA	NA	NA	798	Aluminum Arsenic Barium Beryllium Cadmium Chromium Iron Manganese Mercury Vanadium Zinc	4 5 1 1 1 3 66 6 1 12 1	Ingestion Dermal contact Ingestion of vegetables	60 2 39
Future adult rural resident at current concentrations (soil)	4.3E-03	Beryllium Total PCBs Uranium-234 Uranium-238	72 5 6 17	Dermal contact External exposure Ingestion of vegetables	6 2 1	28.4	Barium Beryllium Cadmium Chromium Iron Nickel Vanadium	2 2 2 22 63 2 8	Dermal contact Ingestion of vegetables	14 85
Future adult rural resident at current concentrations (RGA groundwater)	7.0E-03	Arsenic Beryllium 1,1-Dichloroethene Carbon tetrachloride Chloroform Trichloroethene Vinyl chloride Technetium-99	8 22 15 7 5 20 2 21	Ingestion Dermal contact Inhalation while showering/household Ingestion of vegetables	26 3 30 41	158	Aluminum Arsenic Boron Chromium Iron Manganese Vanadium Carbon tetrachloride Trichloroethene	3 1 1 1 57 4 1 7 22	Ingestion Dermal contact Inhalation of vapors/particles Ingestion of vegetables	51 2 19 28

Table 6.3 (continued)

Receptor	Total ELCR	COCs	% Total ELCR	POCs	% Total ELCR	Total HI	COCs	% Total HI	POCs	% Total HI
Future adult rural resident at current concentrations (McNairy groundwater)	>1.0E-02*	Arsenic Beryllium Technetium-99	21 77 2	Ingestion Dermal contact Ingestion of vegetables	58 8 35	303	Aluminum Arsenic Barium Beryllium Cadmium Chromium Iron Manganese Vanadium Zinc	4 5 1 1 1 3 66 6 12 1	Ingestion Dermal contact Ingestion of vegetables	65 2 32
Future child recreational user at current concentrations (soil)	NA	NA	NA	NA	NA	< 1	—	—	—	—
Future teen recreational user at current concentrations (soil)	NA	NA	NA	NA	NA	< 1	—	—	—	—
Future adult recreational user at current concentrations (soil)	<1.0E-06	—	—	—	—	< 1	—	—	—	—
Future excavation worker at current concentrations (soil and waste)	2.7E-03	Arsenic Beryllium Total dioxins/furans Total PCBs Radium-226 Total uranium Uranium-238	1 7 4 2 2 83 1	Ingestion Dermal contact External exposure	37 10 54	2.61	Aluminum Arsenic Barium Beryllium Cadmium Chromium Iron Manganese Vanadium	8 4 2 2 1 24 24 14 20	Ingestion Dermal contact	13 87

Notes:

NA = ECLR not applicable to child and teen cohorts. Values for adult include exposure as child and teen.

– = There are no COCs or POCs.

* = The ELCR is approximate because the linearized multistage model returns imprecise values at risks >1.0E-02.

Table 6.4. Summary of human health risk characterization for SWMU 5 *without lead as a COPC*

Receptor	Total ELCR	COCs	% Total ELCR	POCs	% Total ELCR	Total HI	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil)	4.1E-04	Arsenic Beryllium Total PAHs	6 49 45	Ingestion Dermal contact	2 98	< 1	—	—	—	—
Future industrial worker at current concentrations (soil)	4.1E-04	Arsenic Beryllium Total PAHs	6 49 45	Ingestion Dermal contact	2 98	< 1	—	—	—	—
Future industrial worker at current concentrations (RGA groundwater)	5.4E-04	Beryllium 1,1-Dichloroethene Radium-226	35 1 64	Ingestion Dermal contact	90 9	26.8	Aluminum Barium Cadmium Chromium Iron Manganese Vanadium	4 1 1 2 73 16 2	Ingestion Dermal contact	96 4
Future industrial worker at current concentrations (McNairy groundwater)	1.2E-03	Beryllium Radium-226	42 58	Ingestion Dermal contact	89 11	63	Aluminum Cadmium Chromium Iron Manganese Vanadium	4 1 7 79 3 5	Ingestion Dermal contact	95 5
Future child rural resident at current concentrations (soil)	NA	NA	NA	NA	NA	46.2	Aluminum Arsenic Beryllium Chromium Nickel Zinc	24 53 1 17 3 1	Ingestion Dermal contact Ingestion of vegetables	1 12 87
Future child rural resident at current concentrations (RGA groundwater)	NA	NA	NA	NA	NA	283	Aluminum Barium Cadmium Chromium Iron Manganese Vanadium	4 1 1 2 77 12 1	Ingestion Dermal contact Ingestion of vegetables	61 1 37

Table 6.4 (continued)

Receptor	Total ELCR	COCs	% Total ELCR	POCs	% Total ELCR	Total HI	COCs	% Total HI	POCs	% Total HI
Future child rural resident at current concentrations (McNairy groundwater)	NA	NA	NA	NA	NA	680	Aluminum Cadmium Chromium Iron Manganese Vanadium	4 1 6 81 3 4	Ingestion Dermal contact Ingestion of vegetables	60 1 39
Future adult rural resident at current concentrations (soil)	>1.0E-02*	Arsenic Beryllium Total PAHs Total PCBs	21 9 68 2	Dermal contact Ingestion of vegetables	9 90	13.9	Aluminum Arsenic Beryllium Chromium Nickel Zinc	24 55 1 15 3 1	Dermal contact Ingestion of vegetables	8 92
Future adult rural resident at current concentrations (RGA groundwater)	3.9E-03	Beryllium 1,1-Dichloroethene Radium-226 Technetium-99	33 4 57 5	Ingestion Dermal contact Inhalation while showering/household Ingestion of vegetables	56 3 4 37	107	Aluminum Barium Cadmium Chromium Iron Manganese Vanadium	4 1 1 2 76 13 1	Ingestion Dermal contact Ingestion of vegetables	67 2 31
Future adult rural resident at current concentrations (McNairy groundwater)	8.2E-03	Beryllium Radium-226	43 57	Ingestion Dermal contact Ingestion of vegetables	61 4 34	257	Aluminum Cadmium Chromium Iron Manganese Vanadium	4 1 6 81 3 4	Ingestion Dermal contact Ingestion of vegetables	65 2 33
Future child recreational user at current concentrations (soil)	NA	NA	NA	NA	NA	< 1	—	—	—	—
Future teen recreational user at current concentrations (soil)	NA	NA	NA	NA	NA	< 1	—	—	—	—
Future adult recreational user at current concentrations (soil)	1.0E-05	Arsenic Total PAHs Total PCBs	2 96 2	Ingestion of venison Ingestion of rabbit Ingestion of quail	16 63 21	< 1	—	—	—	—

Table 6.4 (continued)

Receptor	Total ELCR	COCs	% Total ELCR	POCs	% Total ELCR	Total HI	COCs	% Total HI	POCs	% Total HI
Future excavation worker at current concentrations (soil and waste)	2.9E-04	Arsenic Beryllium Total PAHs Total PCBs	8 62 28 1	Ingestion Dermal contact	13 87	2.16	Aluminum Arsenic Barium Beryllium Chromium Iron Manganese	9 7 2 3 18 38 22	Ingestion Dermal contact	18 82

Notes:

NA = ECLR not applicable to child and teen cohorts. Values for adult include exposure as child and teen.

– = There are no COCs or POCs.

* = The ELCR is approximate because the linearized multistage model returns imprecise values at risks >1.0E-02.

Table 6.5. Summary of human health risk characterization for SWMU 6 without lead as a COPC

Receptor	Total ELCR	COCs	% Total ELCR	POCs	% Total ELCR	Total HI	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil)	2.4E-04	Beryllium Total PAHs	90 10	Dermal contact	99	< 1	—	—	—	—
Future industrial worker at current concentrations (soil)	2.4E-04	Beryllium Total PAHs	90 10	Dermal contact	99	< 1	—	—	—	—
Future industrial worker at current concentrations (RGA groundwater)	2.3E-04	Arsenic Beryllium Trichloroethene	15 74 11	Ingestion Dermal contact Inhalation while showering	76 22 2	19.1	Aluminum Arsenic Barium Cadmium Chromium Iron Manganese Vanadium Trichloroethene	3 1 1 2 2 61 20 3 6	Ingestion Dermal contact Inhalation while showering	92 6 2
Future industrial worker at current concentrations (McNairy groundwater)	7.8E-04	Arsenic Beryllium	24 76	Ingestion Dermal contact	79 21	41.7	Aluminum Arsenic Barium Cadmium Chromium Iron Manganese Vanadium	5 3 1 1 6 74 3 5	Ingestion Dermal contact	95 5
Future child rural resident at current concentrations (soil)	NA	NA	NA	NA	NA	9.38	Beryllium Chromium Nickel Zinc	8 72 15 5	Dermal contact Ingestion of vegetables	34 65
Future child rural resident at current concentrations (RGA groundwater)	NA	NA	NA	NA	NA	223	Aluminum Arsenic Barium Cadmium Chromium Iron Manganese Vanadium Trichloroethene	3 1 1 1 2 58 14 2 17	Ingestion Dermal contact Inhalation while showering/household Ingestion of vegetables	54 1 12 33

Table 6.5 (continued)

Receptor	Total ELCR	COCs	% Total ELCR	POCs	% Total ELCR	Total HI	COCs	% Total HI	POCs	% Total HI
Future child rural resident at current concentrations (McNairy groundwater)	NA	NA	NA	NA	NA	451	Aluminum Arsenic Barium Cadmium Chromium Iron Manganese Vanadium	5 3 1 1 6 76 2 5	Ingestion Dermal contact Ingestion of vegetables	59 1 39
Future adult rural resident at current concentrations (soil)	2.4E-03	Beryllium Total PAHs	54 46	Dermal contact Ingestion of vegetables	30 69	2.57	Beryllium Chromium Nickel Zinc	7 70 17 6	Dermal contact Ingestion of vegetables	24 75
Future adult rural resident at current concentrations (RGA groundwater)	2.3E-03	Arsenic Beryllium Trichloroethene Technetium-99	12 51 16 21	Ingestion Dermal contact Inhalation while showering/household Ingestion of vegetables	41 6 8 46	79.9	Aluminum Arsenic Barium Cadmium Chromium Iron Manganese Vanadium Trichloroethene	3 1 1 1 2 61 15 2 12	Ingestion Dermal contact Inhalation while showering/household Ingestion of vegetables	62 2 7 29
Future adult rural resident at current concentrations (McNairy groundwater)	5.7E-03	Arsenic Beryllium	28 72	Ingestion Dermal contact Ingestion of vegetables	59 7 34	170	Aluminum Arsenic Barium Cadmium Chromium Iron Manganese Vanadium	5 3 1 1 6 76 2 5	Ingestion Dermal contact Ingestion of vegetables	65 2 33
Future child recreational user at current concentrations (soil)	NA	NA	NA	NA	NA	< 1	—	—	—	—
Future teen recreational user at current concentrations (soil)	NA	NA	NA	NA	NA	< 1	—	—	—	—

Table 6.5 (continued)

Receptor	Total ELCR	COCs	% Total ELCR	POCs	% Total ELCR	Total HI	COCs	% Total HI	POCs	% Total HI
Future adult recreational user at current concentrations (soil)	< 1.0E-06	—	—	—	—	< 1	—	—	—	—
Future excavation worker at current concentrations (soil and waste)	2.3E-04	Beryllium Total PAHs	90 9	Ingestion Dermal contact	5 95	2.44	Aluminum Barium Beryllium Chromium Iron Manganese Vanadium	8 2 3 15 32 15 26	Ingestion Dermal contact	12 88

Notes:

NA = ECLR not applicable to child and teen cohorts. Values for adult include exposure as child and teen.

– = There are no COCs or POCs.

Table 6.6. Summary of chemicals with maximum detected concentrations resulting in ecological hazard quotients greater than 1 for one or more nonhuman receptor groups

Receptor group	Site		
	SWMU 4	SWMU 5	SWMU 6
Plants[a]	Chromium, nickel, vanadium[b], zinc[b]	Aluminum, arsenic[b], chromium, nickel[b], zinc	Nickel[b], zinc[b]
Soil invertebrates[a]	Chromium, copper	Chromium, zinc, fluoranthene, phenanthrene	Zinc[b]
Terrestrial wildlife[c]	Chromium	Aluminum	None

[a] Plant and soil invertebrate results are based on maximum detected concentrations or activities.

[b] Greater than background at only one station in the SWMU.

[c] Terrestrial wildlife results are based on comparison of maximum exposure estimates to lowest observed adverse effect levels.

7. CONCLUSIONS

7.1 INTRODUCTION

This chapter presents conclusions about the hydrogeologic setting, contaminant sources, contaminant migration pathways, affected environmental media, human health risk assessment, and ecological risk assessment at the three WAG 3 sites. These conclusions are drawn from known site conditions, the nature and extent of contamination, the fate and transport of contaminants, and the risk to human health and the ecological communities associated with the identified contaminants.

7.1.1 Major Findings of Contaminant Distribution

The WAG 3 RI found the following major contaminant distribution.

- Impact to subsurface soils and groundwater from SWMU 4 includes VOA, PCB, and radiological contamination. This contamination has entered the RGA, and SWMU 4 appears to be a major contributor to the Southwest Plume.

- Impact to all media from releases as a result of past activities at SWMUs 5 and 6 has been minimal. Isolated occurrences of VOAs and elevated levels of metals, PCBs, and radiological contamination are in the subsurface soils and UCRS groundwater. However, impact to the RGA is, at most, minimal.

- Groundwater data indicate that vertical migration from RGA into the underlying McNairy Formation at WAG 3 is not a significant contaminant migration pathway.

7.1.2 Hydrogeologic Setting

During the WAG 3 RI process, data were gathered on the stratigraphy and hydrogeologic conditions at each of the three sites. Because of the proximity of the investigated sites, the basic subsurface geology and hydrogeology were found to be generally similar among the areas studied. Several of the DQO questions that were developed during the WAG 3 Work Plan development stage concern the physical and chemical properties and stratigraphy of the geologic units at each of the sites. To minimize redundancy, these related DQO questions are addressed here in a single section.

What is the stratigraphy (and physical and chemical properties) of the soil and water?

Three primary units are encountered in the subsurface at WAG 3. These are, in ascending order: the McNairy Formation, the RGA, and the UCRS. The McNairy Formation is predominantly gray lignitic clays and silts that subcrop at approximately 120–100 ft bgs. The McNairy sediments are overlain by 40–60 ft of porous and permeable, coarse-grained sands and chert gravels of the RGA. The RGA is in turn overlain by a fining-upward sequence of gravels, sands, silts, and clays that comprise the UCRS. Sands and gravels within the UCRS are typically fine-grained, poorly sorted, and occur as laterally discontinuous lenses within a matrix of finer-grained material.

At WAG 3, the stratigraphy at all three SWMUs generally fits the PGDP model described in the preceding paragraph, with the notable exception that the base of the RGA dips down on the western edge of SWMU 4. This results in a thickening of the RGA in this area.

The physical and chemical properties of the subsurface soil and the depth to the water table at WAG 3 play an important role in the migration and distribution of contaminants in the subsurface. The most common contaminants identified at the WAG 3 sites were VOAs, radiological contaminants, PCBs, and metals. The downward mobility of metal ions would be expected to be inhibited by the low permeability of the clay-rich UCRS soil and by absorption processes. However, the UCRS sediments are not an aquiclude, and leaching of contaminants and downward migration of precipitation toward the RGA, although retarded, would be expected to be a contaminant dispersion pathway at each of the sites investigated. Because most of the UCRS sediments are within the vadose zone and because of the lack of laterally continuous sands within the UCRS, conduits for long-distance lateral migration of contaminants in the shallow subsurface would not be expected to be a significant contaminant distribution process.

Downward migrating contaminated fluids that reached the RGA would then be incorporated into the RGA groundwater and transported laterally to the west-northwest as part of the Southwest and/or Northwest Plume. Because the McNairy Formation has a lower permeability than the overlying RGA sediments and because groundwater flow typically will follow the path of least resistance, mixing of the contaminated RGA groundwater in the off-site plumes with the deeper McNairy flow system has not been extensive. As a result, McNairy groundwater samples collected during the WAG 3 RI were found to be relatively uncontaminated (and the limited contamination that was found does not appear to be attributable to the WAG 3 SWMUs).

7.2 WAG 3 SWMU-SPECIFIC DQO QUESTIONS

The primary DQO questions that were developed during scoping of the work plan have been grouped into like categories and are addressed individually for each of the three SWMUs investigated.

7.2.1 SWMU 4 (C-747 Contaminated Burial Yard)

Goal 1: Nature of Source Zone

What are the suspected contaminants? What are the plant processes that contributed to the contamination? When and over what duration did the release occur?

It is known that SWMU 4 was used as a burial ground for various plant wastes from 1951 to 1958. These wastes included radiologically contaminated and uncontaminated trash and excess equipment. The suspected contaminants included radiological contaminants, metals, and various VOAs. Plant processes that could contribute to this would include the gaseous diffusion process (that would radiologically contaminate equipment), machine shop wastes (including degreasers and metal parts and shavings), and miscellaneous trash. Releases may have started shortly after burial and may be continuing to date.

What are the concentrations and activities at the source? What are the areas and volumes of the source zones? What are the chemical and physical properties of associated material at the source areas?

Contaminants at SWMU 4 are buried in several burial cells of varying size to a depth of approximately 16 ft. Some of these contaminants have leached out of the burial cells and into the underlying soils and groundwater. These contaminants include TCE and degradation products and various radiological contaminants. PCBs are found at shallow depths (3–6 ft bgs) and may be the result of waste handling practices.

Limited data within the burial cells were collected due to the high hazards (both chemical and radiological) that were encountered. The few samples collected indicated the presence of radiological contaminants, PCBs, and various VOAs.

TCE contamination is present in soils at depths of approximately 10 to 60 ft bgs (at the confirmed top of the RGA). In addition, both the shallow UCRS groundwater and the RGA are also contaminated. The highest concentration of TCE was 41,000 μg/kg in the RGA and 23,000 μg/kg in the UCRS. Although the highest levels of VOAs are confined to the areas beneath the burial cells, a conservative estimate of the contaminated volume would include the entire UCRS from a depth of 10 ft bgs (the highest elevation where VOAs are encountered) to 60 ft bgs (the top of the RGA). With an approximate dimension of 286,700 ft^2, the contaminated volume would be 14,335,000 ft^3.

Radiological contamination is also found widespread in SWMU 4. Alpha activities up to 3,076.71 pCi/g and beta activities up to 3,253.97 pCi/g are present. Measured radioisotopes including total uranium (up to 6,260 pCi/g), technetium-99 (up to 269 pCi/g), and plutonium-239 (up to 4.17 pCi/g) are found in the surface and subsurface soils, and in the shallow groundwater. Assuming contamination from surface to 60 ft bgs, the total radiologically contaminated volume of the SWMU would be 17,202,000 ft^3.

PCBs are found in significant quantities at various points in the shallow subsurface soils. All of the samples with concentrations detected above screening levels are contained within an area from surface to 11 ft bgs. A conservative estimate of the area of the SWMU that is contaminated with PCBs would be 3,153,700 ft^3.

Associated chemical and physical properties of the source areas consist of various industrial wastes and soil backfill in the burial cells, and sands, silts, and clays of the UCRS in the remainder of the SWMU. The entire SWMU is covered with a cap consisting of approximately 3 ft of soil with a vegetative cover.

Goal 2: Extent of Source Zone and Contamination in Soil and Secondary Sources at All Units

What are the past, current, and potential future migratory paths? What are the past, current, and potential future release mechanisms? What are the contaminant concentrations or activity gradients? What are the vertical and lateral extents of contamination? What is the relationship of the UCRS gradient to the source, to surface water bodies, and to the RGA?

Current and future migratory paths for SWMU 4 are restricted to material in the burial cells leaching out of the bottoms of the cells and migrating generally downward to the RGA. Some migration along the surface may be occurring (primarily for radiological contaminants and PCBs).

Contaminant concentrations and activity gradients are greatest within the burial cells and immediately below the cells. Some high contaminant concentrations are found adjacent to the burial cells.

Contamination is found adjacent to and beneath the burial cells from near the surface to the RGA. The lateral extent of contamination is confined to gravel lenses that do not have a wide lateral extent. Groundwater flow in the UCRS is predominantly downward to the RGA. Surface water bodies are not likely impacted by contamination at SWMU 4 because of the pathway of contamination and the absence of surface contamination.

Goal 3: Determine Subsurface Transport Mechanisms and Pathways

What are the contaminant migration trends? To what area is the dissolved-phase plume migrating? What are the effects of underground utilities and plant operations on migration pathways? What is the role of the UCRS in contaminant transport? What are the physical and chemical properties of the formations and subsurface matrices?

Contaminant migration trends are generally downward out of the burial cells and to the RGA. Once the contaminants enter the RGA (joining the Southwest Plume), the trend is generally northwest, with some possibility that the contaminants are also moving west.

There were no identified underground utilities in SWMU 4. Plant operations are not believed to be playing any role in the current contaminant release and migration.

The UCRS appears to play a limited role in lateral contaminant migration. Groundwater in the UCRS is sporadic and generally confined to semipermeable lenses of gravel and sand within the predominant matrix of silt and clay. The contaminants are generally moving downward. Small trends of lateral contaminant movement within the UCRS are observed (in some borings adjacent to the burial cells, some contaminants, primarily VOAs, were observed at relatively shallow depths).

The UCRS is comprised primarily of clays and silts with interspersed sand and gravel lenses. Groundwater resources in the UCRS are limited to isolated perched zones. The RGA is a regional aquifer comprised of gravel and sand units.

Goal 4: Support Evaluation of Remedial Alternatives

What are the possible remedial technologies applicable for this unit? What are the physical and chemical properties of media to be remediated? Are cultural impediments present? What is the extent of contamination (geologic limitations presented by the source zone or secondary source?) What would be the impact of action on and by other sources? What would be the impact of an action at the source on integrator units? What are stakeholders' perceptions of contamination at or migrating from source zone or secondary sources?

Determinations of remedial actions will be addressed in the feasibility studies and subsequent decision documents for the appropriate integrator OUs.

Goal 5: Support Continuing Characterization of Surface Water and Groundwater Integrator Units

What is the stratigraphy (as it relates to the entire PGDP facility)? What would be the impact of action on and by other sources? What is the hydrological information necessary to support facility-wide modeling? At what point do potential releases enter into the integrator units?

The stratigraphy at SWMU 4 is similar to the PGDP site-wide stratigraphy (i.e., silts and clays of the UCRS overlie the RGA and the McNairy clays). The integrator OUs remedial actions will evaluate impacts on and by other sources. Facility-wide modeling is ongoing and uses a synthesis of data collected from previous investigations. To facilitate comparison of results from various SWMUs, consistent parameters are used in all site-wide modeling. Releases from SWMU 4 are entering the groundwater OU at the interface between the UCRS and the RGA.

7.2.2 SWMU 5 (C-746-F Classified Burial Yard)

Goal 1: Nature of Source Zone

What are the suspected contaminants? What are the plant processes that contributed to the contamination? When and over what duration did the release occur?

It is known that SWMU 5 was used as a burial ground for security-classified weapons components, radionuclide-contaminated scrap metal, and slag from nickel and aluminum smelters from approximately 1965 to 1987. The suspected contaminants included radiological contaminants and metal. Because the site is security-classified, little information regarding waste generating processes is available. Releases may have started shortly after burial and may be continuing to date.

What are the concentrations and activities at the source? What are the areas and volumes of the source zones? What are the chemical and physical properties of associated material at the source areas?

Contaminants at SWMU 5 are buried in several burial cells of varying size to a depth of approximately 15 ft. Only sporadic and widely spaced contaminants were detected, including some PAHs, pesticides and herbicides, and PCBs in shallow soils. No data within the burial cells were collected, due to the security-classified nature of the wastes.

Radiological contamination was limited to a few occurrences of technetium-99 (ranging from 4.2 to 5.85 pCi/g). There is no evidence that this contamination is widespread, so no estimate of volumes of contaminated areas is offered.

PCBs were found in limited surface and shallow subsurface soils. The concentrations ranged from 35 to 306 μg/kg. There is no evidence that this contamination is widespread, so no estimate of volumes of contaminated areas is offered.

Pesticides, herbicides, and PAHs were found at approximately five surface and shallow subsurface soil samples. Because these samples are above the expected level at which the wastes were buried, and because the nature of these contaminants is inconsistent with what is known about the buried material (i.e., weapons components and metal slag), it is unlikely that these contaminants are associated with the burial cells. No estimate of volumes of contaminated areas is offered.

Associated chemical and physical properties of the source areas consist of various industrial wastes and soil backfill in the burial cells, and sands, silts, and clays of the UCRS in the remainder of SWMU 5. The entire SWMU is covered with a cap consisting of approximately 3 ft of soil with a vegetative cover.

Goal 2: Extent of Source Zone and Contamination in Soil and Secondary Sources at All Units

What are the past, current, and potential future migratory paths? What are the past, current, and potential future release mechanisms? What are the contaminant concentrations or activity gradients? What are the vertical and lateral extents of contamination? What is the relationship of the UCRS gradient to the source, to surface water bodies, and to the RGA?

Potential current and future migratory paths for SWMU 5 are restricted to material in the burial cells leaching out of the bottoms of the cells and migrating generally downward to the RGA. Because no significant levels of contaminants were found, it is presumed that no releases have occurred, and no migration of contaminants is taking place.

Contamination is found adjacent to and beneath the burial cells from near the surface to the RGA. The lateral extent of contamination is confined to gravel lenses that do not have a wide lateral extent. The groundwater flow gradient in the UCRS is predominantly downward to the RGA. Surface water bodies are not likely impacted by contamination at SWMU 5 because of the pathway of contamination and the absence of surface contamination.

Goal 3: Determine Subsurface Transport Mechanisms and Pathways

What are the contaminant migration trends? To what area is the dissolved-phase plume migrating? What are the effects of underground utilities and plant operations on migration pathways? What is the role of the UCRS in contaminant transport? What are the physical and chemical properties of the formations and subsurface matrices?

Potential contaminant migration trends would likely be generally downward out of the burial cells and to the RGA (based on evidence shown in SWMU 4, a waste disposal area similar in nature to SWMU 5). Once the contaminants entered the RGA (joining the Northwest Plume), the trend would be northwest.

The only identified underground utilities in SWMU 5 are nonfunctioning water lines that originally supplied fire hydrants. These lines are at a shallow depth (~6 ft bgs) and likely play little or no role in any contaminant migrations out of the burial cells. Plant operations are not believed to be playing any role in the current contaminant release and migration.

The UCRS appears to play a limited role in contaminant migration. Groundwater in the UCRS is sporadic and generally confined to semipermeable lenses of gravel and sand within the predominant matrix of silt and clay. Any contaminants would generally move downward. Small trends of lateral contaminant movement within the UCRS are possible.

The UCRS is comprised primarily of clays and silts with interspersed sand and gravel lenses. Groundwater resources in the UCRS are limited to isolated perched zones. The RGA is a regional aquifer comprised of gravel and sand units.

Goal 4: Support Evaluation of Remedial Alternatives

What are the possible remedial technologies applicable for this unit? What are the physical and chemical properties of media to be remediated? Are cultural impediments present? What is the extent of contamination (geologic limitations presented by the source zone or secondary source?) What would be the impact of action on and by other sources? What would be the impact of an action at the source on integrator units? What are stakeholders' perceptions of contamination at or migrating from source zone or secondary sources?

Determinations of remedial actions will be addressed in the feasibility studies and subsequent decision documents for the appropriate integrator OUs.

Goal 5: Support Continuing Characterization of Surface Water and Groundwater Integrator Units

What is the stratigraphy (as it relates to the entire PGDP facility)? What would be the impact of action on and by other sources? What is the hydrological information necessary to support facility-wide modeling? At what point do potential releases enter into the integrator units?

The stratigraphy at SWMU 5 is similar to the PGDP site-wide stratigraphy (i.e., silts and clays of the UCRS overlie the RGA and the McNairy clays). The integrator OUs remedial actions will evaluate impacts on and by other sources. Facility-wide modeling is ongoing and uses a synthesis of data collected from previous investigations. To facilitate comparison of results from various SWMUs, consistent parameters are used in all site-wide modeling. Releases from SWMU 5 would enter the groundwater OU at the interface between the UCRS and the RGA.

7.2.3 SWMU 6 (C-747-B)

Goal 1: Nature of Source Zone

What are the suspected contaminants? What are the plant processes that contributed to the contamination? When and over what duration did the release occur?

It is known that SWMU 6 was used as a burial ground for magnesium scrap, exhaust fans, contaminated aluminum, and a modine trap from approximately 1961 to 1971. The suspected contaminants included radiological contaminants and metals. Plant processes associated with the buried wastes include the gaseous diffusion process, various machine shop wastes (including machined parts, but no apparent degreasers), and laboratory materials. Releases may have started shortly after burial and may be continuing to date.

What are the concentrations and activities at the source? What are the areas and volumes of the source zones? What are the chemical and physical properties of associated material at the source areas?

Contaminants at SWMU 6 are buried in several burial cells of varying size to a depth of approximately 6 ft bgs. Only sporadic and widely spaced contaminants were detected, including some SVOAs, metals, and radioisotopes in shallow soils, and some PCBs and radioisotopes in groundwater. Limited data collected within the burial cells indicated the presence of radioisotopes and PCBs.

Radiological contamination was limited to a few occurrences of technetium-99, neptunium-237, and thorium-234 (ranging from 0.125 to 8.51 pCi/g). There is no evidence that this contamination is widespread, so no estimate of volumes of contaminated areas is offered.

PCBs were found only in a water sample within one of the burial cells. The concentrations ranged from 53 to 270 µg/L. Assuming the burial cell to be 110 × 37 × 6 ft deep, a conservative estimate for the contaminated area is 24,420 ft^3.

SVOAs were detected in two surface samples in an adjoining ditch. Because these samples are above the expected level at which the wastes were buried, and because the nature of these contaminants is inconsistent with what is known about the buried material, it is unlikely that these contaminants are associated with the burial cells. No estimate of volumes of contaminated areas is offered.

Associated chemical and physical properties of the source areas consist of various industrial wastes and soil backfill in the burial cells, and sands, silts, and clays of the UCRS in the remainder of the SWMU.

Goal 2: Extent of Source Zone and Contamination in Soil and Secondary Sources at All Units

What are the past, current, and potential future migratory paths? What are the past, current, and potential future release mechanisms? What are the contaminant concentrations or activity gradients? What are the vertical and lateral extents of contamination? What is the relationship of the UCRS gradient to the source, to surface water bodies, and to the RGA?

Potential current and future migratory paths for SWMU 6 are restricted to material in the burial cells leaching out of the bottoms of the cells and migrating generally downward to the RGA. Because no significant levels of contaminants were found, it is presumed that no releases have occurred, and no migration of contaminants is taking place.

Goal 3: Determine Subsurface Transport Mechanisms and Pathways

What are the contaminant migration trends? To what area is the dissolved-phase plume migrating? What are the effects of underground utilities and plant operations on migration pathways? What is the role of the UCRS in contaminant transport? What are the physical and chemical properties of the formations and subsurface matrices?

Potential contaminant migration trends would likely be generally downward out of the burial cells and to the RGA (based on evidence shown in SWMU 4, a waste disposal area similar in nature to SWMU 6). Once the contaminants entered the RGA (joining the Northwest Plume), the trend would be northwest.

The only identified underground utilities in SWMU 6 are nonfunctioning water lines that originally supplied fire hydrants. These lines are at a shallow depth (~6 ft bgs) and likely play little or no role in any contaminant migrations out of the burial cells. Plant operations are not believed to be playing any role in the current contaminant release and migration.

The UCRS appears to play a limited role in contaminant migration. Groundwater in the UCRS is sporadic and generally confined to semipermeable lenses of gravel and sand within the predominant matrix of silt and clay. Any contaminants would generally move downward. Small trends of lateral contaminant movement within the UCRS are possible.

The UCRS is comprised primarily of clays and silts with interspersed sand and gravel lenses. Groundwater resources in the UCRS are limited to isolated perched zones. The RGA is a regional aquifer comprised of gravel and sand units.

Goal 4: Support Evaluation of Remedial Alternatives

What are the possible remedial technologies applicable for this unit? What are the physical and chemical properties of media to be remediated? Are cultural impediments present? What is the extent of contamination (geologic limitations presented by the source zone or secondary source?) What would be the impact of action on and by other sources? What would be the impact of an action at the source on integrator units? What are stakeholders' perceptions of contamination at or migrating from source zone or secondary sources?

Determinations of remedial actions will be addressed in the feasibility studies and subsequent decision documents for the appropriate integrator OUs.

Goal 5: Support Continuing Characterization of Surface Water and Groundwater Integrator Units

What is the stratigraphy (as it relates to the entire PGDP facility)? What would be the impact of action on and by other sources? What is the hydrological information necessary to support facility-wide modeling? At what point do potential releases enter into the integrator units?

The stratigraphy at SWMU 6 is similar to the PGDP site-wide stratigraphy (i.e., silts and clays of the UCRS overlie the RGA and the McNairy clays). The integrator OUs remedial actions will evaluate impacts on and by other sources. Facility-wide modeling is ongoing and uses a synthesis of data collected from previous investigations. To facilitate comparison of results from various SWMUs, consistent parameters are used in all site-wide modeling. Releases from SWMU 6 would enter the groundwater OU at the interface between the UCRS and the RGA.

7.3 BASELINE RISK ASSESSMENT

The decision rules for the WAG 3 RI are addressed individually for SWMUs 4, 5, and 6 in Tables 7.1 through 7.3. Conclusions based on the DQO process and the risk-based decision rules indicate that risk from exposure to contaminated media exists at each of these sites. Summaries follow at the end of the tables for each SWMU. Risk-based analysis of data generated during the investigation indicates that response actions may be appropriate for impacted media at each of the three sites.

Table 7.1. WAG 3 SWMU 4-specific decision rules and conclusions

Decision rule	Conclusion	Comments
D1a: If the concentration of analytes found in the source zone results in a cumulative excess lifetime cancer risk greater than 1×10^{-6} or a cumulative hazard index greater than 1 through contact with contaminated media, or if the concentration of analytes in the source zone results in detrimental impacts to nonhuman receptors through contact with contaminated media as indicated by exceeding ecological screening criteria, and if the concentrations of analytes in the source zone are greater than those that are expected to occur naturally in the environment, then evaluate actions that will mitigate risk; otherwise pursue a "no further action" decision (see D1b and D1c).	Direct contact with surface soil (at SWMU 4) results in both cancer risks and systemic toxicity that exceed KDEP's *de minimis* levels for industrial workers as specified in the decision rules. ELCRs also exceeded EPA's *de minimis* range of 1×10^{-4} to 1×10^{-6}. Risks to the excavation worker exposed to contaminated subsurface soils exceed *de minimis* levels. Risks from potential use of the RGA as a drinking water source at the SWMU exceed *de minimis* levels for the industrial worker. Risks to nonhuman receptors are generally *de minimis* under current conditions. Additionally, the contaminant concentrations are such that risks may not exceed *de minimis* levels in the future.	Risks for the industrial worker from exposure to surface soil fell below *de minimis* levels when the analysis was performed using site-specific exposure parameters. When the assessment was performed using reduced dermal absorption values for inorganic chemicals, the cancer risk remained above *de minimis* levels. Risks were greater than *de minimis* levels for the excavation worker when default exposure parameters were used. Furthermore, when the assessment was performed using site-specific exposure parameters, the risk remained greater than *de minimis* levels. Groundwater drawn from the RGA is not currently used at PGDP. Risks to nonhuman receptors are driven by a single "hot-spot" sample with a high concentration of chromium and nickel. Migration of contaminants from soil to groundwater and surface water is discussed under Decision Rules D3a and D3b, respectively.
D1b: If concentrations of analytes found in the source zone exceed ARARs, then evaluate actions that will bring contamination within the source zone into compliance with ARARs; otherwise, pursue a "no further action" decision (see D1a and D1c).	Concentrations in RGA groundwater exceed MCLs for some contaminants.	No chemical-specific ARARs are available for screening contaminant concentrations in sediment or soil. Migration of contaminants from soil to groundwater and surface water is discussed under Decision Rules D3a and D3b, respectively.

Table 7.1 (continued)

Decision rule	Conclusion	Comments
D1c: If contaminants found at the site are known to transform or degrade into chemicals that could lead to increased risks to human health or the environment or into chemicals for which there are ARARs, and if the concentrations of these contaminants may result in risks greater than those defined in D1a or concentrations greater than ARARs, then evaluate actions that will mitigate potential future risk or promote compliance with ARARs; otherwise, pursue a "no further action" decision (see D1a and D1b).	The organic COCs driving the risk from direct contact with groundwater at SWMU 4 may degrade into more toxic substances, potentially leading to increased risk and/or concentrations that may exceed chemical-specific ARARs.	Trichloroethene is one of several chlorinated hydrocarbons that are risk drivers in RGA groundwater at SWMU 4.
D2a: If secondary sources are found, and if the concentrations of analytes within the secondary sources are found to result in a potential cumulative excess lifetime cancer risk greater than 1×10^{-6} or a cumulative hazard index greater than 1 through contact with contaminated media at the unit, and if the concentrations of analytes are greater than those that are expected to occur naturally in the environment, then evaluate actions that will mitigate risk; otherwise, do not consider secondary sources when making remedial decisions for the unit.	Secondary sources were identified. These secondary sources may continue to release contaminants to groundwater.	Beryllium and uranium (total) are present in subsurface soil at SWMU 4.
D3a: If contaminants are found in the source zone, or if secondary sources are found, and if these contaminants are found to be migrating or may migrate from the source zone or from secondary sources at concentrations that may result in a potential cumulative excess lifetime cancer risk greater than 1×10^{-6} or a cumulative hazard index greater than 1 through use of contaminated media at downgradient points of exposure, and the concentrations of analytes are greater than those that are expected to occur naturally in the environment, then evaluate actions that will mitigate risk; otherwise, do not consider risk posed by migratory pathways when evaluating remedial alternatives for the unit (see D3b).	Multimedia transport modeling indicates that contaminants may be released from soils and secondary sources at SWMU 4, potentially resulting in risk to off-site residential groundwater users that could exceed *de minimis* levels at some point in the future. Pathway analysis performed as part of fate and transport modeling indicates that releases to surface water bodies are unlikely.	A suite of inorganic, organic, and radioactive contaminants are SWMU 4-specific COCs with potential to migrate to off-site groundwater in concentrations that may impact human health at some future time.

Table 7.1 (continued)

Decision rule	Conclusion	Comments
D3b: If contaminants are found in the source zone, or if secondary sources are found, and if these contaminants are found to be migrating or may migrate from the source zone or from the secondary sources at concentrations that exceed ARARs, then evaluate actions that will bring migratory concentrations into compliance with ARARs; otherwise, do not consider ARARs when examining migratory pathways during the evaluation of remedial actions (see D3a).	Multimedia transport modeling indicates that contaminants released from source soil at SWMU 4 will result in concentrations in off-site groundwater that exceed MCLs.	The model predicts off-site groundwater concentrations in excess of the current MCLs for copper, 1,1-dichloroethene, trichloroethene, and vinyl chloride, based on the levels arising from the amounts of these contaminants currently detectable in subsurface soil at SWMU 4.
D4a: If Decision Rules D1a, D1b, D1c, D2a, D3a, or D3b indicate that remedial actions are needed, then evaluate response actions to mitigate risk in the source zone. (Refer to Sects. 5.11 and 5.12 of the WAG 3 Work Plan for discussions of the possible response actions.)	Results for Decision Rules D1a, D1b, D1c, D2a, and D3a indicate that response actions are needed. Evaluations of response actions to mitigate risk in the source zone may be appropriate.	
D5a: If contaminants in the source zone are found to migrate to the RGA, then determine the contributions from the source zone to support future remedial actions for existing groundwater contamination in the groundwater integrator unit; otherwise, do not determine contributions.	Multimedia transport modeling to off-site locations was completed because contaminants were suspected of migrating to the RGA. This information will be considered when determining remedial actions for the Groundwater Operable Unit at PGDP.	Multimedia transport modeling was completed using MEPAS and RESRAD. A more sophisticated modeling tool may be appropriate when determining remedial actions for the Groundwater Operable Unit.
D5b: If contaminants in the source zone are found to migrate to the Surface Water Integrator Unit (i.e., Bayou and Little Bayou Creeks and ditches discharging directly to regulated outfalls), then determine the contributions from the source zone to support future remedial actions for past releases to the Surface Water Integrator Unit; otherwise, do not determine contributions.	Pathway analysis performed as part of fate and transport modeling indicates that releases to surface water bodies are unlikely.	

Table 7.1 (continued)

General Conclusions for SWMU 4

(1) Contamination is present in surface soil at SWMU 4 that may lead to risks to industrial workers exceeding *de minimis* levels. Per Decision Rule D4a, response actions to mitigate the risks from direct contact with this medium may be appropriate.

(2) Contamination is present in subsurface soil at SWMU 4 that may lead to risks to unprotected excavation workers exceeding *de minimis* levels. Per Decision Rule D4a, response actions to mitigate the risks from direct contact with this medium may be appropriate.

(3) Contamination is present in RGA groundwater at SWMU 4 that may lead to risks to industrial workers exceeding *de minimis* levels. Additionally, results indicate that the contamination present in soil and in secondary sources at concentrations could lead to continuing contamination of groundwater. Per Decision Rule D4a, response actions to mitigate the risks from direct contact with this medium and to address continued contaminant migration thereto might be appropriate.

Table 7.2. WAG 3 SWMU 5-specific decision rules and conclusions

Decision rule	Conclusion	Comments
D1a: If the concentration of analytes found in the source zone may result in a cumulative excess lifetime cancer risk greater than 1 × 10^{-6} or a cumulative hazard index greater than 1 through contact with contaminated media, or if the concentration of analytes in the source zone may result in detrimental impacts to nonhuman receptors through contact with contaminated media as indicated by exceeding ecological screening criteria, and if the concentrations of analytes in the source zone are greater than those that are expected to occur naturally in the environment, then evaluate actions that will mitigate risk; otherwise pursue a "no further action" decision (see D1b and D1c).	Carcinogenic risks from direct contact with surface soil exceed the KDEP *de minimis* levels and the EPA *de minimis* range (1 × 10^{-4} to 1 × 10^{-6}) for industrial workers, but noncarcinogenic hazards do not exceed *de minimis* levels for the same receptors. Risks to the excavation worker exposed to contaminated soils exceed *de minimis* levels. Risks from potential use of the RGA as a drinking water source at the SWMU exceed *de minimis* levels for the industrial worker. Risks to nonhuman receptors are generally *de minimis* under current conditions. Additionally, contaminant concentrations are such that risks are unlikely to exceed *de minimis* levels in the future.	Carcinogenic risks to the industrial worker from exposure to surface soil at SWMU 5 were greater than *de minimis* levels when the analysis was performed using site-specific exposure parameters or with reduced dermal absorption values for inorganic chemicals. Risks were greater than *de minimis* levels for the excavation worker when default exposure parameters were used. Furthermore, when the assessment was performed using site-specific exposure parameters, the cancer risk remained greater than *de minimis* levels (3.34 × 10^{-5}). Groundwater drawn from the RGA is not currently used at PGDP. Nickel and zinc are the primary risk drivers for nonhuman receptors at SWMU 5, based on elevated concentrations of these contaminants in discrete "hot-spots." Migration of contaminants from soil to groundwater and surface water is discussed under Decision Rules D3a and D3b, respectively.
D1b: If concentrations of analytes found in the source zone exceed ARARs, then evaluate actions that will bring contamination within the source zone into compliance with ARARs; otherwise, pursue a "no further action" decision (see D1a and D1c).	Concentrations in RGA groundwater exceed MCLs for some contaminants.	No chemical-specific ARARs are available for screening contaminant concentrations in sediment or soil. Migration of contaminants from soil to groundwater and surface water is discussed under Decision Rules D3a and D3b, respectively.

Table 7.2 (continued)

Decision rule	Conclusion	Comments
D1c: If contaminants found at the site are known to transform or degrade into chemicals that could lead to increased risks to human health or the environment or into chemicals for which there are ARARs, and if the concentrations of these contaminants may result in risks greater than those defined in D1a or concentrations greater than ARARs, then evaluate actions that will mitigate potential future risk or promote compliance with ARARs; otherwise, pursue a "no further action" decision (see D1a and D1b).	The COCs constituting primary risk drivers through direct contact with groundwater at SWMU 5 may degrade into more toxic substances, potentially leading to increased risk at concentrations that may exceed chemical-specific ARARs.	Trichloroethene was detected in RGA groundwater at SWMU 5.
D2a: If secondary sources are found, and if the concentrations of analytes within the secondary sources are found to potentially result in a cumulative excess lifetime cancer risk greater than 1×10^{-6} or a cumulative hazard index greater than 1 through contact with contaminated media at the unit, and if the concentrations of analytes are greater than those that are expected to occur naturally in the environment, then evaluate actions that will mitigate risk; otherwise, do not consider secondary sources when making remedial decisions for the unit.	Secondary sources were identified. These secondary sources may continue to release contaminants to groundwater.	Beryllium is present in subsurface soil at SWMU 5.
D3a: If contaminants are found in the source zone, or if secondary sources are found, and if these contaminants are found to be migrating or may migrate from the source zone or from secondary sources at concentrations that may potentially result in a cumulative excess lifetime cancer risk greater than 1×10^{-6} or a cumulative hazard index greater than 1 through use of contaminated media at downgradient points of exposure, and the concentrations of analytes are greater than those that are expected to occur naturally in the environment, then evaluate actions that will mitigate risk; otherwise, do not consider risk posed by migratory pathways when evaluating remedial alternatives for the unit (see D3b).	Multimedia transport modeling indicates that contaminants may be released from soils and secondary sources at SWMU 5, potentially resulting in risk to off-site residential groundwater users that could exceed *de minimis* levels at some point in the future. Pathway analysis performed as part of fate and transport modeling indicates that releases to surface water bodies are unlikely.	Priority COCs include iron and manganese.

Table 7.2 (continued)

Decision rule	Conclusion	Comments
D3b: If contaminants are found in the source zone, or if secondary sources are found, and if these contaminants are found to be migrating or may migrate from the source zone or from the secondary sources at concentrations that exceed ARARs, then evaluate actions that will bring migratory concentrations into compliance with ARARs; otherwise, do not consider ARARs when examining migratory pathways during the evaluation of remedial actions (see D3a).	Multimedia transport modeling indicates that the contaminants released from soil at SWMU 5 will not result in concentrations in off-site groundwater that exceed primary MCLs.	The model predicts a concentration in excess of the current secondary MCL for manganese, a level arising from the subsurface soil levels of this contaminant at SWMU 5.
D4a: If Decision Rules D1a, D1b, D1c, D2a, D3a, or D3b indicate that remedial actions are needed, then evaluate response actions to mitigate risk in the source zone. (Refer to Sects. 5.11 and 5.12 of the WAG 3 Work Plan for discussions of the possible response actions.)	Results for Decision Rules D1a, D1b, D1c, D2a, D3a, and D3b indicate that response actions are needed. Evaluations of response actions to mitigate risk in the source zone may be appropriate.	
D5a: If contaminants in the source zone are found to migrate to the RGA, then determine the contributions from the source zone to support future remedial actions for existing groundwater contamination in the groundwater integrator unit; otherwise, do not determine contributions.	Multimedia transport modeling to off-site locations was completed because contaminants were suspected of migrating to the RGA. This information will be considered when determining remedial actions for the Groundwater Operable Unit at PGDP.	Multimedia transport modeling was completed using MEPAS and RESRAD. A more sophisticated modeling tool may be appropriate when determining remedial actions for the Groundwater Operable Unit.
D5b: If contaminants in the source zone are found to migrate to the Surface Water Integrator Unit (i.e., Bayou and Little Bayou Creeks and ditches discharging directly to regulated outfalls), then determine the contributions from the source zone to support future remedial actions for past releases to the Surface Water Integrator Unit; otherwise, do not determine contributions.	Pathway analysis performed as part of fate and transport modeling indicates that releases to surface water bodies are unlikely.	

Table 7.2 (continued)

General Conclusions for SWMU 5

(1) Contamination is present in surface soil at SWMU 5 that may lead to risks to industrial workers exceeding *de minimis* levels. Per Decision Rule D4a, response actions to mitigate the risks from direct contact with this medium may be appropriate.

(2) Contamination is present in subsurface soil at SWMU 5 that may lead to risks to unprotected excavation workers exceeding *de minimis* levels. Per Decision Rule D4a, response actions to mitigate the risks from direct contact with this medium may be appropriate.

(3) Contamination is present in RGA groundwater at SWMU 5 that may lead to risks to industrial workers exceeding *de minimis* levels. Additionally, results indicate that the contamination present in soil and in secondary sources at concentrations could lead to continuing contamination of groundwater. Per Decision Rule D4a, response actions to mitigate the risks from direct contact with this medium and to address continued contaminant migration might be appropriate.

Table 7.3. WAG 3 SWMU 6-specific decision rules and conclusions

Decision rule	Conclusion	Comments
D1a: If the concentration of analytes found in the source zone may result in a cumulative excess lifetime cancer risk greater than 1×10^{-6} or a cumulative hazard index greater than 1 through contact with contaminated media, or if the concentration of analytes in the source zone may result in detrimental impacts to nonhuman receptors through contact with contaminated media as indicated by exceeding ecological screening criteria, and if the concentrations of analytes in the source zone are greater than those that are expected to occur naturally in the environment, then evaluate actions that will mitigate risk; otherwise pursue a "no further action" decision (see D1b and D1c).	Carcinogenic risks from direct contact with surface soil exceed the KDEP *de minimis* levels and the EPA *de minimis* range (1×10^{-4} to 1×10^{-6}) for industrial workers, but noncarcinogenic hazards do not exceed *de minimis* levels for the same receptors. Risks to the excavation worker exposed to contaminated soils exceed *de minimis* levels for both carcinogenicity and systemic toxicity. Risks from potential use of the RGA as a drinking water source at the SWMU exceed *de minimis* levels for the industrial worker. Risks to nonhuman receptors are generally *de minimis* under current conditions. Additionally, contaminant concentrations are such that risks are unlikely to exceed *de minimis* levels in the future.	Risks for the industrial worker from exposure to surface soil fell below *de minimis* levels when the analysis was performed using site-specific exposure parameters. However, cancer risk remained above *de minimis* levels when the assessment was performed using default exposure parameters but reduced dermal absorption values for inorganic chemicals. Risks were greater than *de minimis* levels for the excavation worker when default exposure parameters were used. Furthermore, when the assessment was performed using site-specific exposure parameters, the cancer risk remained greater than *de minimis* levels (3.4×10^{-6}). Groundwater drawn from the RGA is not currently used at PGDP. Migration of contaminants from soil to groundwater and surface water is discussed under Decision Rules D3a and D3b, respectively.
D1b: If concentrations of analytes found in the source zone exceed ARARs, then evaluate actions that will bring contamination within the source zone into compliance with ARARs; otherwise, pursue a "no further action" decision (see D1a and D1c).	Concentrations exceed MCLs in RGA groundwater for some contaminants.	No chemical-specific ARARs are available for screening contaminant concentrations in sediment or soil. Migration of contaminants from soil to groundwater and surface water is discussed under Decision Rules D3a and D3b, respectively.

Table 7.3 (continued)

Decision rule	Conclusion	Comments
D1c: If contaminants found at the site are known to transform or degrade into chemicals that could lead to increased risks to human health or the environment or into chemicals for which there are ARARs, and if the concentrations of these contaminants may result in risks greater than those defined in D1a or concentrations greater than ARARs, then evaluate actions that will mitigate potential future risk or promote compliance with ARARs; otherwise, pursue a "no further action" decision (see D1a and D1b).	Contaminants in the subsurface soil at SWMU 6 will not degrade substantially to other, potentially toxic substances.	Beryllium is the primary risk driver at this SWMU.
D2a: If secondary sources are found, and if the concentrations of analytes within the secondary sources are found to potentially result in a cumulative excess lifetime cancer risk greater than 1×10^{-6} or a cumulative hazard index greater than 1 through contact with contaminated media at the unit, and if the concentrations of analytes are greater than those that are expected to occur naturally in the environment, then evaluate actions that will mitigate risk; otherwise, do not consider secondary sources when making remedial decisions for the unit.	Secondary sources were identified at SWMU 6. These secondary sources may continue to release contaminants to groundwater.	Beryllium is present in subsurface soil at SWMU 6.
D3a: If contaminants are found in the source zone, or if secondary sources are found, and if these contaminants are found to be migrating or may migrate from the source zone or from secondary sources at concentrations that may potentially result in a cumulative excess lifetime cancer risk greater than 1×10^{-6} or a cumulative hazard index greater than 1 through use of contaminated media at downgradient points of exposure, and the concentrations of analytes are greater than those that are expected to occur naturally in the environment, then evaluate actions that will mitigate risk; otherwise, do not consider risk posed by migratory pathways when evaluating remedial alternatives for the unit (see D3b).	Multimedia transport modeling indicates that SWMU-specific contaminants have the potential to be released from soils at rates that will result in risks to off-site residential groundwater users exceeding *de minimis* levels.	Iron has the potential to migrate off-site from this SWMU.

Table 7.3 (continued)

Decision rule	Conclusion	Comments
D3b: If contaminants are found in the source zone, or if secondary sources are found, and if these contaminants are found to be migrating or may migrate from the source zone or from the secondary sources at concentrations that exceed ARARs, then evaluate actions that will bring migratory concentrations into compliance with ARARs; otherwise, do not consider ARARs when examining migratory pathways during the evaluation of remedial actions (see D3a).	Multimedia transport modeling indicates that the contaminants released from subsurface soil at SWMU 6 do not result in concentrations in off-site groundwater that exceed MCLs.	Modeled amounts of manganese in the downgradient RGA exceed the secondary MCL.
D4a: If Decision Rules D1a, D1b, D1c, D2a, D3a, or D3b indicate that remedial actions are needed, then evaluate response actions to mitigate risk in the source zone. (Refer to Sects. 5.11 and 5.12 of the WAG 3 Work Plan for discussions of the possible response actions.)	Results for Decision Rules D1a, D3a, and D3b indicate that response actions are needed. Evaluations of response actions to mitigate risk in the source zone may be appropriate.	
D5a: If contaminants in the source zone are found to migrate to the RGA, then determine the contributions from the source zone to support future remedial actions for existing groundwater contamination in the groundwater integrator unit; otherwise, do not determine contributions.	Multimedia transport modeling to off-site locations was completed because contaminants were suspected of migrating to the RGA. This information will be considered when determining remedial actions for the Groundwater Operable Unit at PGDP.	Multimedia transport modeling was completed using MEPAS and RESRAD. A more sophisticated modeling tool may be appropriate when determining remedial actions for the Groundwater Operable Unit.
D5b: If contaminants in the source zone are found to migrate to the Surface Water Integrator Unit (i.e., Bayou and Little Bayou Creeks and ditches discharging directly to regulated outfalls), then determine the contributions from the source zone to support future remedial actions for past releases to the Surface Water Integrator Unit; otherwise, do not determine contributions.	Pathway analysis performed as part of fate and transport modeling indicates that releases to surface water bodies are unlikely.	

Table 7.3 (continued)

General Conclusions for SWMU 6

(1) Contamination is present in surface soil at SWMU 6 that may lead to risks to industrial workers exceeding *de minimis* levels (a cumulative HI of 1.0 or a cumulative ELCR of 1.0E-06). Per Decision Rule D4a, response actions to mitigate the risks from direct contact with this medium may be appropriate.

(2) Contamination is present in subsurface soil at SWMU 6 that may lead to risks to unprotected excavation workers exceeding *de minimis* levels. Per Decision Rule D4a, response actions to mitigate the risks from direct contact with this medium may be appropriate.

(3) Results indicate that the contamination present in subsurface soil has the capacity to migrate to groundwater, with the potential for impacting the health of off-site receptors. Per Decision Rule D4a, response actions to mitigate the risks from direct contact with this medium and to address continued contaminant migration thereto might be appropriate.

8. REFERENCES

Battelle (Battelle Memorial Institute) 1995. *Multimedia Environmental Pollutant Assessment System (MEPAS) Application Guidance.* PNL-10395. Prepared by Pacific Northwest Laboratory.

Bechtel Jacobs Company LLC 1999. *Waste Acceptance Criteria for the Department of Energy Treatment Storage, and Disposal Units at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, BJC/PAD-11.

Bechtel Jacobs Company LLC 2000. *Trichloroethene and Technetium-99 Groundwater Contamination in the Regional Gravel Aquifer for Calendar Year 1999 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, BJC/PAD-169.

Birge, W. J., Short, T. M., and Lauth, J. R. 1990. *Biological Monitoring Program for the Paducah Gaseous Diffusion Plant, Three-Year Draft Report.* Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN.

CDM Federal Programs Corporation (CDM Federal) 1992. *Remedial Investigation of the Underground Storage Tanks at the C-200, C-710, and C-750 Buildings, Paducah Gaseous Diffusion Plant, Paducah, Kentucky.* Martin Marietta Energy Systems, Inc., Paducah, KY.

CDM Federal 1994. *Investigation of Sensitive Ecological Resources Inside the Paducah Gaseous Diffusion Plant, Paducah, Kentucky.* Doc. No. 7916-003-FR-BBRY. Paducah, KY.

CH2M HILL 1991. *Results of the Site Investigation, Phase I, Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* KY/ER-4. Paducah, KY.

CH2M HILL 1992. *Results of the Site Investigation, Phase II, Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* KY/Sub/13B-97777C P03/1991/1. Paducah, KY.

Clausen, J. L., Davis, K. R., Douthitt, J. W., and Phillips, B. E. 1992a. *Paducah Gaseous Diffusion Plant Groundwater Protection Program Plan,* KY/ER-2, Rev. 1. Paducah, KY.

Clausen, J. L., Douthitt, J. W., Davis, K. R., and Phillips, B. E. 1992b. *Report of the Paducah Gaseous Diffusion Plant Groundwater Investigation Phase III,* KY/E-150. Paducah, KY.

Clausen, J. L. 1996. *Modeling of Soil and Contaminants from the C-750-A&B Underground Storage Tanks Using SESOIL, Paducah, Kentucky*, KY/EM-158. Paducah, KY.

COE (U.S. Army Corps of Engineers) 1994. *Environmental Investigations at the Paducah Gaseous Diffusion Plant and Surrounding Area, McCracken County, Kentucky.* Paducah, KY.

Davis, R. W., Lambert, T. W., and Hansen, A. J., Jr. 1973. *Subsurface Geology and Groundwater Resources of the Jackson Purchase Region, Kentucky.* U.S. Geological Survey Water Supply Paper No. 1987.

DOE (U.S. Department of Energy) 1982. *Environmental Measurements Laboratory Procedures Manual,* 25th Ed. HASL-300.

DOE 1993. *Human Health Baseline Risk Assessment for the Northwest Plume, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1202&D1.

DOE 1995. *Northeast Plume Preliminary Characterization Summary Report*, DOE/OR/07-1339/V1&D2. Paducah, KY.

DOE 1996. *Methods for Conducting Human Health Risk Assessment and Risk Evaluations at the Paducah Gaseous Diffusion Plant*, DOE/OR/07-1506&D1. August.

DOE 1997. *Background Levels of Selected Radionuclides and Metals in Soils and Geologic Media at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1586&D2. Paducah, KY.

DOE 1998a. *Work Plan for Waste Area Grouping 3 Remedial Investigation/Feasibility Study at the Paducah Gaseous Diffusion Plant, Paducah,* Kentucky, DOE/OR/07-1649&D2. Paducah, KY.

DOE 1998b. *Site Management Plan, Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-1207&D3. Paducah, KY.

DOE 1998c. *Waste Area Grouping 6 Remedial Investigation Report, Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-1727/V1&D1. Paducah, KY.

DOE 1999a. *Remedial Investigation Report for Waste Area Grouping 28 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1846/V4&D0.

DOE 1999b. *Remedial Investigation Report for Waste Area Grouping 27 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1777/V1&D2.

DOE 1999c. *Remedial Investigation Report for Waste Area Grouping 6 at Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1727/V1&D2.

DOE 2000a. *Data Report for the Sitewide Remedial Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1845&D0.

DOE 2000b. *Feasibility Study for the Groundwater Operable Unit at Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1857&D1.

Dragun, J. 1988. *The Soil Chemistry of Hazardous Materials*, Hazardous Materials Control Research Institute, Silver Springs, MD.

EDGe (Engineering, Design, & Geosciences Group, Inc.) 1989. *Groundwater Monitoring/Phase II: Preliminary Hydrogeological Characterization of the Department of Energy Reservation and the C-404 Post Closure Compliance Program,* ESO 16749, Report 08-38-910819003, ERC Environmental and Energy Service Company, Nashville, TN.

EPA (U.S. Environmental Protection Agency) 1980. *Prescribed Procedures for Measurement of Radioactivity in Drinking Water*, EPA-600/4-80-032.

EPA 1984. *Radiochemistry Procedures Manual,* EPA/520/5-84-006. Eastern Environmental Radiation Facility, Montgomery, AL.

EPA 1986. *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods.* SW-846. Third Edition.

EPA 1989. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A, Baseline Risk Assessment)*, EPA/540/1-89/002, Office of Emergency and Remedial Response, Washington, DC.

EPA 1995. *Supplemental Guidance for Superfund, Volume 1: Human Health Risk Assessment, Interim.* Office of Health Assessment, Region 4 EPA, Atlanta, GA.

EPA 1996. *Standard Operating Procedures and Quality Assurance Manual.* Region 4 Environmental Sciences Division, Athens, GA.

EPA 1998. *Guidelines for Ecological Risk Assessment*, EPA/630/R-95/002F, U.S. Environmental Protection Agency, Washington, DC.

Finch, W. I. 1967. *Geologic Map of Part of the Joppa Quadrangle, McCracken County, Kentucky,* GQ-562. U.S. Department of the Interior, U.S. Geologic Survey.

Fortune, M. B. 1973. *The Discard of Scrap Materials by Burial at the Paducah Plant.* 01-13-930506584.

Frye, J. C., et al. 1972. *Geology and Paleontology of Late Pleistocene Lake Saline, Southeastern Illinois,* Circular 471. Illinois State Geologic Survey.

GeoTrans, Inc. 1992. *Groundwater Modeling and Offsite Containment Evaluation at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, GeoTrans Project No. 6506-003. Prepared for Martin Marietta Energy Systems, Inc., Paducah, KY.

Jacobs (Jacobs Engineering Group, Inc.) 1995. *Functions and Values Analysis for the Drainage Area South of Solid Waste Management Units 2 and 3 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, JE/PAD/95-0237. Paducah, KY.

Jacobs 1997. *Numerical Ground-Water Model Recalibration and Evaluation of the Northwest Plume Interim Remedial Action Report for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* JE/PAD/97-0185. Paducah, KY.

Miller, G. R., and Douthitt, J. 1993. *Groundwater Protection Program, Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* KY/ER-30. Paducah, KY.

MMES (Martin Marietta Energy Systems, Inc.) 1995. *Final Report on Drive Point-Profiling of the Northwest Plume and Analysis of Related Data, Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* KY/ER-66. April.

Olive, W. W. 1980. *Geologic Maps of the Jackson Purchase Region, Kentucky.* U.S. Department of the Interior, U.S. Geological Survey.

SAIC (Science Applications International Corporation) 1998. *Remedial Investigation Report for Solid Waste Management Units 7 and 9 of Waste Area Grouping 22 at Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1604/V1&D2. Paducah, KY.

TCT-St. Louis 1991. *Final Project Report of the Phase I Contamination Evaluation at Former Kentucky Ordnance Works, McCracken County, Kentucky.* Paducah, KY.

USDA (U.S. Department of Agriculture) 1976. *Soil Survey of Ballard and McCracken Counties, Kentucky.* USDA Soil Conservation Service and Kentucky Agricultural Experiment Station.

Wehran (Wehran Engineering Corporation) 1981. *Hydrogeologic Investigation—Existing Sanitary Landfill Closure, Union Carbide Corporation, Gaseous Diffusion Plant, Paducah, Kentucky,* WE Project No. 02340166, Middletown, NY.