Department of Energy

Portsmouth/Paducah Project Office
1017 Majestic Drive, Suite 200
Lexington, Kentucky 40513
(859) 219-4000

APR 2 8 2010

Mr. W. Turpin Ballard
U.S. Environmental Protection Agency, Region 4
Federal Facilities Branch
61 Forsyth Street
Atlanta, Georgia 30303

PPPO-02-144-10

Mr. Edward Winner, FFA Manager
Kentucky Department for Environmental Protection
Division of Waste Management
200 Fair Oaks Lane, 2nd Floor
Frankfort, Kentucky 40601

Dear Mr. Ballard and Mr. Winner:

TRANSMITTAL OF THE D1 FEASIBILITY STUDY FOR THE BURIAL GROUND OPERABLE UNIT AT THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY (DOE/LX/07-0130&D1)

Please find enclosed the certified D1 *Feasibility Study for the Burial Ground Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE/LX/07-0130&D1) for your review.

If you have any questions or require additional information, please contact Jennifer Woodard at (270) 441-6820.

Sincerely,

Reinhard Knerr
Paducah Site Lead
Portsmouth/Paducah Project Office

Enclosures:
1. Certification Page
2. D1 FS for the BGOU

cc w/enclosures:
AR File/Kevil

cc w/enclosures:
ballard.turpin@epa.gov, EPA/Atlanta
brandy.mitchell@prs-llc.net, PRS/Kevil
dennis.ferrigno@prs-llc.net, PRS/Kevil
edward.winner@ky.gov, KDEP/Frankfort
fraser.johnstone@prs-llc.net, PRS/Kevil
gaye.brewer@ky.gov, KDEP/Frankfort
jana.white@prs-llc.net, PRS/Kevil
janet.miller@lex.doe.gov, PRC/PAD
jeff.snook@lex.doe.gov, PPPO/PAD
jeffrey.gibson@ky.gov, KDEP/Frankfort
jennifer.woodard@lex.doe.gov, PPPO/PAD
leo.williamson@ky.gov, KDEP/Frankfort
msmith@techlawinc.com, TechLaw/Alpharetta
myrna.redfield@prs-llc.net, PRS/Kevil
rachel.blumenfeld@lex.doe.gov, PPPO/LEX
reinhard.knerr@lex.doe.gov, PPPO/PAD
rich.bonczek@lex.doe.gov, PPPO/LEX
richard.bateman@prs-llc.net, PRS/Kevil
todd.butz@prs-llc.net, PRS/Kevil
tufts.jennifer@epa.gov, EPA/Atlanta

CERTIFICATION

Document Identification: ***Feasibility Study for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky***
DOE/LX/07-0130&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.

Paducah Remediation Services, LLC
Operator

Dennis Ferrigno, PM, Site Manager — 4-27-10
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.

U.S. Department of Energy (DOE)
Owner

Reinhard Knerr, Paducah Site Lead
Portsmouth/Paducah Project Office — 4/27/10
Date Signed

DOE/LX/07-0130&D1
PRIMARY DOCUMENT

Feasibility Study for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

CLEARED FOR PUBLIC RELEASE

DOE/LX/07-0130&D1
PRIMARY DOCUMENT

Feasibility Study for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued–April 2010

Prepared for the
U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Environmental Management Activities at the
Paducah Gaseous Diffusion Plant
Paducah, Kentucky 42001

managed by
Paducah Remediation Services, LLC
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC30-06EW05001

CLEARED FOR PUBLIC RELEASE

PORTAGE ENVIRONMENTAL, INC., AND SHAW ENVIRONMENTAL AND INFRASTRUCTURE, INC.

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

PREFACE

This *Feasibility Study for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0130&D1, was prepared to evaluate remedial alternatives for potential application at the U.S. Department of Energy's Paducah Gaseous Diffusion Plant. This work was prepared in accordance with the requirements of the *Federal Facility Agreement for the Paducah Gaseous Diffusion Plant* (FFA) (EPA 1998a). In accordance with Section IV of the FFA, this integrated technical document was developed to satisfy applicable requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 *USC* § 9601 *et seq.* 1980) and the Resource Conservation and Recovery Act (42 *USC* § 6901 *et seq.* 1976). As such, the phases of the investigation process are referenced by CERCLA terminology within this document to reduce the potential for confusion.

THIS PAGE INTENTIONALLY LEFT BLANK

CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

TABLES

FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

ACRONYMS

amsl	above mean sea level
ARAR	applicable or relevant and appropriate requirement
ARD	anaerobic reductive dechlorination
AT123D	Analytical Transient 1-,2-,3-Dimensional
BHHRA	baseline human health risk assessment
BGOU	Burial Grounds Operable Unit
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
cis-1,2-DCE	*cis*-1,2-dichloroethene
COC	contaminant of concern
COE	U.S. Army Corps of Engineers
COPC	chemical of potential concern
CRMP	Cultural Resources Management Plan
CSM	Conceptual Site Model
DAF	dilution attenuation factor
DCE	dichloroethene
D&D	decontamination and decommissioning
DNAPL	dense nonaqueous-phase liquid
DO	dissolved oxygen
DOE	U.S. Department of Energy
DPE	dual-phase extraction
DPT	direct-push technology
DSA	documented safety analysis
EDE	effective dose equivalent
ELCR	excess lifetime cancer risk
E/PP	excavation/penetration permit
EPA	U.S. Environmental Protection Agency
ERA	Ecological Risk Assessment
ERH	electrical resistance heating
FFA	Federal Facility Agreement
FS	feasibility study
FML	flexible membrane liner
f_{oc}	fraction of organic carbon
FR	*Federal Register*
FS	feasibility study
FY	fiscal year
GAC	granular-activated carbon
GDP	gaseous diffusion plant
GPS	groundwater protection standard
GRA	general response action
HASP	health and safety plan
HDPE	high-density polyethylene
HEPA	high-efficiency particulate air
HI	hazard index
HTTD	high temperature thermal desorption
HU	hydrogeologic unit
ISB	*in situ* bioremediation
ISB-ARD	*in situ* bioremediation-anaerobic reductive dechlorination

ISCO	*in situ* chemical oxidation
ISRM	*in situ* redox manipulation
KAR	*Kentucky Administrative Regulations*
K_d	soil/water partition coefficient
KDEP	Kentucky Department for Environmental Protection
KEEC	Kentucky Energy and Environment Cabinet
K_H	Henry's Law constant value
K_{oc}	soil organic carbon partition coefficient
K_{ow}	octanol-water partition coefficient
KOW	Kentucky Ordnance Works
KPDES	Kentucky Pollutant Discharge Elimination System
LCD	Lower Continental Deposits
LLW	low-level waste
LTTD	low temperature thermal desorption
LUC	Land Use Control
LUCIP	land use control implementation plan
MCL	maximum contaminant level
MMO	methane monooxygenase
MSC	Manufacturing Sciences Corporation
MW	monitoring well
N/A	not applicable
NAL	no action level
NAPL	nonaqueous-phase liquid
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act of 1969
NHPA	National Historic Preservation Act
NOAA	National Oceanic and Atmospheric Administration
NPL	National Priorities List
NRCS	Natural Resources Conservation Service
NRDA	Natural Resource Damage Assessment
NSDD	North-South Diversion Ditch
O&M	Operation & Maintenance
ORP	oxidation reduction potential
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	perchloroethene (tetrachloroethene)
PGDP	Paducah Gaseous Diffusion Plant
pH	hydrogen-ion concentration
POC	point of contact
POE	point of exposure
PPE	personal protective equipment
PRB	permeable reactive barrier
PTW	principal threat waste
RAO	remedial action objective
RAWP	Remedial Action Work Plan
RCRA	Resource Conservation and Recovery Act
RD	remedial design
RG	remediation goal
RGA	Regional Gravel Aquifer
RI	remedial investigation

ROD	Record of Decision
RPO	representative process option
S-ISCO	surfactant *in situ* chemical oxidation
SADA	Statistical Analysis and Decision Acceptance
SAP	sampling and analysis plan
scfm	standard cubic ft per minute
SERA	screening ecological risk assessment
SESOIL	Seasonal Soil Compartment Model
SI	site investigation
SMP	Site Management Plan
SOD	soil oxidant demand
SPH	six-phase heating
SVE	soil vapor extraction
SVOC	semivolatile organic compound
SWMU	solid waste management unit
T&E	threatened and endangered
TBC	to be considered
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TCE	trichloroethene
TCH	thermal conduction heating
TEQ	toxicity equivalent concentration
TSCA	Toxic Substances Control Act
TVA	Tennessee Valley Authority
UCD	Upper Continental Deposits
UCRS	Upper Continental Recharge System
UF_6	uranium hexafluoride
USC	*United States Code*
USFWS	U. S. Fish and Wildlife Service
UTL	upper tolerance limit
VOC	volatile organic compound
WAC	waste acceptance criteria
WAG	waste area grouping
WCP	waste characterization plan
WDF	waste disposal facility
WKWMA	West Kentucky Wildlife Management Area
WMP	waste management plan
ZVI	zero valent iron

THIS PAGE INTENTIONALLY LEFT BLANK

EXECUTIVE SUMMARY

This *Feasibility Study for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0130&D1, (FS) was prepared to evaluate remedial alternatives for potential application at the Paducah Gaseous Diffusion Plant (PGDP). This work was prepared in accordance with the requirements of the *Federal Facility Agreement for the Paducah Gaseous Diffusion Plant* (FFA) (EPA 1998a).

The Burial Grounds Operable Unit (BGOU) consists of contamination associated with PGDP's landfills (except C-746-K Sanitary Landfill) and burial grounds and additional disposal areas that might exist beneath the scrap yards. Burial grounds investigated in the BGOU Remedial Investigation (RI) and in this FS are listed in Table ES.1.

Table ES.1. Summary of Source Areas and Solid Waste Management Units Investigated by the BGOU RI

SWMU No.	Description
2	C-749 Uranium Burial Grounds
3	C-404 Low-Level Radioactive Waste Burial Grounds
4	C-747 Contaminated Burial Yard and C-748-B Burial Area
5	C-746-F Burial Yard
6	C-747-B Burial Grounds
7 and 30	C-747-A Burial Grounds and Burn Area
145	Area P (residential/inert borrow area) and old North-South Diversion Ditch disposal trench (the area for SWMU 145 includes that beneath SWMUs 9 and 10)

SWMU = solid waste management unit

Under a work plan approved by U.S. Environmental Protection Agency (EPA) and the Commonwealth of Kentucky (KY) (DOE 2006a), the U. S. Department of Energy (DOE) conducted an RI, which was the continuation of earlier investigative activities, to evaluate source areas of contamination associated with PGDP's landfills and burial grounds and additional disposal areas that might exist beneath the scrap yards. Results of the RI were reported in the *Remedial Investigation Report for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0030&D2/R1 (DOE 2010).

The C-746-S [Solid Waste Management Unit (SWMU) 9] and C-746-T (SWMU 10) Landfills are included in the overall scope of the BGOU, but were not included in the RI. These SWMUs were assumed to require no action in the fiscal year 2009 Site Management Plan (SMP) (DOE 2009a). There is no further discussion of SWMUs 9 and 10 in this document because no action is required, and they will be proposed as "no further action" (NFA) in the Proposed Plan and Record of Decision (ROD).

A Soils Operable Unit (OU) SWMU, SWMU 12, is part of the BGOU and overlaps a portion of SWMU 7. Any buried material beneath SWMU 12 is considered part of SWMU 7.

Subsequent to development of the BGOU RI/FS Work Plan (DOE 2006a) and concurrent with the RI field investigation, an interview with a former plant operator identified potential areas of buried metal within the C-746-P and C-746-P1 Scrap Yards (SWMU 13). The results of the sampling and an assessment of these burial areas, as characterized by an approved Field Sampling Plan addendum to the BGOU RI/FS Work Plan and follow-on-site investigation, will be documented separately in a Site Evaluation Report. The results will be discussed with the FFA parties and, if further action is necessary, a path forward will be determined.

SCOPE OF THE BGOU

The BGOU at PGDP is one of five media-specific, sitewide OUs associated with pre-shutdown scope being used to evaluate and implement remedial actions. A final Comprehensive Site OU evaluation will be conducted following plant shutdown and completion of pre- and post-shutdown actions to ensure long-term protectiveness of human health and the environment. The five media-specific, strategic cleanup initiatives that have been agreed upon by the DOE, EPA, and the KY, as documented in the SMP (DOE 2009a), are as follows:

- Groundwater OU Strategic Initiative
- Burial Grounds OU Strategic Initiative
- Surface Water OU Strategic Initiative
- Soils OU Strategic Initiative
- D&D OU Strategic Initiative

The Burial Grounds contain various waste and other materials. Some of the materials potentially may be principal threat waste (PTW).

The BGOU will employ the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) remedial process to accomplish the following goals as defined in the RI Report (DOE 2010):

- Contribute to the protection of current and future residential receptors from exposure to contaminated groundwater by addressing sources of groundwater contamination;

- Protect industrial workers from exposure to waste and contaminated soils; and

- Treat or remove PTW wherever practicable, consistent with 40 *CFR* § 300.430(a)(1)(iii)(A).

PREVIOUS INVESTIGATIONS

Table ES.2 identifies the previously completed reports and/or investigations primarily relied on in the development of this FS.

SOURCE AREAS AND NATURE AND EXTENT OF CONTAMINATION

The SWMUs comprising the BGOU consist primarily of landfills and belowground burial cells in which various PGDP wastes have been placed. Infiltration of water (i.e., precipitation) descending through the buried waste could mobilize contaminants within the waste. Once mobilized, the most likely pathway of the contaminants would be downward through the Upper Continental Recharge System (UCRS) soils, ultimately reaching the Regional Gravel Aquifer (RGA). Some lateral movement of contaminants would occur in the UCRS, but these pathways are known to be limited.

Based on this conceptual model, any contamination resulting from buried waste found at the BGOU SWMUs would be expected to be found concentrated in the soils and groundwater of the UCRS immediately within and under the burial cells and landfills, with little lateral dispersion of contamination in the UCRS from the cells and immediately adjacent soils. The RI Report provides an assessment of data from the BGOU RI, along with data from historical investigations, to evaluate the nature and extent of contamination (vertical and lateral) associated with the BGOU SWMUs.

Table ES.2. Summary of Previous Investigations of BGOU

Dates	Title	SWMU 2	SWMU 3	SWMU 4	SWMU 5	SWMU 6	SWMU 7	SWMU 30	SWMU 145	SWMUs 9 and 10
1989	Post Closure Permit Application C-404 Low-Level Radioactive Waste Burial Ground		✓							
1990–1992	Phase II Site Investigation	✓	✓	✓	✓	✓	✓	✓		
1996	Closure Plan C-404 Low-Level Radioactive Waste Burial Ground		✓							
1996–1997	WAG 22 SWMUs 2 and 3 Remedial Investigation and Addendum (including SWMU 2 Data Summary Report)	✓	✓							
1996–1998	WAG 22 SWMUs 7 and 30 RI/FS						✓	✓		
1998–2001	WAG 3 RI/FS			✓	✓	✓				
1999–2001	Data Gaps Investigation			✓	✓		✓	✓	✓	
2000–2001	Old NSDD Sampling								✓	
2002–2003	Scrap Yards Site Characterization				✓	✓	✓	✓		
2003–2004	C-746-S and—T Landfill Site Investigation								✓	✓
2004	Southwest Plume Site Investigation			✓						
2006	Burial Grounds RI/FS Work Plan	✓	✓	✓	✓	✓	✓	✓	✓	
2007	Burial Grounds Remedial Investigation	✓	✓	✓	✓	✓	✓	✓	✓	

Table ES.2 is based on Table 1.4 of the *Remedial Investigation Report for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0030&D2/R1, February (DOE 2010).
NSDD = North-South Diversion Ditch; SWMU = solid waste management unit; WAG = waste area group
Blank cells indicate the investigation is not applicable to the SWMU.

The BGOU SWMUs contain two potential PTWs: trichloroethene (TCE) dense nonaqueous-phase liquid (DNAPL) at SWMU 4 and between SWMUs 7 and 30, and uranium wastes at SWMUs 2 and 3. Dissolved contaminant trends in the RGA indicate that SWMU 4 is a DNAPL source. The data also indicate that the adjoining area in the UCRS between SWMUs 7 and 30 also may contain TCE sources as DNAPL. The mobility and toxicity of DNAPLs make them PTW. Additionally, historical records of TCE disposal at SWMU 2 indicate that a DNAPL source potentially could exist at the SWMU and will require evaluation of a treatment alternative.

BASELINE RISK ASSESSMENT CONCLUSIONS

PGDP is an industrial facility. Land use within the current plant boundary is expected to remain industrial. These factors should be considered in examination of risk information provided in this report.

For surface soil, results from previous risk assessments were used, and no new surface soil data were collected at most of the SWMUs. The risk for the on-site resident for soil exceeds 1E-04 and the hazard index (HI) is greater than 1 at all SWMUs except for SWMUs 2, 3, and 145 (which were not evaluated for soil exposure for these scenarios). The contaminants that are risk drivers for soil are aluminum, arsenic, beryllium, chromium, iron, nickel, uranium, vanadium, zinc, total polycyclic aromatic hydrocarbons (PAHs), uranium-234, and uranium-238.

Residential use of groundwater was evaluated at the SWMU boundary, plant boundary, property boundary, and Ohio River (or seeps) for all SWMUs except SWMU 6 [SWMU 6 had no groundwater chemicals of potential concern (COPCs)] and SWMU 145 (SWMU 145 was not evaluated at the plant boundary since it lies outside that boundary). At the SWMU boundary, risks and hazards from groundwater use for all evaluated SWMUs exceeded 1E-04 risk and exceeded an HI of 1. The major contaminants driving the groundwater risks and hazards at the SWMU boundary point of exposure (POEs) are arsenic (at SWMUs 3, 5, 7, and 145); antimony (at SWMU 145); Aroclor-1260 (at SWMU 145); *cis*-1,2-dichlorethene (DCE) (at SWMUs 2 and 7); 1-1-DCE (at SWMUs 7 and 30); manganese (at SWMUs 3 and 5); naphthalene (at SWMU 5); Aroclor-1254 (at SWMU 7); TCE (at SWMUs 2, 4, 7, and 30); technetium-99 (at SWMU 3); uranium (at SWMU 3); and vinyl chloride (at SWMUs 4 and 7). At the plant boundary, risks and hazards from groundwater for SWMUs 2, 3, 4, 5, 7, and 30 exceeded 1E-04 risk or exceeded an HI of 1. At the property boundary, risks and hazards from groundwater for SWMUs 2, 4, 7, 30, and 145 exceeded 1E-04 risk or exceeded an HI of 1. At the Ohio River (or seeps), risks and hazards from groundwater for SWMUs 2, 4, 7, and 30 exceeded 1E-04 risk or exceeded an HI of 1. The major contaminants driving the groundwater risks and hazards at the property boundary and Ohio River (or Little Bayou Creek seeps) POEs are arsenic, *cis*-1,2-DCE, 1,1-DCE, TCE, technetium-99, and vinyl chloride. While the migration of contamination from the potential TCE DNAPL zones at SWMU 4 and SWMUs 7 and 30 was not modeled due to uncertainties in source term development, a qualitative analysis completed considering results from previous studies done for the PGDP (e.g., C-400 DNAPL source) indicates that TCE migration from these sources would have resulted in potential risks exceeding 1E-04 at all POEs.

For exposure to soil, excess lifetime cancer risk (ELCR) at all SWMUs, except SWMU 145 where surface soil exposure was not assessed, exceeded 1E-06. For exposure to soil, SWMUs 4, 5, 6, 7, and 30 have HIs > 1. Soil exposures of workers are more relevant to the potential future uses of the site.

Based on correspondence with the BGOU Integrated Project Team, it was determined that the excavation worker scenario evaluated in the RI Report (DOE 2010) uses exposure parameters that would not be consistent with a reasonably expected maximum exposure for an excavation worker in contact with subsurface soil at the BGOU. It was decided that the term outdoor worker better describes the future worker expected to have intimate contact with surface and subsurface soil consistent with the excavation worker exposure parameters used in the RI Report. Accordingly, the term outdoor worker is used in this FS, instead of excavation worker when presenting preliminary remediation goals (RGs) for a worker directly exposed to subsurface soil for extended periods of time.

For the outdoor worker who is exposed to both surface soil and subsurface soil, HIs were greater than one at SWMUs 4, 5, 6, 7, and 30. ELCR for the outdoor worker exceeded 1E-04 at SWMUs 4, 5, 6, 7, and 30. The ELCR/hazard drivers for the outdoor worker scenario were arsenic, beryllium, Total PAHs, uranium, uranium-235, and uranium-238.

The most likely future scenario identified in the RI Report is the industrial worker. The ELCR for the scenario exceeded 1E-04 at SWMUs 2, 3, 4, 5, 6, 7, and 30 primarily due to risk from arsenic, beryllium, Total PAHs, uranium-235, and uranium-238. The HI exceeds 1 for the industrial worker at SWMUs 4, 7, and 30; aluminum, beryllium, chromium, iron, manganese, uranium, and vanadium are the hazard drivers. Risks for the current worker (at 16 days per year of exposure) were less than those for the future industrial worker; risks for the current industrial worker exceeded 1E-04 at SWMUs 4, 5, 6, 7, and 30. Table ES.3 details the exposure pathways and contaminants of concern (COCs) associated with dominant risk for each SWMU for exposure to subsurface soil and groundwater.

The inclusion of beryllium as a risk driver is a result of incorporating the historical risk assessments. At the time those risk assessments were developed, beryllium still was evaluated as a carcinogen through the incidental ingestion exposure route. Since then, the oral cancer slope factor for beryllium has been withdrawn, and no longer is used for PGDP risk assessments by EPA. As a result, the total ELCR becomes much lower at those SWMUs where beryllium is a COC. For SWMUs 4 and 6, removal of the contribution of beryllium to the ELCR reduces the total ELCR to within the EPA risk range for the industrial worker scenario.

REMEDIAL ACTION OBJECTIVES

General site cleanup objectives were developed that serve as guiding principles for creating more detailed remedial action objectives (RAOs) to focus OUs on site-specific problems. A primary objective for the BGOU is to contribute to the protection of workers at the site and the protection of off-site residents by addressing sources of groundwater contamination. Based on the current and reasonably anticipated future land use, on-site industrial workers, future outdoor workers, recreational users, and off-site residents are the primary human receptors having the greatest potential for exposure to site contamination originating from PGDP. The primary pathways of exposure are (1) groundwater use by off-site residents; (2) direct contact with COCs in surface water and sediments by recreational users (assumed to be primarily local residents); and (3) direct contact with COCs by industrial and outdoor workers. The FS includes general RAOs for the BGOU, and it also includes SWMU-specific RAOs, developed jointly by DOE and the regulators during scoping meetings. These RAOs address source areas, including treatment and/or removal of potential PTWs consistent with CERCLA, the National Contingency Plan (including the Preamble), and any pertinent EPA guidance. The following general RAOs were developed and used in screening technologies and developing and evaluating alternatives in the FS for the BGOU SWMUs:

(1) Contribute to the protection of current and future off-site residential receptors from exposure to contaminated groundwater by reducing/controlling sources of groundwater contamination;

(2) Protect industrial workers from exposure to waste and contaminated soils; and

(3) Treat or remove PTW wherever practicable, consistent with 40 *CFR* § 300.430 (a)(1)(iii)(A).

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Applicable or relevant and appropriate requirements (ARARs) include the substantive requirements of federal or more stringent state environmental or facility siting laws/regulations; they do not include occupational safety or worker protection requirements. Additionally, per 40 *CFR* § 300.400(g)(3), other advisories, criteria, or guidance may be considered in determining remedies [to be considered (TBC) category]. CERCLA § 121(d)(4) provides several ARAR waiver options that may be invoked, provided that human health and the environment are protected.

Table ES.3. Exposure Routes and Exposure Pathways and Contaminants of Concern Associated with Dominant Risk for Each SWMU for Exposure to Subsurface Soil and Groundwater

Source Area	HI	ELCR
SWMU 2	– Ingestion of groundwater and household inhalation of vapors(TCE; *cis*-1,2-DCE)	– Household inhalation of vapors (TCE) – Ingestion of groundwater (TCE) – External exposure to subsurface soil (uranium-235, uranium-238)
SWMU 3	– Ingestion of groundwater (arsenic, uranium)	– Ingestion of groundwater (arsenic, ^{99}Tc) – External exposure to subsurface soil (uranium-235, uranium-238)
SWMU 4	– Ingestion of groundwater (TCE) – Dermal exposure to soil (chromium, iron)	– Household inhalation of vapors and dermal exposure (TCE, vinyl chloride) – Dermal exposure to subsurface soil (beryllium)
SWMU 5	– Ingestion of RGA groundwater (arsenic, naphthalene) – Ingestion of vegetables (arsenic, aluminum)	– Ingestion of RGA groundwater (arsenic)
SWMU 6	– Ingestion of vegetables (chromium) – Dermal exposure to soil (chromium)	– Dermal exposure to subsurface soil (PAHs, beryllium) – Ingestion of vegetables (PAHs, beryllium)
SWMU 7	– Ingestion of RGA groundwater (TCE, arsenic, Aroclor-1254) – Ingestion of vegetables (iron, uranium) – Dermal exposure to soil (vanadium, iron, uranium)	– Household inhalation of vapors and ingestion of RGA groundwater (1,1-DCE) – Dermal exposure and ingestion of vegetables (beryllium, uranium-238)
SWMU 30	– Ingestion of RGA groundwater (TCE) – Ingestion of subsurface soil (uranium) – Dermal exposure to soil (vanadium, iron)	– Household inhalation of vapors (TCE) – Ingestion of vegetables (beryllium, uranium-238)
SWMU 145	– Ingestion of RGA groundwater (antimony, arsenic)	– Ingestion of RGA groundwater (Aroclor-1260)

Table ES.3 is based on Table 7.7 of the BGOU RI (DOE 2010).
DCE = dichloroethene
PAH = polyaromatic hydrocarbon
PCB = polychlorinated biphenyl
RGA = Regional Gravel Aquifer
^{99}Tc = technetium-99
TCE = trichloroethene

ARARs typically are divided into three categories: (1) chemical-specific, (2) location-specific, and (3) action-specific. Chemical-specific ARARs provide health- or risk-based concentration limits or discharge limitations in various environmental media (i.e., surface water, groundwater, soil, or air) for specific hazardous substances, pollutants, or contaminants. Location-specific ARARs establish restrictions on permissible concentrations of hazardous substances or establish requirements for how activities will be conducted because they are in special locations (e.g., floodplains or historic districts). Action-specific ARARs include operation, performance, and design of the preferred alternative based on waste types and/or media to be addressed and removal/remedial activities to be implemented.

REMEDIATION GOAL DEVELOPMENT

Soil RGs were calculated for each SWMU for both direct contact exposure to surface and subsurface soil and for protection of groundwater. The direct contact RGs for COCs in soil that are protective of exposures of future industrial workers to COCs in surface soil (Table ES.4) and future outdoor workers to COCs in subsurface soil (Table ES.5) were based on no action levels (NALs) given in the Risk Methods Document (DOE 2001). Direct contact RGs for individual COCs in surface soil correspond to a cancer risk (ELCR) of 5E-06 and hazard quotient (HQ) = 0.5. Direct contact RGs for subsurface soil correspond to ELCR = 5.0E-05 and HQ = 1. Groundwater COC concentrations corresponding to maximum contaminant levels (MCLs) established by the Safe Drinking Water Act were used to back-calculate Groundwater protective RGs for soil at each SWMU. Naphthalene is the only COC identified at BGOU SWMUs without an MCL. A groundwater concentration protective of human health was used to back-calculate the groundwater protective RGs for naphthalene in soil. The lower of the direct contact RG and the groundwater protective RG for a COC was selected as the preliminary RG for soil. A comparison of the detected concentrations of metals and radionuclides in soil samples from the BGOU SWMUs to the range of PGDP background concentration was performed, consistent with the uncertainty identified in the RI Report. Although this represents just one line of evidence to support whether the detected concentrations should be considered to be within the range of background, the comparison shows that all detectable concentrations of metals that were identified as COCs in the Baseline Human Health Risk Assessment (BHHRA) are consistent with natural background concentrations at the PGDP with the following exceptions:

- **Surface soil:** uranium, cesium-137, neptunium-237, plutonium-239, technetium-99, thorium-230, uranium-234, and uranium-238.
- **Subsurface soil**: uranium, cesium-137, neptunium-237, technetium-99, uranium-234, uranium-235, and uranium-238.

Preliminary RGs for metals and radionuclides were developed for the constituents listed above. The other metals and radionuclides identified in the RI Report as COCs were determined by the FS background metals evaluation to be within the range of background. If the background concentration is greater than the lower of the direct contact RG and groundwater protective RG, the RG was equated to the background concentration. The direct contact RG for total polychlorinated biphenyl (PCB) compounds is 10 mg/kg. This RG was agreed upon as part of risk management discussions during a June 2009 BGOU scoping meeting among DOE, EPA, and KY. At that meeting, the group recognized that, when used as the upper-bound goal for individual detections, the average concentration of PCBs for the unit is expected to be significantly lower. The preliminary RGs for surface soil and subsurface soil are summarized in Tables ES.4 and ES.5, respectively. These RGs serve, in part, as the basis for development of remedial alternatives in the FS for the COCs identified at each SWMU. The preliminary RGs for each SWMU and their roles in remedial alternative development are discussed in Sections 5 through 12.

Upon completion of remedial actions at each SWMU, it will be necessary to show that the cumulative ELCR to the industrial worker from exposure to SWMU-specific COCs in surface soil will be below 1E-05 and the noncancer HI will be below 1 for all COCs at the SWMU. It will be necessary also to show that the cumulative ELCR to the outdoor worker from exposure to subsurface soil will be below 1E-04 and the noncancer HI will be below 1 for all COCs at the SWMU. These criteria were adopted in June 2009 scoping meetings held in Lexington and Frankfort, Kentucky, with representatives of EPA Region 4, Kentucky Department for Environmental Protection, and DOE.

This eventual evaluation of soil concentrations to verify cleanup will be based on postremediation sampling (e.g., samples collected after action is complete to determine if RAOs have been met). The evaluation of soil concentrations will be based on cumulative ELCR and cumulative HI calculations using postremediation sampling results, will follow the same approach described in the Risk Methods Document (DOE 2001) and will be consistent with EPA (1991) guidance.

Table ES.4. Preliminary BGOU FS Remediation Goals for Surface Soil

Contaminant of Concern[1]	Preliminary Remediation Goals for Surface Soil[2] (mg/kg) (pCi/g) SWMU 2	SWMU 3	SWMU 4	SWMU 5	SWMU 7	SWMU 30	SWMU 145
Neptunium-237	X	X	X	X	1.36E+00	1.36E+00	X
Technetium-99	9.90E+00	4.50E+00	6.30E+00	5.40E+00	7.20E+00	1.17E+01	8.10E+00
Uranium (metal)	X	X	X	X	1.01E+02	1.01E+02	X
Uranium-234	X	X	X	X	9.90E+01	9.90E+01	X
Uranium-235, Uranium-235/236	1.98E+00	1.98E+00	X	X	1.98E+00	1.98E+00	X
Uranium-238	8.55E+00	8.55E+00	8.55E+00	X	8.55E+00	8.55E+00	X
1,1-Dichloroethene	X	X	X	X	1.61E-01	4.80E-01	X
cis-1,2-Dichloroethene	2.17E+00	X	7.70E-01	X	1.47E+00	X	X
Trichloroethene	1.25E-01	X	4.00E-02	X	1.00E-01	6.35E-01	X
Naphthalene	2.85E-03	X	X	5.99E-03	X	X	X
Vinyl chloride	X	X	3.60E-02	X	8.20E-02	X	X
Total PCBs[3]	1.00E+01	X	1.00E+01	1.00E+01	1.00E+01	1.00E+01	X

[1] COCs identified according to criteria specified in the BHHRA (DOE 2010). Uranium (metal) refers to uranium analyzed by chemical methods and reported in mass concentration units of mg U/kg soil. U-234, U-235, U-235/236, and U-238 refer to the individual uranium isotope analyzed by radiochemical methods and reported in radiation concentration units of pCi isotope/g soil.
[2] Preliminary RG was developed to ensure that cumulative cancer risk (ELCR) from direct contact exposure by the ingestion, inhalation, and dermal contact pathways are within the 1E-06 to 1E-04 range and noncancer hazard (HI) associated with the same pathways are below 1, respectively, and that impact to groundwater due to leaching from the SWMU will not result in exceeding the MCL at the RGA beneath the SWMU. For chemicals that have both a cancer and noncancer endpoint and that are considered both as isotopes and metals (e.g., uranium), RGs would need to be equated to ensure that neither RG is exceeded.
[3] The direct contact RG for total PCBs was agreed upon as part of risk management discussions during a June 2009 BGOU scoping meeting among DOE, EPA, and KY
X = not a COC for soil at this SWMU.

ALTERNATIVE DEVELOPMENT AND SCREENING

A primary objective of the FS is to identify remedial technologies and process options that potentially meet the RAOs and then combine them into a range of remedial alternatives. EPA guidance states that alternatives for source control actions should range from one that would eliminate, to the extent feasible, long-term management to one that would use treatment as a primary component of an alternative to address principal threats at a site; include one or more alternatives that involve containment of the waste with little or no treatment; and a No Action alternative (EPA/540/G-89/004 at pages 4-7). The selected final remedy must comply with ARARs, unless waived, and must protect human health and the environment. The technology screening process consists of a series of steps that include these:

- Identifying general response actions (GRAs) that may meet RAOs, either individually or in combination with other GRAs;

Table ES.5. Preliminary BGOU FS Remediation Goals for Subsurface Soil

Contaminant of Concern[1]	Preliminary Remediation Goals for Subsurface Soil[2] (mg/kg) (pCi/g)						
	SWMU 2	SWMU 3	SWMU 4	SWMU 5	SWMU 7	SWMU 30	SWMU 145
Neptunium-237	X	X	X	X	1.36E+00	1.36E+00	X
Technetium-99	9.90E+00	4.50E+00	6.30E+00	5.40E+00	7.20E+00	1.17E+01	8.10E+00
Uranium (metal)	X	X	X	X	1.01E+02	1.01E+02	X
Uranium-234	X	X	X	X	9.90E+01	9.90E+01	X
Uranium-235, Uranium-235/236	1.98E+00	1.98E+00	X	X	1.98E+00	1.98E+00	X
Uranium-238	8.55E+00	8.55E+00	8.55E+00	X	8.55E+00	8.55E+00	X
1,1-Dichloroethene	X	X	X	X	1.61E-01	4.80E-01	X
cis-1,2-Dichloroethene	2.17E+00	X	7.70E-01	X	1.47E+00	X	X
Trichloroethene	1.25E-01	X	4.00E-02	X	1.00E-01	6.35E-01	X
Naphthalene	2.85E-03	X	X	5.99E-03	X	X	X
Vinyl chloride	X	X	3.60E-02	X	8.20E-02	X	X
Total PCBs[3]	1.00E+01	X	1.00E+01	1.00E+01	1.00E+01	1.00E+01	X

[1] COCs identified according to criteria specified in the BHHRA (DOE 2010) as having ELCR >1E-06 or HQ >0.1 for the ingestion, inhalation and dermal contact pathways.
[2] Preliminary RG was developed to ensure that cumulative cancer risk (ELCR) from direct contact exposure by the ingestion, inhalation, and dermal contact pathways are within the 1E-06 to 1E-04 range and noncancer hazard (HI) associated with the same pathways are below 1, respectively, and that impact to groundwater due to leaching form the SWMU will not result in exceeding the MCL at the RGA beneath the SWMU. For chemicals that have both a cancer and noncancer endpoint and that are considered both as isotopes and metals (e.g., uranium), RGs would need to be equated to ensure that neither RG is exceeded.
[3] This RG was agreed upon as part of risk management discussions during a June 2009 BGOU scoping meeting among DOE, EPA, and KY. At that meeting, the group recognized that, when used as the upper-bound goal for individual detections, the average concentration of PCBs for the unit is expected to be significantly lower.
X = not a COC for soil at this SWMU.

- Identifying, screening, and evaluating remedial technology types for each GRA; and
- Selecting one or more representative process options (RPOs) for each technology type.

GRAs applicable to the BGOU source areas were identified; these include no action, containment, removal, treatment, and disposal. Technology types and process options representative of each GRA then were identified, screened, and evaluated. The criteria for identifying, screening, and evaluating technologies are provided in EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, (EPA 1988) and the National Contingency Plan. The initial technology screening eliminated some technologies on the basis of technical impracticability.

Following the technology screening, RPOs were identified for each technology type. RPOs were selected on the basis of effectiveness, technical and administrative implementability, and cost, relative to other technologies in the same technology type. Alternatives then were developed by combining RPOs into a range of comprehensive strategies to meet the RAOs. Remedial alternatives were developed for (1) radioactive and inorganic source areas and (2) DNAPL source areas, combining RPOs as appropriate, to remediate the type and nature of contamination identified at each SWMU. This approach results in alternatives that are configured of one or more RPOs to remediate all categories of COCs present within the entire OU being addressed by the FS.

Table ES.6 presents the remedial alternatives that were developed for the BGOU SWMUs. Alternatives are analyzed in detail and compared based on the CERCLA evaluation criteria. Overall protection of human health and the environment and compliance with ARARs (in the absence of a CERCLA waiver) are categorized as threshold criteria that any viable alternative must meet. Long-term effectiveness and permanence; reduction of toxicity, mobility, and volume through treatment; short-term effectiveness; implementability; and cost are considered primary balancing criteria upon which the detailed analysis is primarily based. State and community acceptance are considered modifying criteria and are evaluated following comment on the RI/FS report and the Proposed Plan and are addressed as a final decision is made and the ROD is prepared. Table ES.7 identifies the alternatives that were analyzed in detail for each BGOU SWMU.

The comparative analysis identifies the relative advantages and disadvantages of each alternative, so that the key tradeoff that risk managers must balance can be identified. Alternatives are ranked with respect to the evaluation criteria, and the overall detailed and comparative evaluations are summarized. Results of the detailed and comparative analysis form the basis for preparing the Proposed Plan. The following list details the tables ES.8 through ES.23 in the Executive Summary where the comparative analysis and costs are provided for source area alternatives, as appropriate, for each SWMU. A summary of the evaluation of alternatives against the CERCLA criteria for each individual SWMU is presented in Table ES.24.

SWMU	**Executive Summary Table**
SWMU 2	ES.8 ES.9
SWMU 3	ES.10 ES.11
SWMU 4	ES.12 ES.13
SWMU 5	ES.14 ES.15
SWMU 6	ES.16 ES.17
SWMU 7	ES.18 ES.19
SWMU 30	ES.20 ES.21
SWMU 145	ES.22 ES.23

Table ES.6. Alternative Formulation for PGDP BGOU Source Areas

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	Alternative 9
No Action	**Limited Action**	**Soil Cover and Long-Term Monitoring**	**Soil Cover combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring**	**RCRA Cover with Hydraulic Isolation and Long-Term Monitoring**	**Excavation and Disposal[1]**	**Excavation and Disposal combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring**	**Excavation and Disposal combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring**	***In situ* Containment and Long-Term Monitoring**
	Long-term groundwater monitoring Land use controls	Soil cover Long-term groundwater monitoring Land use controls	Partial excavation to remove debris, rubble, or metallic waste that could interfere with the installation or operation of the *in situ* DNAPL source treatment system, if necessary. *In situ* DNAPL source treatment Process monitoring Postremediation sampling Soil cover Long-term groundwater monitoring Land use controls	Vertical subsurface hydraulic isolation barrier RCRA cover Long-term groundwater monitoring Land use controls	Sheet pilings to shore excavation Excavation Treat or dispose of residual groundwater, as indicated by sampling Postremediation and WAC sampling and analysis Physical/chemical waste treatment Transportation to disposal facility Backfill with clean soil	Sheet pilings to shore excavation Excavation Treat or dispose of residual groundwater, as indicated by sampling Postremediation and WAC sampling and analysis Physical/chemical waste treatment Transportation to disposal facility Backfill with clean soil *In situ* source treatment for DNAPL Process monitoring Postremediation sampling Long-term groundwater monitoring	Sheet pilings to shore excavation Excavation Treat or dispose of residual groundwater, as indicated by sampling Postremediation and WAC sampling and analysis Physical/chemical waste treatment Transportation to disposal facility Backfill with clean soil Vertical barrier to protect deep excavation Deep excavation of DNAPL source area *Ex situ* source treatment for DNAPL Process monitoring WAC sampling of treated soil Postremediation sampling Backfill with clean, decontaminated soil Long-term groundwater monitoring	Construct subsurface horizontal barrier Construct subsurface vertical barrier Construct structure Long-term groundwater monitoring Land use controls.

BGOU = Burial Grounds Operable Unit; PGDP = Paducah Gaseous Diffusion Plant; RCRA = Resource Conservation and Recovery Act; RD = Remedial Design; WAC = waste acceptance criteria
[1] Metal melting, an option associated with SWMU 5 only, includes treatability study, sorting and size reduction, cleaning of metal surfaces, and melting and casting of cleaned metal for reuse.

Table ES.7. BGOU SWMU Remedial Action Alternative Summary

Alternative	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Alternative Description	**No Action**	**Limited Action**	**Soil Cover and Long-Term Monitoring[a]**	**Soil Cover combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring**	**RCRA Cover with Hydraulic Isolation and Long-Term Monitoring**	**Excavation and Disposal**	**Excavation and Disposal combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring[b]**	**Excavation and Disposal combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring[c]**	***In situ* Containment and Long-Term Monitoring**
SWMU No.									
2	X				X		X	X	X
3[d]	X[e]	X[f]				X[g]			X
4[h]	X						X	X	
5	X		X			X[i]			
6	X	X							
7	X			X[j]			X	X	
30	X		X			X			
145	X		X			X[k]			

X-Indicates an alternative that was analyzed in detail for a particular SWMU.
[a] A soil cover was evaluated for those SWMUs where surface contact with the waste management unit is to be prevented and infiltration resulting from precipitation does not appear to pose any threat to human health or groundwater.
[b] *In situ* treatment is evaluated as a contingency alternative at SWMUs 2 and 7 if DNAPL is present upon completion of the excavation.
[c] *Ex situ* treatment is evaluated as a contingency alternative at SWMUs 2 and 7 if DNAPL is present upon completion of the excavation.
[d] SWMU 3 is a closed RCRA landfill lined with compacted soil, covered with a RCRA Subtitle C cap, equipped with a leachate collection system and managed under a RCRA postclosure permit.
[e] No action would be taken at SWMU 3 under the CERCLA program, but it would continue to be managed under the RCRA program.
[f] This alternative is for long-term monitoring based on results of the demonstration required under 40 *CFR* § 294.90(f)(1) and (2), but performed under the CERCLA program.
[g] SWMU 3 was evaluated for excavation of the documented waste disposal volume. No further action is required for the ditch at SWMU 3 under the BGOU.
[h] DNAPL at SWMU 4 is assumed to extend to sufficient depth to be present in both the UCRS and RGA.
[i] Metal melting is evaluated as a supplementary technology to excavation at SWMU 5 for metal recovery/recycle.
[j] A soil cover combined with *in situ* source treatment was evaluated for SWMU 7 where radioactive/inorganic contamination is limited to the surface. *In situ* treatment was evaluated to remediate DNAPL reported potentially to be present at SWMU 7.
[k] Excavation at SWMU 145 will be limited to course of the former North-South Diversion Ditch. Soil cover will be placed over uncovered portions, if necessary.

Table ES.8. Summary of Comparative Analysis of Source Area Alternatives SWMU 2

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 1: No Action	Does not meet the threshold criterion because no action would be taken. Although it is unlikely that disposed uranium is pyrophoric, it would remain untreated. Potential DNAPL source would remain untreated other than through natural processes. No protection for future off-site groundwater users.	No actions implemented; no ARARs identified.	No long-term effectiveness or permanence.	Low. No direct treatment or containment provided.	High. RAOs would not be met. No actions implemented; therefore, no change to existing conditions.	High. No action would be implemented. High technical and administrative implementability.
Alternative 5: RCRA Cover, Hydraulic Isolation, and Long-Term Monitoring	Moderate. Meets this criterion. More protective than Alternative 1, but less protective than Alternative 7. Prevents direct contact with waste and reduces migration potential by containing uranium and potential DNAPL. Land use controls protect current and future site workers and the public.	High. Complies with ARARs and potential TBCs.	Moderate. Protects against direct contact. Significantly reduces potential for contaminant migration to RGA. Reliability is dependent upon proper design and O&M.	Moderate. No reduction of toxicity or volume. Mobility is greatly reduced through containment. Some potential for contaminated waste generation during construction of vertical barrier.	High. No negative impacts to community. Potential exposure to remediation workers during installation of vertical barrier and cover is much less than for excavation. More short term risk to workers during implementation than Alternative 1, but much less than Alternative 7. Could be completed in months.	High. Proven, reliable technologies that are readily available. While groundwater flow is predominantly downward in the UCRS, there will be some minor lateral flow due to heterogeneities in the shallow soils that may impact the implementation of hydraulic isolation technology.

Table ES.8. Summary of Comparative Analysis of Source Area Alternatives SWMU 2 (Continued)

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 7: Excavation and Disposal combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring	High. Threshold criterion met. Removal of contaminated waste offers the highest degree of overall protection and achievement of RAOs. Potential DNAPL source would be treated in UCRS. Significant reduction in DNAPL mass should be achieved by treatment. Remaining TCE DNAPL would be remediated over time by natural processes. Soil target concentrations should be attained based on results of C-400 Six-Phase Heating (SPH) Study.	High. Threshold criterion met. Complies with ARARs and potential TBCs. Should provide groundwater protection based on results of C-400 SPH Study.	High. Contaminant sources removed. Most adequate overall level of protection to humans and the environment. Long-term monitoring will not be required after action is complete and DNAPL is removed to level that is protective of groundwater.	High. Excavation, treatment and disposal would eliminate mobility of radionuclides, reduce or destroy toxicity of organics and DNAPL, and remove the pyrophoric characteristic from uranium.	Moderate. Potential negative impacts to community from waste excavation (if pyrophoric uranium present) and transportation for off-site disposal. Risk to remediation workers much higher than non-intrusive alternatives but can be managed by applying appropriate health and safety procedures. Improves to high for on-site disposal. Transportation issues become negligible since waste will not leave PGDP property. Implementation could take years.	Moderate. Excavation and associated technologies are readily implementable, although presence of potentially pyrophoric uranium may increase the complexity of excavation procedures in some areas. Proximity to SWMU 3 makes logistics challenging. Some excavated waste materials or soil may have multiple regulatory classifications, increasing the complexity of treatment required for transportation and/or disposal. An on-site waste disposal facility (WDF) is being evaluated as part of the waste disposal option project, and a ROD has not been issued.

Table ES.8. Summary of Comparative Analysis of Source Area Alternatives SWMU 2 (Continued)

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 8: Excavation and Disposal combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring	High. Threshold criterion met. Removal of contaminated waste offers the highest degree of overall protection and achievement of RAOs. Potential DNAPL source would be treated in UCRS. Removal of DNAPL mass should be achieved by excavation and treatment. Soil target concentrations should be attained. Long-term monitoring would verify that target concentrations are met after action is complete.	High. Threshold criterion met. Complies with ARARs and potential TBCs. Should provide groundwater protection.	High. Contaminant sources removed; therefore, no residual risks should remain. Long-term monitoring conducted to confirm no further impacts to groundwater.	High. Excavation, treatment and disposal would remove contamination sources.	Low. Potential negative impacts to community from waste excavation (if pyrophoric uranium present) and from waste transportation for off-site disposal. Risk to workers higher than other alternatives because depth of excavation, and volumes of waste and contaminated soils to be handled. Higher potential for fugitive dust and vapors because of the volumes being treated. Transportation issues less for on-site disposal because waste will not leave PGDP property. Implementation could take years.	Low. Presence of potentially pyrophoric uranium may increase the complexity of excavation procedures in some areas. Proximity to SWMU 3 and overall depth of excavation makes logistics challenging. Some excavated waste materials or soil may have multiple regulatory classifications, increasing the complexity of treatment, transportation and/or disposal. WDF is being evaluated as part of the waste disposal option project. and a ROD has not been issued.
Alternative 9: *In situ* Containment and Long-Term Monitoring	Moderate to high. Meets this criterion. More protective than Alternative 5, but less protective than Alternative 7. Prevents direct contact with waste and reduces migration potential by containing uranium and potential DNAPL. Land use controls protect current and future site workers and the public.	High. Complies with ARARs and potential TBCs.	Moderate to high. Protects against direct contact. Significantly reduces potential for contaminant migration to RGA. Effectiveness and reliability are primarily dependent upon proper design and construction to ensure integrity of horizontal barrier.	Moderate. No reduction of toxicity or volume. Mobility is greatly reduced through containment. Some potential for contaminated waste generation during construction of horizontal and vertical barriers.	Moderate. Negative impacts to community from construction can be controlled. Potential for exposure to contaminated soil and slurry by remediation workers during construction of horizontal and vertical barriers. Potentially more short-term risk to workers during implementation than Alternative 5, but less than Alternative 7. Could be completed in months.	Moderate. Mostly proven, reliable technologies that are readily available. The construction of horizontal subsurface barriers and verifying their integrity are less proven than the other construction elements. While groundwater flow is predominantly downward in the UCRS, there will be some minor lateral flow due to heterogeneities in the shallow soils that may impact the implementation of hydraulic isolation technology.

Table ES.9 SWMU 2 Remedial Alternatives Cost Estimate Summary

			PRESENT WORTH[1]		ESCALATED	
Alternative Description	**Annual Time Period, yrs**	**Capital $ (2010 Constant Dollars)**	**Total Annual $**	**Total $ (Capital and Annual)**	**Total Annual $**	**Total $ (Capital and Annual)**
Alternative 1—No Action	0	$0	$0	$0	$0	$0
Alternative 5—RCRA Cover with Hydraulic Isolation and Long-Term Monitoring	30	$8,337,000	$5,914,000	$14,251,000	$23,974,000	$32,819,000
Alternative 7a— Excavation and Disposal	0	$37,177,000	$0	$37,177,000	$0	$39,441,000
Alternative 7b—Excavation and Disposal (at Proposed On-Site WDF)	0	$28,994,000	$0	$28,994,000	$0	$30,760,000
Contingency for Alternative 7—Combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring	30	$8,556,000	$733,000	$9,289,000	$2,283,000	$11,360,000
Alternative 8a—Excavation and Disposal	0	$37,177,000	$0	$37,177,000	$0	$39,441,000
Alternative 8b—Excavation and Disposal (at the WDF)	0	$28,994,000	$0	$28,994,000	$0	$30,760,000
Contingency for Alternative 8—Combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring	30	$25,510,000	$739,000	$26,249,000	$2,296,000	$29,359,000
Alternative 9—*In situ* Containment with Long-Term Monitoring	30	$13,695,000	$3,767,000	$17,462,000	$14,981,000	$29,510,000

[1] Not used for budgeting or planning purposes because value is based on investing funds for outyear expenditures.

Table ES.10. Summary of Comparative Analysis of Source Area Alternatives SWMU 3

	Threshold Criteria	Primary Balancing Criteria				
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 1: No Action. SWMU 3 is a closed RCRA facility that is managed under a RCRA postclosure permit. No Action for SWMU 3 is continued postclosure care under the RCRA Permit	Moderate. Existing RCRA cap meets this threshold criterion. Provides continued protection for future on-site industrial workers and off-site groundwater users.	High. Compliance with regulatory requirements in RCRA permit.	Moderate. RCRA cap provides containment of buried waste. Leachate collection system in place. Groundwater monitoring data indicate that contaminants are not migrating from SWMU 3.	Moderate. No treatment provided. Existing cap minimizes surface infiltrations and is equipped with a leachate collection system that further reduces contaminant mobility. Approximately 2,500 gal/yr of leachate are collected and treated on-site. Results are reported to the Kentucky RCRA program.	High. Cap appears to be effective. No actions implemented; therefore, no impact to workers or the surrounding community.	High. No action would be implemented. Continued O&M under the RCRA permit.
Alternative 2: Limited Action. Modify RCRA permit to allow use of alternative requirements for monitoring pursuant to 40 *CFR* § 264.90(f) and implement postclosure care under a CERCLA remedial action document	Moderate. Provides continued groundwater monitoring in accordance with substantive requirements of ARARS. Land use controls protect current and future site workers and the public.	High. Provides continued groundwater monitoring in accordance with substantive requirements of ARARs.	Moderate. RCRA cap provides containment of buried waste. Leachate collection system in place. Groundwater monitoring data indicate that contaminants are not migrating from SWMU 3.	Moderate. No treatment provided. Existing cap minimizes surface infiltrations and is equipped with a leachate collection system that further reduces contaminant mobility. Approximately 2,500 gal/yr of leachate is collected and treated on-site.	High. Cap appears to be effective. No actions implemented; therefore, no impact to workers or the surrounding community.	Moderate. Requires approval of a RCRA permit modification to obtain an enforceable document (e.g., CERCLA remedial action document) with alternative requirements for monitoring and corrective action. Postclosure O&M would be performed under CERCLA.

Table ES.10. Summary of Comparative Analysis of Source Area Alternatives SWMU 3 (Continued)

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 6: Excavation and Disposal	High. Removal of contaminated waste offers the highest degree of overall protection with respect to RAOs.	High. Complies with ARARs and potential TBCs.	High. Contaminant sources removed. Most adequate overall level of protection to humans and the environment.	High. Excavation, waste treatment and disposal would reduce or eliminate mobility of radionuclides and inorganic COCs, and reduce or eliminate toxicity of organics.	Moderate to High. Potential negative impacts to community from waste transportation to off-site disposal facility. Potential impacts reduced greatly if waste disposed of at the WDF. Risk to workers higher than other alternatives but can be managed through site procedures during implementation. Implementation could take years.	Moderate to high. Excavation and associated technologies are readily implementable. Some excavated waste materials or soil may have multiple regulatory classifications, increasing the complexity of treatment required for transportation and/or disposal. WDF is being evaluated as part of the waste disposal option project, and a ROD has not been issued.
Alternative 9: *In situ* Containment and Long-Term Monitoring	Moderate to high. Meets this criterion. More protective than Alternative 2 because subsurface horizontal barrier constructed, but less protective than Alternative 6. Provides greater protection against direct contact with waste by constructing a building over the RCRA cap and further reduces migration potential by containing buried waste on all sides. Land use controls protect current and future site workers and the public.	High. Complies with ARARs and potential TBCs.	Moderate to high. Protects against direct contact. Reduces potential for contaminant migration to RGA. Increased effectiveness and reliability are primarily dependent upon proper design and construction to ensure integrity of horizontal barrier.	Moderate. No reduction of toxicity or volume. Mobility is further reduced through additional containment. Some potential for contaminated waste generation during construction of horizontal and vertical barriers.	Moderate. Negative impacts to community from construction can be controlled. Potential for exposure to contaminated soil and slurry by remediation workers during construction of horizontal and vertical barriers. More short-term risk to workers during implementation than Alternative 2, but much less than Alternative 6. Could be completed in months.	Moderate. Mostly proven, reliable technologies that are readily available. The construction of horizontal subsurface barriers and verifying their integrity are less proven than the other construction elements. While groundwater flow is predominantly downward in the UCRS, there will be some minor lateral flow due to heterogeneities in the shallow soils that may impact the implementation of hydraulic isolation technology.

Table ES.11. SWMU 3 Remedial Alternatives Cost Estimate Summary

			PRESENT WORTH[1]		ESCALATED	
Alternative Description	**Annual Time Period, yrs**	**Capital $ (2010 Constant Dollars)**	**Total Annual $**	**Total $ (Capital and Annual)**	**Total Annual $**	**Total $ (Capital and Annual)**
Alternative 1—No Action	0	$0	$0	$0	$0	$0
Alternative 2—Limited Action	30	$0	$1,944,000	$1,944,000	$8,245,000	$8,245,000
Alternative 6a—Excavation and Disposal	0	$88,358,000	$0	$88,358,000	$0	$93,739,000
Alternative 6b—Excavation and Disposal (at the WDF)	0	$62,438,000	$0	$62,438,000	$0	$66,241,000
Alternative 9—*In situ* Containment with Long-Term Monitoring	30	$16,094,000	$4,362,000	$20,456,000	$17,476,000	$34,550,000

[1] Not used for budgeting or planning purposes because value is based on investing funds for outyear expenditures.

Table ES.12. Summary of Comparative Analysis of Source Area Alternatives SWMU 4

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 1: No Action	Does not meet the threshold criterion. Waste would remain untreated. Potential DNAPL source would remain untreated other than through natural processes. No protection for future off-site groundwater users.	No actions implemented; no ARARs identified.	No long-term effectiveness or permanence.	Low. No direct treatment or containment provided.	High. No actions implemented; therefore, no change to existing conditions.	High-No action would be implemented. High technical and administrative implementability.
Alternative 7: Excavation and Disposal with *In situ* DNAPL Source Treatment and Long-Term Monitoring	High. Threshold criterion met. Removal of contaminated waste offers the highest degree of overall protection and achievement of RAOs. Potential DNAPL source would be treated in UCRS and RGA. Significant reduction in DNAPL mass should be achieved by treatment. Remaining TCE DNAPL would be remediated over time by natural processes. Soil target concentrations should be attained based on results of C-400 SPH Study.	High. Threshold criterion met. Complies with ARARs and potential TBCs. Should provide groundwater protection based on results of C-400 SPH Study.	High. Contaminant sources removed; therefore, residual risks are negligible. Most adequate overall level of protection to humans and the environment.	Moderate to high. Excavation, treatment and disposal would reduce mobility of radionuclides, reduce or destroy toxicity of organics and VOCs. DNAPL source at SWMU 4 extends to RGA.	Moderate to High. Potential negative impacts to community from waste transportation for off-site disposal. Risk to workers higher than other alternatives but can be managed by applying appropriate health and safety procedures. Improves to high for on-site disposal. Transportation issues become negligible since waste will not leave PGDP property. Implementation could take years.	Moderate. Excavation and associated technologies are readily implementable Some excavated waste materials or soil may have multiple regulatory classifications, increasing the complexity of treatment required for transportation and/or disposal. WDF is being evaluated as part of the waste disposal option project, and a ROD has not been issued.

Table ES.12. Summary of Comparative Analysis of Source Area Alternatives SWMU 4 (Continued)

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 8: Excavation and Disposal combined with *Ex Situ* DNAPL Source Treatment and Long-Term Monitoring	High. Threshold criterion met. Removal of contaminated waste offers the highest degree of overall protection and achievement of RAOs. DNAPL source would be treated in the UCRS and the RGA. Removal of DNAPL mass should be achieved by excavation and treatment. Soil target concentrations should be attained. Long-term monitoring would verify that target concentrations are met after action is complete.	High. Threshold criterion met. Complies with ARARs and potential TBCs. Should provide groundwater protection.	High. Contaminant sources removed; therefore, no residual risks should remain. Long-term monitoring conducted to confirm no further impacts to groundwater.	High. Excavation, treatment and disposal would remove contamination sources.	Low. Potential negative impacts to community from waste transportation for off-site disposal. Risk to workers higher than other alternatives because depth of excavation, and volumes of waste and contaminated soils to be handled Higher potential for fugitive dust and vapors because of the volumes being treated. Transportation issues less for on-site disposal because waste will not leave PGDP property. Implementation could take years.	Low. Some excavated waste materials or soil may have multiple regulatory classifications, increasing the complexity of treatment, transportation and/or disposal. Excavation to remove DNAPL extending into RGA may be impractical depending on its depth. WDF is being evaluated as part of the waste disposal option project, and a ROD has not been issued.

Table ES.13. SWMU 4 Remedial Alternatives Cost Estimate Summary

			PRESENT WORTH[1]		ESCALATED	
Alternative Description	**Annual Time Period, yrs**	**Capital $ (2010 Constant Dollars)**	**Total Annual $**	**Total $ (Capital and Annual)**	**Total Annual $**	**Total $ (Capital and Annual)**
Alternative 1—No Action	0	$0	$0	$0	$0	$0
Alternative 7a—Excavation and Disposal	0	$146,328,000	$0	$146,328,000	$0	$155,239,000
Alternative 7b—Excavation and Disposal (at the WDF)	0	$82,605,000	$0	$82,605,000	$0	$87,636,000
Contingency for Alternative 7—*In situ* DNAPL Source Treatment and Long-Term Monitoring	30	$80,876,000	$733,000	$81,609,000	$2,283,000	$88,084,000
Alternative 8a—Excavation and Disposal	0	$146,328,000	$0	$146,328,000	$0	$155,239,000
Alternative 8b—Excavation and Disposal (at the WDF)	0	$82,605,000	$0	$82,605,000	$0	$87,636,000
Contingency for Alternative 8—*Ex situ* DNAPL Source Treatment and Long-Term Monitoring	30	$99,652,000	$739,000	$100,391,000	$2,296,000	$108,017,000

[1] Not used for budgeting or planning purposes because value is based on investing funds for outyear expenditures.

Table ES.14. Summary of Comparative Analysis of Source Area Alternatives SWMU 5

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 1: No Action	Does not physically prevent contact with contaminated surface soil. Threat to groundwater is low.	No actions implemented; no ARARs identified.	No long-term effectiveness or permanence. Site risk would remain at current levels.	Low. No treatment provided.	High. No actions implemented; therefore, no change to existing conditions.	High. No action would be implemented.
Alternative 3: Soil Cover and Long-Term Monitoring	High. Much more protective than Alternative 1 and less protective than Alternatives 6. Prevents direct contact with waste and reduces migration potential of contamination in surface soils. Land use controls protect current and future site workers and the public.	High. Complies with ARARs and potential TBCs.	High. Protects site workers from direct contact with waste and surface soil. Some reduction in mobility of contaminants by reducing infiltration.	Moderate. No reduction of toxicity or volume. Contaminant mobility is reduced through containment.	High. No negative impacts to community. Exposure to workers low during installation of cover. More short term risk to workers during implementation than Alternative 1, but much less than Alternative 6. Could be completed in months.	High. Services and materials are readily available.

Table ES.14. Summary of Comparative Analysis of Source Area Alternatives SWMU 5 (Continued)

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 6: Excavation and Disposal	High. Removal of contaminated waste offers the highest degree of overall protection with respect to RAOs.	High. Complies with ARARs and potential TBCs.	High. Contaminant sources removed; therefore, residual risks are negligible. Most adequate overall level of protection to humans and the environment.	Moderate to high. Excavation, waste treatment and disposal would reduce or eliminate mobility of radionuclides and inorganic COCs. Excavated metal will be treated to remove surface contamination so that the metal can be recycled. Overall reduction in waste volume for disposal is possible.	Low to moderate. Potential negative impacts to community from waste transportation to off-site disposal facility. Potential impacts reduced greatly if waste disposed at the WDF. Risk to workers higher than other alternatives but can be managed through site procedures during implementation. Additional potential for worker exposure during metal decontamination process and management of residuals. Implementation could take years. Time to complete action would be increased by treatability study needed to define cleaning process for nickel and the design, construction and start up of metal melting facility.	Low to Moderate. Excavation and associated technologies are readily implementable. Metal melting will increase technical complexity. Some excavated waste materials or soil may have multiple regulatory classifications, increasing the complexity of treatment required for transportation and/or disposal. WDF is being evaluated as part of the waste disposal option project, and a ROD has not been issued. Nature of waste and DOE moratorium on nickel recycling increases administrative complexity. Metal melting facility would involve compliance with more comprehensive and complicated regulatory requirements.

Table ES.15. SWMU 5 Remedial Alternatives Cost Estimate Summary

			PRESENT WORTH[1]		ESCALATED	
Alternative Description	**Annual Time Period, yrs**	**Capital $ (2010 Constant Dollars)**	**Total Annual $**	**Total $ (Capital and Annual)**	**Total Annual $**	**Total $ (Capital and Annual)**
Alternative 1—No Action	0	$0	$0	$0	$0	$0
Alternative 3—Soil Cover and Long-Term Monitoring	30	$4,288,000	$1,415,000	$5,703,000	$5,143,000	$9,692,000
Alternative 6a—Excavation and Disposal	0	$131,105,000	$0	$131,105,000	$0	$139,089,000
Alternative 6b—Excavation and Disposal (at the WDF)	0	$76,060,000	$0	$76,060,000	$0	$80,692,000
Contingency for Alternative 6—Metal Recovery/Recycle	0	$32,010,000	$0	$32,010,000	$0	$33,959,000
Metal Scrap Estimated Value	0	$30,000,000	$0	$30,000,000	0	$30,000,000

[1] Not used for budgeting or planning purposes because value is based on investing funds for outyear expenditures.

Table ES.16. Summary of Comparative Analysis of Remedial Alternatives SWMU 6

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 1: No Action	High. Meets the threshold criterion. Maintenance of current site procedures would prevent exposure to waste materials. None of the chemicals detected at SWMU 6 present a threat to groundwater. Site-related COCs in soil are below RGs.	High. Meets the threshold criterion.	Moderate. None of the chemicals detected at SWMU 6 present a threat to groundwater. Site-related COCs in soil are below RGs. No other controls would be required to address residual contamination.	Low. No treatment provided, but none is required based on RI results.	High. No threat to community, site workers, or the environment.	High. No other action would be implemented.
Alternative 2: Limited Action	High. Meets the threshold criterion. None of the chemicals detected at SWMU 6 present a threat to groundwater. Site-related COCs in soil are below RGs. Long-term groundwater monitoring is an additional risk mitigation component used to protect groundwater. Land use controls protect current and future site workers and the public.	High. Meets the threshold criterion. Complies with ARARs.	High. None of the chemicals detected at SWMU 6 present a threat to groundwater. Site-related COCs in soil are below RGs. Long-term groundwater monitoring is an additional risk mitigation component used to protect groundwater.	Low. No treatment provided, but none is required based on RI results.	High. No threat to community or the environment. Potential risks to site workers during well construction and sampling are easily managed.	High. Monitoring well construction and sampling easily implemented.

Table ES.17. SWMU 6 Remedial Alternatives Cost Estimate Summary

			PRESENT WORTH[1]		ESCALATED	
Alternative Description	**Annual Time Period, yrs**	**Capital $ (2009 Constant Dollars)**	**Total Annual $**	**Total $ (Capital and Annual)**	**Total Annual $**	**Total $ (Capital and Annual)**
Alternative 1—No Action	0	$0	$0	$0	$0	$0
Alternative 2—Limited Action	30	$1,047,000	$727,000	$1,774,000	$2,262,000	$3,373,000

[1] Not used for budgeting or planning purposes because value is based on investing funds for outyear expenditures.

Table ES.18. Summary of Comparative Analysis of Source Area Alternatives SWMU 7

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 1: No Action	Does not meet the threshold criterion because no action would be taken. Potential DNAPL source would remain untreated other than through natural processes. Not protective of RGA groundwater beneath the SWMU.	No actions implemented; no ARARs identified.	No long-term effectiveness or permanence.	Low. No direct treatment or containment provided.	High. No actions implemented; therefore, no change to existing conditions.	High. No action would be implemented. High technical and administrative implementability.
Alternative 4: Soil Cover with *In situ* DNAPL Source Treatment and Long-Term Monitoring	Moderate to high. Much more protective than Alternative 1 and less protective than Alternatives 7 and 8. Prevents direct contact with waste and reduces migration potential. Potential DNAPL source would be treated in UCRS. Significant reduction in DNAPL mass should be achieved by treatment. Land use controls protect current and future site workers and the public.	High. Threshold criterion met. Complies with ARARs and potential TBCs. Should provide groundwater protection based on results of C-400 SPH Study.	High. Protects site workers from direct contact with waste and surface soil. Significant reduction in DNAPL mass should be achieved by treatment. Remaining TCE DNAPL would be remediated over time by natural processes. Soil target concentrations should be attained based on results of C-400 SPH Study.	Moderate to high. No reduction of toxicity or volume of radioactive and inorganic COCs; however, mobility is reduced through containment. Potential DNAPL source would be treated in UCRS.	Moderate. No negative impacts to community. Exposure to workers low to moderate during installation of *in situ* DNAPL source treatment system and cover.	Moderate to high. Services and materials are readily available. Implementability could be impacted by presence of large pieces of buried debris or metallic waste in vicinity of potential DNAPL source.

Table ES.18. Summary of Comparative Analysis of Source Area Alternatives SWMU 7 (Continued)

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 7: Excavation and Disposal with *In situ* DNAPL Source Treatment and Long-Term Monitoring	High. Threshold criterion met. Removal of contaminated waste offers the highest degree of overall protection and achievement of RAOs. Potential DNAPL source would be treated in UCRS. Significant reduction in DNAPL mass should be achieved by treatment. Remaining TCE DNAPL would be remediated over time by natural processes. Soil target concentrations should be attained based on results of C-400 SPH Study.	High. Threshold criterion met. Complies with ARARs and potential TBCs. Should provide groundwater protection based on results of C-400 SPH Study.	High. Contaminant sources removed; therefore, residual risks are negligible. Most adequate overall level of protection to humans and the environment.	High. Excavation, treatment and disposal would reduce mobility of radionuclides, reduce or destroy toxicity of organics and DNAPL.	Moderate to High. Potential negative impacts to community from waste transportation for off-site disposal. Risk to workers higher than other alternatives but can be managed by applying appropriate health and safety procedures. Improves to high for on-site disposal. Transportation issues become negligible since waste will not leave PGDP property. Implementation could take years.	Moderate. Excavation and associated technologies are readily implementable. Some excavated waste materials or soil may have multiple regulatory classifications, increasing the complexity of treatment required for transportation and/or disposal. WDF is being evaluated as part of the waste disposal option project, and a ROD has not been issued.

Table ES.18. Summary of Comparative Analysis of Source Area Alternatives SWMU 7 (Continued)

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 8: Excavation and Disposal combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring	High. Threshold criterion met. Removal of contaminated waste offers the highest degree of overall protection and achievement of RAOs. Potential DNAPL source would be treated in UCRS. Removal of DNAPL mass should be achieved by excavation and treatment. Soil target concentrations should be attained. Long-term monitoring would verify that target concentrations are met after action is complete.	High. Threshold criterion met. Complies with ARARs and potential TBCs. Should provide groundwater protection.	High. Contaminant sources removed; therefore, no residual risks should remain. Long-term monitoring conducted to confirm no further impacts to groundwater.	High. Excavation, treatment and disposal would remove contamination sources.	Low. Potential negative impacts to community from waste transportation for off-site disposal. Risk to workers higher than other alternatives because depth of excavation, and volumes of waste and contaminated soils to be handled. Higher potential fugitive dust and vapors because of the volumes being treated. Transportation issues less for on-site disposal because waste will not leave PGDP property. Implementation could take years.	Low. Some excavated waste materials or soil may have multiple regulatory classifications, increasing the complexity of treatment, transportation and/or disposal. WDF is being evaluated as part of the waste disposal option project, and a ROD has not been issued.

Table ES.19. SWMU 7 Remedial Alternatives Cost Estimate Summary

Alternative Description	Annual Time Period, yrs	Capital $ (2010 Constant Dollars)	PRESENT WORTH[1]		ESCALATED	
			Total Annual $	Total $ (Capital and Annual)	Total Annual $	Total $ (Capital and Annual)
Alternative 1—No Action	0	$0	$0	$0	$0	$0
Alternative 4—Soil Cover and Long-Term Monitoring	30	$4,554,000	$2,043,000	$6,597,000	$7,659,000	$12,490,000
Contingency for Alternative 4—*In situ* DNAPL Source Treatment[2]	0	$17,786,000	$0	$17,786,000	$0	$18,869,000
Alternative 7a—Excavation and Disposal	0	$77,889,000	$0	$77,889,000	$0	$82,632,000
Alternative 7b—Excavation and Disposal (at the WDF)	0	$54,265,000	$0	$54,265,000	$0	$57,570,000
Contingency for Alternative 7—*In situ* DNAPL Source Treatment and Long-Term Monitoring	30	$8,556,000	$733,000	$9,288,000	$2,283,000	$11,360,000
Alternative 8a—Excavation and Disposal	0	$77,889,000	$0	$77,889,000	$0	$82,632,000
Alternative 8b—Excavation and Disposal (at the WDF)	0	$54,265,000	$0	$54,265,000	$0	$57,570,000
Contingency for Alternative 8—*Ex situ* DNAPL Source Treatment and Long-Term Monitoring	30	$24,868,000	$739,000	$25,607,000	$2,296,000	$28,678,000

[1] Not used for budgeting or planning purposes because value is based on investing funds for outyear expenditures.

[2] Includes excavation of landfill contents above treatment area.

Table ES.20. Summary of Comparative Analysis of Source Area Alternatives SWMU 30

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 1: No Action	May meet the threshold criterion. Site procedures protect future on-site industrial workers. Threat to groundwater is low.	No actions implemented; no ARARs identified.	No long-term effectiveness or permanence. Site risk would remain at current levels.	Low. No treatment provided.	High. No actions implemented; therefore, no change to existing conditions.	High. No action would be implemented.
Alternative 3: Soil Cover and Long-Term Monitoring	High. Much more protective than Alternative 1 and less protective than Alternatives 6. Prevents direct contact with waste and reduces migration potential of contamination in surface soils. Land use controls protect current and future site workers and the public.	High. Complies with ARARs and potential TBCs.	High. Protects site workers from direct contact with waste and surface soil. Some reduction in mobility of contaminants by reducing infiltration.	Moderate. No reduction of toxicity or volume. Contaminant mobility is reduced through containment.	High. No negative impacts to community. Exposure to workers low during installation of cover. More short term risk to workers during implementation than Alternative 1, but much less than Alternative 6. Could be completed in months.	High. Services and materials are readily available.
Alternative 6: Excavation and Disposal	High. Removal of contaminated waste offers the highest degree of overall protection with respect to RAOs.	High. Complies with ARARs and potential TBCs.	High. Contaminant sources removed; therefore, residual risks are negligible. Most adequate overall level of protection to humans and the environment.	High. Excavation, waste treatment and disposal would reduce or eliminate mobility of radionuclides and inorganic COCs, and reduce or eliminate toxicity of organics.	Moderate to High. Potential negative impacts to community from waste transportation to off-site disposal facility Potential impacts reduced greatly if waste disposed at the WDF. Risk to workers higher than other alternatives but can be managed through site procedures during implementation. Implementation could take years.	Moderate to high. Excavation and associated technologies are readily implementable. Some excavated waste materials or soil may have multiple regulatory classifications, increasing the complexity of treatment required for transportation and/or disposal. WDF is being evaluated as part of the waste disposal option project, and a ROD has not been issued.

Table ES.21. SWMU 30 Remedial Alternatives Cost Estimate Summary

			PRESENT WORTH[1]		ESCALATED	
Alternative Description	**Annual Time Period, yrs**	**Capital $ (2010 Constant Dollars)**	**Total Annual $**	**Total $ (Capital and Annual)**	**Total Annual $**	**Total $ (Capital and Annual)**
Alternative 1—No Action	0	$0	$0	$0	$0	$0
Alternative 3—Soil Cover and Long-Term Monitoring	30	$3,266,000	$1,423,000	$4,689,000	$5,059,000	$8,524,000
Alternative 6a—Excavation and Disposal	0	$25,235,000	$0	$25,235,000	$0	$26,772,000
Alternative 6b—Excavation and Disposal (at the WDF)	0	$17,906,000	$0	$17,906,000	$0	$18,996,000

[1] Not used for budgeting or planning purposes because value is based on investing funds for outyear expenditures.

Table ES.22. Summary of Comparative Analysis of Remedial Alternatives SWMU 145

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 1: No Action	Does not meet the threshold criterion. Site procedures would be maintained to prevent direct contact with buried waste, but concentrations of Tc-99 in soil along NSDD will remain at levels that could pose a threat to groundwater. No controls implemented to mitigate or manage residual risk. Groundwater monitoring not performed to assess future groundwater quality.	ARARs are not applicable to the No Action alternative.	Not effective. Site risk would remain at or near current levels. Tc-99 in soil along NSDD could pose a future threat to groundwater. No controls implemented to mitigate or manage residual risk. Groundwater monitoring not performed to assess future groundwater quality.	Low. No treatment provided.	High. No actions implemented; therefore, no risks to community, site workers or the environment from implementation.	No additional action would be implemented. Current site procedures would be maintained.
Alternative 3: Soil Cover and Long-Term Monitoring	Moderate. Meets threshold criterion. More protective than Alternative 1 and less protective than Alternatives 6. Prevents direct contact with waste and reduces migration potential of contamination in surface soils and postulated TCE contaminations. Land use controls protect current and future site workers and the public.	High. Complies with ARARs and potential TBCs.	Moderate. Protects site workers from direct contact with waste and surface soil. Some reduction in mobility of contaminants by reducing infiltration.	Low to Moderate. No reduction of toxicity or volume. Contaminant mobility is reduced through containment.	High. No negative impacts to community. Exposure to workers low during installation of cover. More short term risk to workers during implementation than Alternative 1, but much less than Alternative 6. Could be completed in months.	High. Services and materials are readily available.

Table ES.22. Summary of Comparative Analysis of Remedial Alternatives SWMU 145 (Continued)

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 6: Excavation and Disposal (Excavation of NSDD, soil cover of identified surface contamination "hot spots" and long-term monitoring in vicinity of postulated TCE contamination.) with Long-Term Groundwater Monitoring	High. Meets threshold criterion. Removal of contaminated soil reduces COCs in soil to RGs target concentrations, reducing direct contact threat and protecting groundwater. Long-term groundwater monitoring verifies that waste left in place does not contribute to further groundwater degradation.	High. Meets threshold criterion by complying with ARARs.	High. Reduces residual risk from COCs in soil to acceptable levels. Site procedures prevents exposure to buried waste. Long-term groundwater monitoring verifies that waste left in place does not contribute to further groundwater degradation.	Moderate to high. Removal and relocation of contaminated soil to engineered disposal facility reduces mobility of COCs and volume of contaminated soil at site.	Moderate to high. Risks to community, site workers and the environmental are minimal or readily managed. Approximately 3 years would be required to achieve implement and achieve RAOs.	High. Alternative is readily implementable at SWMU 145. Excavation would occur along the course of the former NSDD. Hot spots in surface soils would be covered. Groundwater monitoring is easily implemented.

Table ES.23. SWMU 145 Remedial Alternatives Cost Estimate Summary

			PRESENT WORTH[1]		ESCALATED	
Alternative Description	**Annual Time Period, yrs**	**Capital $ (2010 Constant Dollars)**	**Total Annual $**	**Total $ (Capital and Annual)**	**Total Annual $**	**Total $ (Capital and Annual)**
Alternative 1—No Action	0	$0	$0	$0	$0	$0
Alternative 3—Soil Cover and Long-Term Monitoring	30	$7,885,000	$5,006,000	$12,891,000	$20,207,000	$28,572,000
Alternative 6a—Excavation and Disposal[2]	0	$19,133,000	$0	$19,133,000	$0	$20,298,000
Alternative 6b—Excavation and Disposal (at the WDF)[2]	0	$18,109,000	$0	$18,109,000	$0	$19,212,000
Contingency for Alternative 6—Soil Cover and Long-Term Monitoring[3]	30	$3,378,000	$1,370,000	$4,748,000	$4,975,000	$8,559,000

[1] Not used for budgeting or planning purposes because value is based on investing funds for outyear expenditures.

[2] Excavation of only North-South Diversion Ditch.

[3] Assumed reductions in soil cover area based on results of proposed surface soil investigation.

Table ES.24. Summary of Detailed Analysis of Alternatives for the SWMUs

KEY

○ Unfavorable Score

◉ Moderate Score

● Favorable Score

Evaluation Criteria	**Overall protection of human health and the environment**	**Compliance with ARARs**	**Long-term effectiveness and permanence**	**Reduction of toxicity, mobility, or volume through treatment**	**Short-term effectiveness**	**Implementability**	**Cost**
SWMU 2							
Alternative 1—No Action	○		○	○	●	●	●
Alternative 5—RCRA Cover with Hydraulic Isolation and Long-Term Monitoring	◉	●	◉	◉	●	●	◉
Alternative 7—Excavation and Disposal Combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring	●	●	●	●	◉[1]	◉[2]	○[3]
Alternative 8—Excavation and Disposal Combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring	●	●	●	●	○[1]	○[2]	○[3]
Alternative 9—*In situ* Containment and Long-Term Monitoring	◉	●	●	◉	◉	◉	◉
SWMU 3							
Alternative 1—No Action	◉	●	◉	◉	●	●	●
Alternative 2—Limited Action	◉	●	◉	◉	●	◉	●
Alternative 6—Excavation and Disposal	●	●	●	●	◉[1]	◉[2]	○[3]
Alternative 9—*In situ* Containment and Long-Term Monitoring	◉	●	●	◉	◉	◉	◉

Table ES.24. Summary of Detailed Analysis of Alternatives for the SWMUs (Continued)

Evaluation Criteria	Overall protection of human health and the environment	Compliance with ARARs	Long-term effectiveness and permanence	Reduction of toxicity, mobility, or volume through treatment	Short-term effectiveness	Implementability	Cost
SWMU 4							
Alternative 1—No Action	○		○	○	●	●	●
Alternative 7—Excavation and Disposal Combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring	●	●	●	●	◉[1]	◉[2]	○[3]
Alternative 8—Excavation and Disposal Combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring	●	●	●	●	○[1]	○[2]	○[3]
SWMU 5							
Alternative 1—No Action	○		○	○	●	●	●
Alternative 3—Soil Cover and Long-Term Monitoring	●	●	●	◉	●	●	●
Alternative 6—Excavation and Disposal (with Metal Recovery/ Recycle)	●	●	●	●	○[4]	◉[2]	○[5]
SWMU 6							
Alternative 1—No Action	●		◉	○	●	●	●
Alternative 2—Limited Action	●	●	●	○	●	●	◉
SWMU 7							
Alternative 1—No Action	○		○	○	●	●	●
Alternative 4—Soil Cover with *In situ* DNAPL Source Treatment and Long-Term Monitoring	●	●	●	●	◉	●	◉
Alternative 7—Excavation and Disposal Combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring	●	●	●	●	◉[1]	◉[2]	○[3]
Alternative 8—Excavation and Disposal Combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring	●	●	●	●	○[1]	○[2]	○[3]

Table ES.24. Summary of Detailed Analysis of Alternatives for the SWMUs (Continued)

Evaluation Criteria	Overall protection of human health and the environment	Compliance with ARARs	Long-term effectiveness and permanence	Reduction of toxicity, mobility, or volume through treatment	Short-term effectiveness	Implementability	Cost
SWMU 30							
Alternative 1—No Action	○		○	○	●	●	●
Alternative 3—Soil Cover and Long-Term Monitoring	●	●	●	◉	●	●	●
Alternative 6—Excavation and Disposal	●	●	●	●	◉[1]	◉[2]	○[3]
SWMU 145							
Alternative 1—No Action	○		○	○	●	●	●
Alternative 3—Soil Cover and Long-Term Monitoring	◉	●	◉	◉	●	●	◉
Alternative 6—Excavation and Disposal (NSDD) with Soil Cover and Long-Term Monitoring	●	●	●	●	◉	●	○

Notes:
[1] More favorable score for disposal of waste at the WDF due to cost savings.
[2] WDF is being evaluated as part of the waste disposal option project, and a ROD has not been issued.
[3] Moderate for disposal of waste at the WDF.
[4] Lower if metal melter is constructed at PGDP.
[5] If metal is recovered, recovery cost would be added to excavation and disposal costs, but other criteria would not be affected by either metal recovery or disposal.

THIS PAGE INTENTIONALLY LEFT BLANK

1. INTRODUCTION

This section provides a brief introduction to the Paducah Gaseous Diffusion Plant (PGDP) and an explanation of the purpose and organization of the report. Background information, including the site background and regulatory setting, is summarized. Site and area-specific descriptions including land use, demographics, climate, air quality, noise, ecological resources, and cultural resources are summarized. An overview is provided of the topography, surface water hydrology, geology, and hydrogeology of the region and the study area. A conceptual site model summarizing the nature and extent of contamination and fate and transport modeling of selected contaminants of concern (COCs) are discussed.

1.1 SCOPE OF THE BGOU

The Burial Grounds Operable Unit (BGOU) at PGDP is one of five media-specific, sitewide operable units (OUs) associated with pre-shutdown scope being used to evaluate and implement remedial actions. A final Comprehensive Site OU evaluation will be conducted following plant shutdown and completion of pre- and post-shutdown actions to ensure long-term protectiveness of human health and the environment. The five media-specific, strategic cleanup initiatives that have been agreed upon by the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the Commonwealth of Kentucky (KY), as documented in the *Site Management Plan* (SMP) (DOE 2009), are as follows:

- Groundwater OU Strategic Initiative
- Burial Grounds OU Strategic Initiative
- Surface Water OU Strategic Initiative
- Soils OU Strategic Initiative
- D&D OU Strategic Initiative

The burial grounds contain various wastes and other materials. Some of the materials may be principal threat waste (PTW).

PTW is defined by EPA as “source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur” (EPA 1991). EPA also recognizes that “although no threshold level of risk has been established to identify principal threat waste, a general rule of thumb is to consider as a principal threat those source materials with toxicity and mobility characteristics that combine to pose a potential risk several orders of magnitude greater than the risk level that is acceptable for the current or reasonably anticipated future land use, given realistic exposure scenarios” (EPA 1997).

The BGOU solid waste management units (SWMUs) contain two potential PTWs: trichloroethene (TCE) dense nonaqueous-phase liquid (DNAPL) at SWMU 4 and between SWMUs 7 and 30, and uranium wastes at SWMUs 2 and 3. Dissolved contaminant trends in the Regional Gravel Aquifer (RGA) indicate that SWMU 4 is a DNAPL source. The data also indicate that the adjoining area in the Upper Continental Recharge System (UCRS) between SWMUs 7 and 30 also may contain TCE sources as DNAPL. The mobility and toxicity of DNAPLs make them PTW. Additionally, historical records of TCE disposal at SWMU 2 indicate that a DNAPL source potentially could exist at the SWMU and will require evaluation of a treatment alternative.

The uranium at SWMU 2 presents risk greater than 1E-03 under some hypothetical exposure scenarios. Some forms of the buried uranium could be considered potential PTW where toxicity and mobility combine to pose such a risk to human health. These hypothetical exposure scenarios assume a direct contact exposure to buried waste (DOE 1997a). The uranium metal present at SWMUs 2 and 3 likely is not mobile due to its insolubility in water. The Data Summary and Interpretation Report (DOE 1997a) concluded that only some forms of uranium present may be mobile (e.g., uranyl fluoride at SWMU 2). Uncertainties concerning the risks associated with the toxicity and mobility of the uranium are considered further during alternative evaluation in this feasibility study (FS).

The BGOU will employ the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedial process. Remedial Action Objectives (RAOs) are developed and discussed in Section 2.

The BGOU consists of contamination associated with PGDP's landfills and burial grounds and additional disposal areas that might exist beneath the scrap yards. Burial grounds addressed by this remedial investigation (RI) are listed in Table 1.1 (DOE 2006a).

Table 1.1. Summary of Source Areas and SWMU Numbers Within the Scope of the BGOU RI

SWMU No.	Description
2	C-749 Uranium Burial Grounds
3	C-404 Low-Level Radioactive Waste Burial Grounds
4	C-747 Contaminated Burial Yard and C-748-B Burial Area
5	C-746-F Burial Yard
6	C-747-B Burial Grounds
7 and 30	C-747-A Burial Grounds and Burn Area
145	Area P (residential/inert borrow area) and old North-South Diversion Ditch disposal trench (the area for SWMU 145 includes that beneath SWMUs 9 and 10)

SWMUs 9 (C-746-S Landfill) and 10 (C-746-T Landfill) are included in the overall scope of the BGOU, but were not included in the RI. These SWMUs were assumed to require No Further Action in the fiscal year 2005 SMP since the nature and extent of contamination is understood at these units and No Further Action is warranted (DOE 2009a). The Site Investigation (SI) of the C-746-S&T Landfill documents results of an investigation performed for these units. C-746-S&T Landfills were closed under Subtitle D landfill regulations. Contamination present in the area is likely from SWMU 145, which is addressed in this FS. There is no further discussion of SWMUs 9 and 10 in this document because they are documented as No Further Action and will be proposed as such in the Proposed Plan and Record of Decision (ROD).

A Soils OU SWMU, SWMU 12, overlaps a portion of SWMU 7. Any buried material beneath SWMU 12 is considered part of SWMU 7. The remainder of SWMU 12 surface soil is covered under the Soils OU.

Subsequent to development of the BGOU RI/FS Work Plan (DOE 2006a) and concurrent with the RI field investigation, an interview with a former plant operator identified potential areas of buried metal within the C-746-P and C-746-P1 Scrap Yards (SWMU 13). The results of the sampling and an assessment of these burial areas, as characterized by an approved Field Sampling Plan addendum to the BGOU RI/FS Work Plan and follow-on site evaluation, will be documented separately in a Site Evaluation Report. The results will be discussed with the *Federal Facility Agreement for the Paducah Gaseous Diffusion Plant* (FFA) (EPA 1998a) parties, and, if further action is necessary, a path forward will be determined.

1.2 PURPOSE AND ORGANIZATION OF REPORT

This *Feasibility Study for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0130&D1, was prepared to evaluate remedial alternatives for potential application at DOE's PGDP. This work was prepared in accordance with the requirements of the FFA (EPA 1998a). In accordance with Section IV of the FFA, this integrated technical document was developed to satisfy applicable requirements of CERCLA (42 *USC* § 9601 *et seq.*) and the Resource Conservation and Recovery Act (RCRA) (42 *USC* § 6901 *et seq.*). In addition to the EPA requirements, National Environmental Policy Act of 1969 (NEPA) values, consistent with the DOE's Secretarial Policy Statement on NEPA in June 1994 (DOE 1994a), are evaluated and documented in this FS. In consideration of the U.S. Department of the Interior's Natural Resource Damage Assessment (NRDA) and Restoration Program, the BGOU FS will be provided to trustee agencies for their review. The NRDA is a process whereby a natural resource trustee may pursue compensation on behalf of the public for injury to natural resources resulting from releases of hazardous substances. It is DOE's policy to integrate natural resource concerns early into the investigation and remedy selection process to minimize unnecessary resource injury.

This FS also has been prepared in accordance with the Integrated FS/Corrective Measures Study Report outline prescribed in Appendix D of the FFA for PGDP, except for format changes agreed to in previous Scoping Meetings and approved by all parties. As such, this FS is considered a primary document. Primary documents may be described generally as those documents that the DOE is required to issue to EPA and the Kentucky Energy and Environment Cabinet (KEEC) to fulfill the obligations of the FFA (EPA 1998a). All subsections contained in the referenced outline have been included for completeness. Additional subsections have been added to the outline, as appropriate, and have been included to provide clarity and enhance the organization of the document.

1.3 BACKGROUND INFORMATION

The following section presents background information concerning the site background and regulatory setting at PGDP. It also provides a site description of the PGDP region and source areas, as well as a summary of the process history, nature and extent of contamination, contaminant fate and transport, and the risks associated with the source areas.

1.3.1 Site Description

PGDP is located approximately 10 miles west of Paducah, KY, and 3.5 miles south of the Ohio River in the western part of McCracken County (Figure 1.1). The PGDP industrial area occupies approximately 650 acres of the DOE site, and is surrounded by an additional 800-acre buffer zone. DOE licenses most of the remaining acreage to the KY as part of the West Kentucky Wildlife Management Area (WKWMA). Tennessee Valley Authority's (TVA's) Shawnee Steam Plant borders the DOE site to the northeast, between the plant and the Ohio River (Figure 1.2).

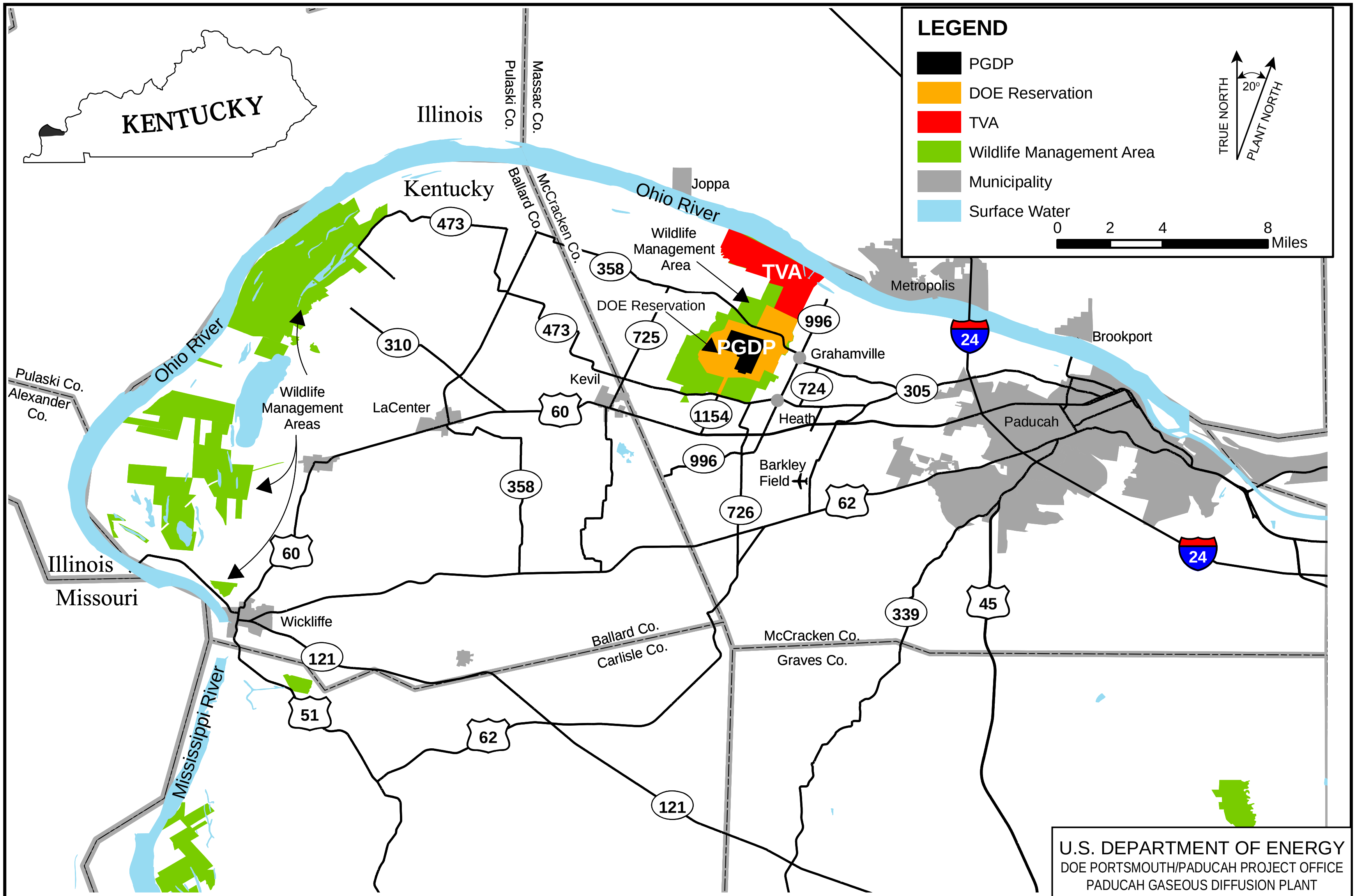


Figure 1.1. PGDP Site Location

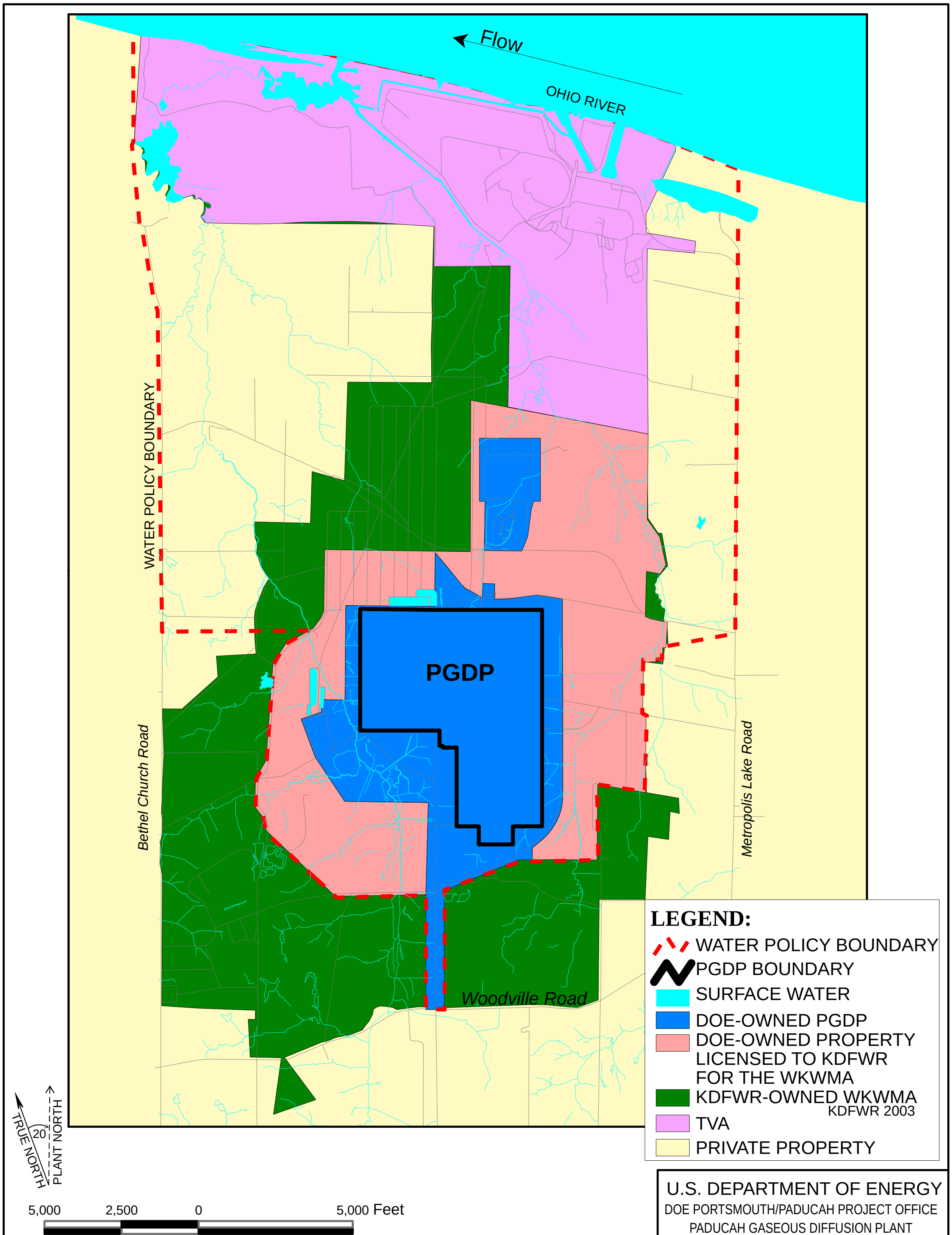


Figure 1.2. PGDP Land Ownership Map

Figure No. C5AC90005sk003r3.mxd
DATE 04-09-10

Before the PGDP was built, a munitions-production facility, the Kentucky Ordnance Works (KOW), was operated at the current PGDP location and in adjoining areas southwest of the site. Munitions, including trinitrotoluene, were manufactured in an area southwest of PGDP and stored at the KOW between 1942 and 1945. The KOW was shut down immediately after World War II. Construction of PGDP was initiated in 1951 and the plant began operations in 1952. Construction was completed in 1955 and PGDP became fully operational in 1955, supplying enriched uranium for commercial reactors and military defense reactors.

PGDP was operated by Union Carbide Corporation until 1984, when Martin Marietta Energy Systems, Inc., (which later became Lockheed Martin Energy Systems, Inc.) was contracted to operate the plant for DOE. On July 1, 1993, DOE leased the plant production/operations facilities to the United States Enrichment Corporation; however, DOE maintains ownership of the plant and is responsible for environmental restoration and waste management activities. On April 1, 1998, Bechtel Jacobs Company LLC, replaced Lockheed Martin Energy Systems, Inc., in implementing the Environmental Management Program at PGDP. On April 23, 2006, Paducah Remediation Services, LLC, replaced Bechtel Jacobs Company LLC, in implementing the Environmental Management Program at PGDP.

Contamination as a result of PGDP operations has resulted in three dissolved-phase plumes that are migrating from PGDP toward the Ohio River. These groundwater plumes are the Northwest Groundwater Plume (SWMU 201), the Northeast Groundwater Plume (SWMU 202), and the Southwest Plume (SWMU 210) (Figure 1.3).

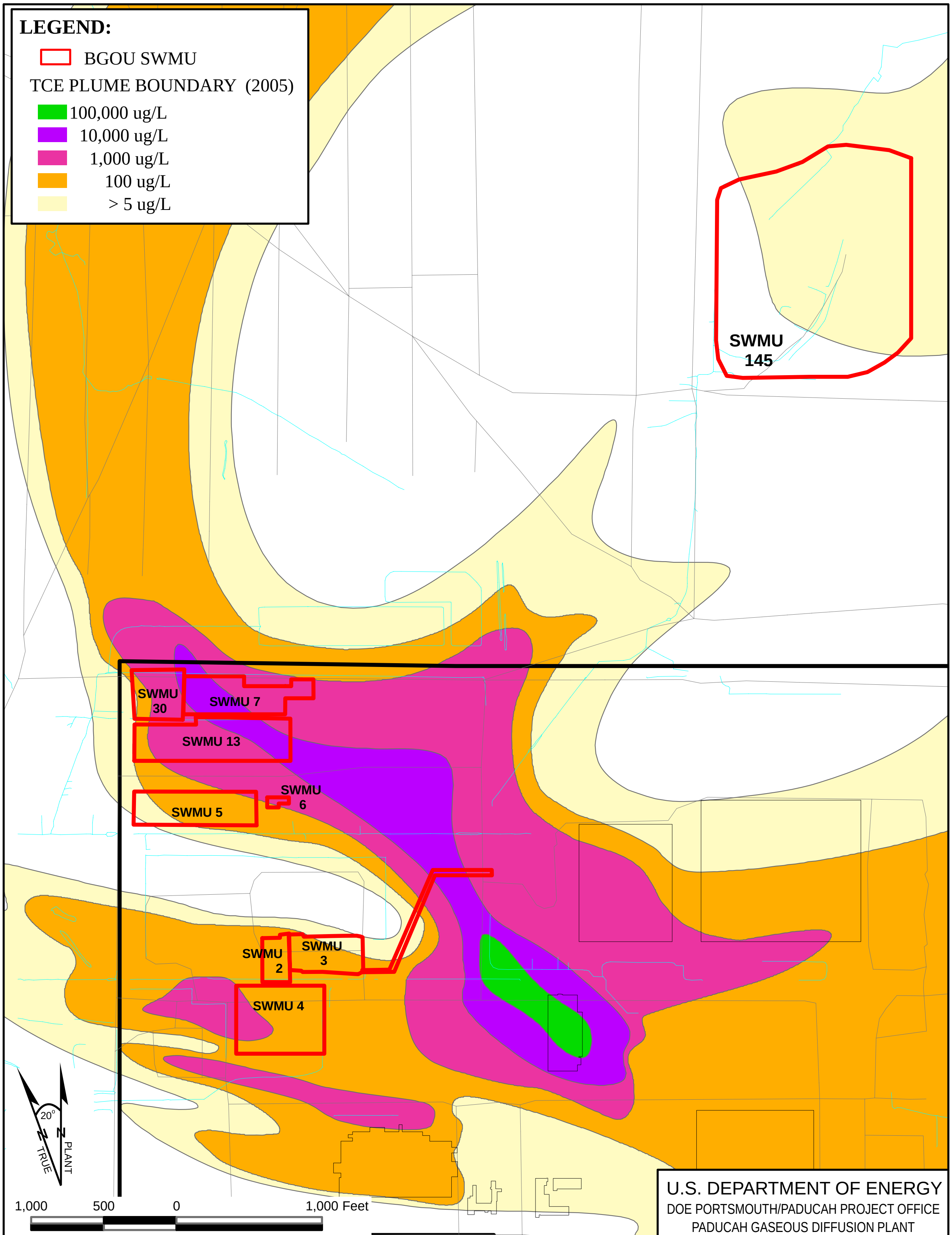
1.3.1.1 Regulatory setting

This section summarizes the regulatory framework for environmental restoration at PGDP, including the major statutes and accompanying regulations driving response actions, such as the CERCLA, RCRA, and NEPA. It also describes environmental programs and the documents controlling response actions, such as the FFA and the SMP (DOE 2009). The scope of this action within the overall response strategy for PGDP is described.

Major Statutes, Regulations, and Controlling Documents. Section 105(a)(8)(B) of CERCLA, as amended by the Superfund Amendments and Reauthorization Act, requires EPA to promulgate a list of national priorities among the known or threatened releases of hazardous substances, pollutants, or contaminants throughout the United States. On June 30, 1994, EPA placed PGDP on the National Priorities List (NPL) [59 *Federal Register* (*FR*) 27989 (May 31, 1994)]. The NPL lists sites that are designated by EPA as high priority sites for remediation under CERCLA. in accordance with CERCLA's National Contingency Plan (NCP). As the lead agency under CERCLA, DOE is responsible for conducting cleanup activities at PGDP in compliance with NCP. CERCLA is not the only driver for cleanup at PGDP. RCRA requires corrective action for releases of hazardous constituents from SWMUs.

Section 120 of CERCLA requires federal facilities listed on the NPL to enter into an FFA. The FFA coordinates the CERCLA remedial action and RCRA corrective action process into a set of comprehensive requirements for site remediation. The FFA requires that DOE develop and submit an annual SMP to EPA and KEEC. The SMP outlines the programmatic framework for implementing the FFA.

Environmental Programs. Environmental sampling at PGDP is a multimedia (air, water, soil, sediment, direct radiation, and biota) program of chemical, radiological, and ecological monitoring. Environmental monitoring consists of two activities: effluent monitoring and environmental surveillance. As part of the ongoing environmental activities, SWMUs and areas of concern have been identified. Characterization



U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Figure 1.3. BGOU SWMUs in Relation to PGDP Groundwater Plume

Figure No. BGOU FS...SWMU_plumeR2.mxd
DATE 09-18-09

and/or remediation of these sites will continue pursuant to CERCLA and Hazardous and Solid Waste Amendments corrective action conditions of the RCRA Permit.

National Environmental Policy Act. The intent of NEPA is to promote a decision-making process that results in minimization of adverse impacts to human health and the environment. On June 13, 1994, the Secretary of Energy issued a Secretarial Policy (Policy) on NEPA that addresses NEPA requirements for actions taken under CERCLA. Section II.E of the Policy indicates that DOE CERCLA documents will incorporate NEPA values, to the extent practicable, such as analysis of cumulative, off-site, ecological, cultural, and socioeconomic impacts.

1.3.1.2 Land use, demographics, surface features, and environment

Land Use. The PGDP is heavily industrialized; however, the area surrounding the plant is mostly agricultural and open land, with some forested areas (see Figure 1.4). TVA’s Shawnee Steam Plant, adjacent to the northeast border of the DOE Reservation, is the only other major industrial facility in the immediate area. The PGDP is posted government property and trespassing is prohibited. Access to the PGDP site is controlled by guarded checkpoints, a perimeter fence, and vehicle barriers and is subject to routine patrol and visual inspection by plant protective forces. The PGDP site includes 1,986 acres licensed to the Kentucky Department of Fish and Wildlife Resources. This area is part of the WKWMA and borders PGDP to the north, west, and south. The WKWMA is an important recreational resource for western Kentucky and is used by more than 10,000 people each year. Major recreational activities include hunting, field trials for dogs and horses, trail riding, fishing, and skeet shooting.

Demographics. Total population within a 50-mile radius of PGDP is approximately 731,500. Approximately 88,500 people live within the three counties that contain the 10-miles radius of PGDP. The estimated population of Paducah, Kentucky, for 2006 was approximately 25,600. Metropolis, Illinois, had an estimated population in 2006 of approximately 6,400 (U.S. Census Bureau 2007) The closest communities to PGDP are the unincorporated towns of Grahamville [about 1.6 kilometers (1 mile) to the east] and Heath [about 1.6 kilometers (1 mile) southeast]. Current and anticipated future land use for PGDP and surrounding areas is depicted in Figure 1.5 and represents the future land use scenario from the PGDP SMP (DOE 2009).

Major employers in the area of PGDP include the United States Enrichment Corporation (approximately 1,200 employees), Uranium Disposition Services, LLC (approximately 140 employees), DOE Environmental Management contractors (approximately 650 employees), and TVA’s Shawnee Steam Plant (approximately 260 employees).

Surface Features and Topography. PGDP lies in the Jackson Purchase Region of western Kentucky between the Tennessee and Mississippi Rivers, bounded on the north by the Ohio River. The confluence of the Ohio and Mississippi Rivers is approximately 35 miles downstream (southwest) from the site. The confluence of the Ohio and Tennessee Rivers is approximately 15 miles upstream (east) from the site.

Local elevations range from 290 ft above mean sea level (amsl) along the Ohio River to 450 ft amsl southwest of PGDP near Bethel Church Road. Generally, the topography in the PGDP area slopes toward the Ohio River at an approximate 27 ft/mile gradient (CH2M Hill 1992). Within the plant boundaries where most of the BGOU SWMUs are located, ground surface elevations vary from 360 to 390 ft amsl. At SWMU 145, north of PGDP, ground surface elevations range from 360 to 410 ft amsl.

The terrain in the vicinity of the plant is slightly modified by the dendritic drainage systems associated with the two principal streams in the area, Bayou Creek and Little Bayou Creek. These streams have eroded small valleys, which are about 20 ft below the adjacent plain.

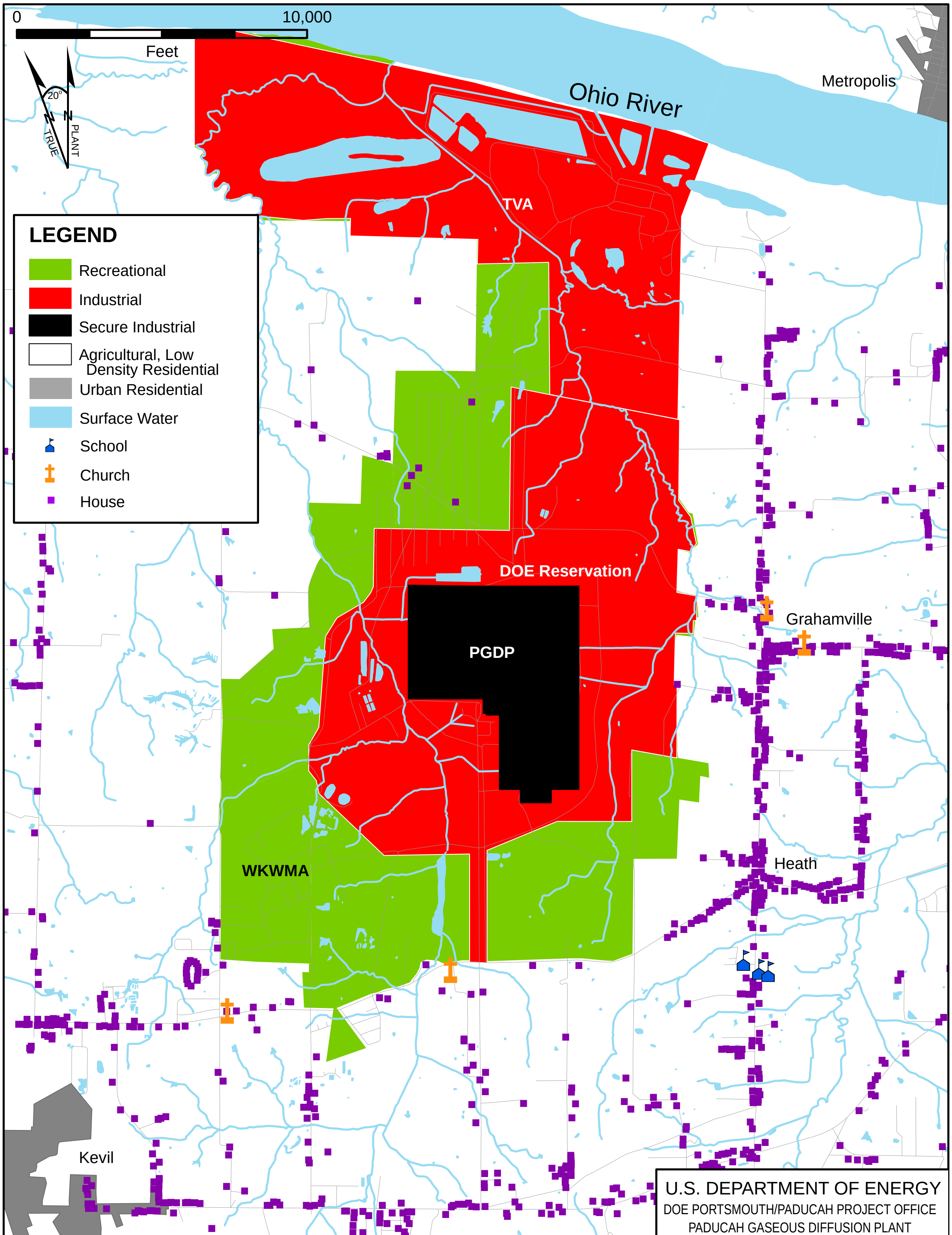
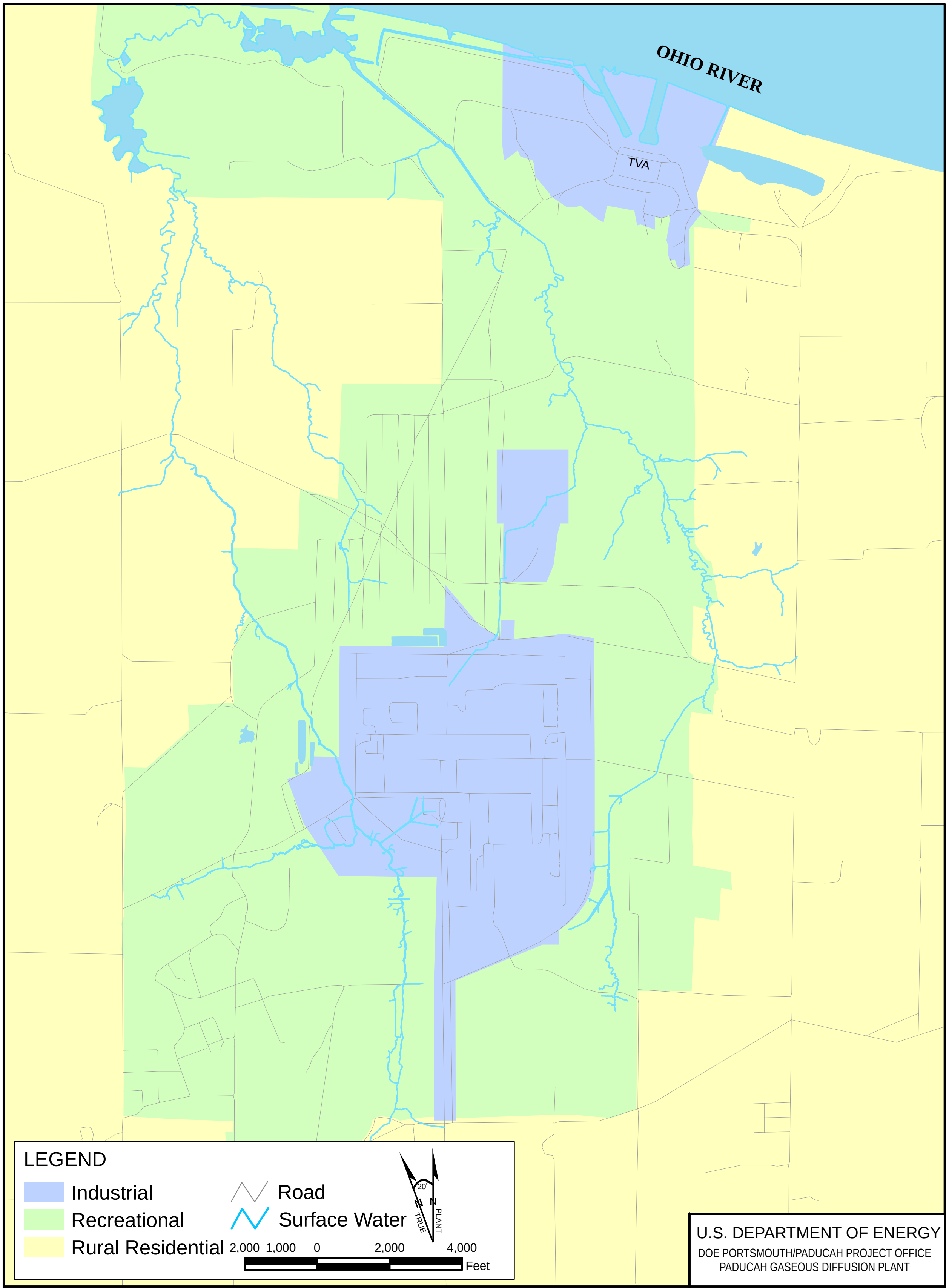


Figure 1.4. Land Use in Proximity to PGDP

FIGURE No. Site_Location--LandUse_PGDParea4.mxd
DATE 04-09-10



U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Figure 1.5. Anticipated Future Land Use

Figure No. C5AC90005SK007_1-5.mxd
DATE 10-28-08

Approximately 100 small lakes and ponds exist on DOE property (TCT-St. Louis 1991). A marsh covering 165 acres exists off-site of DOE property, immediately south of the confluence of Bayou Creek and Little Bayou Creek (TCT-St. Louis 1991).

Climate. The climate of the region may be broadly classified as humid-continental. The term "humid" refers to the surplus of precipitation versus evapotranspiration that normally is experienced throughout the year. The 30-year average monthly precipitation for the period 1961 through 1990 is 4.11 inches,[1] varying from an average of 3.00 inches in October (the monthly average low) to an average of 5.01 inches in April (the monthly average high). Monthly estimates of evapotranspiration using the Thornthwaite method (Thornthwaite and Mather 1957) equal or exceed average rainfall for the period May through September (season of no net infiltration).

The "continental" nature of the local climate refers to the dominating influence of the North American landmass. Continental climates typically experience large temperature changes between seasons. The 22-year average monthly temperature is 58.0 °F, with the coldest month being January with an average temperature of 35 °F and the warmest month being July with an average temperature of 79 °F.

The average mean prevailing wind speed is 10 miles per hour. Historically, stronger winds are recorded when the winds are from the southwest.

Air Quality. PGDP is located in the Paducah-Cairo Interstate Air Quality Control Region of Kentucky, which includes McCracken County and 16 other counties in western Kentucky. Data from the state's air monitors are used to assess the region's ambient air quality for the criteria pollutants (ozone, nitrogen oxides, carbon monoxide, particulates, lead, and sulfur dioxide) and to designate nonattainment areas (i.e., those areas for which one or more of the National Ambient Air Quality Standards are not met). McCracken County is classified as an attainment area for all six criteria pollutants [*Fiscal Year 2008 Annual Report* (KDAQ 2008)]. Ten ambient air sampling stations are operated by the Kentucky Radiation Health and Toxic Agents Branch to monitor airborne radionuclides from PGDP.

Noise. Noises associated with plant activities generally are restricted to areas inside buildings located on-site. Currently, noise levels beyond the security fence are limited to wildlife, hunting, traffic moving through the area, and operation and maintenance activities associated with outside waste storage areas located close to the security fence.

1.3.1.3 Ecological, cultural, archeological, and historical resources

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

Soils and Prime Farmland. Six soil types are associated with PGDP as mapped by the Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (USDA 1976). These are Calloway silt loam, Grenada silt loam, Loring silt loam, Falaya-Collins silt loam, Vicksburg silt loam, and Henry silt loam.

---

[1] For the recent five-year period June 2002 through May 2007, average monthly precipitation was slightly less (3.90 inches), ranging from 3.25 inches in October (monthly average low) to 4.94 inches in September (monthly average high).

The dominant soil types, the Calloway and Henry silt loams, consist of nearly level, somewhat poorly drained to poorly drained soils that formed in deposits of loess and alluvium. These soils tend to have low organic content, low buffering capacity, and acidic hydrogen-ion concentration (pH) ranging from 4.5 to 5.5. The Henry and Calloway series have a fragipan horizon, a compact and brittle silty clay loam layer that extends from 26 inches below ground surface (bgs) to a depth of 50 inches or more. The fragipan reduces the vertical movement of water and causes a seasonally perched water table in some areas at PGDP. In areas within the PGDP where past construction activities have disturbed the fragipan layer, the soils are best classified as "urban."

Prime farmland, as defined by the NRCS, is land that is best suited for food, feed, forage, fiber, and oilseed productions, excluding "urban built-up land or water" [7 *CFR* § 657 and 658]. The NRCS determines prime farmland based on soil types found to exhibit soil properties best suited for growing crops. These characteristics include suitable moisture and temperature regimes, pH, drainage class, permeability, erodibility factor, and other properties needed to produce sustained high yields of crops in an economical manner. Prime farmland is located north of the PGDP plant area. The prime farmland north of the plant is predominantly located in areas having soil types of Calloway, Grenada, and Waverly.

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 upland vegetative communities consist primarily of grassland, forest, and thicket habitats with agricultural areas. The main crops grown in the PGDP area include soybeans, corn, tobacco, and sorghum.

Most of PGDP has been cleared of vegetation at some time, and much of the grassland habitat currently is mowed by PGDP personnel. The Kentucky Division of Fish and Wildlife Resources manages a large percentage of the adjacent WKWMA to promote native prairie vegetation by burning, mowing, and various other techniques. These areas have the greatest potential for restoration and for establishment of a sizeable prairie preserve in the Jackson Purchase area (KSNPC 1991).

Dominant overstory species of the forested areas include oaks, hickories, maples, elms, and sweetgum. Understory species include snowberry, poison ivy, trumpet creeper, Virginia creeper, and Solomon's seal. Thicket areas consist predominantly of maples, black locust, sumac, persimmon, and forest species in the sapling stage with herbaceous ground cover similar to that of the forest understory.

Wildlife commonly found in the PGDP area consists of species indigenous to open grassland, thicket, and forest habitats. Small mammal surveys conducted on WKWMA documented the presence of southern short-tailed shrew, prairie vole, house mouse, rice rat, and deer mouse (KSNPC 1991). Large mammals commonly present in the area include coyote, eastern cottontail, opossum, groundhog, whitetail deer, raccoon, and gray squirrel.

Typical birds of the area include European starling, cardinal, red-winged blackbird, mourning dove, bobwhite quail, turkey, killdeer, American robin, eastern meadowlark, eastern bluebird, bluejay, red-tail hawk, and great horned owl.

Amphibians and reptiles present include cricket frog, Fowler's toad, common snapping turtle, green tree frog, chorus frog, southern leopard frog, eastern fence lizard, and red-eared slider (KSNPC 1991).

Mist netting activities in the area have captured red bat, little brown bat, Indiana bat, northern long-eared bat, evening bat, and eastern pipistrelle (KSNPC 1991).

Aquatic Systems. The aquatic communities in and around PGDP area that could be contaminated by plant discharges include two perennial streams (Bayou Creek and Little Bayou Creek), the North-South

Diversion Ditch (NSDD) (a former ditch for the discharge of plant effluents to Little Bayou Creek), a marsh located at the confluence of Bayou Creek and Little Bayou Creek, and other smaller drainage areas. The dominant taxa in all surface waters include several species of sunfish, especially bluegill and green sunfish, as well as bass and catfish. Shallow streams, characteristic of the two main area creeks, are dominated by bluegill, green and longear sunfish, and stonerollers.

Threatened and Endangered Species. Potential habitat for federally listed T&E species was evaluated for the area surrounding PGDP during the 1994 U.S. Army Corps of Engineers (COE) environmental investigation of the PGDP (COE 1994) and inside the fence of the PGDP during the 1994 investigation of sensitive resources at the PGDP (CDM 1994). Investigation inside the PGDP security fence did not detect any T&E species or their preferred habitats, and the U.S. Fish and Wildlife Service (USFWS) has not designated critical habitat for any species within DOE property; however, a 2007 USFWS investigation determined that most of the PGDP is within a maternity circle for Indiana bat (listed endangered). Subsequently, the USFWS has conducted a biological assessment of Indiana bat in support of the draft Indiana Bat Recovery Plan (USFWS 2007). The assessment indicates that PGDP is designated within the Mississippi River Recovery and Mitigation Focus Area where Indiana bat minimization and mitigation efforts will be undertaken or attempted.

Cultural, Archaeological, and Historic Resources. In accordance with the National Historic Preservation Act (NHPA), a Programmatic Agreement among the DOE Paducah Site Office, the Kentucky State Historic Preservation Officer, and the Advisory Council on Historic Preservation Concerning Management of Historical Properties, was signed in January 2004. DOE developed the *Cultural Resources Management Plan for the Paducah Gaseous Diffusion Plant, Paducah Gaseous Diffusion Plant, McCracken County, Kentucky* (CRMP) (BJC 2006) to define the preservation strategy for PGDP and direct efficient compliance with the NHPA and federal archaeological protection legislation at PGDP. PGDP facilities are documented with survey forms and photographs in the *Cultural Resources Survey for the Paducah Gaseous Diffusion Plant, Paducah, Kentuck*y, BJC/PAD–688/R1. No archaeological resources have been identified within the vicinity of the BGOU facilities.

1.3.1.4 Surface water hydrology, wetlands, and floodplains

Surface Water Hydrology. PGDP is located in the western portion of the Ohio River drainage basin, approximately 15 miles downstream of the confluence of the Ohio River with the Tennessee River and approximately 35 miles upstream of the confluence of the Ohio River with the Mississippi River. Locally, PGDP is within the drainage areas of the Ohio River, Bayou Creek, and Little Bayou Creek.

The plant is situated on the divide between the two creeks. Surface flow is east-northeast toward Little Bayou Creek and west-northwest toward Bayou Creek. Bayou Creek is a perennial stream on the western boundary of the plant that flows generally northward, from approximately 2.5 miles south of the plant site to the Ohio River along a 9-mile course. The Little Bayou Creek's intermittent drainage originates within WKWMA and extends northward and joins Bayou Creek near the Ohio River along a 6.5-mile course.

Most of the flow within Bayou and Little Bayou Creeks is from process effluents or surface water runoff from PGDP. Plant discharges are monitored at the Kentucky Pollutant Discharge Elimination System (KPDES) outfalls prior to discharge into the creeks.

Wetlands. The 1994 COE environmental investigations identified 1,083 separate wetland areas and grouped them into 16 vegetative cover types encompassing forested, scrub/shrub, and emergent wetlands (COE 1994). Wetland vegetation consists of species such as sedges, rushes, spikerushes, and various other grasses and forbs in the emergent portions; red maple, sweet gum, oaks, and hickories in the forested portions; and black willow and various other saplings of forested species in the thicket portions.

Five acres of potential wetlands were identified inside the fence at PGDP (COE 1995). The COE made the determination that these areas are jurisdictional wetlands. Wetlands inside the plant security fence are confined to portions of drainage ditches traversing the site. These areas provide some groundwater recharge, floodwater retention, and sediment retention. While the opportunity for these functions and values is high, the effectiveness is low due to water exiting the area quickly through the drainage system. Other functions and values (e.g., wildlife benefits, recreation, diversity, etc.) are very low.

Floodplains. Floodplains were evaluated during the 1994 COE environmental investigation of PGDP (COE 1994). This evaluation used the Hydrologic Engineering Center Computer Program-2 model to estimate 100- and 500-year flood elevations. Flood boundaries from the Hydrologic Engineering Center Computer Program-2 model were delineated on topographic maps of the PGDP area to determine areal extent of the flood waters associated with these events.

Flooding is associated with the Ohio River, Bayou Creek, and Little Bayou Creek. The majority of overland flooding at PGDP is associated with storm water runoff and flooding from Bayou and Little Bayou Creeks. A floodplain analysis performed by COE (1994) found that much of the built-up portions of the plant lie outside the 100- and 500-year floodplains of these streams. Drainage ditches inside the PGDP security fence can contain nearly all of the expected 100- and 500-year flood discharges (COE 1994). It should be noted that precipitation frequency estimates for the 100- and 500-year events were updated in 2004 in the National Oceanic and Atmospheric Administration's (NOAA) Atlas 14 (NOAA 2004). In the updated report, the mean precipitation estimate for the 100-year, 24-hour event in Atlas 14 for the Paducah area is 10.1% to 15% greater than the mean estimate in previous publications. As stated in Atlas 14, in many cases, the mean precipitation estimate used previously still is within the confidence limits provided in Atlas 14; therefore, it is assumed the plant ditches still will contain the 100- and 500-year discharges. The BGOU SWMUs are not located within the floodplain.

1.3.1.5 Regional and study area geology and hydrogeology

Regional Geology. 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. The stratigraphic sequence in the region consists of Cretaceous, Tertiary, and Quaternary sediments unconformably overlying Paleozoic bedrock. Figure 1.6 summarizes the geologic and hydrogeologic systems of the PGDP region.

Within the Jackson Purchase Region, strata deposited above the Precambrian basement rock attain a maximum thickness of 12,000 to 15,000 ft. Exposed strata in the region range in age from Devonian to Holocene. The Devonian stratum crops out along the western shore of Kentucky Lake. Mississippian carbonates form the nearest outcrop of bedrock and are exposed approximately 9 miles northwest of PGDP in southern Illinois (MMES 1992). 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.

Relative to the shallow groundwater flow system in the vicinity of PGDP, the Continental Deposits and the overlying loess and alluvium are of key importance. The Continental Deposits resemble a large low-gradient alluvial fan that covered much of the region and eventually buried the erosional topography. A principal geologic feature in the PGDP area is the Porters Creek Clay Terrace, a subsurface terrace that trends approximately east to west across the southern portion of the plant. The Porters Creek Clay Terrace represents the southern limit of erosion or scouring of the ancestral Tennessee River. Thicker sequences of Continental Deposits, as found underlying PGDP, represent valley fill deposits and can be informally divided into a lower unit (gravel facies) and an upper unit (clay facies). The Lower Continental Deposits (LCD) is the 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. In total, the gravel units average approximately 30 ft thick, but some thicker deposits (as much as 50 ft) exist in deeper scour channels. The Upper Continental Deposits (UCD) is primarily a sequence of fine-grained, clastic facies varying in thickness from 15 to 60 ft that consist of clayey silts with lenses of sand and occasional gravel.

The BGOU area lies within the buried valley of the ancestral Tennessee River in which Pleistocene Continental Deposits (the fill deposits of the ancestral Tennessee River Basin) rest unconformably on Cretaceous marine sediments. Pliocene through Paleocene formations in the BGOU area have been removed by erosion from the ancestral Tennessee River Basin. In this area, the upper McNairy Formation consists of 60 to 70 ft of interbedded units of silt and fine sand and underlies the Continental Deposits. Total thickness of the McNairy Formation is approximately 225 ft.

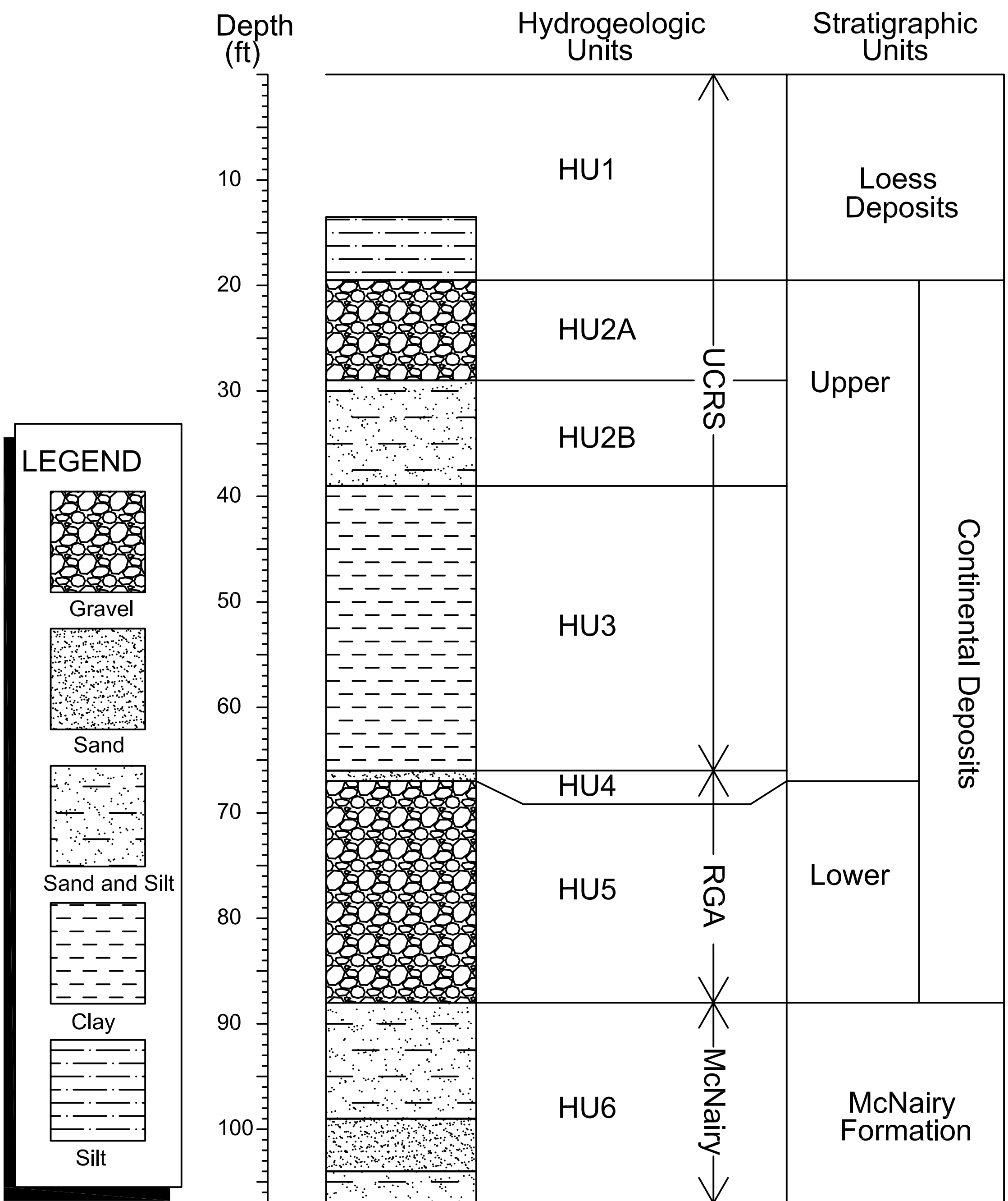
The surface deposits found in the vicinity of PGDP consist of loess and alluvium. Both units are composed of clayey silt or silty clay and range in color from yellowish-brown to brownish-gray or tan, making field differentiation difficult.

Regional Hydrogeology. The significant geologic units relative to shallow groundwater flow at PGDP include the Terrace Gravel and Porters Creek Clay (south sector of the DOE site) and the Pleistocene Continental Deposits and McNairy Formation (underlying PGDP and adjacent areas to the north). Groundwater flow in the Pleistocene Continental Deposits is a primary pathway for transport of dissolved contamination from PGDP. The following paragraphs provide the framework of the shallow groundwater flow system at PGDP.

(1) Terrace Gravel Flow System. The Porters Creek Clay is a confining unit to downward groundwater flow south of PGDP. A shallow water table flow system is developed in the Terrace Gravel, where it overlies the Porters Creek Clay south of PGDP. Discharge from this water table flow system provides baseflow to Bayou Creek and underflow to the Pleistocene Continental Deposits to the east of PGDP.

The elevation of the top of the Porters Creek Clay is an important control to the area's groundwater flow trends. A distinct groundwater divide is centered in hills located approximately 9,000 ft southwest of PGDP, where the Terrace Gravel and Eocene sands overlie a "high" on the top of the Porters Creek Clay. In adjacent areas where the top of the Porters Creek Clay approaches land surface, as it does south of PGDP and near the subcrop of the Porters Creek Clay to the west of the industrial complex, the majority of groundwater flow is forced to discharge into surface streams (gaining reaches) and little underflow occurs into the Pleistocene Continental Deposits. To the east of PGDP, the Terrace Gravel overlies a lower terrace eroded into the top of the Porters Creek Clay. In this area, a thick sequence of Terrace Gravel occurs adjacent to the Pleistocene Continental Deposits, allowing significant underflow from the Terrace Gravel. Surface drainages in this area are typically loosing reaches.

(2) UCRS. The upper strata, where infiltration of water from the surface occurs and where the uppermost zone of saturation exists in the Upper Continental Deposits (beneath PGDP and the contiguous land to the north) is called the UCRS. Groundwater flow is primarily downward in the Upper Continental Deposits. Vertical hydraulic gradients generally range from 0.5 to 1 ft/ft where measured by wells completed at different depths in the UCRS. Vertical gradients are 1 to 2 orders of magnitude greater than lateral hydraulic gradients. While groundwater flow is predominantly downward, there will be some lateral flow due to heterogeneities in the shallow soils.



Geology based on SI Phase 1 Boring H007.
Actual depths of hydrogeologic units and stratigraphic units vary across the site.

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Figure 1.6. Example Stratigraphic and Hydrogeologic Units

Direct measurements of the UCRS water table elevation are available only for the south-central PGDP industrial area, where water levels commonly occur in the screen interval of the wells, and the location of two source unit investigations (the SWMU 2 Interim Remedial Design Investigation and the SWMUs 7 and 30 RI) in the west PGDP industrial area. All other well measurements, where water levels occur above the well screen interval, provide lower bounds to the elevation of the water table. Hydrographs of UCRS monitoring wells (MWs) on-site indicate fluctuations of only a few ft over the past 10 years. The main features of the water table are a broad trough in the northeast and central areas, a linear discharge area associated with a ditch in the northwest, and a lateral hydraulic gradient toward Bayou Creek on the west side. In general, the water table is less than 20 ft deep in the western half of PGDP and as much as 40 ft deep in the northeastern corner.

The infiltration rate for the PGDP area is approximately 6.6 inches/yr based on site-specific groundwater modeling. This 6.6 inches/yr applied over the area of the industrial area of the plant yields approximately 0.4 mgd of recharge to the shallow groundwater system. Leakage from plant water utilities, ditches, lagoons, and cooling tower basins is suspected to be another important source of infiltration at PGDP. Water use for PGDP for calendar year 2006 averaged 13 mgd. Municipal water systems lose as much as 24% of their daily conveyance (Jowitt and Xu 1990). A similar loss of the PGDP system would equal 3.1 mgd. Since the UCRS groundwater flow is predominantly downward, areas with higher anthropogenic recharge creates mounding of hydraulic head in the RGA that can affect contaminant transport. Because the hydraulic conductivity in the RGA on-site is relatively large, the mounding is only slight (often less than 1 ft) and difficult to measure.

(3) RGA. Vertically infiltrating water from the UCRS moves downward into a basal sand member of the UCD and the Pleistocene gravel member of the LCD and then laterally north toward the Ohio River. This lateral flow system is called the RGA. The RGA is the shallow aquifer beneath PGDP and contiguous lands to the north. Groundwater of the RGA meets requirements of a Class II groundwater.

Hydraulic potential in the RGA declines toward the Ohio River, which is the control of base level of the region's surface water and groundwater systems. The RGA potentiometric surface gradient beneath PGDP is commonly 10^{-4} ft/ft, but increases by an order of magnitude near the Ohio River. (Vertical gradients are not well documented, but small.)

The hydraulic conductivity of the RGA varies spatially. Pumping tests have documented the hydraulic conductivity of the RGA ranges from 53 ft/day to 5,700 ft/day. East-to-west flow of the ancestral Tennessee River, which laid down the Pleistocene Continental Deposits gravel member, tended to orient permeable gravel and sand lenses east-west. Thus, with the hydraulic head in the RGA generally decreasing northward toward the Ohio River, groundwater flow trends to the northeast and northwest from PGDP in response to the anisotropy of the hydraulic conductivity as well as the anthropogenic recharge, which is greatest in the industrial portion of the plant. Antrhopogenic recharge from waterline leaks, lagoons, cooling tower basins, and other sources provides the primary driving force in moving groundwater in northeastern and northwestern flow directions from the industrial plant area. Ambient groundwater flow rates in the more permeable pathways of the RGA commonly range from 1 to 3 ft/day.

(4) McNairy Flow System. Groundwater flow in the fine sands and silts of the McNairy Formation is called the McNairy Flow System. The overall McNairy groundwater flow direction in the area of PGDP is northward to the Ohio River, similar to that of the RGA. Hydraulic potential is greater in the RGA than in the McNairy Flow System beneath PGDP. Area monitoring well clusters document an average downward vertical gradient of 0.03 ft/ft. Because the RGA has a steeper hydraulic potential slope toward the Ohio River than does the McNairy Flow System, the vertical gradient reverses nearer the Ohio River. [The "hinge line," which is where the vertical hydraulic gradient between the RGA and McNairy Flow System changes from a downward vertical gradient to an upward vertical gradient and parallels the Ohio River near the northern DOE property boundary (LMES 1996).]

The contact between the LCD and the McNairy Formation is a marked hydraulic properties boundary. Representative lateral and vertical hydraulic conductivities of the upper McNairy Formation in the area of PGDP are approximately 0.02 ft/day and 0.0005 ft/day, respectively. Vertical infiltration of groundwater into the McNairy Formation beneath PGDP is on the order of 0.1 inch per year. (Lateral flow in the McNairy Formation beneath PGDP is on the order of 0.03 inch per year.) As a result, little interchange occurs between the RGA and McNairy Flow System.

Hydrogeologic Units. Five hydrogeologic units (HUs) are commonly used to discuss the shallow groundwater flow system beneath the DOE site and the contiguous lands to the north (Figure 1.6). In descending order, the HUs are described below:

- Upper Continental Deposits
  - HU 1 (UCRS): Loess that covers the entire site.
  - HU 2 (UCRS): Discontinuous, sand and gravel lenses in a clayey silt matrix. In some areas of the plant, the HU2 interval consists of an upper sand and gravel member (HU2A) and a lower sand and gravel member (HU2B) separated by a thin silt unit.
  - HU 3 (UCRS): Relatively impermeable unit that acts as the upper semiconfining-to-confining layer for the RGA. The lithologic composition of HU 3 varies from clay to fine sand, but is predominantly silt and clay.
  - HU 4 (RGA): Near-continuous sand unit with a clayey silt matrix that forms the top of the RGA.
- Lower Continental Deposits
  - HU 5 (RGA): Gravel, sand, and silt.

1.3.2 Site History

The disposal of solid waste began with construction of the plant in 1951. Scrap and wastes have been buried in a minimum of 22 different locations, and scrap has been stored in at least five storage yards. These known areas have been identified as SWMUs or areas of concern (Union Carbide 1978).

Table 1.2 identifies the previously completed reports and/or investigations primarily used.

Reference information for these investigations can be found in Section 13.

In addition to the reports of previous investigations, the following documents provide important information on the content and volume of the Burial Grounds:

- *The Discard of Scrap Materials by Burial at the Paducah Plant* (Union Carbide 1973) and
- *The Disposal of Solid Waste at the Paducah Gaseous Diffusion Plant* (Union Carbide 1978).

The BGOU RI primarily consisted of a field investigation of the following Burial Grounds: C-749 (SWMU 2); C-404 (SWMU 3); C-746-F (SWMU 5); C-747-B (SWMU 6); C-747-A (SWMUs 7 and 30); and the residential/inert borrow area and old NSDD disposal trench (SWMU 145). C-747 (SWMU 4) is also included in the BGOU RI, but was not investigated during the RI. Historical information that is known about these SWMUs is compiled in Table 1.3.

Table 1.2. Summary of Investigations of the BGOU

Dates	Title	SWMU 2	SWMU 3	SWMU 4	SWMU 5	SWMU 6	SWMU 7	SWMU 30	SWMU 145	SWMUs 9 and 10
1989	Post Closure Permit Application C-404 Low-Level Radioactive Waste Burial Ground		✓							
1990–1992	Phase II Site Investigation	✓	✓	✓	✓	✓	✓	✓		
1996	Closure Plan C-404 Low-Level Radioactive Waste Burial Ground		✓							
1996–1997	WAG 22 SWMUs 2 and 3 Remedial Investigation and Addendum (including SWMU 2 Data Summary Report)	✓	✓							
1996–1998	WAG 22 SWMUs 7 and 30 RI/FS						✓	✓		
1998–2001	WAG 3 RI/FS			✓	✓	✓				
1999–2001	Data Gaps Investigation			✓	✓		✓	✓	✓	
2000–2001	Old NSDD Sampling								✓	
2002–2003	Scrap Yards Site Characterization				✓	✓	✓	✓		
2003–2004	C-746-S and -T Landfill Site Investigation								✓	✓
2004	Southwest Plume Site Investigation			✓						
2006	Burial Grounds RI/FS Work Plan	✓	✓	✓	✓	✓	✓	✓	✓	
2007	Burial Grounds Remedial Investigation	✓	✓	✓	✓	✓	✓	✓	✓	

Table 1.2 is based on Table 1.4 of the *Remedial Investigation Report for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0030&D2/R1, February 2010 (DOE 2010).
NSDD = North-South Diversion Ditch; SWMU = solid waste management unit; WAG = waste area group
Blank cells indicate the investigation is not applicable to the SWMU.

1.3.3 Nature and Extent of Contamination

The SWMUs comprising the BGOU consist primarily of landfills and below ground burial cells in which various PGDP wastes have been placed. Infiltration of water (i.e., precipitation) descending through the buried waste could mobilize contaminants within the waste. Once mobilized, the most likely pathway of the contaminants would be downward through the UCRS soils, ultimately reaching the RGA. Some lateral movement of contaminants would occur in the UCRS, but these pathways are known to be limited.

Table 1.3. Summary of BGOU SWMUs

Sub Unit	Dates of Operation	Area of Waste	Cap[a]	Known or Expected Contents (Special Hazards)
SWMU 2 C-749 Uranium Burial Ground				
	1951–1977	32,000 ft^2 (7-17 ft deep)	6-inch clay 18-inch soil	Uranium (including uranium metal that may be pyrophoric), waste oil [polychlorinated biphenyl (PCB?)], TCE
SWMU 3 C-404 Low-Level Radioactive Waste Burial Ground				
	1952–1986	53,000 ft^2 (8-12 ft deep)	RCRA multilayered cap	Uranium precipitated from aqueous solutions, uranium tetrafluoride, uranium metal, uranium oxides, degreasing sludge, and radioactively contaminated trash
SWMU 4 C-747 Burial Yard and C-748-B Burial Area				
C-747	1951 to 1958	8,300 ft^2 (16 ft deep)	2 to 3 ft soil 6-inch clay	Debris (radiologically contaminated) from uranium hexafluoride feed plant
C-748-B	potentially 1973–1987	278,400 ft^2 (16 ft deep)	2 to 3 ft soil 6-inch clay	Proposed chemical landfill[b]
SWMU 5 C-746-F Burial Yard				
	1965–1987	197,400 ft^2 6-15 ft deep)	2 to 3 ft soil	Radionuclide-contaminated scrap metal, slag from nickel and aluminum smelters
SWMU 6 C-747-B Burial Ground				
Area H	1971	180 ft^2 (6 ft deep)	3 ft soil	Magnesium scrap
Area I	1966	280 ft^2 (8 ft deep)	5 ft soil	Exhaust fans (contaminated with perchloric acid)
Area J	Early 1960s	4,000 ft^2 (6 ft deep)	3 ft soil	Contaminated aluminum
Area K	1968–1969	180 ft^2 (6 ft deep)	3 ft soil	Magnesium scrap
Area L	1969	600 ft^2 (6 ft deep)	3 ft soil	Modine trap
SWMU 7 C-747-A Burial Ground				
Pit B	?	10,320 ft^2 (6–7 ft deep)	3 ft soil	Noncombustible trash, contaminated material and equipment
Pit C	?	10,320 ft^2 (6–7 ft deep)	3 ft soil	Noncombustible trash, contaminated material and equipment,
Pit D	?	1,485 ft^2 (6–7 ft deep)	3 ft soil	Uranium-contaminated concrete pieces of reactor tray bases from fluorination process of uranium tetrafluoride to uranium hexafluoride
Pit E	?	2,145 ft^2 (6–7 ft deep)	3 ft soil	Uranium-contaminated concrete pieces of reactor tray bases
Pits F1–F5	?	1,600 ft^2 (6–7 ft deep)	3 ft soil	Uranium-contaminated scrap metal, equipment, empty uranium/magnesium powder drums
Pit G	?	3,294 ft^2 (6–7 ft deep)	3 ft soil	Noncombustible trash, contaminated material and equipment
SWMU 30 C-747-A Burn Area				
Pit A	1951–1970	128,000 ft^2 (12 ft deep)	4 ft soil	Ash and debris from combustible trash, possibly uranium-contaminated
SWMU 145 Area P				
	1952–1980	44 acres (individual landfills estimated 6-10 ft deep)		Construction debris, roofing materials, wire, wood, and shingles with asbestos

Table 1.3 is based on Table 1.3 of the BGOU RI (DOE 2010).
[a]The source material used for capping is unknown (with the exception of the SWMU 3 RCRA cap that came from the Old Hickory Clay Company).
[b]The "Proposed Chemical Landfill" is the only name used to describe this burial area (Union Carbide 1973).
? indicates dates of operation are not known.

1.3.3.1 Conceptual site model

Based on this conceptual model, any contamination resulting from buried waste found at the BGOU SWMUs would be expected to be found concentrated in the soils and groundwater of the UCRS immediately within and under the burial cells and landfills, with little lateral dispersion of contamination in the UCRS from the cells and immediately adjacent soils. This chapter provides an assessment of data from the BGOU RI along with data from historical investigations to evaluate the nature and extent of contamination (vertical and lateral) associated with the BGOU SWMUs.

The historical data of operational events that provide an explanation for the presence of contamination at each of the study areas is described in Section 1.3.2, Site History and in subsequent chapters. The degree to which these events impacted the surrounding areas was determined by the analytical results of the samples collected.

The conceptual site model (CSM) for the BGOU sites describes site conditions including nature and extent of contamination, contaminant fate and transport, and potential receptors. The CSM is described herein narratively and pictorially. The pictorial conceptual model, provided in Figure 1.7 summarizes the description, shows surface and subsurface conditions, and aids in visualizing the narrative information. A graphical CSM (see Figure 2.1) focuses on the sources, release mechanisms, secondary sources and transport pathways that are addressed by the BGOU RI baseline human health risk assessment (BHHRA) and the CSM is a basis for developing the RAOs. All of the CSM information provided is used in identifying and screening technologies and developing and analyzing alternatives in this FS.

1.3.3.2 DOE plant controls

Current DOE plant controls for the PGDP consist of the following:

- The sites are within areas protected from trespassing under the 1954 Atomic Energy Act as amended (referred to as the 229 Line). These areas are posted as "no trespassing" and trespassers are subject to arrest and prosecution. Physical access to the PGDP is prohibited by security fencing, and armed guards patrol the DOE property 24 hours per day to restrict workers entry and prevent uncontrolled access by the public/site visitors. These existing access controls are maintained outside of the requirements of CERCLA due to the nature and security needs of the facility (DOE 2008).

- Vehicle access to the sites is restricted by passage through Security Post 57 and by the plant vehicle protection barrier.

- The sites are in areas that are subject to routine patrol and visual inspection by plant protective forces, at a minimum once per shift.

- Protection of the current PGDP industrial workers is addressed under DOE's Integrated Safety Management System/Environmental Management System program and 29 *CFR* § 1910. Interim work area access controls that may be used under these programs during implementation of a remedy include warning and informational signage, temporary fencing and/or barricades, and visitor sign-in controls. These existing access controls are implemented for protection of worker safety and health and are outside the requirements of CERCLA. The designated locations for these interim access controls are provided in the Remedial Action Work Plan (RAWP) and depicted in a figure of appropriate scale. Upon completion of the remedial action, these interim controls would cease.

- Section XLII of the FFA requires the sale or transfer of the site to comply with Section 120(h) of CERCLA. In the event DOE determines to enter into any contract for the sale or transfer of any of

PGDP, DOE will comply with the applicable requirements of Section 120(h) in effectuating that sale or transfer, including all notice requirements. In addition, DOE will notify EPA and Kentucky of any such sale or transfer at least 90 days prior to such sale or transfer.

1.3.4 Contaminant Fate and Transport

1.3.4.1 Contaminant fate

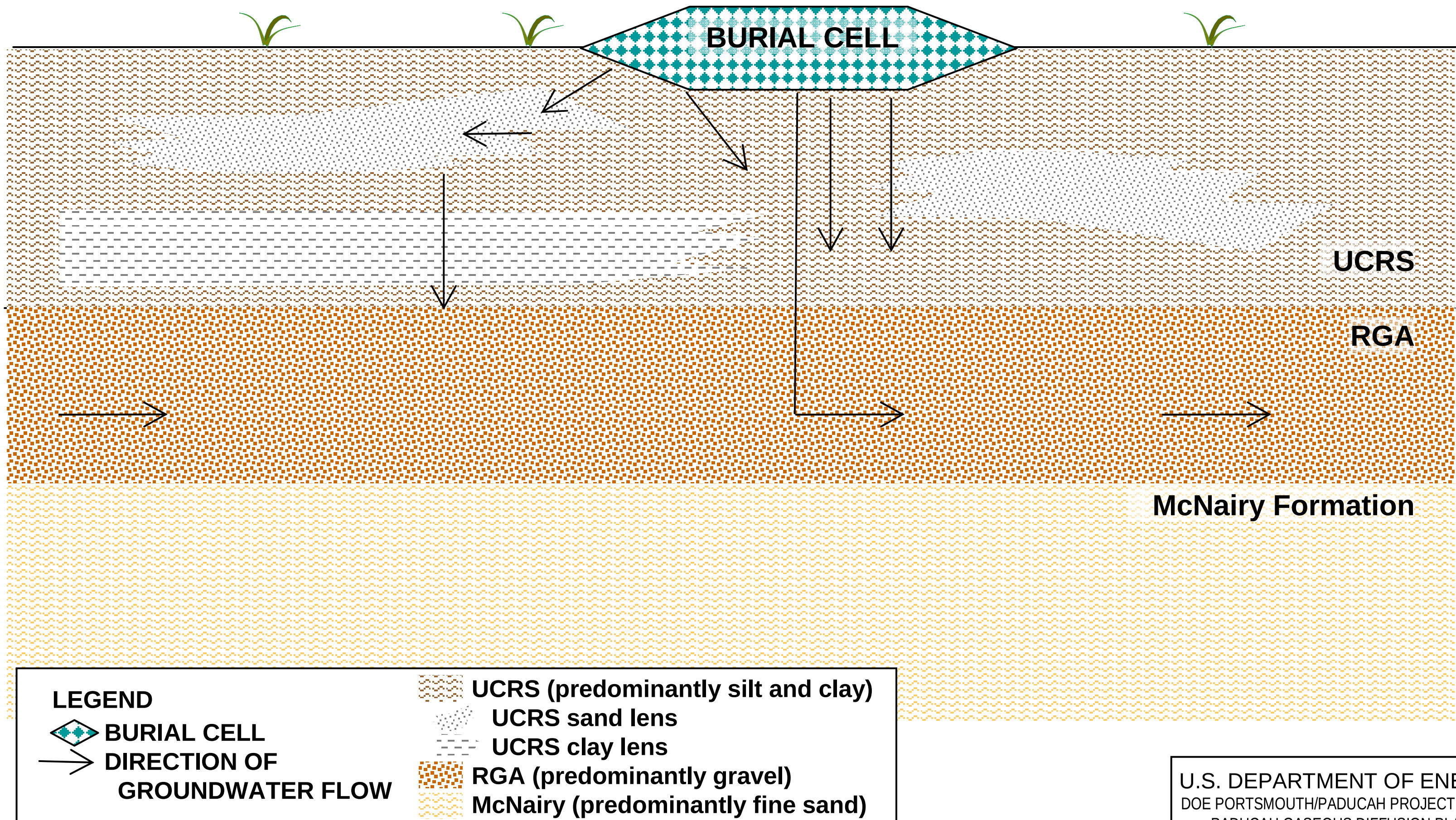
Some contaminants may be transformed to new constituents in the environment; organic compounds may decompose or be transformed by various processes including hydrolysis, oxidation/reduction, photolysis, or biological processes, and radioisotopes may decay by nuclear reactions. All transformations produce new constituents, daughter products, some of which may also have hazardous or toxic effects. Transformations of organic compounds are governed by environmental conditions, pH or oxidation reduction potential levels, and the presence of bacteria and electron donors. Transformations of radionuclides are dependent on the decay constant of the isotope alone.

TCE and its Degradation Products. TCE is identified as a COC at SWMUs 2, 4, and 7. TCE is the parent of an anerobic degradation chain that produces *cis*-1,2-dichloroethene (DCE) and vinyl chloride as daughter products. Each step in the degredation has a lower rate than TCE and requires stronger reducing conditions than those required for reduction of TCE. Degradation products of TCE are identified as COCs at the SWMUs where TCE also is identified as a COC. In addition to the anerobic pathway, aerobic biodegradation of TCE may occur under certain conditions where specialized microorganisms are present. The aerobic degredation pathway requires the presence of ammonia, methane, and toluene, and degrades TCE directly to epoxides, aldehydes, chlorinated oxides, and ethanols. TCE degredation is assumed to be occurring at the BGOU and is considered in the screening and evaluation of alternatives.

Radioisotope Decay. Although radionuclides behave chemically as metals, the radioactive nuclides undergo spontaneous transformations that involve the emission of particles (alpha and beta particles) and radiant energy (gamma energy). The resulting daughters (i.e., product nuclides) may be radioactive themselves or may be stable nuclides. Natural uranium consists of three primary isotopes: uranium-234, uranium-235, and uranium-238. Decay products of uranium isotopes also are radioactive, with unique decay chains.

1.3.4.2 Contaminant transport

The transport contaminants from the BGOU SWMUs will occur primarily in the dissolved phase, due to partitioning from the solid or adsorbed phase to infiltration from rainfall. The dissolution of contaminants will be controlled by the rate of water infiltrating through soil and waste at the waste units, the solubility of the contaminants, and equilibrium partitioning between the liquid phase and the soil, described by a partitioning coefficient: K_d. For volatile compounds, partitioning to the soil gas phase, described by a Henry's Law constant, also may be an important transport pathway. The K_d for organic compounds is a function of the organic carbon coefficient (K_{oc}) and fraction of organic carbon in the soil (f_{oc}). The range of K_{oc} for the volatile COCs and f_{oc} values for the BGOU soils indicates that chlorinated volatile organic compounds (VOCs) are relatively mobile through soils as dissolved constituents and tend not to partition significantly from water to soil (DOE 2010). The mobility of metals is dependent on soil pH and cation exchange capacity of the soils. The range of K_d for inorganic COCs is very large and some metals are expected to be relatively mobile and some are expected to be immobile. Technetium has a low K_d, is soluble, and may be mobile in soils; therefore, this radionuclide, known to be present at certain SWMUs in waste-impacted soils, has a potential to reach the RGA.



U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Figure 1.7. Pictorial Conceptual Model of the BGOU

Solvents may have been placed in some of the SWMUs as a liquid waste and as DNAPL, may form discreet masses that are immiscible with water. The transport mechanisms for a DNAPL include gravity-driven migration of this liquid as a mobile mass; however, some of the liquid may be retained in pore spaces as residual saturation. A DNAPL migrates principally under the influence of gravity and will migrate vertically, but can spread laterally by fingering out among available pore space, and may spread laterally along lower permeability zones, potentially pooling at a lower permeability zone. Capillary forces act to retain a portion of the DNAPL within the soil matrix (DNAPL at residual saturation) and remain unless there is a change in the matrix. The amount of DNAPL that will be trapped in pore space is a function of the soil texture and may range from approximately 4% to 10% of the pore space in the unsaturated soil zone to as high as 20% of the pore space in the saturated zone (Abriola *et al.* 1998). Thus, DNAPL may take a circuitous path downward and may be trapped at residual saturation within the vadose and saturated zone, or form pools at changes of lithology, making characterizing its presence difficult in the subsurface soils at the BGOU. The BGOU source areas that were identified in the BGOU RI (DOE 2010) as containing residual DNAPL TCE were based on process knowledge. TCE trends in the RGA indicate that TCE DNAPL likely is present at SWMU 4 and in the vicinity of the shared border between SWMUs 7 and 30. Concentrations of TCE at SWMU 4 suggest this potential TCE DNAPL may be present both in the waste cells and underlying soils of the UCRS and in the matrix of the RGA. TCE trends at SWMUs 7 and 30 indicate that this potential TCE DNAPL source likely is constrained to the UCRS soils. There is potential for a TCE DNAPL source at SWMU 2 based on historical disposal records; however, neither the subsurface soil nor shallow groundwater data at SWMU 2 support the presence of a DNAPL source.

1.3.4.3 Groundwater fate and transport modeling

Modeling for the BGOU RI used the Statistical Analysis and Decision Assistance (SADA), Seasonal Soil Compartment Model (SESOIL), and Analytical Transient 1-,2-,3-Dimensional (AT123D) models, consistent with Tier 3 of the modeling matrix in the PGDP Risk Methods Document (DOE 2001). SADA was used for the definition of the source terms, SESOIL for fate and transport modeling through the UCRS and AT123D for fate and transport modeling through the RGA to the points of exposure (POEs). In addition to the models used, the MODFLOW/MODPATH models were used along with the previously developed PGDP sitewide groundwater model to establish input parameters for AT123D (i.e., distances to the POEs along flow paths, hydraulic gradient, and hydraulic conductivity). These models, along with the fixed parameter values chosen for the analyses (i.e., deterministic analysis), and model implementation are discussed in detail in the BGOU RI (DOE 2010). The fate and transport modeling for the BGOU RI incorporates the sampling results of the RI and more sophisticated geospatial analysis of the source terms than those of previous models for these SWMUs; therefore, these model results differ from those of the previous models.

Modeling predicted the maximum concentration of analytes in groundwater at the boundary of each BGOU SWMU (Table 1.4). Table 1.5 presents the results of the deterministic modeling effort for the BGOU RI for the plant boundary and off-site POEs. Among the modeled analytes, arsenic, technetium-99, TCE, and related VOCs commonly exceeded maximum contaminant levels (MCLs) (EPA 2006a).

1.3.5 Baseline Human Health Risk Assessment

The BHHRA for the BGOU RI characterized the baseline risks posed to human health from contact with contaminants in soil and water at the BGOU SWMUs and at locations to which contaminants may migrate. The BHHRA utilized information collected during the RI of the BGOU SWMUs, in addition to information collected during previous investigations. Tables 1.6 through 1.13 provide summaries of the risk characterization by location presented in the RI BHHRA. They present land use scenarios of concern, COCs, and point of contacts (POCs). In addition, each table lists the following:

- Receptor risks for each land use scenario of concern.
- Percent contribution by pathway to the total risk.
- Percent contribution each COC contributes to the total risk.

Based on correspondence with the BGOU Integrated Project Team, it was determined that the excavation worker scenario evaluated in the RI Report (DOE 2010) uses exposure parameters that would not be consistent with a reasonably expected maximum exposure for an excavation worker in contact with subsurface soil at the BGOU. It was decided that the term outdoor worker better describes the future worker expected to have intimate contact with surface and subsurface soil consistent with the excavation worker exposure parameters used in the RI Report.

- SWMU 5—aluminum, arsenic, beryllium, chromium, nickel, Total polycyclic aromatic hydrocarbons (PAHs), and Total PCBs.

- SWMU 6—beryllium, chromium, nickel, and Total PAHs.

- SWMU 7—aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, manganese, nickel, uranium, vanadium, Total PAHs, Total PCBs, plutonium-239, uranium-234, uranium-235, uranium-235/236, and uranium-238.

- SWMU 30—aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, manganese, mercury, nickel, uranium, vanadium, Total PAHs, Total PCBs, uranium-234, uranium-235, uranium-235/236, and uranium-238.

Risk and hazard estimates could vary if different assumptions were used in deriving the risk estimates or if better information were available for some parameters. No uncertainties were estimated to have a large effect on the risk characterization, and only the following were estimated to have a moderate effect:

- Exclusion of some potential biota (produce and fish) for future receptors,
- Migration of groundwater to off-site receptors,
- Calculation of toxicity values for chemicals (particularly TCE), and
- Updates to toxicity values.

Table 1.4. Concentrations of the Analytes in Groundwater at the BGOU SWMU Boundaries Predicted in SESOIL and AT123D Modeling

Analyte	Predicted Maximum Groundwater Concentration (mg/L or pCi/L)[a]	MCL (mg/L or pCi/L)
SWMU 2		
Arsenic	***3.54E-02***	0.01
cis-1,2-DCE	***1.15E+01***	0.07
Manganese	7.16E-01	[b]
Naphthalene	9.38E-04	[b]
PCB-1254	1.54E-03	[b]
PCB-1260	8.73E-05	[b]
Technetium-99	1.02E+02	900[c]
TCE	***1.48E+00***	0.005
Uranium-234	1.58E+00	20[d]
Uranium-238	1.81E+00	20[d]
Uranium	9.86E-03	0.03
SWMU 3		
Arsenic	***3.29E-02***	0.01
Manganese	8.95E-01	[b]
Technetium-99	***5.560E+03***	900[c]
Uranium-238	1.59E+01	20[d]
Uranium	***4.89E-02***	0.03
SWMU 4		
Arsenic	***1.77E-02***	0.01
cis-1,2-DCE	***6.68E-01***	0.07
Manganese	5.76E-01	[b]
Technetium-99	***9.008E+03***	900[c]
TCE	***1.18E+00***	0.005
Vinyl Chloride	***2.61E-02***	0.002
SWMU 5		
Acenaphthene	6.10E-03	[b]
Arsenic	9.25E-03	0.01
Manganese	1.01E+00	[b]
Naphthalene	5.55E-03	[b]
Technetium-99	1.27E+02	900[c]
Uranium	***4.60E-01***	0.03
SWMU 6		
Manganese	8.32E-02	[b]
SWMU 7		
1,1-DCE	***8.98E-02***	0.07
Arsenic	***1.78E-02***	0.01
cis-1,2-DCE	2.35E-02	0.07
Manganese	3.32E-01	[b]
PCB-1254	5.23E-05	[b]
Technetium-99	***9.09E+02***	900[c]
TCE	***1.09E-02***	0.005
Uranium-234	7.94E+00	20[d]
Uranium-238	7.59E+00	20[d]
Uranium	3.46E-03	0.03
Vinyl Chloride	***1.35E-02***	0.002
SWMU 30		
1,1-DCE	8.18E-05	0.07
Arsenic	***1.82E-02***	0.01

Table 1.4. Concentrations of the Analytes in Groundwater at the BGOU SWMU Boundaries Predicted in SESOIL and AT123D Modeling (Continued)

Analyte	Predicted Maximum Groundwater Concentration (mg/L or pCi/L)[a]	MCL (mg/L or pCi/L)
Manganese	3.78E-01	[b]
Selenium	1.51E-02	0.05
Technetium-99	2.87E+02	900[c]
TCE	9.11E-04	0.005
Uranium-234	3.99E+00	20[d]
Uranium-238	5.91E+00	20[d]
Uranium	8.40E-03	0.03
SWMU 145		
Antimony	***7.99E-02***	0.006
Arsenic	***6.21E-02***	0.01
PCB-1260	1.92E-03	
Technetium-99	***1.01E+04***	900[c]
Manganese	8.44E-01	[b]
Uranium-238	7.67E-02	20[d]

Table 1.4 is taken from Table 5.2 of the BGOU RI (DOE 2010).
[a]Values in bold, italic font with highlight exceed the analyte's MCL.
[b]MCLs not available for these contaminants.
[c]Technetium-99 MCL based on a critical organ dose at 4 mrem/yr from drinking water consumption.
[d]The MCLs for U-234 and U-238 from Table A.20 of the Risk Methods Document (DOE 2001).

Table 1.5. Concentrations of the Analytes in Groundwater Predicted in SESOIL and AT123D Modeling of the BGOU SWMUs

Analyte	Predicted Maximum Groundwater Concentration[a,b] Plant Boundary (mg/L)	Property Boundary (mg/L)	Little Bayou seeps (mg/L)	Ohio River (mg/L)	MCL (mg/L or pCi/L)
SWMU 2					
Arsenic	2.91E-03	8.35E-09	N/A	0.00E+00	0.01
cis-1,2-DCE	***1.74E+00***	***8.58E-01***	N/A	***3.38E-01***	0.07
Manganese	1.86E-05	0.00E+00	N/A	0.00E+00	[c]
Naphthalene	1.57E-04	8.27E-05	N/A	3.42E-05	[c]
PCB-1248	1.28E-09	0.00E+00	N/A	0.00E+00	[c]
PCB-1260	0.00E+00	0.00E+00	N/A	0.00E+00	[c]
Technetium-99	1.59E+01	8.06E+00	N/A	3.11E+00	900[d]
TCE	***2.17E-01***	***1.10E-01***	N/A	***4.12E-02***	0.005
Uranium-234	1.75E-05	0.00E+00	N/A	0.00E+00	20[e]
Uranium-238	2.03E-05	0.00E+00	N/A	0.00E+00	20[e]
Uranium	8.33E-08	0.00E+00	N/A	0.00E+00	0.03
SWMU 3					
Arsenic	1.22E-03	0.00E+00	0.00E+00	N/A	0.01
Manganese	4.08E-10	0.00E+00	0.00E+00	N/A	[c]
Technetium-99	***1.81E+03***	***1.36E+03***	8.04E+02	N/A	900[d]
Uranium-238	1.59E+01	7.32E-11	0.00E+00	N/A	20[e]
Uranium	2.27E-13	0.00E+00	0.00E+00	N/A	0.03
SWMU 4					
Arsenic	2.70E-03	4.89E-06	N/A	0.00E+00	0.01
cis-1,2-DCE	***1.96E-01***	***8.94E-02***	N/A	3.16E-02	0.07
Manganese	5.01E-03	0.00E+00	N/A	0.00E+00	[c]
Technetium-99	***2.50E+03***	***1.20E+03***	N/A	3.79E+02	900[d]
TCE	***4.22E-01***	***2.14E-01***	N/A	***7.67E-02***	0.005
Vinyl Chloride	***5.95E-03***	***2.53E-03***	N/A	7.82E-04	0.002
SWMU 5					
Acenaphthene	2.42E-03	1.34E-03	N/A	5.01E-04	NA
Arsenic	1.78E-03	1.27E-04	N/A	0.00E+00	0.01
Manganese	8.69E-02	2.30E-11	N/A	0.00E+00	[c]
Naphthalene	9.82E-04	3.72E-04	N/A	1.08E-04	NA
Technetium-99	4.99E+01	2.64E+01	N/A	8.72E+00	900[d]
Uranium	***3.32E-02***	4.65E-11	N/A	0.00E+00	0.03
SWMU 6					
Manganese	1.17E-02	2.890E-04	0.00E+00	N/A	[c]
SWMU 7					
1,1-DCE	***8.24E-02***	1.10E-02	4.02E-03	N/A	0.07
Arsenic	***1.26E-02***	2.35E-03	0.00E+00	N/A	0.01
cis-1,2-DCE	2.15E-02	3.13E-03	1.17E-03	N/A	0.07
Manganese	2.41E-01	1.05E-06	0.00E+00	N/A	[c]
PCB-1254	3.09E-05	3.05E-06	1.32E-12	N/A	[c]
Technetium-99	8.25E+02	2.70E+02	1.32E+02	N/A	900[d]
TCE	***9.87E-03***	1.42E-03	5.06E-04	N/A	0.005
Uranium-234	5.79E+00	5.84E-06	0.00E+00	N/A	20[e]
Uranium-238	5.58E+00	5.85E-06	0.00E+00	N/A	20[e]
Uranium	2.53E-03	2.68E-09	0.00E+00	N/A	0.03
Vinyl Chloride	***1.24E-02***	1.21E-03	4.13E-04	N/A	0.002

Table 1.5. Concentrations of the Analytes in Groundwater Predicted in SESOIL and AT123D Modeling of the BGOU SWMUs (Continued)

Analyte	Predicted Maximum Groundwater Concentration[a,b]				
	Plant Boundary (mg/L)	Property Boundary (mg/L)	Little Bayou seeps (mg/L)	Ohio River (mg/L)	MCL (mg/L or pCi/L)
SWMU 30					
1,1-DCE	7.65E-05	6.14E-06	1.86E-06	N/A	0.07
Arsenic	***1.21E-02***	2.50E-03	0.00E+00	N/A	0.01
Manganese	2.51E-01	2.85E-04	0.00E+00	N/A	[c]
Selenium	8.30E-03	9.21E-04	3.15E-04	N/A	0.05
Technetium-99	2.64E+02	7.08E+01	2.92E+01	N/A	900[d]
TCE	8.60E-04	7.70E-05	2.60E-05	N/A	0.005
Uranium-234	2.75E+00	1.44E-03	0.00E+00	N/A	20[e]
Uranium-238	4.07E+00	1.98E-03	0.00E+00	N/A	20[e]
Uranium	4.81E-03	2.41E-06	0.00E+00	N/A	0.03
SWMU 145					
Antimony	N/A	1.51E-06	N/A	0.00E+00	0.006
Arsenic	N/A	1.61E-03	N/A	0.00E+00	0.01
PCB-1260	N/A	0.00E+00	N/A	0.00E+00	[c]
Manganese	N/A	0.00E+00	N/A	0.00E+00	[c]
Technetium-99	N/A	***1.84E+03***	N/A	***9.65E+02***	900[d]
Uranium-238	N/A	0.00E+00	N/A	0.00E+00	20[e]

Table 1.5 is taken from Table 5.3 of the BGOU RI (DOE 2010).
[a]Values in bold, italic font with highlight exceed the analyte's MCL.
[b]Radionuclide concentrations are in pCi/L.
[c]MCLs not available for these contaminants.
[d]Technetium-99 MCL based on a critical organ dose at 4 mrem/yr from drinking water consumption.
[e]The MCLs for U-234 and U-238 are from Table A.20 of the Risk Methods Document (DOE 2001).
N/A = The point of exposure is not applicable. Groundwater flow pathways do not reach the specific discharge point from this SWMU as demonstrated in the RI Report (DOE 2010).

Significant findings from the RI BHHRA are summarized below. The following are land use scenarios of concern for BGOU:

- Industrial worker: SWMUs 2, 3, 4, 5, 6, 7, and 30;
- Excavation worker (now termed outdoor worker): SWMUs 4, 5, 6, 7, and 30;
- Recreational: SWMUs 5, 7, and 30;
- On-Site Residential: SWMUs 2, 3, 4, 5, 6, 7, 30, and 145;
- Off-Site Residential: SWMUs 2, 3, 4, 5, 7, 30, and 145.

Contaminants with chemical-specific hazard indices (HIs) or ELCRs exceeding 0.1 and 1×10^{-6}, respectively are deemed COCs. Priority COCs are contaminants whose chemical-specific HI is greater than 1 or whose excess lifetime cancer risk (ELCR) is greater than 1×10^{-4} for one or more scenarios. The following are priority COCs found in soil at individual SWMUs.

- SWMU 2—none.

- SWMU 3—none.

- SWMU 4—barium, beryllium, cadmium, chromium, iron, nickel, uranium, vanadium, total dioxins/furans, Total polychlorinated biphenyls (PCBs), uranium-234, and uranium-238.

Table 1.6. Summary of Risk Characterization for SWMU 2

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker/intruder at current concentrations (soil) (from WAG 22 RI Addendum[b])	1.2E-05	^{235}U + daughters ^{238}U + daughters	83.8 10.7	External exposure	94.7	6.8E-03	*No COCs		*No COCs	
Future industrial worker at current concentrations (soil) (from WAG 22 RI Addendum[b])	1.2E-04	Arsenic ^{235}U + daughters ^{238}U + daughters	2.8 83.9 10.7	Ingestion External exposure	4.7 94.7	7.0E-02	*No COCs		*No COCs	
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	1.30E+03	Arsenic Manganese Uranium *cis*-1,2-DCE Naphthalene TCE	0.9 0.1 0.1 46.8 0.0 52.1	Ingestion Dermal Inhalation while showering Household inhalation	46.0 11.7 4.8 37.5

Table 1.6. Summary of Risk Characterization for SWMU 2 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future adult rural resident at current concentrations (RGA groundwater only)	4.72E-02	Arsenic Aroclor-1248 Aroclor-1268 TCE ^{99}Tc ^{234}U ^{238}U	2.0 0.4 0.1 97.5 0.0 0.0 0.0	Ingestion Dermal Inhalation while showering Household inhalation	19.8 11.3 7.8 61.0	3.79E+02	Arsenic Manganese Uranium *cis*-1,2-DCE Naphthalene TCE	0.9 0.1 0.1 36.8 0.0 62.1	Ingestion Dermal Inhalation while showering Household inhalation	45.0 23.9 3.5 27.5
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	NA	NA	NA	NA	NA	1.92E+02	Arsenic *cis*-1,2-DCE Naphthalene TCE	0.5 48 0.1 52	Ingestion Dermal Inhalation while showering Household inhalation	45 12.4 5.4 38
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	6.82E-03	Arsenic TCE	1.1 98.9	Ingestion Dermal Inhalation while showering Household inhalation	19.2 11.1 7.9 61.8	5.08E+01	Arsenic *cis*-1,2-DCE Naphthalene TCE	0.5 16.2 0.1 83.1	Ingestion Dermal Inhalation while showering Household inhalation	60 32 1 7.2
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA	9.56E+01	*cis*-1,2-DCE TCE	47.4 52.6	Ingestion Dermal Inhalation while showering Household inhalation	45.4 11.8 4.9 38.0
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	3.42E-03	TCE	100	Ingestion Dermal Inhalation while showering Household inhalation	18.3 11.2 8.0 62.5	2.79E+01	*cis*-1,2-DCE TCE	37.3 62.7	Ingestion Dermal Inhalation while showering Household inhalation	44.4 24.1 3.6 27.9
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	NA	NA	NA	NA	NA	2.25E+01	*cis*-1,2-DCE TCE	79.4 20.5	Ingestion Dermal Inhalation while showering Household inhalation	16.2 18.8 7.4 57.7
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	1.28E-03	TCE	100	Ingestion Dermal Inhalation while showering Household inhalation	18.3 11.2 8.0 62.5	6.7E+00	*cis*-1,2-DCE TCE	61.2 38.7	Ingestion Dermal Inhalation while showering Household inhalation	15.5 37.7 5.3 41.5

Table 1.6 is taken from Table 6.6 of the BGOU RI (DOE 2010).
ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern
Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.
. *No COCs = there are no COCs or POCs at this SWMU for this endpoint (may apply to ELCR or HI)
[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.
[b] RI Addendum for WAG 22 (DOE 1994). Attachment 2-1 through 2-6. This risk assessment combined SWMU 2 and 3.

Table 1.7. Summary of Risk Characterization for SWMU 3

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker/intruder at current concentrations (soil) (from WAG 22 RI Addendum[b])	1.2E-05	^{235}U + daughters ^{238}U + daughters	83.8 10.7	External exposure	94.7	6.8E-03	*No COCs		*No COCs	NE
Future industrial worker at current concentrations (soil) (from WAG 22 RI Addendum[b])	1.2E-04	Arsenic ^{235}U + daughters ^{238}U + daughters	2.8 83.9 10.7	Ingestion External exposure	4.7 94.7	7.0E-02	*No COCs		*No COCs	NE
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	2.03E+01	Arsenic Manganese Uranium	51.9 9.6 38.6	Ingestion Dermal	99.5 0.5
Future adult rural resident at current concentrations (RGA groundwater only)	1.20E-03	Arsenic ^{99}Tc ^{238}U	72.4 25.3 2.3	Ingestion Dermal	99.8 0.2	5.83E+00	Arsenic Manganese Uranium	51.7 9.9 38.3	Ingestion Dermal	98.9 1.1
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	NA	NA	NA	NA	NA	3.98E-01	Arsenic	100	Ingestion	97.9
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	1.32E-04	Arsenic ^{99}Tc	24.6 75.4	Ingestion	99.9	1.12E-01	Arsenic	100	Ingestion	99.6
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA		*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	7.46E-05	^{99}Tc	100	Ingestion	100		*No COCs		*No COCs	

Table 1.7. Summary of Risk Characterization for SWMU 3 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future child rural resident at modeled concentrations (RGA groundwater drawn at Little Bayou seeps)	NA	NA	NA	NA	NA		*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Little Bayou seeps)	4.41E-05	^{99}Tc	100.0	Ingestion	100		*No COCs		*No COCs	
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		Not a POE for groundwater from this SWMU.								
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		Not a POE for groundwater from this SWMU.								

Table 1.7 is taken from Table 6.7 of the BGOU RI (DOE 2010).
ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern
Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.
*No COCs = there are no COCs or POCs.
[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.
[b] RI Addendum for WAG 22 (DOE 1994). Attachment 2-1 through 2-6. This risk assessment combined SWMU 2 and 3.

Table 1.8. Summary of Risk Characterization for SWMU 4

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil) (WAG 3 RI[b])	5.4E-04	Beryllium ^{238}U	97 2	Dermal External exposure	97 2	3.62E+00	Beryllium Chromium Iron Vanadium Barium	5 45 24 24 2	Dermal	99
Future industrial worker at current concentrations (soil) (WAG 3 RI[b])	5.4E-04	Beryllium ^{238}U	97 2	Dermal External exposure	97 2	3.62E+00	Beryllium Chromium Iron Vanadium Barium	5 45 24 24 2	Dermal	99
Future child rural resident at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	9.82E+01	Barium Beryllium Cadmium Chromium Iron Nickel Vanadium	2 2 2 24 60 2 9	Ingestion Dermal Ingestion of vegetables	1 21 78
Future adult rural resident at current concentrations (soil) (WAG 3 RI[b])	4.3E-03	Beryllium Total PCB ^{234}U ^{238}U	72 5 6 17	Dermal External exposure Ingestion of vegetables	36 2 61	2.84E+01	Barium Beryllium Cadmium Chromium Iron Nickel Vanadium	2 2 2 22 63 2 8	Dermal Ingestion of vegetables	14 85
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	5.82E+02	Arsenic Manganese *cis*-1,2-DCE TCE Vinyl Chloride	1.0 0.2 6.1 92.5 0.2	Ingestion Dermal Inhalation while showering Household inhalation	67.2 20.2 1.4 11.2
Future adult rural resident at current concentrations (RGA groundwater only)	5.41E-02	Arsenic TCE Vinyl chloride ^{99}Tc	0.9 67.7 30.5 0.9	Ingestion Dermal Inhalation while showering Household inhalation	15.4 36.7 5.4 42.4	1.98E+02	Arsenic Manganese *cis*-1,2-DCE TCE Vinyl chloride	0.8 0.2 4.1 94.7 0.2	Ingestion Dermal Inhalation while showering Household inhalation	56.5 35.6 0.9 7.0
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	NA	NA	NA	NA	NA	2.04E+02	Arsenic *cis*-1,2-DCE TCE Vinyl chloride	0.4 4.6 94.4 0.1	Ingestion Dermal Inhalation while showering Household inhalation	67.5 20.6 1.4 10.6

Table 1.8. Summary of Risk Characterization for SWMU 4 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	2.03E-02	Arsenic TCE Vinyl chloride ^{99}Tc	0.4 98.0 0.9 0.7	Ingestion Dermal Inhalation while showering Household inhalation	13.6 7.2 5.2 74.0	6.97E+01	Arsenic *cis*-1,2-DCE TCE	0.4 3.0 96.6	Ingestion Dermal Inhalation while showering Household inhalation	56.5 36.1 0.8 6.6
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA	1.03E+02	*cis*-1,2-DCE TCE Vinyl chloride	4.6 95.3 0.1	Ingestion Dermal Inhalation while showering Household inhalation	67.6 20.8 1.3 10.3
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	6.79E-03	TCE Vinyl chloride ^{99}Tc	97.9 1.1 1.0	Ingestion Dermal Inhalation while showering Household inhalation	19.8 11.0 7.8 61.3	3.51E+01	*cis*-1,2-DCE TCE	3.1 96.8	Ingestion Dermal Inhalation while showering Household inhalation	56.4 36.3 0.8 6.4
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	NA	NA	NA	NA	NA	3.33E+01	*cis*-1,2-DCE TCE	1.7 98.2	Ingestion Dermal Inhalation while showering Household inhalation	74.6 22.9 1.4 1.0
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	2.43E-03	TCE Vinyl chloride ^{99}Tc	98.2 0.9 0.9	Ingestion Dermal Inhalation while showering Household inhalation	19.6 11.0 7.9 61.5	1.26E+01	*cis*-1,2-DCE TCE	3.0 96.9	Ingestion Dermal Inhalation while showering Household inhalation	56.4 36.3 0.8 6.4
Future child recreational user at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	< 1	*No COCs		*No COCs	
Future teen recreational user at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	< 1	*No COCs		*No COCs	
Future adult recreational user at current concentrations (soil) (WAG 3 RI[b])	< 1.0E-06	*No COCs		*No COCs		< 1	*No COCs		*No COCs	
Future excavation worker at current concentrations (soil and waste) (WAG 3 RI[b])	2.7E-03	Arsenic Beryllium Total dioxins/furans Total PCB ^{226}Ra Total uranium[c] ^{238}U	1 7 4 2 2 83 1	Ingestion Dermal External exposure	37 10 54	2.61E+00	Aluminum Arsenic Barium Beryllium Cadmium Chromium Iron Manganese Vanadium	8 4 2 2 1 24 24 14 20	Ingestion Dermal	13 87

Table 1.8 is taken from Table 6.8 of the BGOU RI (DOE 2010). ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern; Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen. *No COCs = There are no COCs or POCs. [a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs. [b] WAG 3 RI (DOE 2000a), Table 1.55. In this table, lead has been excluded as a COC. [c] Risk associated with total uranium at SWMU 4 was calculated using a total uranium analytical result in pCi/g units and toxicity information for ^{238}U. Individual isotopes also were included in the risk calculation, resulting in a double-counting of risk due to uranium isotopes. This approach likely accounts for the discrepancy between risk related to total uranium and ^{238}U.

Table 1.9. Summary of Risk Characterization for SWMU 5

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil) (WAG 3 RI[b])	4.1E-04	Arsenic Beryllium Total PAH	6 49 45	Ingestion Dermal	2 98	< 1	*No COCs		*No COCs	
Future industrial worker at current concentrations (soil) (WAG 3 RI[b])	4.1E-04	Arsenic Beryllium Total PAH	6 49 45	Ingestion Dermal	2 98	< 1	*No COCs		*No COCs	
Future child rural resident at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	4.62E+01	Aluminum Arsenic Beryllium Chromium Nickel Zinc	24 53 1 17 3 1	Ingestion Dermal Ingestion of vegetables	1 12 87
Future adult rural resident at current concentrations (soil) (WAG 3 RI[b])	>1.0E-02*	Arsenic Beryllium Total PAH Total PCB	21 9 68 2	Dermal Ingestion of vegetables	9 90	1.39E+01	Aluminum Arsenic Beryllium Chromium Nickel Zinc	24 55 1 15 3 1	Dermal Ingestion of vegetables	8 92
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	8.15E+01	Uranium Arsenic Manganese Naphthalene	90.3 3.6 2.6 3.4	Ingestion Dermal Inhalation while showering Household inhalation	96.4 0.2 0.4 3.0
Future adult rural resident at current concentrations (RGA groundwater only)	2.52E-04	Arsenic ^{99}Tc	97.2 2.8	Ingestion Dermal	99.7 0.3	2.31E+01	Uranium Arsenic Manganese Naphthalene	91.0 3.7 2.7 2.6	Ingestion Dermal Inhalation while showering Household inhalation	97.1 0.3 0.3 2.3
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	NA	NA	NA	NA	NA	6.56E+00	Uranium Arsenic Manganese Naphthalene	81 9 27.5	Ingestion Household inhalation	92.4 6.6
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	4.99E-05	Arsenic ^{99}Tc	94.5 5.5	Ingestion	99.7	1.84E+00	Uranium Arsenic Naphthalene Manganese	82.4 8.9 5.8 2.1	Ingestion Household inhalation	93.9 5.1

Table 1.9. Summary of Risk Characterization for SWMU 5 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA	2.28E-01	Naphthalene	82.2	Household inhalation	72.0
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	4.81E-06	Arsenic ^{99}Tc	69.9 30.1	Ingestion	99.8	<0.1	*No COCs		*No COCs	
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	NA	NA	NA	NA	NA		*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		*No COCs		*No COCs			*No COCs		*No COCs	
Future child recreational user at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	< 1	*No COCs		*No COCs	
Future teen recreational user at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	< 1	*No COCs		*No COCs	
Future adult recreational user at current concentrations (soil) (WAG 3 RI[b])	1.0E-05	Arsenic Total PAH Total PCB	2 96 2	Ingestion of venison Ingestion of rabbit Ingestion of quail	16 63 21	< 1	*No COCs		*No COCs	
Future excavation worker at current concentrations (soil and waste) (WAG 3 RI[b])	2.9E-04	Arsenic Beryllium Total PAH Total PCB	8 62 28 1	Ingestion Dermal	13 87	2.16E+00	Aluminum Arsenic Barium Beryllium Chromium Iron Manganese	9 7 2 3 18 38 22	Ingestion Dermal	18 82

Table 1.9 is taken from Table 6.9 of the BGOU RI (DOE 2010).
ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern
Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.
*No COCs = There are no COCs or POCs.
* = The ELCR is approximate because the linearized multistage model returns imprecise values at risks > 1.0E-02.
[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.
[b] WAG 3 RI (DOE 2000a), Table 1.56. In this table, lead has been excluded as a COC.

Table 1.10. Summary of Risk Characterization for SWMU 6

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil) (WAG 3 RI[b])	2.4E-04	Beryllium Total PAH	90 10	Dermal	99	< 1	*No COCs		*No COCs	
Future industrial worker at current concentrations (soil) (WAG 3 RI[b])	2.4E-04	Beryllium Total PAH	90 10	Dermal	99	< 1	*No COCs		*No COCs	
Future child rural resident at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	9.38E+00	Beryllium Chromium Nickel Zinc	8 72 15 5	Dermal Ingestion of vegetables	34 65
Future adult rural resident at current concentrations (soil) (WAG 3 RI[b])	2.4E-03	Beryllium Total PAH	54 46	Dermal Ingestion of vegetables	30 69	2.57E+00	Beryllium Chromium Nickel Zinc	7 70 17 6	Dermal Ingestion of vegetables	24 75
Future child rural resident at current concentrations (RGA groundwater only)		*No COCs		*No COCs		1.77E-01	Manganese	100	Ingestion of water Dermal	97.9 2.1
Future adult rural resident at current concentrations (RGA groundwater only)		*No COCs		*No COCs		5.18E-02	Manganese	100	Ingestion of water Dermal	95.7 4.3
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)		*No COCs		*No COCs			*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)		*No COCs		*No COCs			*No COCs		*No COCs	
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)		*No COCs		*No COCs			*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)		*No COCs		*No COCs			*No COCs		*No COCs	
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		*No COCs		*No COCs			*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		*No COCs		*No COCs			*No COCs		*No COCs	

Table 1.10. Summary of Risk Characterization for SWMU 6 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future child recreational user at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	< 1	*No COCs		*No COCs	
Future teen recreational user at current concentrations (soil) (WAG 3 RI[b])	NA	NA	NA	NA	NA	< 1	*No COCs		*No COCs	
Future adult recreational user at current concentrations (soil) (WAG 3 RI[b])	< 1.0E-06	*No COCs		*No COCs		< 1	*No COCs		*No COCs	
Future excavation worker at current concentrations (soil and waste) WAG 3 RI[b])	2.3E-04	Beryllium Total PAH	90 9	Ingestion Dermal	5 95	2.44E+00	Aluminum Barium Beryllium Chromium Iron Manganese Vanadium	8 2 3 15 32 15 26	Ingestion Dermal	12 88

Table 1.10 is taken from Table 6.10 of the BGOU RI (DOE 2010).
ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern
Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.
* There are no COCs or POCs.
[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.
[b] WAG 3 RI (DOE 2000a), Table 1.57. In this table, lead has been excluded as a COC.

Table 1.11. Summary of Risk Characterization for SWMU 7

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil) (from WAG 22 RI[b])	3.8E-03	Arsenic Beryllium Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np ^{234}U ^{235}U $^{235/236}U$ ^{238}U	0.6 97.6 <0.1 0.3 <0.1 0.4 0.1 <0.1 <0.1 0.2 0.3 2.1	Ingestion Dermal External exposure	0.5 97.4 2.5	5.0E+00	Aluminum Antimony Arsenic Beryllium Chromium Iron Manganese Uranium Vanadium	4.1 4.4 2.6 9.6 13.6 20.6 10.7 13.7 17.7	Ingestion Dermal	3.6 96.4
Future industrial worker at current concentrations (soil) (from WAG 22 RI[b])	3.9E-03	Arsenic Beryllium Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np ^{234}U ^{235}U $^{235/236}U$ ^{238}U	0.6 96.0 <0.1 0.3 <0.1 0.4 0.1 <0.1 <0.1 0.2 0.3 2.1	Ingestion Dermal External exposure	0.5 97.1 2.4	5.0E+00	Aluminum Antimony Arsenic Beryllium Chromium Iron Manganese Uranium Vanadium	4.1 4.4 2.6 9.6 13.6 20.6 10.7 13.7 17.7	Ingestion Dermal	3.6 96.4
Future child rural resident at current concentrations (soil) (from WAG 22 RI[b])	NA	NA	NA	NA	NA	3.7E+02	Aluminum Antimony Arsenic Barium Beryllium Cadmium Chromium Cobalt Copper Iron Manganese Nickel Uranium Vanadium Zinc Aroclor-1254	2.7 0.9 6.2 0.3 1.3 0.8 2.7 0.1 0.3 19.7 1.9 0.4 58.4 2.4 0.2 1.7	Ingestion Dermal Ingestion of vegetables from soil	1.4 7.7 90.9

Table 1.11. Summary of Risk Characterization for SWMU 7 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future adult rural resident at current concentrations (soil) (from WAG 22 RI[b])	3.4E-02	Arsenic	7.3	Ingestion	0.5	1.1E+02	Aluminum	2.7	Ingestion	0.5
		Beryllium	65.4	Dermal	33.0		Antimony	0.8	Dermal	5.0
		Aroclor-1254	0.2	External exposure	1.9		Arsenic	6.5	Ingestion of vegetables from soil	94.6
		Aroclor-1260	0.4	Ingestion of vegetables from soil	64.6		Barium	0.3		
		Benzo(a)anthracene	0.2				Beryllium	1.1		
		Benzo(a)pyrene	1.7				Cadmium	0.8		
		Benzo(b)fluoranthene	0.2				Chromium	2.3		
		Benzo(k)fluoranthene	<0.1				Copper	0.3		
		Dibenzo(a,h)anthracene	1.9				Iron	19.8		
		Indeno(1,2,3-cd)pyrene	0.3				Manganese	1.6		
		^{237}Np	0.2				Nickel	0.4		
		^{239}Pu	0.4				Uranium	59.5		
		^{234}U	3.3				Vanadium	2.0		
		^{235}U	0.3				Zinc	0.2		
		$^{235/236}$U	0.5				Aroclor-1254	1.7		
		^{238}U	17.6							
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	1.89E+01	Arsenic	30.2	Ingestion	60.9
							Manganese	3.7	Dermal contact	21.0
							Uranium	2.9	Inhalation while showering	2.0
							1,1-DCE	4.5	Inhalation household use	16.0
							cis-1,2-DCE	6.6		
							Aroclor-1254	22.3		
							TCE	26.4		
							Vinyl chloride	3.4		
Future adult rural resident at current concentrations (RGA groundwater only)	3.13E-03	Arsenic	15.1	Ingestion	61.2	6.39E+00	Arsenic	25.5	Ingestion	51.4
		1,1-DCE	66.4	Dermal contact	3.7		Manganese	3.2	Dermal contact	37.2
		Total PCBs	0.2	Inhalation while showering	4.9		Uranium	2.5	Inhalation while showering	1.3
		TCE	4.1				1,1-DCE	3.1	Inhalation household use	10.1
		Vinyl chloride	11.9	Inhalation during household use	30.3		*cis*-1,2-DCE	4.5		
		^{99}Tc	1.6				Total PCBs	31.4		
		^{234}U	0.4				TCE	27.1		
		^{238}U	0.4				Vinyl chloride	2.7		

Table 1.11. Summary of Risk Characterization for SWMU 7 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	NA	NA	NA	NA	NA	1.45E+01	Arsenic Manganese Uranium 1,1-DCE *cis*-1,2-DCE Total PCBs TCE Vinyl chloride	27.9 3.6 2.8 5.4 7.9 17.2 31.2 4.1	Ingestion Dermal contact Inhalation while showering Inhalation household use	62.3 18.7 2.2 16.9
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	2.98E-03	Arsenic 1,1-DCE Total PCBs TCE Vinyl chloride ^{99}Tc ^{234}U ^{238}U	11.2 63.9 0.2 10.3 12.3 1.5 0.3 0.3	Ingestion Dermal contact Inhalation while showering Inhalation during household use	55.4 3.4 4.7 36.5	4.78E+00	Arsenic Manganese Uranium 1,1-DCE *cis*-1,2-DCE Total PCBs TCE Vinyl chloride	24.2 3.1 2.4 3.8 5.5 24.8 32.9 3.3	Ingestion of groundwater Dermal contact Inhalation household use	53.8 33.8 11.0
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA	1.97E+00	Arsenic 1,1-DCE *cis*-1,2-DCE Total PCBs TCE	38.1 5.3 8.4 12.4 32.9	Ingestion Dermal contact Inhalation household use	66.3 15.8 15.9
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	4.11E-04	Arsenic 1,1-DCE TCE Vinyl chloride ^{99}Tc	15.1 61.8 10.7 8.7 3.6	Ingestion Dermal contact Inhalation while showering Inhalation during household use	56.7 3.2 4.5 35.5	6.36E-01	Arsenic Total PCBs TCE	33.9 18.4 35.5	Ingestion Dermal contact	58.8 29.3
Future child rural resident at modeled concentrations (RGA groundwater drawn at Little Bayou seeps)	NA	NA	NA	NA	NA	3.373E-01	TCE	61.0	Ingestion Inhalation household use	52.5 30.0
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Little Bayou seeps)	1.28E-04	1,1-DCE TCE Vinyl chloride ^{99}Tc	72.6 12.3 9.5 5.7	Ingestion Dermal contact Inhalation while showering Inhalation during household use	49.6 3.6 5.3 41.4	1.15E-01	*No COCs		*No COCs	

Table 1.11. Summary of Risk Characterization for SWMU 7 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		Not a POE for groundwater from this SWMU.								
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		Not a POE for groundwater from this SWMU.								
Future child recreational user at current concentrations (from WAG 22 RI[b])	NA	NA	NA	NA	NA	7.3E-02	*No COCs		*No COCs	
Future teen recreational user at current concentrations (from WAG 22 RI[b])	NA	NA	NA	NA	NA	6.4E-02	*No COCs		*No COCs	
Future adult recreational user at current concentrations (from WAG 22 RI[b])	1.1E-05	Aroclor-1260 Benzo(a)pyrene Dibenzo(a,h)anthracene ^{238}U	18.6 9.5 42.5 15.7	Ingestion of deer Ingestion of rabbit Ingestion of quail	10.0 70.9 21.8	7.5E-02	*No COCs		*No COCs	
Future excavation worker at current concentrations (soil) (from WAG 22 RI[b])	1.6E-03	Arsenic Beryllium Benzo(a)pyrene Dibenzo(a,h)anthracene ^{237}Np ^{239}Pu ^{234}U ^{235}U $^{235/236}U$ ^{238}U	1.8 42.2 0.1 1.7 0.4 0.5 3.4 9.1 0.4 41.3	Ingestion Dermal External exposure	25.6 43.8 32.5	5.4E+00	Aluminum Antimony Arsenic Chromium Copper Iron Manganese Nickel Uranium Vanadium	5.0 11.3 3.4 17.6 2.9 21.3 11.0 3.9 7.5 10.9	Ingestion Dermal	18.4 81.5

Table 1.11 is taken from Table 6.11 of the BGOU RI (DOE 2010).
ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern
Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.
*No COCs = There are no COCs or POCs.
[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.
[b] RI for SWMUs 7 and 30 (DOE 1998a), Tables 1.59 through 1.68, excluding lead as a COC.

Table 1.12. Summary of Risk Characterization for SWMU 30

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Current industrial worker at current concentrations (soil) (from WAG 22 RI[b])	3.7E-03	Arsenic Beryllium Aroclor-1260 Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np ^{234}U ^{235}U $^{235/236}$U ^{238}U	0.5 97.5 0.1 0.1 0.8 0.1 0.3 0.1 <0.1 <0.1 0.2 0.3 1.4	Ingestion Dermal External exposure	0.5 97.3 1.7	4.4E+00	Aluminum Antimony Arsenic Beryllium Cadmium Chromium Iron Manganese Uranium Vanadium	5.1 3.7 2.7 10.8 3.5 13.5 19.8 11.3 9.0 17.6	Ingestion Dermal	2.9 97.1
Future industrial worker at current concentrations (soil) (from WAG 22 RI[b])	3.8E-03	Arsenic Beryllium Aroclor-1260 Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np ^{34}U ^{35}U $^{235/236}$U ^{238}U	0.5 96.2 0.1 0.1 0.8 0.1 0.3 0.1 <0.1 <0.1 0.2 0.3 1.4	Ingestion Dermal External exposure	0.5 97.8 1.7	4.4E+00	Aluminum Antimony Arsenic Beryllium Cadmium Chromium Iron Manganese Uranium Vanadium	5.1 3.7 2.7 10.8 3.5 13.5 19.8 11.3 9.0 17.6	Ingestion Dermal	2.9 97.1
Future child rural resident at current concentrations (soil) (from WAG 22 RI[b])	NA	NA	NA	NA	NA	2.6E+02	Aluminum Antimony Arsenic Barium Beryllium Cadmium Chromium Copper Iron Manganese Mercury Nickel Uranium Vanadium Zinc Aroclor-1254	4.1 0.9 7.5 0.6 1.8 2.2 3.2 0.6 22.6 2.5 0.7 0.8 46.8 3.0 0.2 2.6	Ingestion Dermal Ingestion of vegetables from soil	1.3 9.4 89.3

Table 1.12. Summary of Risk Characterization for SWMU 30 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future adult rural resident at current concentrations (soil) (from WAG 22 RI[b])	3.2E-02	Arsenic Beryllium Aroclor-1254 Aroclor-1260 Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene bis(2-ethylhexyl)phthalate Chrysene Dibenzo(a,h)anthracene Indeno(1,2,3-cd)pyrene ^{237}Np ^{234}U ^{235}U $^{235/236}U$ ^{238}U	6.8 66.7 0.2 1.8 0.4 4.4 0.5 <0.1 <0.1 <0.1 1.7 0.4 0.2 4.5 0.3 0.6 11.5	Ingestion Dermal External exposure Ingestion of vegetables from soil	0.5 35.4 1.3 62.8	7.9E+01	Aluminum Antimony Arsenic Barium Beryllium Cadmium Chromium Copper Iron Manganese Mercury Nickel Uranium Vanadium Zinc Aroclor-1254	4.1 0.8 7.9 0.6 1.5 2.2 2.9 0.6 22.8 2.1 0.7 0.9 47.5 2.4 0.2 2.7	Ingestion Dermal Ingestion of vegetables from soil	0.5 6.1 93.4
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	9.14E+00	Arsenic Manganese Selenium Uranium 1,1-DCE TCE	63.8 8.8 3.2 14.7 5 4.6	Ingestion Dermal contact Inhalation while showering Inhalation household use	93.3 1.3 0.6 4.7
Future adult rural resident at current concentrations (RGA groundwater only)	5.44E-04	Arsenic 1,1-DCE TCE ^{99}Tc ^{234}U ^{238}U	88.6 0.3 5.2 2.9 1 1.3	Ingestion Dermal contact Inhalation while showering Inhalation household use	95.3 0.9 0.4 3.4	3.31E+00	Arsenic Manganese Selenium Uranium 1,1-DCE TCE	50.5 7.1 2.5 11.6 23.9 4.4	Ingestion Dermal contact Inhalation while showering Inhalation household use	88.8 9.8 0.2 1.2
Future child rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	NA	NA	NA	NA	NA	6.14E+00	Arsenic Manganese Selenium Uranium 1,1-DCE TCE	63.1 8.7 2.6 12.5 0.1 12.9	Ingestion of groundwater Dermal contact Inhalation while showering Inhalation household use	91.1 1.7 0.1 7.1
Future adult rural resident at modeled concentrations (RGA groundwater drawn at plant boundary)	3.75E-04	Arsenic 1,1-DCE TCE ^{99}Tc ^{234}U ^{238}U	85.6 0.5 7.1 3.9 1 1.9	Ingestion Dermal contact Inhalation while showering Inhalation household use	93.6 1.1 0.6 4.7	2.10E+00	Arsenic Manganese Selenium Uranium 1,1-DCE TCE	52.9 7.4 2.2 10.5 0.4 26.6	Ingestion Dermal contact Inhalation while showering Inhalation household use	76.1 3 0 20.8

Table 1.12. Summary of Risk Characterization for SWMU 30 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA	8.40E-01	Arsenic Selenium 1,1-DCE TCE Manganese	89.2 2.1 0.1 8.5 0.1	Ingestion Dermal contact Inhalation while showering Inhalation household use	94.2 1.1 0 4.6
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	6.85E-05	Arsenic 1,1-DCE TCE Technetium-99	90.6 0.2 3.5 5.7	Ingestion Dermal contact Inhalation while showering Inhalation household use	96.7 0.7 0.3 2.3	2.76E-01	Arsenic Selenium 1,1-DCE TCE Manganese	77.9 1.8 0.3 19.9 0.1	Ingestion Dermal contact Inhalation while showering Inhalation household use	82 2 1.8 14.2
Future child rural resident at modeled concentrations (RGA groundwater drawn at Little Bayou seeps)	NA	NA	NA	NA	NA	3.02E-02	Selenium 1,1-DCE TCE	20 0.6 79.3	Ingestion Dermal contact Inhalation household use	47.5 8.6 0.4 43.5
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Little Bayou seeps)	2.45E-06	1,1-DCE TCE ^{99}Tc	1.8 32.9 65.3	Ingestion Dermal contact Inhalation while showering Inhalation household use	72.1 3.7 2.7 21.4	9.17E-03	Selenium 1,1-DCE TCE	18.9 2.3 78.8	Ingestion Dermal contact Inhalation while showering Inhalation household use	44.7 17 18.3 20
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		Not a POE for groundwater from this SWMU								
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)		Not a POE for groundwater from this SWMU								
Future child recreational user at current concentrations (from WAG 22 RI[b])	NA	NA	NA	NA	NA	4.2E-02	*No COCs		*No COCs	
Future teen recreational user at current concentrations (from WAG 22 RI[b])	NA	NA	NA	NA	NA	3.8E-02	*No COCs		*No COCs	

Table 1.12. Summary of Risk Characterization for SWMU 30 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future adult recreational user at current concentrations (from WAG 22 RI[b])	1.5E-05	Aroclor-1260	48.2	Ingestion of deer	8.7	4.3E-02	*No COCs		*No COCs	
		Benzo(a)pyrene	12.9	Ingestion of rabbit	80.0					
		Dibenzo(a,h)anthracene	20.8	Ingestion of quail	11.3					
Future excavation worker at current concentrations (soil) (from WAG 22 RI[b])	1.2E-03	Arsenic	1.9	Ingestion	6.3	4.5E+00	Aluminum	4.6	Ingestion	26.4
		Beryllium	93.7	Dermal	91.7		Antimony	6.3	Dermal	73.5
		Aroclor-1248	0.1	External exposure	3.3		Arsenic	3.3		
		Benzo(a)anthracene	0.1				Beryllium	3.8		
		Benzo(a)pyrene	0.8				Cadmium	3.0		
		Benzo(b)fluoranthene	0.1				Chromium	10.2		
		Dibenzo(a,h)anthracene	0.4				Copper	7.6		
		Indeno(1,2,3-cd)pyrene	0.1				Iron	19.8		
		^{237}Np	0.3				Manganese	14.3		
		^{239}Pu	0.2				Uranium	12.2		
		^{234}U	0.8				Vanadium	12.7		
		^{235}U	0.1							
		$^{235/236}U$	0.8							
		^{238}U	0.6							

Table 1.12 is taken from Table 6.12 of the BGOU RI, October 2009 (DOE 2010).
ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern
Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.
[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.
[b] RI for SWMUs 7 and 30 (DOE 1998a), Tables 1.59 through 1.68, excluding lead as a COC.

Table 1.13. Summary of Risk Characterization for SWMU 145

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future child rural resident at current concentrations (RGA groundwater only)	NA	NA	NA	NA	NA	4.17E+01	Antimony Arsenic Manganese	48.0 47.7 4.3	Ingestion Dermal contact	97.8 2.2
Future adult rural resident at current concentrations (RGA groundwater only)	3.27E-02	Arsenic ^{99}Tc Aroclor-1260	5.1 1.7 93.2	Ingestion Dermal contact	6.9 93.1	1.22E+01	Antimony Arsenic Manganese	49.0 46.7 4.3	Ingestion Dermal contact	95.5 4.5
Future child rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	NA	NA	NA	NA	NA	5.16E-01	Arsenic	99.9	Ingestion	99.8
Future adult rural resident at modeled concentrations (RGA groundwater drawn at property boundary)	1.44E-04	Arsenic ^{99}Tc	29.7 70.3	Ingestion	99.9	1.48E-01	Arsenic	99.9	Ingestion	99.6
Future child rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	NA	NA	NA	NA	NA		*No COCs		*No COCs	
Future adult rural resident at modeled concentrations (RGA groundwater drawn at Ohio River)	5.29E-05	^{99}Tc	100.0	Ingestion	100		*No COCs		*No COCs	
Future child recreational user at current concentrations (soil)	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

Table 1.13. Summary of Risk Characterization for SWMU 145 (Continued)

Receptor	Total ELCR[a]	COCs	% Total ELCR	POCs	% Total ELCR	Total HI[a]	COCs	% Total HI	POCs	% Total HI
Future teen recreational user at current concentrations (soil)	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Future adult recreational user at current concentrations (soil)	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Future excavation worker at current concentrations	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

Table 1.13 is taken from Table 6.13 of the BGOU RI (DOE 2010).
ELCR = excess lifetime cancer risk; HI = hazard index; POC = point of contact; COC = contaminant of concern
Note: NA = ELCR not applicable to child and teen cohorts. ELCR for adult is for lifetime exposure and takes into account exposure as child and teen.
NE = not evaluated: land use scenario was not assessed because surface soil was not assessed for this SWMU.
[a] Total ELCR and total HI represent total risk or hazard summed across all POCs for all COCs.

Uncertainty on toxicity factors plays a major role in this risk assessment. The inclusion of beryllium as a risk driver is a result of incorporating the historical risk assessments. At the time those risk assessments were developed, beryllium still was evaluated as a carcinogen through the oral route of exposure. Since then, the oral cancer slope factor for beryllium has been withdrawn, by EPA. As a result, the total ELCR becomes much lower at those SWMUs where beryllium is a COC. For SWMUs 4 and 6, removal of the contribution of beryllium to the ELCR reduces the total ELCR to within the EPA risk range for the industrial worker scenario. Other uncertainties for the BGOU SWMUs that may affect the assessment of risk are discussed in Section 1.4.

Prior to EPA's issuing the *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual* (Part E, Supplemental Guidance for Dermal Risk Assessment) (EPA 2004a), the default parameters used to calculate ELCR and HI from the dermal absorption exposure route used a conservative dermal absorption factor to ensure ELCR and HI were not underestimated. From the historical risk assessments included in the RI, dermal exposure to metals was a significant contributor to the HI for SWMUs 4, 7, and 30 current and future industrial worker scenarios. Dermal exposure also was a significant contributor to the HI at SWMU 4, 5, 6, 7, and 30 for the future outdoor worker scenario. Updating the absorption factors for metals reduced the HI from dermal exposure to soil by a factor of 100 in most cases.

Similarly for groundwater (modeled from soil), the following presents priority COCs found in groundwater at individual SWMUs.

- SWMU 2—arsenic; Aroclor-1248; manganese; uranium; *cis*-1,2-DCE; and TCE
- SWMU 3—arsenic; manganese; uranium; and technetium-99
- SWMU 4—arsenic; manganese; *cis*-1,2-DCE; TCE; vinyl chloride; and technetium-99
- SWMU 5—arsenic; manganese; uranium; and naphthalene
- SWMU 6—none
- SWMU 7—arsenic; 1,1-DCE; *cis*-1,2-DCE; Aroclor-1254; TCE; and vinyl chloride
- SWMU 30—arsenic
- SWMU 145—antimony; arsenic; manganese; Aroclor-1260; and technetium-99

1.3.6 Screening Ecological Risk Assessment

For the ecological risk characterization for soil, the results of the previous ERAs are summarized in the BGOU RI (DOE 2010). For most of the SWMUs, no new surface data have been collected since the previous risk assessments were performed. Previous Ecological Risk Assessments (ERAs) were conducted for SWMUs 2, 4, 5, 6, 7, and 30 at PGDP. SWMU 3 is covered with a RCRA cap, and SWMU 145 is situated on 44 acres that now lie primarily beneath the C-746-S&T Landfills.

A summary of the results of the comparison in previous assessments of the site data to the ecological screening levels is provided in Table 1.14. This table lists the number of chemicals of potential concern (COPCs) in each suite retained for each site and the medium for further consideration. This table shows that a number of inorganic analytes detected above background values and detected organic analytes were retained. Radionuclides were eliminated as COPCs for all sites except for SWMUs 7 and 30.

1.4 SUMMARY AND CONCLUSIONS FROM THE BGOU RI

The following are the major contaminant distribution findings for sources investigated in the BGOU RI.

- Environmental media, specifically subsurface soil and groundwater, have been impacted by releases of contaminants at all of the BGOU SWMUs.

- Analytical data and review of disposal records indicate a potential for DNAPL in subsurface soils at one or more of the BGOU SWMUs. TCE trends in the RGA indicate that TCE DNAPL potentially is present at SWMU 4 and in the vicinity of the shared border between SWMUs 7 and 30. Concentrations of TCE at SWMU 4 suggest this potential TCE DNAPL may be present both in the waste cells and underlying soils of the UCRS and in the matrix of the RGA. TCE trends at SWMUs 7 and 30 indicate that the potential TCE DNAPL source likely is constrained to the UCRS soils. Additionally, historical records of TCE disposal at SWMU 2 indicate that a DNAPL source potentially could exist at the SWMU and will require evaluation of a treatment alternative.

Table 1.14. Summary of Suite of COPCs Retained in Surface Soil

Area	Media	Metal	Rad	Pesticide/PCB	SVOC	VOC
SWMU 2	Soil	6	----	----	----	----
SWMU 3	Soil	NE	NE	NE	NE	NE
SWMU 4	Soil	5	----	1	----	----
SWMU 5	Soil	5	----	1	3	----
SWMU 6	Soil	2	----	----	1	----
SWMU 7	Soil	19	Total*	1	----	----
SWMU 30	Soil	17	Total*	1	----	----
SWMU 145	Soil	NE	NE	NE	NE	NE

Table 1.14 is taken from Table 6.16 of the BGOU RI (DOE 2010).
----: no ECOPCs
NE: SWMU did not undergo an ecological evaluation.
*Radionuclide risk was assessed based on a total dose benchmark for all radionuclides.
PCB = polychlorinated biphenyl
SVOC = semivolatile organic compound
SWMU = solid waste management unit
VOC = volatile organic compound

- The BHHRA completed as part of the BGOU RI indicates that ELCRs greater than the upper end of EPA's acceptable risk range (i.e., 1E-04) and HIs greater than 1 exist at all SWMUs, suggesting that remedial action should be evaluated for impacted media at each SWMU. The metals arsenic, beryllium, and uranium, the organic compounds Total PAHs and Total PCBs, and the radionuclides uranium-235 and uranium-238 are common contaminants that present the dominant risks from exposure to surface and subsurface soil. The major contaminants present in soil that pose potential threats to groundwater at the on-site POEs are arsenic, Total PCBs, 1,1-DCE, TCE, technetium-99, and vinyl chloride.

- Migration of contaminants through groundwater from all but SWMU 6 to locations at the SWMU boundary, the plant boundary, property boundary, and near the Ohio River, also posed greater than *de minimis* risks to a hypothetical residential groundwater user, in some case exceeding MCLs. Arsenic, TCE, 1,1-DCE, technetium-99, and vinyl chloride are the primary risk drivers.

- The Screening Ecological Risk Assessment (SERA) retained a number of ecological COPCs, primarily metals, at each of the sites. Ecological risks and remediation of ecological COPCs will be considered during the screening and evaluation of alternatives for the BGOU SWMUs.

1.4.1 Uncertainties Identified in the Remedial Investigation Report and the BGOU FS Scoping Meetings

The BGOU Work Plan identified data gaps for individual SWMUs that were necessary to be filled in order to move forward with the FS. The Work Plan was implemented to reduce uncertainties from previous investigations regarding the nature of the source zone, extent of the source zone and secondary sources, surface and subsurface transport mechanisms, and to support evaluation of remedial technologies in this FS. The uncertainties that follow were identified in the RI Report and will be managed in the evaluation of remedial alternatives.

The BGOU RI was a comprehensive investigation of the BGOU SWMUs; however, there were some uncertainties that still remained after completion of the RI that were to be managed in the FS. These uncertainties are documented in the RI Report (DOE 2010) and include the following.

- Uncertainty related to risks associated with the mobility of uranium (the FS will manage this uncertainty by evaluating appropriate technologies for SWMUs where uranium is a primary contaminant);

- Uncertainty concerning the extent of source zones (burial areas) and unidentified single-point geophysical anomalies and the impact on alternative analyses (the FS will use existing knowledge and manage the uncertainties regarding the volume requiring removal or treatment);

- Uncertainties regarding the potential for acidic leachate, oxidation/reduction conditions, and degree of waste saturation (the FS will manage these uncertainties by evaluating robust technologies that are not sensitive to these types of uncertainties);

- Uncertainties regarding the extent and volume of secondary source zones (TCE DNAPL) (the FS will manage uncertainties regarding the extent and volume of these sources for comparison);

- Uncertainty related to limited groundwater monitoring around the BGOU SWMUs (the FS will manage this uncertainty by incorporating additional groundwater monitoring where appropriate at SWMUs where effectiveness monitoring is needed or where waste is left in place);

- Uncertainties related to the potential for releases from burial areas to impact adjacent surface water ditches (the FS will manage these uncertainties by recommending additional shallow groundwater monitoring during remedial design); and

- Uncertainties related to the nature and extent of contaminants in surface soil at selected SWMUs, primarily SWMU 145. (The FS will manage this uncertainty by evaluating remedial alternatives that would address this uncertainty.

FS Scoping meetings were held in June and July 2009 among representatives of DOE, EPA, and KY to outline the scope of the BGOU FS document and address the uncertainties identified in the RI Report (DOE 2010). The global BGOU uncertainties and uncertainties associated with individual SWMUs, the approach taken to address the uncertainties, and the locations in the FS where the uncertainties are addressed are summarized in Table 1.15 and discussed in the following sections.

1.4.1.1 Uranium mobility

Uranium Data. The analytical results for uranium-235 are reported in the Waste Area Group (WAG) 3 risk assessment (DOE 2000a) either as uranium-235 or uranium-235/236 in some soil and groundwater samples from SWMUs 7 and 30. The identification of combined uranium-235/236 isotopes for some samples is assumed to have resulted from the use of a radioanalytical method that was not able to speciate both isotopes in those samples. The remaining samples probably were analyzed by a different method specific to uranium-235. This uncertainty is expected to be minor because the same RG value is calculated for uranium-235 and uranium-235/236 in the risk assessment (DOE 2000a), and the same applicable RG for soil was developed for both in Section 2.

The preliminary surface and subsurface soil RGs developed for uranium-235 are applied to uranium-235/236 for the development of remediation alternatives at SWMUs 7 and 30. If the same RG concentration were to be carried through the cumulative risk assessments and radiological dose assessments for both uranium-235 and uranium-236 at SWMUs 7 and 30, the cumulative risk and total radiological doses estimated are expected to be overestimated by the contribution of the uncertain uranium-236 concentration. Section 2 shows that the radiotoxicities of uranium-235 and uranium-236 are sufficiently similar that the uncertainty introduced by uranium-236 is small so that remediation alternatives for these SWMUs can be based on the uranium-235 RG alone. This uncertainty will be mitigated by analysis of future postremediation samples by analytical methods that can speciate both uranium isotopes, allowing more accurate cancer risk and radiological dose estimates.

Uranium Mass Estimate. BGOU RI soil sample analytical data from each SWMU were evaluated to develop assumptions for the remedial alternatives. The available data indicate that uranium concentrations below the waste layer decrease to background levels, consistent with the known mobility of uranium in soils. These concentrations do not exceed the RGs established in the FS; however, postremediation sampling will be required to verify that these assumptions are correct and that uranium contamination above target concentrations can be remediated by excavation.

Uranium Transport Modeling. There was uncertainty associated with the 1,000 year time horizon used in the groundwater modeling effort and the ingrowth of U-238 daughters after 1,000 years. The fate and transport modeling for the RI, as documented in Appendix E of the RI Report (DOE 2010), uses a K_d of 66.8 mL/g to minimize the potential of eliminating uranium as a COC so that it could be properly addressed in the BGOU FS. The ingrowth of uranium-238 daughters is slow, such that the contributions of uranium-238 daughters and their related radiation doses to an exposed worker will occur over the next 100,000 to 1 million years. The mechanism, time frames, and activity concentrations for uranium-238 daughter ingrowth is discussed in more detail in Appendix B.

1.4.1.2 Nature of the source zone

The BGOU RI did not conduct intrusive sampling in the existing waste management units. As a result, specific waste characterization data are limited. Historical records and data, past observations, and waste disposal documentation referenced in the BGOU RI Report (DOE 2010) were used to supplement the RI data to establish the basis for selecting remedial alternatives and preparing cost estimates for those alternatives. A key project assumption for the FS is that the available historical documentation and soil and groundwater characterization data are sufficient relative to waste characteristics, to chemical and physical properties, and to waste volume estimates to evaluate general response actions, to screen technology types, to develop effective alternatives, and to conduct a detailed alternative analysis. While the RI field investigation sampled directly beneath the waste units using angled borings, it remains possible that the buried waste contains hazards or constituents that current sample results do not characterize (historical disposal records and waste manifests are incomplete). A related uncertainty is that the RI was unable to sample to the middle of a few of the larger SWMUs (SWMUs 5 and 145, particularly); therefore, there are some uncertainties in the nature and extent of the contaminant source that need to be managed during the decision making process.

Many of the SWMUs have been investigated previously. The BGOU RI used a combination of historical and current sample results of soil and groundwater from the area of each SWMU. The results of previous investigations, as well as the recent RI sampling, documents the presence or absence of metals, organic compounds, and radionuclides in the Burial Grounds. The associated samples were collected and analyzed over several previous and continuing investigations, as well as in the BGOU RI, using several methods. Changes to analytical methods and variations in detection limits restrict a rigorous comparison of data (e.g., laboratory reporting limits have varied over time). During development of the BGOU RI Work Plan, it was decided to limit the historical sample analyses used in the RI to groundwater samples collected in January 1995 and later and soil samples collected in June 1996 and later to minimize the potential for "age" to bias the analysis of the data. This approach maximized the number of historical sample analyses available to the RI, while providing a reasonable assurance of the comparability of the data. There are limited monitoring wells in close proximity to many of the SWMUs that would allow analyses of seasonal variations and analyte trending, but temporary borings provide a snapshot of the conditions where groundwater samples could be obtained.

Maximum COC Concentrations May Not be Known. Because only limited source-term data are available, it is possible that the maximum concentration of the COCs present at the SWMUs have not been established; however, sufficient data exist to determine if an action is needed at each unit. Although these uncertainties exist, postremediation sampling and groundwater monitoring performed in conjunction with implementation of individual remedies will satisfy the RAOs. Screening of technologies and development of alternatives considered this uncertainty. Alternatives were developed to provide protection of human health and the environment in view of this uncertainty.

Approach for Addressing the Limited Source Term Data in the FS. The RGs for the BGOU were developed based on exposure pathways and either direct contact risk levels or soil concentrations protective of groundwater. The SWMUs were evaluated for the FS by comparing actual soils data adjacent to or beneath each SWMU to the RGs to determine if an action is needed. The comparison of soils data to RGs complemented the modeling data performed in the RI and helped to better identify the specific locations and depths of contamination that warranted remedial action.

1.4.1.3 Acidic leachate, oxidation/reduction conditions, and degree of waste saturation

The potential for acidic leachate at each SWMU is uncertain due to the lack of disposal records. SWMUs with the greatest potential for acidic leachate are SWMU 6 (exhaust fans with perchloric acid) and SWMU 4 (records of chemicals buried are incomplete). It should be noted that angled borings beneath SWMU 6 found no evidence of acidic leachate, either from subsurface metal concentrations or groundwater pH. There are no pH measurements from shallow groundwater at SWMU 4 to allow an evaluation of the uncertainty related to acidic leachate. The potential for acid leaching at the SWMUs will need to be managed during the decision-making process.

Uncertainty exists with regard to the dissolved oxygen in the UCRS at SWMUs 4 and 6 due to a lack of data. The majority of dissolved oxygen measurements from UCRS wells ranges from near zero to four mg/L and oxidation/reduction potential commonly ranges from -100 to 300 microVolts, with the majority of measurements greater than zero. Data from all BGOU SWMUs combined demonstrate the trends of dissolved oxygen (517 measurements) and oxidation/reduction potential (136 measurements) in the UCRS at the BGOU SWMUs. The relative abundance of measurements for these SWMUs where measurements were taken demonstrates a trend that appears to be representative of conditions across the BGOU; therefore, the oxidation/reduction potential in the UCRS at SWMUs 4 and 6 will be assumed to be similar to that in the UCRS at other BGOU SWMUs.

For the remedies selected, the assumption is that groundwater is present with some degree of saturation throughout the waste. This means that the selected alternatives will need to include technologies that take into account any groundwater that is encountered by removing, isolating, or containing the waste, or providing a mechanism to dewater the waste.

For SWMUs 2 and 6, where the last disposal occurred more than 30 years ago in 1977 and 1976, respectively, it is reasonable to assume most, if not all, drums have failed (an Oak Ridge National Library researcher estimated that drum failure would be expected to occur within 18 to 36 years). At SWMU 5, where the last disposal occurred in 1987, it is reasonable to assume some drums still may be intact. For SWMUs 4, 7, 30, and 145, it can be assumed that drums likely are breached, since they were dumped rather than being carefully stacked. Because all drummed waste was assumed to have been released to the environment during disposal or through degradation, samples from soils surrounding the buried wastes were used to evaluate potential contaminant migration and risks associated with the SWMUs. The risk assessment concluded that these uncertainties related to the source zone were not estimated to have a large effect on the risk characterization and do not affect FS decision making.

1.4.1.4 Extent and volume of the source zone and secondary sources (TCE DNAPL)

There remains some uncertainty with regard to the boundaries of the burial pits. Geophysical surveys have not been completed across the entire area of all SWMUs. To manage this uncertainty, the FS bases its assumptions on engineering drawings and known burial pit extent. Additional data will be collected as necessary during the Remedial Design (RD) to support technology sizing, design, and optimization and may include geophysics.

Secondary sources of groundwater contamination that are derived from the BGOU Burial Grounds, such as the potential DNAPL source zone beneath SWMUs 2, 4 and SWMU 7, are within the scope of the BGOU for evaluation and remedial action. The evidence for UCRS DNAPL presence is documented in previous investigations (DOE 2007b; DOE 1998a) and discussed in the RI. The primary evidence for the presence of a DNAPL source at SWMU 2 is the historical records documenting the disposal of drums of TCE at this location. Assessment of the secondary source in the UCRS at SWMUs 7 was based on both historical and newly generated data, while the assessment of the secondary source in both the UCRS and RGA at SWMU 4 is based primarily on historical data. Because the UCRS groundwater samples supplement the characterization of the BGOU SWMUs (the analysis of subsurface soil samples is the primary measure that supports the assessment of nature and extent and risk) and secondary sources, the lack of UCRS water samples from all soil borings does not limit the assessment of the SWMUs. There also is potential for a TCE DNAPL at SWMU 2 based on historical disposal records; however, neither the subsurface soil nor shallow groundwater data at SWMU 2 indicate any evidence of a DNAPL source. The volumetric extent of secondary source contamination has been approximated and constitutes a project assumption for evaluation of the alternatives.

Assumptions Used for Area, Depth, and Volume of Contaminant Source Areas are Based on Available RI Data. Assumptions are made regarding the area, depth, and volumes of contaminated source areas throughout the different SWMUs. To address these issues, engineering data collection to support technology sizing, design, and optimization will be included as a component for remedial alternatives where additional information regarding the source term is needed to support the detailed design of the alternative. These assumptions are discussed below.

A source of TCE, possibly DNAPL, is expected to exist in SWMU 4 (RGA). A VOC source, possibly DNAPL, also is suspected at SWMUs 2 and 7 (UCRS). As part of the remedial design of a potential source action at SWMUs 2 and 7, engineering data collection to support technology sizing, design, and optimization will be performed to determine the placement of the source action wells or system components.

The vertical extent of TCE contamination in soil attributable to SWMU 2 is uncertain. Additional evaluation will be required to determine if TCE from SWMU 2 is actually impacting groundwater. Based on the RI data, it is likely that most, if not all, TCE contamination would be remediated if an alternative involving excavation is implemented. Implementation of remedial actions upgradient of the potential SWMU 2 DNAPL source will support a determination of the contribution, if any, of SWMU 2 to the TCE contamination present in the RGA.

Removal of COCs from Soil and Waste Layers. For alternatives that involve excavation, it is assumed that excavation will remove all COCs present in soils from the surface to approximately 20 ft below grade. Based on evaluation of RI data, the COC concentrations present in Layers 4-7 are representative of residual values that are below RGs, and RAOs should be met for radioactive and inorganic COCs. Residual DNAPL contamination would be remediated by implementing an appropriate alternative for these contaminants.

Previous work has shown that the primary pathway for groundwater flow and the site-related contaminants is vertical migration through the UCRS, followed by lateral migration in the RGA. Contaminated groundwater could migrate to the POEs identified in the RI Report for the BGOU SWMUs at the plant boundary, property boundary, surface seeps at Little Bayou Creek, and near the Ohio River. While there is some uncertainty related to modeling in predicting whether a SWMU would contribute to the Little Bayou seeps or the Ohio River, this uncertainty has almost no effect on the modeled contaminant concentrations used to develop RGs and should not affect remedial decisions.

Use of Postremediation Sampling to Reduce Uncertainties: During the FS, RGs are established that are protective of the groundwater exposure pathway, or direct contact if more restrictive. The soils at the SWMUs have been adequately characterized during the BGOU RI to identify that there are current exposure risks, and the data are sufficient for selection of appropriate remedies to mitigate those risks to acceptable levels. Without understanding the full nature and extent of contaminant sources or concentrations, uncertainty is managed by specifying postremediation sampling and groundwater monitoring as appropriate during implementation of the selected remedy to verify that target concentrations are met. No additional analyses for characterization are required, except to support waste management if needed.

Feasibility of Metal Removal: Metal removal and metal melting is proposed at SWMU 5 to reduce cost of remedial action by recovering materials with economic value. Because of expected contamination with radiological COCs, recovered scrap will require decontamination prior to melting, if the metal is to be recycled in a free release scenario. Decontamination will result in waste residuals that require treatment and/or disposal. There is uncertainty associated with the cost-effectiveness of this option because there presently is a DOE moratorium that prevents recycling of metals from a DOE facility.

Estimation of waste volumes for remediation. This section presents the approaches applied to estimating the volumes of waste to be remediated at the BGOU SWMUs.

As part of the excavation alternative, it was assumed that selected SWMUs will require excavation. In general, the volume of waste to be excavated was estimated based on the areal footprint of the SWMU and an assumed excavation depth not to exceed 20 ft bgs. This depth is several ft deeper than the greatest disposal depth reported for any of the SWMUs and corresponds to the bottom of SADA modeling Layer 3. If documentation was available indicating that only a portion of the SWMU was used for waste disposal, the volume of waste material was reduced by an estimated percentage corresponding to the volume of soil that is not likely to have been impacted by contact with wastes. This was accomplished by evaluating the historical layout figures for each SWMU and estimating the volume of the SWMU likely to be in contact with waste, based on the size and position of disposal cells within the SWMU.

If an alternative that includes application of a cover to the SWMU was considered, the reported surface area of the SWMU, plus an additional buffer, was assumed for development of an estimate for installing a cover.

The RI Report concludes that DNAPL may be present in soil beneath SWMU 4 and SWMU 7. The DNAPL at SWMU 4 is assumed to extend into the RGA; SWMU 7 DNAPL is assumed to be confined to the UCRS. In addition, DNAPL potentially is present in the soils beneath SWMU 2. The estimated volumes of soils potentially affected by DNAPL were developed as follows for the affected SWMUs.

The DNAPL contamination potentially present at SWMU 2 and SWMU 7 is assumed, based on available data, to be confined to the UCRS; therefore, the volumes of soil to be remediated at these locations were calculated as follows:

(1) Begin at the top of SADA Layer 4 because Layer 3 is the estimated lower extent of waste excavation. (DNAPL contamination in Layers 1 to 3 were not included in these determinations because it is assumed that contamination in the upper layers either will be removed by excavation or contained by some combination of physical barriers.)

(2) Identify the specific samples for which the VOC concentrations exceed the RG protective of groundwater and, based on the mapped waste cells around the samples exhibiting VOC concentrations above the RG, establish the area requiring remediation. Assuming the typical treatment cell area of approximately 75 ft by 75 ft (consistent with the areal extent of typical DNAPL treatment cell described in the Southwest Plume SI) (DOE 2007b), estimate the number of treatment cells required to treat the SWMU.

(3) Assume the contamination extends to a total depth of approximately 65 ft bgs to the top of the RGA for SWMU 2 and for SWMU 7 (corresponding to a contaminated soil thickness of approximately 45 ft, ranging from the top of Layer 4 to the bottom of Layer 7). This approach yields an approximate volume of 9,375 yd^3 of soil for remediation of DNAPL in the UCRS at SWMU 2 and SWMU 7. To provide for a robust estimate of the mass of VOC-contaminated soils, the masses reported from the SADA geostatistical model of the SWMU subsurface have been used in this estimate; however, the actual sampling data were used to establish the expected location and limits of the treatment cells.

The source area at SWMU 4, based on the distribution of available data at a depth of approximately 20 ft bgs, is estimated to be represented by two adjacent areas: one is 150 x 85 ft and the other is 150 x 160 ft. Since the soil from the surface to 20 ft bgs may be removed by excavation, the thickness of the DNAPL source extends the entire remaining thickness of the UCRS (45 ft) as well as the thickness of the RGA (25 ft), for a total DNAPL thickness of 70 ft.

It is anticipated that the extent of DNAPL contamination at these SWMUs will be more fully delineated during the RD. None of the other BGOU SWMUs is believed to contain a DNAPL source based on the BGOU RI Report (DOE 2010).

1.4.1.5 Limited groundwater monitoring around the BGOU SWMUs

The assumption carried forward from the BGOU RI is that all of the materials disposed in the SWMUs potentially contained hazardous and/or radioactive materials. The conceptual model applicable to all of the BGOU SWMUs is that releases from the SWMUs have impacted soils below or immediately adjacent to the source zones and, through vertical infiltration in the soil, have the potential to contaminate the groundwater underlying these sources.

While the transport modeling conducted for the RI necessarily made simplifying assumptions, the data were adequate to identify the COCs, determine their contribution to risks to human health, and develop RGs for evaluating alternatives. To the extent practicable, the modeling approach simulated actual PGDP site conditions using, as an example, K_ds for metals in soils based on acidic soils with a low cation exchange capacity, consistent with known site conditions. Uncertainty still exists with respect to source material because of limited source data.

1.4.1.6 Potential for leachate from burial areas to impact adjacent surface water ditches

Another potential pathway that exists, at SWMUs 7 and 30 is lateral seepage from the burial pits into nearby ditches. The SWMU 7 and 30 RI Report (DOE 1998a) reported that water was observed emanating from the slope of the ditch following a heavy rainfall. It is uncertain whether the seepage was derived from the burial pits. The RI report concluded that uranium isotope activity ratios argued against waste burial pit waters as contributors to surface water contamination. Likewise, some discharge of shallow groundwater in the ditch south of SWMU 2 has been observed, but the report was unclear as to the contribution of contamination to the ditch (the report concluded that contaminant migration to Outfall 015 and Bayou Creek is unlikely to exceed preliminary RGs) (DOE 1997b). This FS will consider the pathway for leachate flow from the BGOU SWMUs to adjacent surface water features and the need for remedial actions to mitigate releases to surface water. Waste excavation will eliminate this pathway. A cover or cap will be engineered to reduce infiltration and manage runoff.

1.4.1.7 Nature and extent of contaminants in surface soil at selected SWMUs

Delineation Uncertainties. RGs established in the FS are protective of both the direct contact and groundwater exposure pathways. Alternatives will address removal or treatment of soils to meet the RGs. Uncertainties regarding the extent of contamination above the RGs will be managed by excavation guided by postremediation sampling until the effectiveness of excavation is demonstrated or by long-term groundwater monitoring where target concentrations cannot be met in the subsurface soils or media.

Animals that burrow to 5 ft bgs would be expected to encounter ecological COPCs located in Layers 1 and 2, which extend to 10 ft bgs. Because these soils are the only media that would affect ecological receptors and are addressed in the FS by removing Layers 1 through 3 at the SWMUs during waste excavation or, if waste is left in place, selecting an alternative that places an appropriate surface barrier over the soils of interest to prevent contact with residuals also would prevent exposure by ecological receptors.

1.4.1.8 Cost estimate between -30% and +50%

The unknowns associated with source, volume, and characterization information related to waste types and volumes for treatment and/or disposal add uncertainty to the development of remedial cost estimates. Assumptions for these parameters were used to develop costs.

Table 1.15. Summary of Remedial Investigation Report and June/July 2009 BGOU FS Scoping Meetings Uncertainties

SWMU No.	Uncertainty	Response and Citation of Discussion in FS
Global	Whether process knowledge and existing data sufficiently characterize the contents of waste pits and allow for management of uncertainties.	In this FS, uncertainties related to data gaps are discussed in the context of remedial alternatives development for each SWMU. Remedial alternatives are designed to provide a degree of protection greater than that necessary to protect against the maximum observed concentrations of COCs, and to mitigate uncertainties in available data.
	Whether the expected industrial land use will continue in perpetuity.	This uncertainty is addressed throughout the FS document, which develops remedial alternatives according to CERCLA guidance and will support remediation under CERCLA when executed. The remedial alternatives include the necessary postremediation sampling, long-term monitoring, costs, and land use controls appropriate for each SWMU. Alternatives that include long-term monitoring, or leave waste in place, will require five-year reviews under CERCLA. Consistent with guidance, five-year reviews would consider the effects of any changes in land-use on the protectiveness of the selected remedy.

Table 1.15. Summary of Remedial Investigation Report and June/July 2009 BGOU FS Scoping Meetings Uncertainties (Continued)

SWMU No.	Uncertainty	Response and Citation of Discussion in FS
Global	Whether the lateral extent of the burial cell is adequately delineated. Nature and extent of the source zone. Acidic leachate, oxidation/reduction conditions, and degree of waste saturation. Extent and volume of the source zone (burial pit) and secondary sources (TCE DNAPL). Limited groundwater monitoring around the BGOU SWMUs. Potential for leachate from burial areas to impact adjacent surface water ditches. Nature and extent of contaminants in surface soil at selected SWMUs.	Remedial design includes the opportunity to collect engineering data to support technology sizing, design and optimization. These are the features or attributes of the alternatives evaluated for the BGOU. For excavation: • Criterion to remove visible waste • Postremediation sampling • Removal of contaminant source For cover: • Geophysics to fully delineate burial pits • A cover or cap will be engineered to reduce infiltration and manage runoff. • Reduced infiltration to further immobilize contaminants (see Appendix B) • Elimination of direct contact exposure pathway. • Long-term monitoring • Cover maintenance For cap or containment: • Geophysics to fully delineate burial pits • A cover or cap will be engineered to reduce infiltration and manage runoff. • Reduced infiltration to further immobilize contaminants(see Appendix B) • Elimination of direct contact exposure pathway. • Long-term monitoring • Leachate collection and treatment • Cap maintenance For DNAPL source treatment: • Membrane ion probe or suitable technology for determining extent of DNAPL source Remediation will not be considered complete until verified by postremediation sampling or long-term monitoring, or both. Appendix E contains area and volume assumptions for remediation and cost estimates, including postremediation sampling. An FS cost estimate assumes -30/+50%. accuracy to account for some degree of site uncertainty.

Table 1.15. Summary of Remedial Investigation Report and June/July 2009 BGOU FS Scoping Meetings Uncertainties (Continued)

SWMU No.	Uncertainty	Response and Citation of Discussion in FS
Global	Uranium mobility	Uranium modeling demonstrates that uranium is essentially immobile. In addition alternatives evaluated for the FS either removes or further immobilizes uranium. See features of alternatives mentioned above.
	Whether waste has been completely or partially released from buried drums.	A discussion of drum integrity is cited earlier in this section. The features of the remedial alternatives described in this table also address this uncertainty. Appendix B analyses for infiltration reduction also are relevant. For those SWMUs where TCE contamination is present, Appendix B also shows the range of time frames for TCE degradation to occur to the point where MCLs are met in the RGA based on a range of degradation half lives for TCE.
	The uncertainty associated with the 1,000-year time horizon used in the groundwater modeling effort and the ingrowth of uranium-238 daughters after 1,000 years.	This uncertainty was discussed in the RI Report (Appendix E, DOE 2010). The ingrowth of uranium-238 daughters is slow, such that the contributions of uranium-238 daughters and their related radiation doses to an exposed worker will occur over the next 100,000 to 1 million years. The mechanism, time frames, and activity concentrations for uranium-238 daughter ingrowth is discussed in more detail in Appendix B.
	Whether arsenic and other metals are COCs for future residential groundwater users and whether their concentrations might exceed regulatory limits in the RGA.	The BGOU is a source removal action, not a groundwater action. MCLs and risk-based concentrations in groundwater are used only to develop groundwater protective soil RGs, as described in Section 2 and Appendix C. Arsenic and other metals in the BGOU were determined not to pose a threat to groundwater. The uncertainty related to arsenic and other metals on screening of metals and radionuclides in soil is addressed later in Section 1.4.2.

Table 1.15. Summary of Remedial Investigation Report and June/July 2009 BGOU FS Scoping Meetings Uncertainties (Continued)

SWMU No.	Uncertainty	Response and Citation of Discussion in FS
2	Cesium-137 exceeds NALs and background at one location (sample 2-15) within the SWMU boundary, but the cesium-137 sample location is in the drainage ditch in the southern portion of the SWMU. As such, it will be addressed by the Surface Water Operable Unit and is excluded from the BGOU scope.	See Figure 5.2.
	Whether TCE and/or technetium-99 are present at the bottom or the waste pits at levels that will exceed MCLs in the RGA within 1,000 years.	Postremediation sampling is included in all excavation alternatives. Appendix B provides an evaluation of the groundwater protectiveness of a cover based on the degree of infiltration reduction the cover provides. In the cases of both TCE and technetium-99, concentrations in excess of the maximum observed concentrations at each SWMU could remain, and groundwater would be protected with reasonably achievable infiltration reductions. Appendix B also shows the rates for TCE degradation.
	Whether COCs have migrated into a subgrade electrical conduit underlying SWMU 2 and/or outside the current SWMU boundary.	This conduit is described in Figures 5.1 and 5.2 and related text. Cost for engineering data collection prior to remediation and postremediation sampling to determine conduit status is in Appendix E.

Table 1.15. Summary of Remedial Investigation Report and June/July 2009 BGOU FS Scoping Meetings Uncertainties (Continued)

SWMU No.	Uncertainty	Response and Citation of Discussion in FS
2	Whether waste has been completely or partially released from drums into the environment and whether modeling has correctly predicted the extent of future TCE migration.	See response to global uncertainty regarding drum integrity.
	Because the RI Report risk assessment for SWMUs 2 and 3 did not evaluate an outdoor worker scenario, develop the RGs for the outdoor worker scenario for these SWMUs using the full list of COCs for the residential soil direct contact receptor, which is expected to be the most inclusive.	The RI Report risk assessment for SWMUs 2 and 3 did not evaluate an outdoor worker scenario for soil, but did evaluate hypothetical exposure to an adult or child resident to off-site groundwater. See Tables 1.6 and 1.7 of this FS, reproduced from RI Report Appendix F. The COCs for SWMU 2 and SWMU 3 include COCs identified through the assessments of both the on-site industrial worker for soil and off-site groundwater user. Because the soils RGs were developed to include protection of groundwater, these lists are the most comprehensive possible for each SWMU based on the RI Report risk assessment. This is addressed in Section 2.2.3 on Remediation Goals.
	Whether PCBs exist within the waste at levels that would present a direct contact risk to a future outdoor worker, given that PCBs were detected at 4.2 mg/kg in a sample in waste located at 10 ft bgs.	This uncertainty was addressed in the June/July 2009 scoping meetings and throughout this document, which incorporates a 10 mg/kg target for total PCBs in soil. Excavation alternatives include postremediation sampling, Cover alternatives provide containment for PCBs should they be present in concentrations above 10 mg/kg.
	Some discharge has been observed to the ditch south of SWMU 2.	As shown in Figure 5.2, the ditches in proximity to SWMU 2 will be managed as part of the SWOU.
3	Whether subsurface arsenic exists above background concentrations, although the likelihood is considered low.	A comparison of the observed concentrations for arsenic and other naturally occurring metals to PGDP background was performed and is presented in Section 1.4.2. Based on the results of this comparison, arsenic was not determined to be an important COC for alternative screening and evaluation. This will be further examined as part of postremediation activities for some alternatives (i.e., excavation).

Table 1.15. Summary of Remedial Investigation Report and June/July 2009 BGOU FS Scoping Meetings Uncertainties (Continued)

SWMU No.	Uncertainty	Response and Citation of Discussion in FS
3	Whether the existing RCRA cap presents a radiological surface risk to industrial workers or presents hotspot risks, although the likelihood is considered low.	The E/PP will prevent site workers from conducting work that would penetrate the cap.
	Whether TCE DNAPL plume extends into the McNairy Foundation.	Data collection to support RD will address this uncertainty.
	Whether waste in drums has been released into environment.	A general review of drum integrity is presented earlier in this section.
	Whether the operating water pipe cutting through the southeast portion of the SWMU is a conduit for lateral contaminant migration and will significantly impact the implementation of a response action.	This is addressed in Section 7.4 and included in the excavation alternative cost estimates (Appendix E).
5	Sampling information for soil at SWMU 5 is limited; therefore, it was agreed during the June 2009 scoping meetings that any remediation alternative that leaves waste in place would have to include the following components: (1) focus on the removal of direct exposure pathways; (2) incorporate long-term groundwater monitoring; (3) provision to review the decision during five-year reviews or as appropriate, if new information becomes available.	The uncertainty associated with the limited availability of data at SWMU 5 is addressed in. the presentation of features of the various types alternatives. Alternative 3 includes long-term monitoring and removal of exposure pathways. Alternative 6 excavates the waste. Costs for five-year reviews are included in Appendix E.
	Whether conditions are different than presented in the RI Report.	Uncertainties related to COCs for this SWMU are described in the RI Report. The list of COCs was identified through the assessments of all media and scenarios of interest. Soil RGs were developed to include protection of groundwater. These lists of COCs are the most comprehensive for SWMU 5 based on the RI Report risk assessment. The features of the various types of alternatives that address this uncertainty are listed above.
	Whether surface soil PAH concentrations warranting action exist within the SWMU.	PAHs were determined not to warrant an action. Individual PAH compounds were detected only at isolated locations at some SWMUs. The PAH compounds that were detected are not mobile toward groundwater, and remediation alternatives developed for other COCs will remediate the isolated PAH concentrations; therefore, no Total PAH RGs were developed for soil for the purpose of developing remediation alternatives.
	Whether arsenic is a COC because of its detection at 12.2 mg/kg in one sample, which is above the background concentration for surface soils (12 mg/kg).	Arsenic is a COC, but it is not important for screening and evaluating alternatives. This uncertainty is discussed as part of screening metals and radionuclides in Section 1.4.2.

Table 1.15. Summary of Remedial Investigation Report and June/July 2009 BGOU FS Scoping Meetings Uncertainties (Continued)

SWMU No.	Uncertainty	Response and Citation of Discussion in FS
6	Whether leachate acidified by perchloric acid leaching from contaminated exhaust fans has affected the mobility of some contaminants.	Because any perchloric acid present was disposed of over 20 years ago, it is likely that any perchloric acid present has been neutralized and, therefore, is not affecting the mobility of any contaminants that might be present.
	Whether current geophysical data accounts for a portion of the SWMU where equipment was in the way during the original survey.	The features of the various types of alternatives that address this uncertainty are listed above.
	Whether PAHs detected in surface soil near a road are part of the BGOU.	The PAHs detected in the vicinity of SWMU 6 are not part of the BGOU. This uncertainty is addressed in Section 9.1 and Section 9.2.
	Whether metals in subsurface soil are COCs that warrant action based on dermal contact parameters for the outdoor worker scenario and consideration of site background levels.	Metals in the subsurface are not COCs that are important for screening and evaluating alternatives. This uncertainty is addressed later in Section 1.4.2 on screening of metals and radionuclides. Identification of COCs in subsurface soil at SWMU 6 is discussed in Section 2 (Table 2.2).
	Whether buried water lines would interfere with an excavation or have affected contaminant migration from SWMU 6.	The uncertainty of the presence of buried water lines and their impact is considered in the cost estimate in Appendix E.
7	Whether DNAPL is present.	A contingency for remediating DNAPL, should its presence be confirmed, has been included in the alternatives evaluated for SWMU 7. Recognizing that buried construction debris may interfere with identification and remediation also has been considered in the alternatives. This uncertainty is addressed in Section 10.
	Whether buried materials will interfere with potential TCE characterization and treatment options, although the likelihood of this occurrence is considered to be low.	See previous response.
30	SWMU 30 uncertainties addressed above under global uncertainties.	

Table 1.15. Summary of Remedial Investigation Report and June/July 2009 BGOU FS Scoping Meetings Uncertainties (Continued)

SWMU No.	Uncertainty	Response and Citation of Discussion in FS
145	Whether technetium-99 and other radionuclides, PAHs, and PCBs are localized in "hot spots" at the SWMU.	This uncertainty is addressed in Section 12.4 – Alternatives 3 and 6. Excavation and disposal of soil above target concentrations would remove "hot spots." A soil cover would prevent direct contact.
	Whether arsenic presents an unacceptable risk to the industrial worker.	This uncertainty is addressed in Section 1.4.2 on screening of metals and radionuclides.
	Whether residential and recreational land use scenarios should be assessed for SWMU 145, in addition to outdoor worker and off-site residential groundwater use scenarios.	Uncertainties related to selection of land use scenarios and identification of exposure pathways are addressed in the RI Report Section 6.2.2 and Appendix F. This uncertainty is discussed in Section 2.2 (general discussion of RAOs).
	Whether technetium-99 still is present as a potential source for migration to groundwater or may no longer be present in soil due to its mobility.	This uncertainty is discussed in Section 2, regarding groundwater protective soil remediation goals, and Section 12.4 – Alternatives 3 and 6 with long-term groundwater monitoring.

BGOU = Burial Grounds Operable Unit
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
COC = contaminant of concern
DNAPL = dense nonaqueous-phase liquid
DOE = U.S. Department of Energy
FS = feasibility study
LLW = low-level waste
MCL = maximum contaminant level
PAH = polyaromatic hydrocarbon
PCB = polychlorinated biphenyl
NAL = no action level
RAO = remedial action objective
RCRA = Resource Conservation and Recovery Act
RG = remediation goal
RGA = Regional Gravel Aquifer
SWMU = solid waste management unit
TCE = trichloroethene

1.4.2 Screening of Metals and Naturally Occurring Radionuclides

As part of the RI evaluation of metal and radionuclide data for soils, the background 95% upper tolerance limit (UTL) concentration was used as a criterion to establish if a particular metal is a COC. This is one line of evidence to support whether the detected concentrations of a metal should be considered to be within the range of background. Tables 1.16 and 1.17 provide a summary of the range of detected concentrations of metal and radionuclide concentrations in surface and subsurface soil samples for the BGOU SWMUs, and a comparison to the range of background concentrations. The distributions of concentrations were considered to be consistent with the range of background concentrations if two or more of the following criteria were met:

- The mean of detected concentrations is within 50% of the background median value;
- Less than 60% of the detected sample concentrations is greater than the background median value;
- Less than 5% of the sample concentrations is above the background 95% UTL; or
- Less than 2% of the sample concentrations is above the background maximum value.

Some metals were screened out as COCs in the RI because the were detected infrequently (found in less than 5% of the samples) or their maximum detected concentration was less than the no action level (NAL) for the protection of groundwater (DOE 2010). Several metals were identified as COCs in the RI, but were determined in the FS not to be important for screening alternatives for a remedial action in surface or subsurface soil. The metals aluminum, arsenic, iron, manganese and vanadium have 95% UTLs that are greater than their NALs. Barium concentrations detected in subsurface soils were not above the NAL. While the sample median for beryllium in BGOU subsurface soils is nearly twice that for the background samples, beryllium was detectable in less than 50% of the samples and none exceed the maximum concentration of the background data set; therefore, it is considered to be within the range of background. Based on screening conducted in the RI and the qualitative screening against the range of background concentrations presented in this section for the metals and radionuclides in BGOU soil samples (summarized in Tables 1.18 and 1.19), only the following radionuclides are considered to be important when screening technologies because of their potential risk to groundwater or human health:

- **Surface soil:** uranium, cesium-137, neptunium-237, plutonium-239, technetium-99, thorium-230, uranium-234, and uranium-238.
- **Subsurface soil:** uranium, cesium-137, neptunium-237, technetium-99, uranium-234, uranium-235, and uranium-238.

The cesium-137 action level for the industrial worker is 8.58 pCi/g (100 times higher than the no action level). Soil concentrations are above the action levels at only three locations: two at SWMU 2 and one location at SWMU 4; however, all are sediment samples collected from ditches and will be addressed in the Surface Water OU. While these data are included in the evaluation for mapping the extent of contamination within the BGOU, the locations are not within the scope of this FS. Based on the association with sediments rather than soil samples, an RG will not be developed for cesisum-137 as part of the BGOU FS.

Table 1.16. Summary of Detected Concentrations and Comparison to Background and No Action Screening Levels for Metals and Radionuclides in Surface Soils

Parameter	BGOU Data Summary					Background Data Screening						NAL Screen	
	Number of Analyses	Detectable Concen-trations	Min	Mean	Max	Median[a]	Number above Median	95% UTL[a]	Number above 95 % UTL	Maximum[a]	Number above Maximum	No Action Level [b]	Number above NAL
Aluminum	76	76	2.43E+03	8.81E+03	1.60E+04	8.02E+03	45	1.30E+04	6	1.57E+04	3	4.22E+03	< BKG
Antimony[c,e]	76	12	5.00E-01	4.89E+00	1.57E+01	NA	NA	NA	NA	NA	NA	3.46E-01	12
Arsenic	76	35	2.30E+00	7.79E+00	3.00E+01	5.31E+00	5	1.20E+01	4	4.61E+01	0	3.13E-01	< BKG
Barium	76	76	1.21E+01	8.82E+01	2.00E+02	9.09E+01	29	2.00E+02	0	1.98E+02	1	5.92E+02	0.00
Beryllium[c]	76	40	2.60E-01	7.17E-01	1.80E+00	4.49E-01	38	6.70E-01	14	2.40E+01	0	9.48E-01	5.00
Cadmium	76	11	6.50E-02	9.11E-01	2.80E+00	NA	NA	2.10E-01	9	9.68E+00	0	2.12E+00	0.00
Chromium (total)[c]	76	76	5.40E+00	1.92E+01	2.96E+02	1.24E+01	42	1.60E+01	22	2.57E+02	1	2.11E+02	1.00
Cobalt	76	74	2.10E+00	5.17E+00	1.10E+01	6.62E+00	11	1.40E+01	0	3.00E+01	0	3.11E+02	0.00
Copper	76	76	2.60E+00	1.83E+01	1.70E+02	1.19E+01	20	1.90E+01	14	2.30E+02	0	4.37E+02	0.00
Iron	76	76	4.50E+03	1.43E+04	4.20E+04	1.43E+04	28	2.80E+04	4	5.42E+04	0	1.90E+03	< BKG
Lead	76	23	6.36E+00	2.15E+01	7.10E+01	1.75E+01	11	3.60E+01	2	3.24E+02	0	5.00E+01	1.00
Manganese	76	76	4.93E+01	3.77E+02	1.30E+03	3.51E+02	37	1.50E+03	0	2.70E+03	0	2.29E+02	< BKG
Mercury	76	13	2.00E-02	1.45E-01	4.50E-01	1.00E-01	6	2.00E-01	3	7.69E+00	0	1.00E+00	0.00
Nickel	76	71	4.83E+00	3.51E+01	5.70E+02	1.40E+01	25	2.10E+01	17	8.48E+01	6	2.05E+02	1.00
Selenium	76	8	5.80E-01	1.07E+00	1.70E+00	3.01E-01	8	8.00E-01	5	2.50E+01	0	7.13E+01	0.00
Silver	76	5	3.90E-01	2.52E+00	8.66E+00	1.51E+00	2	2.30E+00	1	4.21E+01	0	4.11E+01	0.00
Thallium[c,e]	76	7	5.20E-01	2.00E+00	4.50E+00	NA	NA	NA	NA	NA	NA	7.11E-01	7.00
Uranium[c]	76	18	1.13E+00	2.49E+02	1.27E+03	3.84E+00	17	4.90E+00	17	NA	NA	1.10E+01	16.00
Vanadium	76	76	6.65E+00	2.25E+01	4.78E+01	2.20E+01	40	3.80E+01	2	7.01E+01	0	3.04E+00	< BKG
Zinc	76	68	1.83E+01	8.20E+01	7.50E+02	4.09E+01	44	6.50E+01	23	3.92E+02	2	2.50E+03	0.00
Cesium-137	69	22	1.41E-02	1.27E+01	1.81E+02	NA	NA	NA	NA			8.58E-02	22
Neptunium-237[d]	47	16	2.00E-02	4.52E-01	1.68E+00	NA	NA	NA	NA			2.71E-01	10
Plutonium-238[d]	28	0	-	-	-	NA	NA	NA	NA			1.66E+00	0
Plutonium-239[d]	12	11	3.00E-02	2.70E+00	1.61E+01	NA	NA	NA	NA			1.62E+00	2
Radium-226	7	1	1.80E+00	1.80E+00	1.80E+00	1.09E+00	1	1.50E+00	1			2.56E-02	< BKG
Technetium-99	76	30	4.70E-01	3.58E+01	3.60E+02	NA	NA	NA	NA			5.79E+01	5
Thorium-228	28	1	1.77E-01	4.94E-01	3.39E+00	1.15E+00	1	1.60E+00	1			2.80E-02	< BKG
Thorium-230	40	40	1.94E-01	2.67E+00	4.69E+01	1.12E+00	14	1.50E+00	9			2.22E+00	1
Thorium-232	28	27	2.21E-01	3.97E-01	6.63E-01	1.08E+00	0	1.50E+00	0			1.95E+00	5
Uranium-234	47	30	1.54E-01	2.85E+01	3.18E+02	9.26E-01	25	2.50E+00	23			2.83E+00	22
Uranium-235	37	0	-	-	-	5.40E-02	-	1.40E-01	-			3.95E-01	-
Uranium-238	47	47	2.28E-01	8.02E+01	2.39E+03	9.65E-01	40	1.20E+00	36			1.17E+00	36

Table 1.16. Summary of Detected Concentrations and Comparison to Background and No Action Screening levels for Metals and Radionuclides in Surface Soils (Continued)

a Median and 95% UTL values of background concentrations for surface soil at the PGDP from the 2009 Risk Methods document, DOE/LX/07-0107&D1/V1. Details on the derivation of the values shown for antimony, beryllium, cadmium, thallium, uranium, and all radionuclides are in DOE 1997 (*Background Levels of Selected Radionuclides and Metals in Soils and Geologic Media at the Paducah Gaseous Diffusion Plant* DOE/OR/07-1586&D2). Details on the derivation of the maximum values and other values for all other inorganic chemicals are in (DOE 1995).

b NALs were obtained from BGOU RI, except as indicated.

c Medians for these metals taken from Table 3.4 in DOE 1997.

d Background concentrations for neptunium and plutonium were only determined for surface soil.

e Consistent with the discussion in Table ES.2 of DOE 1997, these background levels are set at the detection limit used in the background study.

NA = Not Applicable. For median values of natural metals; all results for background samples were below the reporting limit. For radioisotopes; isotope is not naturally occurring and a background screening value is not applicable. These include cesium-137, neptunium-237, plutonium, and technitum-99.

<BKG = The NAL value is less than the 95 % UTL of the background dataset.

Maximum background concentrations are not reported.

Table 1.17. Summary of Detected Concentrations and Comparison to Background and No Action Screening Levels for Metals and Radionuclides in Subsurface Soils

Parameter	BGOU Data Summary					Background Data Screening						NAL Screen	
	Number of Analyses	Detectable Concen-trations	Min	Mean	Max	Median[a]	Number above Median	95% UTL[a]	Number above 95 % UTL	Maximum[a]	Number above Maximum	No Action Level [b]	Number above NAL
Arsenic	414	238	8.98E-01	4.11E+00	2.20E+01	2.00E+00	169	7.90E+00	23	4.21E+01	0	3.13E-01	< BKG
Barium	444	444	6.14E+00	6.77E+01	3.50E+02	3.90E+01	296	1.70E+02	10	6.59E+02	0	5.92E+02	0
Beryllium[c]	444	202	2.00E-01	8.62E-01	3.07E+00	4.62E-01	194	6.90E-01	116	2.50E+01	0	9.48E-01	47
Cadmium	444	24	4.20E-02	4.05E-01	2.47E+00	NA	NA	2.10E-01	9	2.10E-01		2.12E+00	2
Chromium (total)[c]	444	442	2.38E+00	1.50E+01	2.96E+02	1.10E+01	259	4.30E+01	12	5.03E+02	0	2.11E+02	1
Cobalt	414	326	1.25E+00	5.88E+00	1.56E+02	4.40E+00	155	1.30E+01	20	6.87E+01	1	3.11E+02	0
Copper	414	391	2.02E+00	8.74E+00	1.35E+02	6.20E+00	201	2.50E+01	10	1.88E+04	0	4.37E+02	0
Iron	414	414	1.05E+03	1.29E+04	5.87E+04	1.18E+04	175	2.80E+04	19	9.77E+04	0	1.90E+03	< BKG
Lead	426	228	1.01E+00	8.93E+00	1.20E+02	6.90E+00	92	2.30E+01	13	1.16E+03	0	5.00E+01	1
Manganese	432	432	4.88E+00	2.10E+02	2.70E+03	1.25E+02	225	8.20E+02	13	8.10E+03	0	2.29E+02	< BKG
Mercury	426	41	1.60E-02	5.31E-02	4.70E-01	1.00E-01	4	1.30E-01	1	1.19E+01	0	1.00E+00	0
Nickel	432	310	4.54E+00	1.30E+01	1.01E+02	7.60E+00	199	2.20E+01	33	1.23E+04	0	2.05E+02	0
Selenium	426	13	4.10E-01	6.29E-01	1.00E+00	3.01E-01	13	7.00E-01	3	3.82E+00	0	7.13E+01	0
Silver	444	6	1.80E-01	4.75E+00	1.96E+01	1.00E+00	6	2.70E+00	1	1.40E+01	0	4.11E+01	0
Thallium[c,e]	432	20	5.50E-01	1.18E+00	2.00E+00	NA	NA	NA	NA	NA	NA	7.11E-01	16
Uranium[c]	274	91	9.21E-01	6.67E+01	1.50E+03	3.62E+00	44	4.60E+00	42	NA	NA	1.10E+01	35
Vanadium	432	403	2.13E+00	2.01E+01	7.91E+01	1.70E+01	236	3.70E+01	23	6.87E+01	3	3.04E+00	< BKG
Zinc	418	261	1.51E+01	3.67E+01	2.61E+02	1.90E+01	264	6.00E+01	27	1.13E+03	0	2.50E+03	0
Cesium-137[d]	460	25	3.00E-02	2.72E-01	1.48E+00	NA	NA	NA	NA			8.58E-02	17
Neptunium-237[d]	380	78	-1.50E-02	1.59E-01	1.84E+00	NA	NA	NA	NA			2.71E-01	11
Plutonium-238[d]	212	0	-	-	-	NA	NA	NA	NA			1.66E+00	0
Plutonium-239[d]	77	77	-2.40E-01	5.78E-02	6.20E-01	NA	NA	NA	NA			1.62E+00	0
Radium-226	89	40	1.60E-01	1.19E+00	2.53E+00	1.09E+00	21	1.50E+00	11			2.56E-02	< BKG
Technetium-99[d]	560	115	-4.37E-02	2.06E+01	2.81E+02	NA	NA	NA	NA			5.79E+01	7
Thorium-228	224	208	9.23E-02	3.76E-01	1.92E+00	1.15E+00	5	1.90E+00	1			2.80E-02	< BKG
Thorium-230	291	213	1.31E-01	2.28E+00	1.93E+02	1.12E+00	53	1.40E+00	20			2.22E+00	10
Thorium-232	221	206	6.51E-02	3.67E-01	2.28E+00	1.08E+00	2	1.50E+00	2			1.95E+00	2
Uranium-234	342	199	4.98E-02	8.85E+00	2.54E+02	9.26E-01	87	2.40E+00	58			2.83E+00	53
Uranium-235	209	13	2.50E-02	6.77E-01	4.20E+00	5.40E-02	8	1.40E-01	7			3.95E-01	4
Uranium-238	346	199	1.18E-01	2.49E+01	9.47E+02	9.65E-01	105	1.20E+00	97			1.17E+00	97

Table 1.17. Summary of Detected Concentrations and Comparison to Background and No Action Screening levels for Metals and Radionuclides in Subsurface Soils (Continued)

a Median and 95% UTL values of background concentrations for surface soil at the PGDP from the 2009 Risk Methods document, DOE/LX/07-0107&D1/V1. Details on the derivation of the values shown for antimony, beryllium, cadmium, thallium, uranium, and all radionuclides are in DOE 1997, *Background Levels of Selected Radionuclides and Metals in Soils and Geologic Media*. Details on the derivation of the maximum values and other values for all other inorganic chemicals are in DOE 1995, *Background Concentrations and Human Health Risk-based Screening Criteria*.

b NALs were obtained from DOE/LX/07-0030&D2/R1, BGOU RI, except as indicated.

c Medians for these metals taken from Table 3.4 in DOE 1997.

d Cesium-137, neptunium, plutonium, and technetium are not naturally occurring elements.

e Consistent with the discussion in Table ES.2 of DOE 1997, these background levels are set at the detection limit used in the background study.

NA = Not Applicable. For median values of natural metals; all results for background samples were below the reporting limit. For radioisotopes; isotope is not naturally occurring and a background screening value is not applicable. These include cesium-137, neptunium-237, plutonium, and technitum-99.

<BKG = The NAL value is less than the 95 % UTL of the background dataset.

Maximum background concentrations are not reported.

Table 1.18. Qualitative Evaluation of Metals and Radionuclides in Surface Soils

Parameter	Number of Analyses	Detectable Concentrations	Is the Metal or Radionuclide a Factor in Remedial Action Decision?
Aluminum	76	76	No, but background is above the NAL
Antimony	76	12	No, all concentrations are estimated or near the reporting limit are considered instrument background
Arsenic	76	35	No, distribution appears consistent with DOE/OR/07-1586&D2,[a] thus within the range of background
Barium	76	76	No, distribution appears consistent with DOE/OR/07-1586&D2, thus within the range of background
Beryllium	76	40	No, detection frequency is less < 50 % and none exceed the background maximum.
Cadmium	76	11	No, distribution appears consistent with DOE/OR/07-1586&D2, thus within the range of background
Chromium (total)	76	76	No, distribution appears consistent with DOE/OR/07-1586&D2, thus within the range of background
Cobalt	76	74	No, distribution appears consistent with DOE/OR/07-1586&D2, thus within the range of background
Copper	76	76	No, all concentrations are below NAL
Iron	76	76	No, distribution appears consistent with DOE/OR/07-1586&D2, thus within the range of background
Lead	76	23	No, all concentrations are below EPA action levels for soils
Manganese	76	76	No, distribution appears consistent with DOE/OR/07-1586&D2, thus within the range of background
Mercury	76	13	No, all concentrations are below NAL
Nickel	76	71	No, distribution appears consistent with DOE/OR/07-1586&D2, thus within the range of background
Selenium	76	8	No, detections are less than 5%
Silver	76	5	No, all concentrations are below NAL
Thallium	76	7	No, all concentrations are estimated or near the reporting limit and are considered false positives
Uranium	76	18	Yes
Vanadium	76	76	No, distribution appears consistent with DOE/OR/07-1586&D2, thus within the range of background
Zinc	76	68	No, all concentrations are below NAL
Cesium-137	69	22	Yes
Neptunium-237	47	16	Yes
Plutonium-238	28	0	No, all detected concentrations are less than the NAL
Plutonium-239	12	11	Yes, 2 detectable concentrations above the NAL
Radium-226	7	1	No, only one detectable concentration present in surface soils
Technetium-99	76	30	Yes
Thorium-228	28	1	No, 1 detectable concentration, NAL is less than the Background 95% UTL
Thorium-230	40	40	Yes
Thorium-232	28	27	No, all concentrations are below the NAL
Uranium-234	47	30	Yes
Uranium-235	37	0	No, not detected
Uranium-238	47	47	Yes

NAL—No Action Level
[a] The distribution is assumed to be either normal or log –normal. The sample mean is within 50% of the background median value, approximately 50% of the detected concentrations are above the median concentration of the background dataset, less than 5 percent of the concentrations are above the background 95% UTL, or less than 2 % of the sample concentrations are above the maximum background concentration.

Table 1.19. Qualitative Evaluation of Metals and Radionuclides in Subsurface Soils

Parameter	Number of Analyses	Detectable Concentrations	Is the Metal or Radionuclide a Factor in Remedial Action Decision?
Aluminum	76	76	No, NAL is below background
Antimony	76	12	No, all but 1 detectable results are estimated and close to the reporting limit are considered instrument background
Arsenic	76	35	No, NAL is below background
Barium	76	76	No, NAL is below background
Beryllium	76	40	No, detection frequency is less < 50 % and none exceed the background maximum.
Cadmium	76	11	No, detection frequency <5 %
Chromium (total)	76	76	No, all but 1 detectable concentration is below the No Action Level
Cobalt	76	74	No, distribution appears consistent with DOE/OR/07-1586&D2, and thus within the range of background
Copper	76	76	No, distribution appears consistent with DOE/OR/07-1586&D2, and thus within the range of background
Iron	76	76	No, distribution appears consistent with DOE/OR/07-1586&D2, and thus within the range of background
Lead	76	23	No, all concentrations but one are below NAL
Manganese	76	76	No, NAL is below background
Mercury	76	13	No, distribution appears consistent with DOE/OR/07-1586&D2, and thus within the range of background
Nickel	76	71	No, all concentrations are below NAL
Selenium	76	8	No, all concentrations are below NAL
Silver	76	5	No, all concentrations are below NAL
Thallium	76	7	No, detection < 5%
Uranium	76	18	Yes
Vanadium	76	76	No, NAL is below background
Zinc	76	68	No, concentrations are below NAL
Cesium-137	69	22	Yes
Neptunium-237	47	16	Yes
Plutonium-238	28	0	No, all detected concentrations are less than the NAL
Plutonium-239	12	11	No, all detected concentrations are less than the NAL
Radium-226	7	7	No, distribution appears consistent with DOE/OR/07-1586&D2, and thus within the range of background
Technetium-99	76	30	Yes
Thorium-228	28	1	No, distribution appears consistent with DOE/OR/07-1586&D2, and thus within the range of background
Thorium-230	40	40	No, distribution appears consistent with DOE/OR/07-1586&D2, and thus within the range of background
Thorium-232	28	27	No, distribution appears consistent with DOE/OR/07-1586&D2, and thus within the range of background
Uranium-234	47	30	Yes
Uranium-235	37	0	Yes
Uranium-238	47	47	Yes

NAL—No Action Level

THIS PAGE INTENTIONALLY LEFT BLANK

2. IDENTIFICATION AND SCREENING OF TECHNOLOGIES

RAOs and RGs for potential remedial actions are introduced and developed in this section. In addition, technology types and process options that may be applicable for remediation of BGOU sources are identified, screened, and evaluated in this section. A primary objective of this FS is to identify remedial technologies and process options that potentially meet the RAOs for this action and then combine them into a range of remedial alternatives. The potential remedial technologies are evaluated for implementability, effectiveness, and relative cost in eliminating, reducing, or controlling risks to human health and the environment. The criteria for identifying, screening, and evaluating potentially applicable technologies are provided in EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988) and the NCP.

CERCLA requires development and evaluation of a range of responses, including a No Action alternative, to ensure that an appropriate remedy is selected. The selected final remedy must comply with applicable or relevant and appropriate requirements (ARARs), unless waived, and must protect human health and the environment. The technology screening process consists of a series of steps that include the following:

- Identifying general response actions (GRAs) that may meet RAOs, either individually or in combination with other GRAs;
- Identifying, screening, and evaluating remedial technology types for each GRA; and
- Selecting one or more representative process options (RPOs) for each technology type.

Following the technology screening, the RPOs are assembled into remedial alternatives that are evaluated further in the detailed and comparative analyses of alternatives.

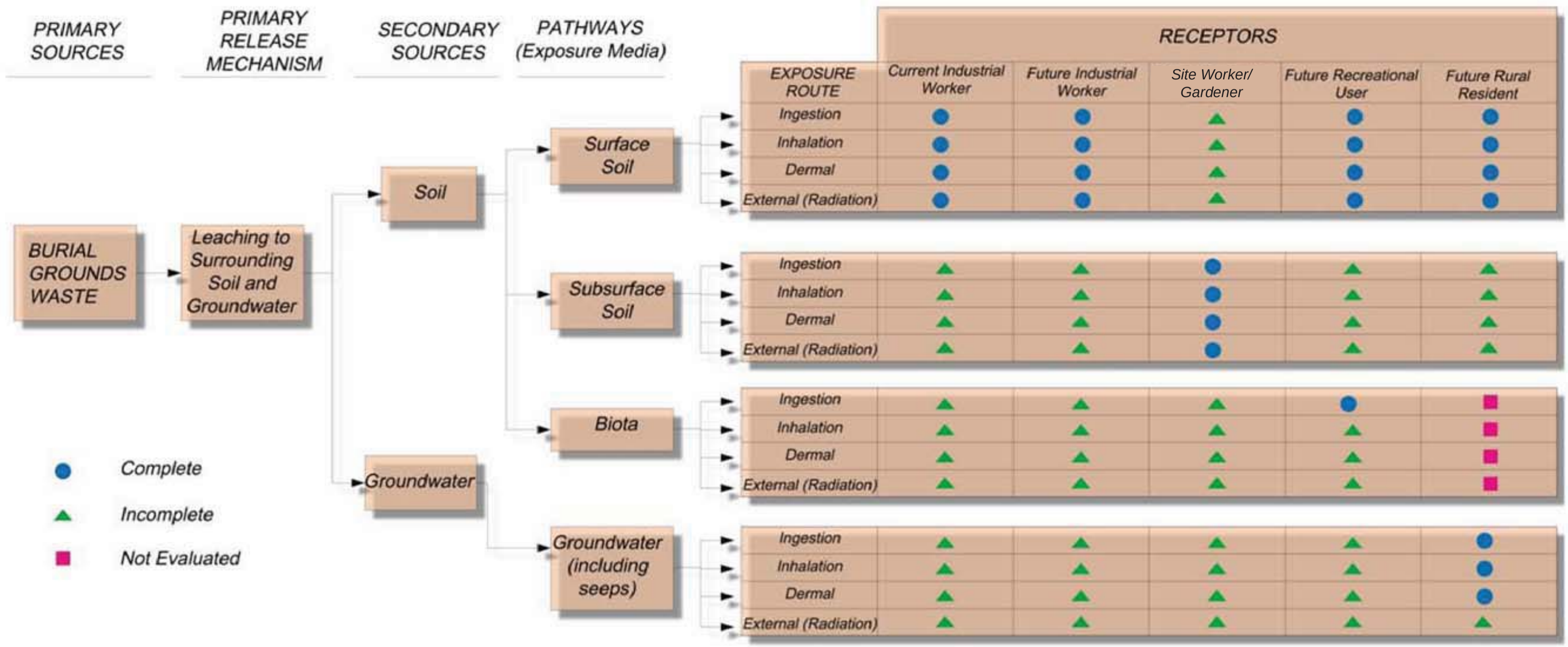
2.1 INTRODUCTION

Previous PGDP investigations and reports used to develop the CSM and to identify and screen remedial technologies are listed in Section 1.

Other sources used in technology identification and screening, including EPA, DOE, and peer-reviewed databases and reports, and journal publications, are cited and the references are provided.

Technologies are identified and evaluated in this FS based on their effectiveness in reducing or eliminating the primary sources.[2] Primary sources fall into two broad categories based on their physical and chemical properties: (1) VOCs to include TCE, TCE degradation products, and other chlorinated solvents; and (2) radioactive materials and inorganic chemicals. Technologies also are identified and evaluated for their effectiveness in reducing or eliminating secondary sources[3] such as DNAPL originating from primary VOC sources, eliminating or mitigating the secondary release mechanisms, or eliminating the exposure pathways, as shown in the CSM of the BGOU source areas (Figure 2.1). Other COCs that occur infrequently at the BGOU are nonvolatile organic chemicals such as PCBs and PAHs. These COCs are amenable to some of the same physical treatment remedial technologies identified for

[2]A primary source is contamination present in the waste material disposed in a waste management unit.
[3]A secondary source is contamination caused by the presence of contaminants that have migrated outside of the waste management unit.



U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Figure 2.1. Conceptual Site Model for BGOU

Figure 2.1 is based on Figure F.1 of the *Remedial Investigation Report for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0030&D2/R1, February (DOE 2010).

radioactive/inorganic COCs, but technologies also were evaluated for remediation of these classes of contaminants.

RPOs were developed from the appropriate technology types necessary to address the physical and chemical nature of the contamination at each SWMU. Alternatives were developed by combining the appropriate RPOs to remediate the full scope of contamination at each SWMU, including, in some cases, both radioactive/inorganic and DNAPL contamination source RPOs.

2.2 DEVELOPMENT OF RAOS

The RAOs for the BGOU FS, developed in accordance with NCP requirements, consist of site-specific goals for protecting human health and the environment (EPA 1988) and meeting ARARs (in the absence of a CERCLA waiver). The RAOs were developed from the CSM, and the BHHRA results by identifying the COCs and their sources, and the contaminant migration pathways and exposure scenarios that the action will address. The resulting RAOs are word statements that specify the media, COCs, potential exposure routes, and potential receptors.

2.2.1 Allowable Exposure Based Upon Risk Assessment (Including ARARs)

ARARs include federal or more stringent state environmental or facility siting laws/regulations that are applicable or relevant and appropriate to the hazardous substances or circumstances at a site unless a CERCLA waiver is granted. ARARs do not include occupational safety or worker protection requirements. Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state environmental or facility siting law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site (40 *CFR* § 300.5). Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state environmental or facility siting law that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site (40 *CFR* § 300.5). In addition to ARARs, there are advisories, criteria, or guidance to be considered (TBC) for a particular release that were developed by other federal agencies or states that may be useful in developing CERCLA remedies. These are not potential ARARs, but are TBC guidance [40 *CFR* § 300.400(g)(3)]. CERCLA § 121(d)(4) provides several ARAR waiver options that may be invoked, provided that human health and the environment are protected.

ARARs typically are divided into three categories: (1) chemical-specific, (2) location-specific, and (3) action-specific. “Chemical-specific ARARs usually are health-or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numerical values” [(53 *FR* 51394, 51437 (December 21, 1988)]. (In the absence of a chemical-specific ARARs, cleanup criteria are based upon risk calculations consistent with those used to complete the BHHRA for the BGOU SWMUs.) Location-specific ARARs generally are restrictions placed upon the concentration of hazardous substances or the conduct of activities solely because they are in special locations [53 *FR* 51394, 51437 (December 21, 1988)]. Action-specific ARARs usually are technology-or activity-based requirements or limitations on actions taken with respect to hazardous wastes or requirements to conduct certain actions to address particular circumstances at a site [53 *FR* 51394, 51437 (December 21, 1988)].

There are no chemical-specific ARARs for remediation of the contaminated soils at the source areas with identified COCs. The Kentucky drinking water standard MCLs were used to back calculate soil RGs (see 401 *KAR* 8:250 for inorganic compounds, 8:420 for VOCs, and 8:550 for radionuclides) but are not ARAR for this source removal action.

DOE Order 5400.5, *Radiation Protection of the Public and Environment*, is TBC for operation of DOE facilities. The DOE 5400.5 requires that all exposure pathways, including those presented from remedial activities at a DOE facility, not result in radiation exposures to members of the general public greater than an effective dose equivalent (EDE) of 100 mrem/year.

2.2.2 RAOs

The FS includes SWMU-specific RAOs for addressing source areas, including treatment and/or removal of PTWs consistent with CERCLA, the NCP (including the Preamble), and any pertinent EPA guidance. The following general RAOs were developed during scoping meetings conducted between the regulators and DOE and were used in screening technologies and developing and evaluating alternatives in the FS for the BGOU SWMUs:

(1) Contribute to the protection of current and future off-site residential receptors from exposure to contaminated groundwater by reducing/controlling sources of groundwater contamination;

(2) Protect industrial workers from exposure to waste and contaminated soils; and

(3) Treat or remove PTW wherever practicable, consistent with 40 *CFR* § 300.430 (a)(1)(iii)(A).

Alternatives determined to meet these general RAOs then were screened against site-specific RAOs and analyzed in more detail, including completion of a comparative analysis of selected alternatives. SWMU-specific sections of this FS present these results.

2.2.3 Remediation Goals

Direct contact RGs were developed for the contaminated surface and subsurface soils in the UCRS. These direct contact RGs are common to the entire BGOU and are not specific to any SWMU. The approach for developing the RGs for individual COCs at each SWMU is presented in detail below. These RGs are media-specific goals that serve as the basis for identifying and screening the treatment processes or mass removal and containment efficiencies required for the alternatives developed in Section 3.

COCs for soil were identified as described in Section 1. RGs developed for COCs in surface soil [0 to 1 ft below ground surface (bgs)] are protective of direct exposures of industrial workers.

RGs developed for COCs in subsurface soil are protective of direct exposures of outdoor worker. The depth of subsurface soil varies according to SWMU, but is expected to extend from 1 to ~16 bgs, with a maximum expected depth of 20 ft bgs at BGOU SWMUs.

Those COCs that represent a threat to groundwater are identified in Table 5.2 of the RI Report (DOE 2010). The approach for establishing soil RGs that are protective of the groundwater exposure pathway was to assume that the COC might leach from either surface or subsurface soil and reach the RGA groundwater beneath the SWMU in concentrations that might exceed the MCL established by the Safe Drinking Water Act. A risk-based concentration is used in the assumption for naphthalene, which is the only COC without an MCL. CERCLA requires that RGs in soil be protective of groundwater throughout the plume when waste is excavated or at and beyond the edge of the waste management area when waste is left in place.

Metals that were identified as COCs according to the BHHRA criteria were compared with natural background concentrations at PGDP, as described in Section 1. Certain metals were found to be consistent with background, and no remediation goals were developed for these metals; therefore, they were not considered further in the FS. The radionuclide COCs that are above background levels at each SWMU, along with the organic COCs identified in either surface or subsurface soil at any BGOU SWMU, are shown in Tables 2.1 and 2.2. COCs that were identified according to the BHHRA criteria and exceed background levels are shown in column 2 of these tables. Background concentrations for the COCs are shown in column 3.

The RGs based on risks from direct exposure to COCs in surface and subsurface soil (ingestion, inhalation, or dermal contact) and the groundwater protective RGs are shown in column 5 of Tables 2.1 and 2.2. The process for establishing the appropriate RG for each COC at each SWMU is illustrated in Figures 2.2 and 2.3, and the details of how these RGs were developed are described in the following sections.

2.2.3.1 Remediation goals for groundwater protection

Preliminary soil RGs for COCs identified in groundwater were developed that are protective of off-site residential groundwater use. These groundwater protective RGs were developed to protect groundwater from COC migration from soil to groundwater. (See column 5 of Tables 2.1 and 2.2).

The MCL established in the Safe Drinking Water Act was established as the groundwater concentration for most COCs (Tables 2.1 and 2.2). Where an MCL was not available for a chemical (naphthalene), a risk-based groundwater concentration was calculated based on the NAL for residential water use shown in Table A.5 of the Risk Methods Document (DOE 2001). Groundwater concentrations used in the development of groundwater protective soil RGs are shown in column 6 of Tables 2.1 and 2.2.

The MCL concentrations for radionuclides are given in EPA (2000a) guidance. The MCL concentration for gross alpha emitters is 15 pCi/L, excluding radon and uranium, and was applied to neptunium-237 and plutonium-239 at SWMUs 7 and 30. The MCL concentrations for beta and photon emitters correspond to an annual radiation dose limit of 4 mrem/yr, which corresponds to a concentration of 900 pCi/L for technetium-99 at BGOU SWMUs. The MCL concentration for uranium-234 and uranium-238 is 30 pCi/L and was applied to these isotopes at BGOU SWMUs. No MCL value is specified for uranium-235 except as included in the MCL of 3.0E-02 mg/L established for uranium metal. Guidance for use of MCL values at CERCLA sites is given by EPA (EPA 2001). The same groundwater protective RG for soil applies to both surface and subsurface soil. COC transport modeling reported in the RI Report indicates that COC concentrations in groundwater beneath all of the modeled SWMUs will decrease in concentration upon transport downgradient to the PGDP property boundary. Groundwater that originates beneath BGOU SWMUs, and contains COC concentrations at or below MCL concentrations, will not contribute higher concentrations to groundwater at down gradient property boundary locations. If the COC has both carcinogenic and noncarciogenic properties, the lower RG concentration is shown in the tables. COCs that were shown to be immobile by modeling reported in the RI Report do not require a groundwater protective RG. Their MCLs are shown in Tables 2.1 and 2.2 for information purposes.

Table 2.1. Preliminary Surface Soil Remediation Goals for COCs Identified in the BGOU RI Report

SWMU No.	Contaminant of Concern[1]	Background[2] Surface Soil (mg/kg) (pCi/g)	Direct Contact Remediation Goal for Surface Soil[3] (mg/kg) (pCi/g)	Groundwater-Protective Remediation Goal for Soil[4] (mg/kg) (pCi/g)	MCL[5] (mg/L) (pCi/L)	Preliminary Remediation Goal for Surface Soil[6] (mg/kg) (pCi/g)
2	Technetium-99	2.5	X	9.90E+00	9.00E+02[7]	9.90E+00
	Uranium (metal)	4.9	X	No load	3.00E-02	X
	Uranium-234	2.5	X	No load	2.0E+01[8]	X
	Uranium-235+D	0.14	1.98E+00	No load	2.0E+01[8]	1.98E+00
	Uranium-238+D	1.2	8.55E+00	No load	2.0E+01[8]	8.55E+00
	cis-1,2-Dichloroethene	NE	X	2.17E+00	7.00E-02	2.17E+00
	Trichloroethene	NE	X	1.25E-01	5.00E-03	1.25E-01
	Naphthalene	NE	X	2.85E-03	*2.85E-04*	2.85E-03
	Total PCBs[9]	NE	1.0E+01[9]	No load	NA[9]	1.0E+01[9]
3	Technetium-99	2.5	X	4.50E+00	9.00E+02[7]	4.50E+00
	Uranium (metal)	4.9	X	No load	3.00E-02	X
	Uranium-235+D	0.14	1.98E+00	No load	2.0E+01[8]	1.98E+00
	Uranium-238+D	1.2	8.55E+00	No load	2.0E+01[8]	8.55E+00
4	Technetium-99	2.5	X	6.30E+00	9.00E+02[7]	6.30E+00
	Uranium (metal)	4.9	Subsurface Soil Only (See Table 2.2)	No load	3.00E-02	Subsurface Soil Only (See Table 2.2)
	Uranium-238+D	1.2	8.55E+00	No load	2.0E+01[8]	8.55E+00
	cis-1,2-Dichloroethene	NE	X	7.70E-01	7.00E-02	7.70E-01
	Trichloroethene	NE	X	4.00E-02	5.00E-03	4.00E-02
	Vinyl chloride	NE	X	3.60E-02	2.00E-03	3.60E-02
	Total Dioxins/Furans[10]	NE	Subsurface Soil Only (See Table 2.2)	No load	3.00E-08[10]	Subsurface Soil Only (See Table 2.2)
	Total PCBs[9]	NE	1.0E+01[9]	No load	NA[9]	1.0E+01[9]
5	Technetium-99	2.5	X	5.40E+00	9.00E+02[7]	5.40E+00
	Naphthalene	NE	X	5.99E-03	*2.85E-04*	5.99E-03
	Total PAH[11]	NE	NA[11]	No load	NA[11]	NA[11]
	Total PCBs[9]	NE	Subsurface Soil Only (See Table 2.2)	No load	NA[9]	Subsurface Soil Only (See Table 2.2)
6	No COCs					

Table 2.1. Preliminary Surface Soil Remediation Goals for COCs Identified in the BGOU RI Report (Continued)

SWMU No.	Contaminant of Concern[1]	Background[2] Surface Soil (mg/kg) (pCi/g)	Direct Contact Remediation Goal for Surface Soil[3](mg/kg) (pCi/g)	Groundwater-Protective Remediation Goal for Soil[4] (mg/kg) (pCi/g)	MCL[5] (mg/L) (pCi/L)	Preliminary Remediation Goal for Surface Soil[6] (mg/kg) (pCi/g)
7	Neptunium-237+D	0.1	1.36E+00	No load	5.0E+00[12]	1.36E+00
	Plutonium-239+D	0.025	Subsurface Soil Only (See Table 2.2)	No load	1.0E+01[12]	Subsurface Soil Only (See Table 2.2)
	Technetium-99	2.5	X	7.20E+00	9.00E+02[7]	7.20E+00
	Uranium (metal)	4.9	1.01E+02	No load	3.00E-02	1.01E+02
	Uranium-234+D	2.5	9.90E+01	No load	2.0E+01[8]	9.90E+01
	Uranium-235/236[13]	0.14	1.98E+00	No load	2.0E+01[8]	1.98E+00
	Uranium-238+D	1.2	8.55E+00	No load	2.0E+01[8]	8.55E+00
	1,1-Dichloroethene	NE	X	1.61E-01	7.00E-03	1.61E-01
	cis-1,2-Dichloroethene	NE	X	1.47E-00	7.00E-02	1.47E+00
	Trichloroethene	NE	X	1.00E-01	5.00E-03	1.00E-01
	Vinyl chloride	NE	X	8.02E-02	2.00E-03	8.02E-02
	Total PCBs[9]	NE	1.0E+01[9]	No load	NA[9]	1.0E+01[9]
30	Neptunium-237+D	0.1	1.36E+00	No load	5.0E+00[12]	1.36E+00
	Plutonium-239+D	0.025	Subsurface Soil Only (See Table 2.2)	No load	1.0E+01[12]	Subsurface Soil Only (See Table 2.2)
	Technetium-99	2.5	X	1.17E+01	9.00E+02[7]	1.17E+01
	Uranium (metal)	4.9	1.01E+02	No load	3.00E-02	1.01E+02
	Uranium-234+D	2.5	9.90E+01	No load	2.0E+01[8]	9.90E+01
	Uranium-235/236[13]	0.14	1.98E+00	No load	2.0E+01[8]	1.98E+00
	Uranium-238+D	1.2	8.55E+00	No load	2.0E+01[8]	8.55E+00
	1,1-Dicloroethene[14]	NE	(X) 4.80E-01	1.56E+00	7.00E-03	4.80E-01
	Trichloroethene	NE	X	6.35E-01	5.00E-03	6.35E-01
	Total PCBs[9]	NE	1.0E+01[9]	No load	NA[9]	1.0E+01[9]
145	Technetium-99	2.5	X	8.10E+00	9.00E+02[7]	8.10E+00

NA: Not applicable as described in Note cited.
NE: Not established in DOE 2001 Risk Methods Document.
No load: Modeling indicates no transport from source to groundwater at any SWMU; therefore, a groundwater protective RG does not apply.
X: Chemical is not identified as a COC for direct contact exposure. If fate and transport modeling at this SWMU also indicates the COC is immobile ("No load" entry), it is not expected to threaten groundwater. No RG is developed.
[1] COC identified according to the risk methods document (DOE 2001, pg. 3-37), *To determine COCs, risk characterization results for chemical hazard (HQi) and risk (ELCRi) over all pathways within a use scenario of concern will be compared to benchmarks of 0.1 and 1 × 10^{-6}, respectively. Chemicals of potential concern within a use scenario of concern exceeding either of these benchmarks will be deemed COCs for the use scenario of concern.*
[2] Provisional background concentrations for surface soil at the PGDP given in Table A.12 of the Risk Methods Document (DOE 2001). Metals given in mg/kg units; radionuclides given in pCi/g units.

Table 2.1. Preliminary Surface Soil Remediation Goals for COCs Identified in the BGOU RI Report (Continued)

[3] Direct contact RG for surface soil is calculated as 5 x the Industrial Worker NAL for carcinogenic COCs. The Industrial Worker NAL for carcinogenic COCs corresponds to a cancer risk of 1 x 10-6; the resulting RG corresponds to a cancer risk of 5 x 10-For noncarcinogenic COCs, the RG is calculated as 5 x the Industrial Worker NAL for noncarcinogenic COCs. The NAL for noncarcinogenic COCs corresponds to a noncancer hazard quotient of 0.1; the resulting RG corresponds to a noncancer hazard quotient of 0.5. The lower of the two values is shown for COCs having both cancer or noncancer health effects. NAL values are given in Table A.4 of the DOE (2000) document.

[4] RG for soil developed to protect groundwater from COC migration from soil to groundwater and is applied to both surface and subsurface soil. The RG is calculated as dilution attenuation factor (DAF) x the MCL. DAF values are given in Table B.4. For naphthalene, which is a noncarcinogen and has no MCL, the groundwater protective soil RG beneath the SWMU is calculated using the DAF and the risk-based concentration protective of groundwater use by a rural resident (see Note 5).

[5] Italics indicate groundwater concentration is a risk-based concentration. Radionuclide concentrations are given in pCi/L units. For naphthalene, which has no MCL, the value equals the NAL concentration for residential groundwater use corresponding to 5 x the HQ = 0.1 value of 2.85E-04 mg/L given in Table A.5 and corresponds to a noncancer hazard quotient of 0.5 (see Note 3).

[6] The RG for Soil is the lower of the direct contact RG and groundwater protective RG for Soil. If the background concentration is greater than the lower of the direct contact RG and groundwater protective RG, the Remediation Goal for Soil equals the background concentration.

[7] The MCL concentration for beta and photon emitters corresponding to specified annual radiation dose limit of 4 mrem/yr equals 900 pCi/L for Tc-99. EPA Facts About Technetium-99, EPA July 2002.

[8] The Risk Methods Document gives a groundwater MCL concentration of 20 pCi/L for all uranium isotopes without regard to relative radiotoxicity (Table A.2, DOE 2001).

[9] The direct contact RG for total PCBs of 10 mg/kg was agreed upon as part of risk management discussions during a June 2009 BGOU scoping meeting among DOE, EPA, and KY. At that meeting, the group recognized that, when used as an upper-bound goal for individual detections, the average concentration of PCBs for the unit is expected to be significantly lower.

[10] The RG value for total dibenzodioxin and dibenzofuran compounds is based on the MCL concentration for 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) toxicity equivalent concentration (TEQ). 2,3,7,8-TCDD is the most toxic of dibenzodioxin and dibenzofuran congeners and the only congener with an MCL.

[11] No COCS were identified for soil at SWMU 6.

[12] The MCL concentration for gross alpha emitter concentrations is 15 pCi/L, excluding radon and uranium. The MCL of 15 pCi/L for Np-237 and Pu-239 was distributed between the two isotopes according to their relative radiotoxicities reflected in their Carcinogenicity Slope Factors for water ingestion (Np-237 = 6.747E-11 pCi-1 and Pu-239 = 1.35E-10 pCi-1) given in Federal Guidance Report No.13 (EPA 1999a). MCL distributed according to cancer morbidity risk = MCL x (Slope Factor(i)/[Slope Factor(i) + Slope Factor(j)].

[13] Uranium-235 and uranium-235/236 both were identified as COCs at this SWMU. This identification is assumed to result from use of data from analytical methods that are not able to differentiate the U-235 and U-236 isotopes. Cancer risk coefficients for morbidity from inhalation, ingestion, and external exposure to these isotopes are given in Table 2.1, Table 2.2a, and Table 2.3 of Federal Guidance Report No. 13 (EPA 1999a). The inhalation risk coefficients for U-235 and U-236 are similar, 1.59E-08 Bq-1 and 1.61E-08 Bq-1, respectively. The risk coefficients for U-235 and U-236 ingestion for water are similar, 1.88E-09 Bq-1 and 1.81E-09 Bq-1, respectively. The external exposure risk coefficient for U-235 exceeds that for U-236, 4.44E-16 kg/Bq-sec and 1.07E-19 kg/Bq-sec, respectively. Because risks from direct exposure to U-235/U-236 is predominantly associated with ingestion exposure, the Remediation Goal developed for U-235 serves for both U-235 and U-235/236 at this SWMU.

[14] Chemical is not identified as a direct contact soil COC in the RI report (DOE 2010); however, the value shown is the direct contact RG calculated as described in Note 3. The preliminary RG (column 7) represents the lower of the direct contact RG and the groundwater protective RG (column 5) back-calculated from the MCL concentration (see Note 4).

Table 2.2. Preliminary Subsurface Soil Remediation Goals for COCs Identified in the BGOU RI Report

SWMU No.	Contaminant of Concern[1]	Background[2] Subsurface Soil (mg/kg) (pCi/g)	Direct Contact Remediation Goal for Subsurface Soil[3](mg/kg) (pCi/g)	Groundwater-Protective Remediation Goal for Soil[4] (mg/kg) (pCi/g)	MCL[5] (mg/L) (pCi/L)	Preliminary Remediation Goal for Subsurface Soil[6] (mg/kg) (pCi/g)
2	Technetium-99	2.8	X	9.90E+00	9.00E+02[7]	9.90E+00
	Uranium (metal)	4.6	X	No load	3.00E-02	X
	Uranium-234	2.4	X	No load	2.0E+01[8]	X
	Uranium-235+D	0.14	2.28E+01	No load	2.0E+01[8]	2.28E+01
	Uranium-238+D	1.2	5.85E+01	No load	2.0E+01[8]	5.85E+01
	cis-1,2-Dichloroethene	NE	X	2.17E+00	7.00E-02	2.17E+00
	Trichloroethene	NE	X	1.25E-01	5.00E-03	1.25E-01
	Naphthalene	NE	X	2.85E-03	*2.85E-04*	2.85E-03
	Total PCBs[9]	NE	1.0E+01[9]	No load	NA[9]	1.0E+01[9]
3	Technetium-99	2.8	X	4.50E+00	9.00E+02[7]	4.50E+00
	Uranium (metal)	4.6	X	No load	3.00E-02	X
	Uranium-235+D	0.14	2.28E+01	No load	2.0E+01[8]	2.28E+01
	Uranium-238+D	1.2	5.85E+01	No load	2.0E+01[8]	5.85E+01
4	Technetium-99	2.8	X	6.30E+00	9.00E+02[7]	6.30E+00
	Uranium (metal)	4.6	1.1.E+02	No load	3.00E-02	1.1.E+02
	Uranium-238+D	1.2	5.85E+01	5.85E+01	2.0E+01[8]	5.85E+01
	cis-1,2-Dichloroethene	NE	X	7.70E-01	7.00E-02	7.70E-01
	Trichloroethene	NE	X	4.00E-02	5.00E-03	4.00E-02
	Vinyl chloride	NE	X	3.60E-02	2.00E-03	3.60E-02
	Total Dioxins/Furans[10]	NE	1.75E-04	No load	3.00E-08[10]	1.75E-04
	Total PCBs[9]	NE	1.0E+01[9]	No load	NA[9]	1.0E+01[9]
5	Technetium-99	2.8	X	5.40E+00	9.00E+02[7]	5.40E+00
	Naphthalene	NE	X	5.99E-03	*2.85E-04*	5.99E-03
	Total PAH[11]	NE	NA[11]	No load	NA[11]	NA[11]
	Total PCBs[9]	NE	1.0E+01[9]	No load	NA[9]	1.0E+01[9]
6	No COCs					
7	Neptunium-237+D	NE	1.64E+01	No load	5.0E+00[12]	1.64E+01
	Plutonium-239+D	NE	8.15E+01	No load	1.0E+01[12]	8.15E+01
	Technetium-99	2.8	X	7.20E+00	9.00E+02[7]	7.20E+00
	Uranium (metal)	4.6	1.13E+02	No load	3.00E-02	1.13E+02
	Uranium-234+D	2.4	1.42E+02	No load	2.0E+01[8]	1.42E+02
	Uranium-235/236 [13]	0.14	2.28E+01	No load	2.0E+01[8]	2.28E+01
	Uranium-238+D	1.2	5.85E+01	No load	2.0E+01[8]	5.85E+01
	1,1-Dichloroethene	NE	X	1.56E+00	7.00E-03	1.61E-01
	cis-1,2-Dichloroethene	NE	X	1.47E-00	7.00E-02	1.47E+00
	Trichloroethene	NE	X	1.00E-01	5.00E-03	1.00E-01

Table 2.2. Preliminary Subsurface Soil Remediation Goals for COCs Identified in the BGOU RI Report (Continued)

SWMU No.	Contaminant of Concern[1]	Background[2] Subsurface Soil (mg/kg) (pCi/g)	Direct Contact Remediation Goal for Subsurface Soil[3](mg/kg) (pCi/g)	Groundwater-Protective Remediation Goal for Soil[4] (mg/kg) (pCi/g)	MCL[5] (mg/L) (pCi/L)	Preliminary Remediation Goal for Subsurface Soil[6] (mg/kg) (pCi/g)
7 (Continued)	Vinyl chloride	NE	X	8.02E-02	2.00E-03	8.02E-02
	Total PCBs[9]	NE	1.0E+01[9]	No load	NA[9]	1.0E+01[9]
30	Neptunium-237+D	NE	1.64E+01	No load	5.0E+00[12]	1.64E+01
	Plutonium-239+D	NE	8.15E+01	No load	1.0E+01[12]	8.15E+01
	Technetium-99	2.8	X	1.17E+01	9.00E+02[7]	1.17E+01
	Uranium (metal)	4.6	1.13E+02	No load	3.00E-02	1.13E+02
	Uranium-234+D	2.4	1.42E+02	No load	2.0E+01[8]	1.42E+02
	Uranium-235/236 [13]	0.14	2.28E+01	No load	2.0E+01[8]	2.28E+01
	Uranium-238+D	1.2	5.85E+01	No load	2.0E+01[8]	5.85E+01
	1,1-Dichloroethene	NE	X	1.56E+00	7.00E-03	1.56E+00
	Trichloroethene	NE	X	6.35E-01	5.00E-03	6.35E-01
	Total PCBs[9]	NE	1.0E+01[9]	No load	NA[9]	1.0E+01[9]
145	Technetium-99	2.8	X	8.10E+00	9.00E+02[7]	8.10E+00

NA: Not applicable as described in Note cited
NE: Not established in DOE 2001 Risk Methods Document.
No load: Modeling indicates no transport from source to groundwater at any SWMU; therefore, a groundwater protective RG does not apply.
X: Chemical is not identified as a COC for direct contact exposure. If fate and transport modeling at this SWMU also indicates the COC is immobile ("No load" entry), it is not expected to threaten groundwater. No RG is developed.

1 COC identified according to the risk methods document (DOE 2001, pg. 3-37), *To determine COCs, risk characterization results for chemical hazard (HQi) and risk (ELCRi) over all pathways within a use scenario of concern will be compared to benchmarks of 0.1 and 1×10^{-6}, respectively. Chemicals of potential concern within a use scenario of concern exceeding either of these benchmarks will be deemed COCs for the use scenario of concern.*

2 Provisional background concentrations for subsurface soil at the PGDP given in Table A.12 of the Risk Methods Document (DOE 2001). Metals given in mg/kg units; radionuclides given in pCi/g units.

3 Direct contact RG for subsurface soil calculated as 50 x the Excavation Worker NAL for carcinogenic COCs. The NAL for carcinogenic COCs corresponds to a cancer risk of 1 x 10^{-6}; the resulting RG corresponds to a cancer risk of 5 x 10^{-5}. For noncarcinogenic COCs, the RG is calculated as 10 x the Excavation Worker NAL for noncarcinogenic COCs. The NAL for noncarcinogenic COCs corresponds to a noncancer hazard quotient of 0.1; the resulting RG corresponds to a noncancer hazard quotient of 1. The lower of the two values is shown for COCs having either cancer or noncancer health effects. NAL values are given in Table A.4 of the DOE (2000) document.

4 RG for soil developed to protect groundwater from COC migration from soil to groundwater and is applied to both surface and subsurface soil. The RG is calculated as dilution attenuation factor (DAF) x the MCL. DAF values are given in Table B.4. For naphthalene, which is a noncarcinogen and has no MCL, the groundwater protective soil RG beneath the SWMU is calculated using the DAF and the risk-based concentration protective of groundwater use by a rural resident (see Note 5).

5 *Italics indicate groundwater concentration is a risk-based concentration for groundwater use.* Radionuclide concentrations are given in pCi/L units. For naphthalene, which has no MCL, the value equals the NAL concentration for residential groundwater use corresponding to 5 x the HQ = 0.1 value of 2.85E-04 mg/L given in Table A.5 and corresponds to a noncancer hazard quotient of 0.5 (see Note 3).

6 The RG for Subsurface Soil is the lower of the direct contact RG and groundwater protective RG for Soil. If the background concentration is greater than the lower of the direct contact RG and groundwater protective RG, the RG for Soil equals the background concentration.

7 The MCL concentration for beta and photon emitters corresponding to specified annual radiation dose limit of 4 mrem/yr equals 900 pCi/L for Tc-99, *EPA Facts About Technetium-99*, EPA July 2002.

8 The Risk Methods Document gives a groundwater MCL concentration of 20 pCi/L for all uranium isotopes without regard to relative radiotoxicity (Table A.2, DOE 2001).
TCDD is the most toxic of dibenzodioxin and dibenzofuran congeners and the only congener with an MCL.

9 The direct contact RG for total PCBs of 10 mg/kg was agreed upon as part of risk management discussions during a June 2009 BGOU scoping meeting among DOE, EPA, and KY. At that meeting, the group recognized that, when used as an upper-bound goal for individual detections, the average concentration of PCBs for the unit is expected to be significantly lower..

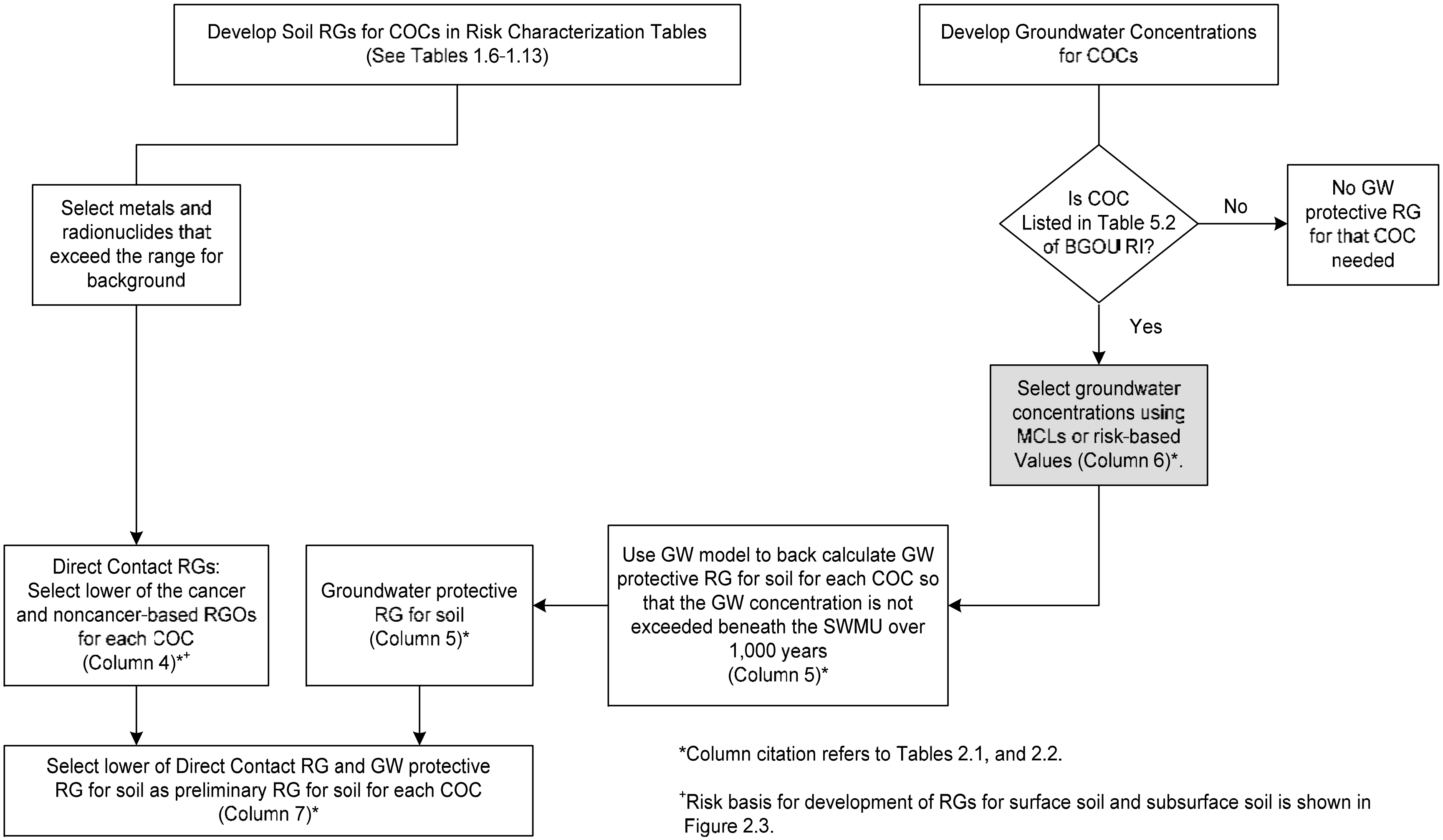
Table 2.2. Preliminary Subsurface Soil Remediation Goals for COCs Identified in the BGOU RI Report (Continued)

[10] The RG value for total dibenzodioxin and dibenzofuran compounds is based on the MCL concentration for 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) toxicity equivalent concentration (TEQ). 2,3,7,8-TCDD is the most toxic of dibenzodioxin and dibenzofuran congeners and the only congener with an MCL.

[11] No COCS were identified for soil at SWMU 6.

[12] The MCL concentration for gross alpha emitter concentrations is 15 pCi/L, excluding radon and uranium. The MCL of 15 pCi/L for Np-237 and Pu-239 was distributed between the two isotopes according to their relative radiotoxicities reflected in their Carcinogenicity Slope Factors for water ingestion (Np-237 = 6.747E-11 pCi^{-1} and Pu-239 = 1.35E-10 pCi^{-1}) given in *HEAST for Radionuclides* (EPA 2001). MCL distributed according to cancer morbidity risk = MCL x (Slope Factor(i)/[Slope Factor(i) + Slope Factor(j)].

[13] Uranium-235 and uranium-235/236 both were identified as COCs at this SWMU. This identification is assumed to result from use of data from analytical methods that are not able to differentiate the U-235 and U-236 isotopes. Cancer risk coefficients for morbidity from inhalation, ingestion, and external exposure to these isotopes are given in Table 2.1, Table 2.2a, and Table 2.3 of *Cancer Risk Coefficients for Environmental Exposure to Radionuclides, Federal Guidance Report No. 13*, EPA 402-R-99-001, (EPA 1999a) The inhalation risk coefficients for U-235 and U-236 are similar, 1.59E-08 Bq^{-1} and 1.61E-08 Bq^{-1}, respectively. The risk coefficients for U-235 and U_236 ingestion for water are similar, 1.88E-09 Bq^{-1} and 1.81E-09 Bq^{-1}, respectively. The external exposure risk coefficient for U-235 exceeds that for U-236, 4.44E-16 kg/Bq-sec and 1.07E-19 kg/Bq-sec, respectively. Because risks from direct exposure to U-235/U-236 is predominantly associated with ingestion exposure, the Remediation Goal developed for U-235 serves for both U-235 and U-235/236 at this SWMU.



*Column citation refers to Tables 2.1, and 2.2.

+Risk basis for development of RGs for surface soil and subsurface soil is shown in Figure 2.3.

Shading indicates groundwater concentration protective of off-site residential user and RG for soil protective of both future industrial worker and off-site residential groundwater user.

U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Figure 2.2. RG Development

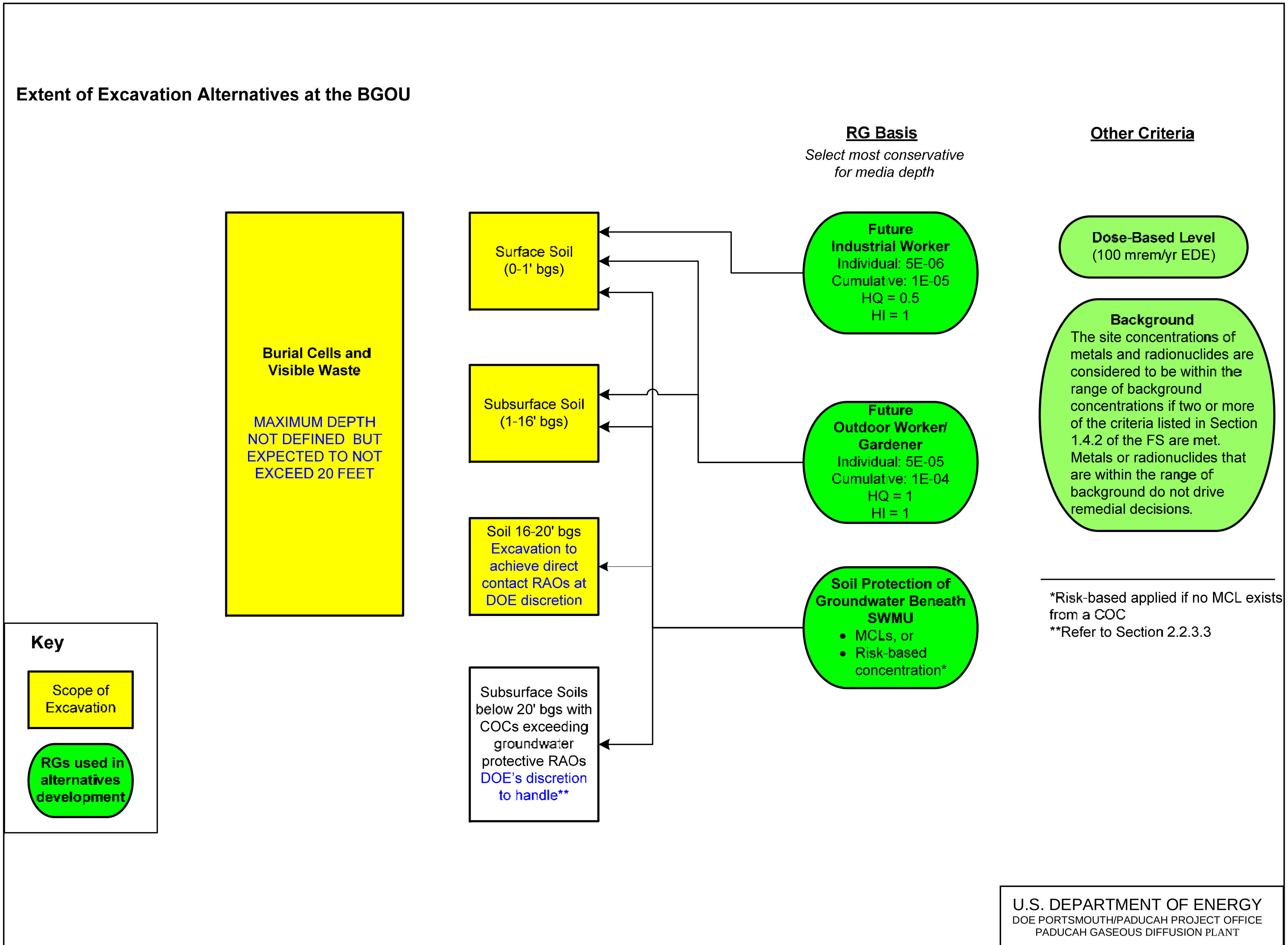


Figure 2.3. BGOU Excavation Extent and Applicable RGs

2.2.3.2 Remediation goals for soil

Remediation Goals for Direct Exposure to COCs in Soil

The direct contact RGs for COCs in soil that are protective of exposures of industrial workers to COCs in surface soil and future outdoor worker to COCs in subsurface soil were based on NALs. NAL values are given in Table A.4 of the Risk Methods Document (DOE 2001). The direct contact RGs for surface soil and subsurface soil are shown in Tables 2.1 and 2.2, respectively.

Surface Soil The direct contact RGs for COCs in surface soil that are protective of the industrial worker from exposure by soil ingestion, inhalation, and dermal contact pathways (column 4, Table 2.1) were calculated as 5 x the Industrial Worker NAL for carcinogenic COCs. The NAL for carcinogenic COCs corresponds to a cancer risk of 1 x 10^{-6}; the resulting RG corresponds to a cancer risk of 5 x 10^{-6}. For noncarcinogenic COCs, the RG is calculated as 5 x the Industrial Worker NAL for noncarcinogenic COCs. The NAL for noncarcinogenic COCs corresponds to a noncancer hazard quotient of 0.1; the resulting RG corresponds to a noncancer hazard quotient of 0.5. The lower of the two direct contact RGs is shown for COCs having either cancer or noncancer health effects.

Subsurface Soil The direct contact RGs for COCs in subsurface soil that are protective of outdoor worker exposures were calculated as 50 x the outdoor worker NAL for carcinogenic COCs. The NAL for carcinogenic COCs corresponds to a cancer risk of 1 x 10^{-6}; the resulting RG corresponds to a cancer risk of 5 x 10^{-5}. For noncarcinogenic COCs, the RG is calculated as 10 x the NAL for noncarcinogenic COCs. The NAL for noncarcinogenic COCs corresponds to a noncancer hazard quotient of 0.1; the resulting RG corresponds to a noncancer hazard quotient of 1. The lower of the two direct contact RGs is shown for COCs having either cancer or noncancer health effects.

Groundwater protective RG values for Total Dioxins and Furans are described as the 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) toxicity equivalent concentration (TEQ), which is the only dibenzodioxin or dibenzofuran species with an MCL.

The preliminary RG for soil is the lower of the direct contact RG and groundwater protective RG for soil. If the background concentration is greater than the lower of the direct contact RG and groundwater protective RG, the RG equals the background concentration. (See column 7 of Tables 2.1 and 2.2). The direct contact RG for total PCBs of 10 mg/kg was agreed upon as part of risk management discussions during a June 2009 BGOU scoping meeting among DOE, EPA, and KY and is applied at other PGDP OUs as the RG for soil at the BGOU.

Remediation Goals for COCS in Soil that are Protective of Groundwater

The approach to developing groundwater protective RGs for soil at each BGOU SWMU was based on data obtained from transport modeling used previously during the BGOU RI and is represented by Figures 2.2 and 2.3. The soil RGs developed in this way are protective of groundwater in the RGA found below the SWMU, which is the treatment zone for the BGOU. The period of model performance was 1,000 years. The 1,000 year time frame is consistent with DOE orders and *CFR* regulations regarding management of radionuclides in soil.

Modeling for the RI at the PGDP BGOU consisted of the following:

- **Geostatistical Modeling of the Distribution of COCs in Soils at Each SWMU.** The distribution of COCs in soil was estimated by numeric interpolation or extrapolation of the known soil concentrations at each SWMU, and the resulting geostatistical model was subdivided into seven vertical layers (L1 to L7 as shown in Figure 2.4) between the surface and the top of the RGA. An average concentration for each COC within the model layers was computed, based on the values derived from the geostatistical model.

- **Vertical Transport Modeling Using SESOIL**. The mean layer concentrations derived from the geostatistical model were used as the initial concentration in the leaching model to determine the potential impact to the RGA groundwater. SESOIL allows for variable soil concentrations within the soil column and for partitioning of the transported constituent between the soil water and the soils during transport. The leachate concentration derived from the SESOIL modeling was used as the contaminant loading input to the RGA groundwater for transport modeling. The soil leaching model provided the peak leachate impact to groundwater, and the time frame in which the peak concentration would reach the RGA. The modeling was limited to a 1,000 year period of performance.

- **Groundwater Transport Modeling Using AT123D**. This was used to estimate the groundwater concentrations at selected POEs downgradient of the SWMU to establish if and when groundwater concentrations will exceed the MCLs or risk-based criteria. The analytical model used assumes a uniform flow gradient and hydraulic properties within the aquifer. Contaminant loading is assumed to be uniform across the length of the source area.

The objective of the modeling conducted for the RI was to determine if, under current conditions, existing soil contamination levels at the SWMUs within the BGOU may result in exceeding groundwater standards at particular POEs. In the FS, the objective of a remedial action is to reduce the impact to human health and the environment to acceptable levels. Modeling was conducted to establish the acceptable levels of COCs in soil that may not result in contributions to the RGA groundwater that would exceed MCLs or appropriate risk-based concentrations beneath the waste disposal area within the SWMU.

A geostatistical estimate was not provided in Appendix E of the RI Report for all COCs identified in the BHHRA; therefore, the layer mean and maximum concentrations for the analytical data from the RI were compared to PGDP background values and the RGs developed in the FS. These comparisons (provided in Appendix A) demonstrate that soil concentrations for metals and naturally occurring radionuclides are within the range of background below Layer 3 and, with few exceptions, soils do not indicate impact by releases from the BGOU SWMUs below depths corresponding to SADA Layer 3.

The RGs in soil that would be protective of groundwater are those concentrations that, if left in place at that depth, would not result in a contribution to groundwater that would cause the groundwater concentration in the RGA at the SWMU to exceed the MCL or a suitable risk-based concentration for those COCs that do not have an MCL. They do not include any transport or residency below the SWMU because the analytical model being employed for lateral transport does not account for lateral heterogeneity in the source material or the underlying aquifer. This method of back-calculating the groundwater protective RG in soil is consistent with the modeling approach used in the RI. It uses the same model parameters developed for the RI (as shown in Table 2.3) to determine if impacts to groundwater would result in unacceptable exposures at the PGDP boundary for each COC indicated as a threat to groundwater in Table 5.2 of the BGOU RI Report (DOE 2010). The groundwater protective RGs are protective of the RGA such that contributions from the SWMU would not impact groundwater at levels exceeding the MCL at the SWMU, and all downgradient concentrations will be lower.

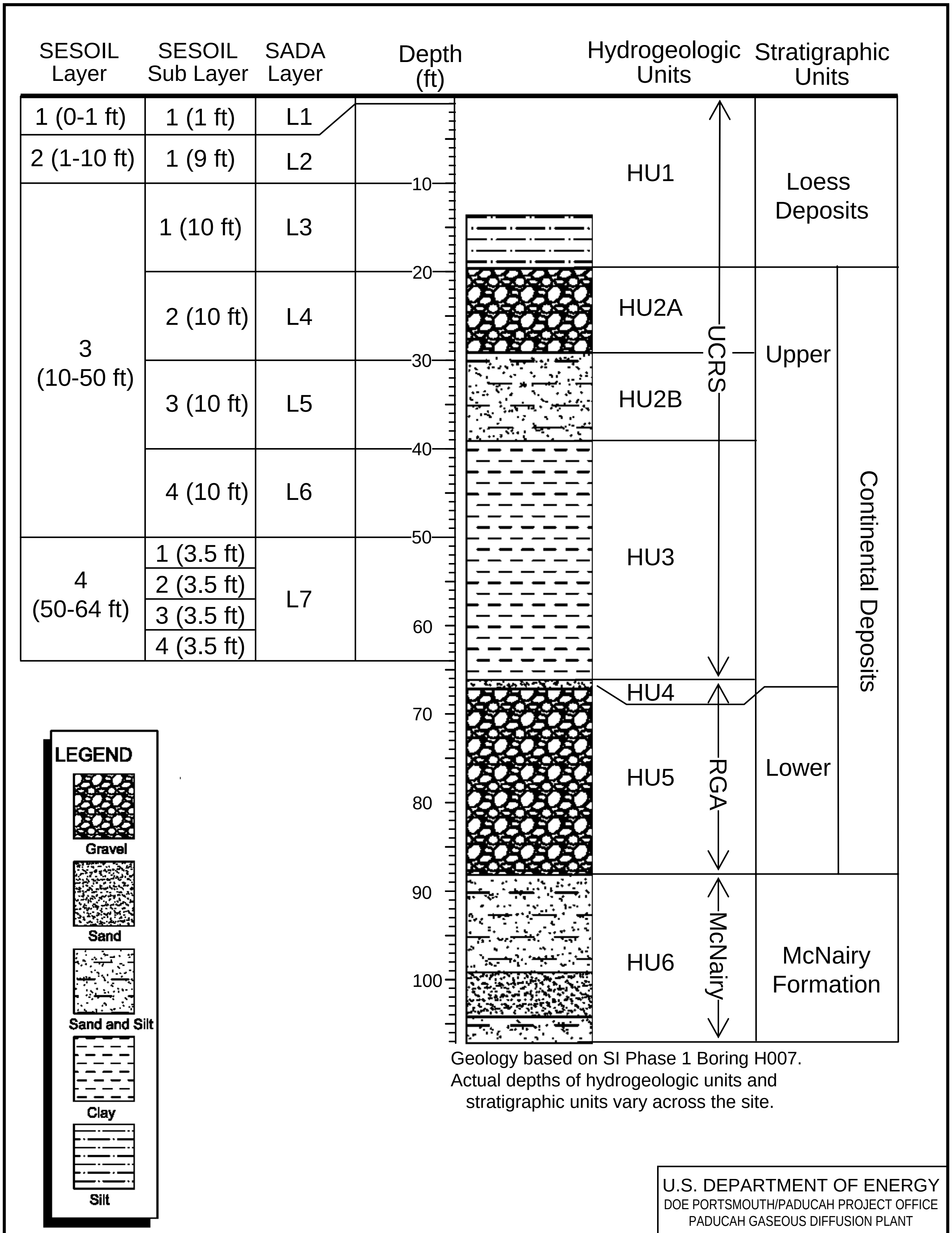


Figure 2.4. Conceptualization of the SADA and SESOIL Layers for Contaminant Loading

Table 2.3. Site Specific Soil and Aquifer Parameters for the BGOU SWMUs used in Modeling COC Transport

	Parameter	Symbol	Units	EPA 1996	BGOU	BGOU Source
UCRS	Soil Type				Silty Clay	BGOU RI Report
	Vadose Zone Dry Bulk Density	ρ	g/cm3	1.5	1.46	
	Fraction of Organic Matter	x_{oc}		0.002	0.0008	
	Fraction of Fines	f		0.1		
	Effective Porosity	n		0.43	0.45	
	Intrinsic Permeability		cm2		1.60E-10	
	Water Filled Porosity	Θ_w		0.3	0.135	
	Air Filled Porosity	Θ_a		0.13	0.389	$n (1-\Theta_w)$
	pH	pH		6.8		
	Unsaturated Depth		m		19.2	
	UCRS Permeability	K_v	cm/sec		3.45E-04	Southwest Plume FS Report
Hydraulic Gradient	SWMU 2, 3, 4, and 5	I	m/m		2.00E-04	BGOU Report
	SWMU 6 and 145				8.00E-04	
	SWMU 7				3.00E-04	
	SWMU 30				3.60E-04	
Hydraulic Conductivity	Southwest Plume	K_s	cm/sec		3.78E-01	Southwest Plume FS Report
	SWMUs 2, 3, 4, 5, 6, 7, and 30	K_s	cm/sec		3.18E+01	BGOU RI Report
	SWMU 145	K_s	cm/sec		1.06E+01	
	Aquifer Bulk Density	ρ	g/cm3	NA	1.67	
	RGA Thickness	b	m		9.14E+00	
	Dispersivity	D	m		1.50E+01	
	Fraction of Organic Matter	x_{oc}		0.002	2.00E-04	
	Percolation (Recharge Rate)		cm/yr	150	11	
	CEC		cmol/kg	25		
		Path Length (m)	Mixing Zone Depth (m)	DAF		
	SWMU-2	100	19.72	1		
	SWMU-3	150	25.01	1		
	SWMU-4	200	30.31	1		
	SWMU-5	100	19.72	1		
	SWMU-7	150	25.01	1		
	SWMU-30	200	30.31	1		
	SWMU-145	500	62.06	1		

L -Length of groundwater flow path under the waste unit

DAF -dilution attenuation factor

The method for establishing the RG followed the modeling methods used in the RI:

1) SESOIL was used to model the transport from the source layer to the RGA, and

2) AT123D was used to model dispersion in groundwater. A unit concentration was used in the source layer (L3) to establish the attenuation and dispersion of the COC during transport.

Then the groundwater target concentration (MCL or risk-based concentration) was used to back-calculate the corresponding maximum allowable soil concentration that would not result in groundwater concentrations exceeding the groundwater target concentration for the COC. For metals and radionuclides, this maximum soil concentration was compared to the established background concentration, and the higher of the two was chosen as the preliminary soil RG protective of the groundwater exposure pathway. The modeling results for COCs at each SWMU are provided in Appendix B.

Assumptions and Methods for Developing Soil RGs Protective of Groundwater at the Treatment Zone

The input values for the modeling runs for the vadose zone and saturated zone soils are the same as those used in the modeling conducted for the BGOU RI Report (DOE 2010). The following information is available for each SWMU model run in Appendix B of this FS:

- A summary of the input data for both SESOIL and AT123D;
- The minimum initial concentrations for each model; and
- The maximum concentration at the endpoint (the RGA for the SESOIL and AT123D, respectively).

It is important that these model runs used input data that are identical (or as close as possible) to those used in the RI model runs so that the results reflect the same conditions that led to the identification and selection of COCs in the BGOU RI Report (DOE 2010). The calculated values represent the soil concentration of the COC that will not result in a groundwater concentration beneath the waste management unit that exceeds the groundwater target concentration for the COC. The resulting groundwater protective RGs for Soil are shown in column 5 of Tables 2.1 and 2.2.

2.2.3.3 Use of preliminary remediation goals for soil and the protection of groundwater

The preliminary RGs for soil (column 7 of Tables 2.1 and 2.2) are used in Sections 5 through 12 to develop remediation alternatives for potential use at individual SWMUs. Upon completion of remedial actions at each SWMU, it will be necessary to attain the RAOs. This eventual evaluation of soil concentrations to verify attainment of RAOs will be based on the results of postremediation sampling.

During the June 2009 scoping meetings with representatives of EPA Region 4, Kentucky Department for Environmental Protection (KDEP), and DOE held in Lexington and Frankfort, Kentucky, it was decided that an excavation alternative would be conducted to 16 ft bgs, deeper if visible contamination continued to be observed. The maximum depth of an excavation was not defined, but is not expected to exceed 20 ft bgs based on available disposal records. In those meetings, it was thought necessary to address circumstances that might lead to deeper excavation and what the ultimate excavation depth could be. It was decided that if COCs were still present above their target concentrations below 20 ft, DOE would evaluate whether additional excavation would be warranted and would consult regulatory agencies, but that additional excavation below 20 ft should be DOE's decision, as represented in Figure 2.3.

To the extent that decisions may be affected by available resources, some of the proposed action may need to be completed in a sequential process instead of a single action. Also, additional excavation may be performed in pursuit of source contaminants exposed directly to area soils and/or groundwater based on the added environmental benefits of the continued action. In this instance, additional discussion of such discretionary expansion of proposed remedial action boundaries would be undertaken with the regulators. The cost estimate assumes excavation nominally to 20 ft bgs.

Although postremediation sampling results cannot be predicted, it is possible that soil concentrations of COCs at a SWMU would represent cumulative ELCR or HI levels above target criteria (Figure 2.3) if all were detected at their preliminary RG concentrations. This situation could not occur at SWMUs 2, 3, 4, 5, or 145 , or SWMU 6 (no COCs). It could occur at SWMU 7 and SWMU 30 because of the larger number of COCs identified for these SWMUs.

Approximate lower bounds to the preliminary RG concentrations for surface and subsurface soil that will meet the target criteria at SWMUs 7 and 30 were estimated under the assumption that all COCs will be detected in soil at their RG concentrations. These approximate concentrations are presented in Appendix C to provide information on possible soil concentrations that might be encountered in postremediation sampling, but are not intended for remediation alternatives development.

2.2.4 Basis for BGOU Technology Identification and Screening

The BGOU RI did not conduct intrusive sampling in the existing waste management units. As a result, specific waste characterization data are limited. Historical records and data, past observations, and waste disposal documentation referenced in the BGOU RI Report (DOE 2010) were used to supplement the RI data to establish the basis for selecting remedial alternatives and preparing cost estimates for those alternatives. It also was necessary to make some assumptions regarding the nature, extent, and quantities of waste and waste-related contamination within the BGOU SWMUs that would require remediation. The assumptions and rationale applied in developing estimates of the extent of contamination and the corresponding waste volumes are presented in Section 1.4.

2.2.4.1 PTW scenarios

Two scenarios for the presence of potential PTW at the BGOU were identified in the BGOU RI Report (DOE 2010): (1) the potential presence of uranium PTW and (2) the potential presence of DNAPL PTW. RAO # 3 requires that PTW be removed and/or treated, where practicable. These potential PTW scenarios were considered in the identification and screening of technologies.

2.2.4.2 Contamination above remediation goals

The data from the BGOU RI Report (DOE 2010) were evaluated to determine which BGOU SWMUs are contaminated with COCs at concentrations above their respective RGs. A layer-by-layer detailed comparison of the maximum concentration, mean of the detectable concentrations, and mean model concentration to the appropriate soil RGs is made in Appendix A using the data available in the BGOU RI Report (DOE 2010).

2.3 GENERAL RESPONSE ACTIONS

GRAs are broad categories of remedial measures that produce similar results when implemented. The GRAs evaluated for this FS include land use controls (LUCs), containment, treatment, removal, and disposal. The identified GRAs may be implemented individually or in combination to meet the RAOs.

Table 2.4 lists the GRAs, as well as the technology types and process options that flow down from each GRA. Identification was based on demonstrated process efficiencies, engineering judgment, and existing policies or procedures.

Formulation of a No Action alternative is required by the NCP [40 *CFR* 300.430(e)(6)]. The No Action alternative serves as a baseline for evaluating other remedial action alternatives and generally is retained throughout the FS process. No action implies that no remediation will be implemented to alter the existing site conditions. As defined in CERCLA guidance (EPA 1988), no action may include environmental monitoring; however, actions taken to reduce exposure, such as administrative LUCs, are not included as a component of a No Action alternative.

LUCs for the CERCLA sites at the PGDP BGOU as described in Section 2.4.1.1 are needed only for those alternatives that will leave waste in place.

2.3.1 Removal

RAOs potentially may be met by removing contaminated soils. Removal generates secondary wastes potentially requiring *ex situ* treatment and disposal or discharge.

2.3.2 Containment

Containment isolates contaminated media from release mechanisms, transport pathways, and exposure routes using surface and/or subsurface barriers, thereby reducing contaminant flux and reducing or eliminating exposures to receptors. Containment alone does not reduce the volume or toxicity of the contaminant source.

2.3.3 Treatment

Treatment reduces the toxicity, mobility, or volume of contaminants or contaminated media. Contaminant sources may be reduced or eliminated, and contaminant migration pathways and exposure routes may be eliminated. *In situ* methods treat contaminants and media in place without removal. *Ex situ* methods treat contaminants or media after removal.

2.3.4 Disposal

Disposal may include land disposal of solid wastes or discharge of liquid or vapor phase effluents generated during waste treatment processes.

2.4 IDENTIFICATION AND SCREENING OF TECHNOLOGY TYPES AND PROCESS OPTIONS

This section identifies remedial technologies and process options that potentially meet the RAOs and provides a preliminary screening based on implementability. The technologies are described and the potential effectiveness in meeting the RAOs and the technical implementability are discussed. Performance data are cited and discussed, and limitations and data needs are identified, as applicable. The results of the technology screening are detailed in the following text and in Table D.1 (see Appendix D) and are summarized in Table 2.4. Technologies and process options that pass the preliminary screening are evaluated further in Section 2.4.2, based on effectiveness and relative cost. RPOs that will be used to develop the remedial alternatives are selected in Section 2.4.3.

Table 2.4. Results of Technology Identification and Screening

General Response Action	Technology Type	Process Options	Screening Comments[a]
Land Use Controls	Institutional Controls	Administrative Controls	Technically implementable. Retained for possible alternative development.
Monitoring	Soil monitoring	Soil cores	Technically implementable. Retained for possible alternative development.
	Groundwater monitoring	Sampling and analysis	Technically implementable. Retained for possible alternative development.
Removal	Excavators	Backhoes, trackhoes	Technically implementable. Retained for possible alternative development.
		Vacuum excavation, remote excavator	Technically implementable. Retained for possible alternative development.
		Crane and clamshell	Technically implementable. Retained for possible alternative development.
		Bucket auger	Technically implementable. Retained for possible alternative development.
Containment	Hydraulic containment	Recharge controls	Technically implementable. Retained for possible alternative development.
		Groundwater extraction	Technically implementable only as a secondary technology for other treatments. Retained for possible alternative development.
	Surface barriers	RCRA Subtitle C cover	Technically implementable. Retained for possible alternative development.
		RCRA Subtitle D cover	Technically implementable. Retained for possible alternative development.
		Soil cover	Technically implementable. Retained for possible alternative development.
		Concrete-based cover	Technically implementable. Retained for possible alternative development.
		Conventional asphalt cover	Technically implementable. Retained for possible alternative development.
		MatCon asphalt	Technically implementable. Retained for possible alternative development.
		Flexible membrane	Technically implementable. Retained for possible alternative development.
	Subsurface horizontal barriers	Freeze walls	Technically implementable, but not practical for permanent hydraulic barrier. Eliminated from alternative development.
		Jet grouting	Technical implementability uncertain. Retained for possible alternative development.
		Permeation grouting	Technical implementability uncertain. Retained for possible alternative development.

Table 2.4. Results of Technology Identification and Screening (Continued)

General Response Action	Technology Type	Process Options	Screening Comments[a]
Containment (Continued)	Subsurface vertical barriers	Freeze walls	Technically implementable, but not practical for permanent hydraulic barrier. Potentially effective as a temporary construction technology to prevent the influx of groundwater into and/or stabilize the sidewalls of deep excavations. Retained for possible alternative development.
		Slurry walls	Technically implementable. Retained for possible alternative development.
		Sheet pilings	Technically implementable. Retained for possible alternative development.
		Jet grouting	Technically implementable. Retained for possible alternative development.
		Permeable reactive barrier	Not technically implementable.
Treatment	Biological	Anaerobic reductive dechlorination—*in situ*	Technical implementability uncertain. Retained for possible alternative development.
		Aerobic cometabolism—*in situ*	Technically implementable. Retained for possible alternative development.
		Phytoremediation—*in situ*	Not technically implementable due to depth of NAPL. Eliminated from alternative development.
	Physical/Chemical	Soil vapor extraction—*in situ*	Technical implementability uncertain. Retained for possible alternative development.
		Dual phase extraction—*in situ*	Technical implementability uncertain. Retained for possible alternative development.
		Air sparging—*in situ*	Not technically implementable. Retained for possible alternative development.
		Soil flushing—*in situ*	Not technically implementable. Retained for possible alternative development.
		Electrokinetics—*in situ*	Technically implementable. Retained for possible alternative development.
		Air stripping—*ex situ*	Technically implementable. Retained for possible alternative development.
		Ion exchange—*ex situ*	Technically implementable. Retained for possible alternative development.
		Granular activated carbon—*ex situ*	Technically implementable. Retained for possible alternative development.
		Vapor condensation	Technically implementable. Retained for possible alternative development.
		Soil fracturing	Technically implementable. Retained for possible alternative development.
		Soil mixing—*in situ*	Technical implementability uncertain. Retained for possible alternative development.

Table 2.4. Results of Technology Identification and Screening (Continued)

General Response Action	Technology Type	Process Options	Screening Comments[a]
Treatment (Continued)	Thermal	Catalytic oxidation—*ex situ*	Technically implementable. Retained for possible alternative development.
		Electrical resistance heating—*in situ*	Technically implementable. Retained for possible alternative development.
		Thermal conduction heating—*in situ*	Technically implementable. Retained for possible alternative development.
		Steam stripping—*in situ*	Technically implementable. Retained for possible alternative development.
		Thermal desorption—*ex situ*	Technically implementable. Retained for possible alternative development.
		Ex situ vitrification	Technically implementable. Retained for possible alternative development.
		Metal melting	Technically implementable. Retained for possible alternative development.
	Chemical	Permanganate—*in situ*	Technical implementability uncertain. Retained for possible alternative development.
		Fenton's reagent—*in situ*	Technical implementability uncertain. Retained for possible alternative development.
		ZVI—*in situ*	Technical implementability uncertain. Retained for possible alternative development.
		Ozonation—*in situ*	Technical implementability uncertain. Retained for possible alternative development.
		Persulfate—*in situ*	Technical implementability uncertain. Retained for possible alternative development.
		Redox manipulation—*in situ*	Technical implementability uncertain. Retained for possible alternative development.
		Surfactant enhanced ISCO	Technical implementability uncertain. Retained for possible alternative development.
	Monitored Natural Attenuation	Monitoring and natural processes—*in situ*	Technically implementable. Retained for possible alternative development.
Disposal	Land disposal	Off-site disposal facility	Technically implementable. Retained for possible alternative development.
		Proposed on-site waste disposal facility (WDF)	Technical implementable. Retained for possible alternative development.
		PGDP C-746-U Landfill	Technically implementable. Retained for possible alternative development.
	Discharge of wastewater	In accordance with substantive requirements of Kentucky surface water standards.	Technically implementable. Retained for possible alternative development.

[a] Gray shading indicates that the technology was screened out as not applicable or not technically implementable.

2.4.1 Identification and Screening of Technologies

Each GRA, technology type, and process option listed in Table 2.4 is discussed in the following subsections.

2.4.1.1 Land use control technologies

LUCs will be implemented at BGOU SWMUs where waste is left in place or contamination remains after active remediation that precludes unrestricted use.

LUCs include administrative restrictions on activities allowed on a property. The primary LUC that may be implemented for the BGOU SWMUs is the Excavation/Penetration Permit (E/PP) program.

This LUC is discussed in more detail below. A discussion of existing DOE plant controls that are being maintained outside of the requirements of CERCLA due to the nature and security needs of the PGDP facility also is provided.

E/PP Program

The E/PP program is a LUC administered by DOE's contractors at PGDP and currently includes a specific permitting procedure (PRS-WCE-0026 or equivalent) designed to provide a common sitewide system to identify and control potential personnel hazards related to trenching, excavation, and penetration. The E/PP are issued by the Paducah Site's DOE Prime Contractor. The primary objective of the E/PP procedure is to provide notice to the organization requesting a permit of existing underground utility lines and/or other structures and to ensure that any E/PP activity is conducted safely and in accordance with all environmental requirements pertinent to the area (DOE 2008).

The E/PP procedure does the following:

- Requires formal authorization (i.e., internal permits/approvals) before beginning any intrusive activities at PGDP;
- Is reviewed annually; and
- Is implemented by trained personnel knowledgeable in its requirements.

An initial draft of an E/PP is reviewed by project support groups to ensure that the latest updates in engineering drawings and utility drawings are considered prior to the issuance of an E/PP.

Existing DOE plant controls are discussed in Section 1.3.3.2. Accordingly, the PGDP is a federal facility with restricted access by the general public. Physical access to PGDP is prohibited by security fencing, and armed guards patrol the DOE property 24 hours per day to restrict worker entry and prevent uncontrolled access by the public/site visitors. These existing access controls are being maintained outside of the requirements of CERCLA due to the nature and security needs of the facility; nonetheless, the existing controls serve to protect against unacceptable/uncontrolled exposures.

2.4.1.2 Monitoring technologies

Monitoring may be used in combination with other technologies to meet RAOs. Monitoring for the BGOU could include determination of soil and groundwater contaminant concentrations during remedial action as well as long-term monitoring.

Soil Monitoring. Soil monitoring may be used before, during, and after remediation to determine extent and concentration of COCs. Collection of soil cores and laboratory analysis for physical/chemical parameters yields data that may be used to support remedial design and verify effectiveness of remedial action. This technology is retained for further evaluation.

Groundwater Monitoring. Groundwater monitoring may be used in the UCRS or RGA saturated zones before, during, and after remediation to determine extent and concentrations of COCs. Conventional groundwater sampling consists of withdrawing a representative sample of groundwater from a well or drive point, using a variety of pump types or bailers, and analyzing the contents either on-site or in a fixed-base laboratory. This technology is widely used for compliance monitoring and is effective, technically implementable, and commercially available. This technology is retained for further evaluation.

2.4.1.3 Removal technologies

Removal, in the context of this FS, is the excavation of source materials disposed in the BGOU, and UCRS soils containing COCs above their RGs. The technical complexity of excavation increases greatly with depths greater than about 20 ft (6m) (Terzaghi *et al.* 1996), and factors including slope stability, control of seepage, worker safety, management of excavated soil, shoring requirements, potential for mobilization of COCs, and others must be considered.

Deep excavations require extensive terracing or elaborate shoring. Piping of groundwater and entry of heaving sands into the excavation can occur as excavation proceeds below the water table.

Excavation can have a large capital cost, but low operation and maintenance costs (O&M), and may have the largest probability of achieving over 99% COC removal at smaller sites with contamination restricted to the upper 12.2 m (40 ft) of the soil (AFCEE 2000). Overall, experience has shown that excavation works best and is most cost-competitive at sites where confining layers are shallow, soil permeabilities are low, the volume of source materials is less than 5,000 m^3 (176,600 ft^3), and the contaminants do not require complex treatment or disposal (NRC 2004). Several types of excavation equipment that potentially could be used at the BGOU SWMUs are discussed below.

Excavators

Backhoes, Trackhoes, and Front-End Loaders. Conventional excavation equipment such as backhoes, trackhoes, front-end loaders, and skid steer loaders can do an effective job of removing contaminated soil and overburden. Practical considerations regarding equipment limitations and sidewall stability can restrict the depth of excavation to a maximum of about 25 to 30 ft in a single lift. Where source zone contamination lies at greater depth, excavation can require a series of progressively deeper lifts or terraces accessed by ramps. This technique can extend the maximum depth of excavation in unconsolidated soil to over 40 ft; however, the unit cost of soil excavation increases rapidly with increasing depth of excavation. Additionally, implementation of methods to control or prevent the movement of groundwater into the excavation may be required if source removal extends below the water table. These methods are expensive and can require placement of caissons or driven sheet piling and dewatering (AFCEE 2000).

Vacuum Excavation. Vacuum excavation can be used to remove contaminated soil to depths of about 30 ft in congested areas where access, obstructions, and buried utilities prevent safe operation of conventional excavators. A combination of high-pressure air (or water) is used to break up the soil, while a high flow vacuum removes the soil and deposits it in the vacuum truck collector body. Vacuum trucks are commercially available with capacities up to 15 yd^3. Additionally, contaminated soil and sludge can be placed directly in vacuum roll-off boxes (20 or 25 yd^3) or bags for disposal without having to decontaminate the vacuum truck.

Effective excavation can be performed as far as 300 ft from the vacuum truck, allowing work inside buildings and in highly congested areas. The high flow vacuum eliminates the need for additional dust control measures typically required during conventional excavation activities.

Cranes and Clamshells. These often are used in deep excavations (e.g., excavation of piers, dredging, and mining). Excavation to depths of over 100 ft is achievable.

Bucket Auger. These use a rotating cylindrical bucket with cutting blades mounted on a hinged bottom to repeatedly cut and lift sediments from the hole, much like the operation of a common post-hole auger. Bucket-auger rigs may be equipped to drill holes from 10 inches to 60 inches in diameter and to depths of 100 ft. Disadvantages of bucket augering include the production of large volumes of cuttings and fluids when operated within the saturated zone. (www.nationaldriller.com)

This technology is technically implementable and commercially available and is retained for further evaluation.

2.4.1.4 Containment technologies

Containment technologies may isolate source areas, reduce infiltration, and thereby minimize contaminant migration to the RGA. Surface barriers potentially could meet the RAO # 1 by reducing or eliminating recharge through the areas of contamination, thereby reducing the driving force for contaminant flux from the UCRS to the RGA.

Infiltrating precipitation and anthropogenic water recharge to the UCRS provide the driving force for transport of COCs from source areas to the RGA. Surface barriers and/or recharge controls potentially may reduce or eliminate surface recharge, thereby eliminating the driving force. Subsurface barriers may reduce or eliminate flux of COCs in infiltrating water beyond the contaminated intervals. Containment technologies are summarized below and screened in Table D.1 (see Appendix D).

Hydraulic Containment

Recharge Controls. Recharge controls can reduce facility process water discharges to the UCRS, promote surface water run-off, and reduce recharge of the UCRS in the BGOU source areas, thereby limiting leaching of COCs from source areas and migration to the RGA. Recharge control options are technically implementable at present using commercially available materials and equipment. Potential recharge control options include the following:

- Identifying saturated zones in the UCRS based on past investigations and determining sources. (artificial groundwater mounding influences of the C-616 lagoons will be considered, as necessary, during remedial design);

- Directing water away from source areas or to storm drains;

- Routing runoff from roofs, roads, and asphalt parking areas to lined ditches or storm drains;
- Eliminating surface water drainage from adjacent areas onto source areas;
- Lining ditches and culverts in the vicinity of the BGOU source areas with concrete or membranes;
- Inspecting and repairing, as needed, asphalt areas to promote runoff and minimize infiltration;
- Inspecting, clearing, and repairing, as needed, discharge pipes, culverts, and storm drains;
- Inspecting, metering, and repairing water lines in the vicinity of the BGOU source areas as needed; and
- Eliminating all French drains, condensate discharge, or other sources of water to the subsurface in the vicinity of the BGOU source areas.

This approach is effective, technically implementable, and commercially available, and is retained for further evaluation.

<u>Groundwater Extraction</u>. Groundwater pumping may be used to contain dissolved-phase contaminant plumes or may be used as a secondary technology to circulate or contain treatment amendments. Groundwater yields from wells completed in the UCRS are insufficient for sustainable pumping or for containment in the BGOU source areas, which constrains the effectiveness and technical implementability of technologies that rely on groundwater pumping or circulation for removal or treatment of contaminants. Groundwater pumping is not effective technology for the BGOU.

Pumping of RGA groundwater may be required for containment during *in situ* treatment of DNAPL TCE in the UCRS (e.g., surfactant flooding). Groundwater pumping is effective as a secondary process for other primary technologies, technically implementable, commercially available, and is retained for further evaluation.

Surface Barriers

Surface barriers reduce recharge of precipitation and/or anthropogenic water to the subsurface, thereby reducing the driving force for infiltration and leaching of COCs from source areas. As soil moisture levels decrease in response to reduction in recharge, the unsaturated hydraulic conductivity of soils also decreases, resulting in reduction of contaminant flux rates.

EPA (2008) identifies the following advantages and limitations of surface barriers for containment of source areas.

- Advantages of containment
  - It is a simple and robust technology.
  - Containment typically is inexpensive compared to treatment, especially for large source areas.
  - A well-constructed containment system almost completely eliminates contaminant transport to other areas and thus prevents both direct and indirect exposures.
  - In unconsolidated soils, containment systems substantially reduce mass flux and source migration potential.

— Containment systems can be combined with *in situ* treatment and, in some cases, might allow the use of treatments that would constitute too great a risk with respect to migration of either contaminants or reagents in an uncontrolled setting.

- Limitations of containment

— Containment does not reduce source zone mass, concentration, or toxicity unless it is used in combination with treatment technologies.

— Containment systems such as slurry walls are not impermeable and, thus, provide containment over a finite period.

— Data are not yet available concerning the long-term integrity of the different types of physical containment systems.

— Long-term monitoring of the containment system is essential for ensuring that contaminants are not migrating.

Surface barriers are commonly used to improve performance of soil vapor extraction systems by reducing airflow from the surface and forcing flow through the contaminated soil intervals. Several types of surface barriers are discussed here.

<u>RCRA Subtitle C Cover</u>. This type of cover is designed to meet performance objectives for RCRA Subtitle C landfill closures under 40 *CFR* § 265.310. C-404 Landfill (SWMU 3) is the only landfill in the BGOU that has been designated a RCRA Subtitle C Landfill and it already contains a RCRA Subtitle C cover. EPA guidance recommends a cover consisting of (top to bottom) an upper vegetated soil layer, a sand drainage layer, and a flexible membrane liner (FML) overlying a compacted clay barrier (EPA 1987). A gas collection layer may be included if gas-generating wastes are capped. Nominal thickness of this type of cover is 4.9 ft, and addition of grading fill would increase the thickness at the crest.

This type of cover is designed to be less permeable than the bottom liner of a RCRA Subtitle C landfill and meets the requirements of 40 *CFR* § 265.310. Other types of covers may be used if equivalent performance can be demonstrated through numerical modeling and/or site-specific large scale lysimeter studies.

A RCRA Subtitle C cover potentially could meet the RAO by reducing recharge through COC source areas. This type of cover is potentially effective, technically implementable, commercially available, and is retained for further consideration.

<u>RCRA Subtitle D Cover.</u> RCRA Subtitle D requirements are for nonhazardous waste landfills. The design of a landfill cover for a RCRA Subtitle D facility is generally a function of the bottom liner system or natural subsoils present. The cover must meet the following specifications:

- The material must have a permeability no greater than 1E-5 cm/s, or equivalent permeability of any bottom liner or natural subsoils present, whichever is less.

- The infiltration layer must contain at least 18 inches of earthen material.

- The erosion control layer must be at least 6 inches of earthen material capable of sustaining native plant growth.

Alternative design can be considered, but must be of equivalent performance as the specifications outlined above. All covers should be designed to prevent the “bathtub” effect, which occurs when a more permeable cover is placed over a less permeable bottom liner or natural subsoil. The landfill then fills up like a bathtub. (Reference: http://www.frtr.gov/matrix2/section4/4-27.html) A RCRA Subtitle D cover potentially could meet the RAO by reducing recharge through COC source areas. This type of cover is potentially effective, technically implementable, commercially available, and is retained for further consideration.

Soil Cover Systems. Soil cover systems use one or more vegetated soil layers to retain water until it is either transpired through vegetation or evaporated from the soil surface. These cover systems rely on the water storage capacity of the soil layer, rather than low hydraulic conductivity materials, to minimize percolation. Alternative earthen cover system designs are based on using the hydrological processes (water balance components) at a site, which include the water storage capacity of the soil, precipitation, surface runoff, evapotranspiration, and infiltration. The greater the storage capacity and evapotranspirative properties, the lower the potential for percolation through the cover system. Alternative earthen cover system designs tend to emphasize the following (Dwyer 2003):

- Fine-grained soils, such as silts and clayey silts that have a relatively high water storage capacity;
- Native vegetation to increase evapotranspiration; and
- Locally available soils to streamline construction and provide for cost savings.

(Evapotranspiration Landfill Cover Systems Fact Sheet, EPA 542-F-03-015, September 2003). The soil cover could be susceptible to vegetative intrusion and desiccation cracking, which will affect long-term effectiveness (http://www.clu-in.org/download/remed/epa542f03015pdf). This type of cover is potentially effective, technically implementable, commercially available, and is retained for further consideration, primarily for its ability to provide protection from direct contact exposure.

Concrete and Asphalt-based Covers. Concrete and asphalt covering systems may consist of a single layer of bituminous or concrete pavement over a prepared subgrade to isolate contaminated soils, reduce infiltration, and provide a trafficable surface. The asphalt surface can be sealed around infrastructure using adhesive sealants and flexible boots; however, constructability is improved by absence of surface infrastructure.

MatCon™ asphalt has been used for RCRA Subtitle C-equivalent closures of landfills and soil contamination sites. MatCon™ is produced using a mixture of a proprietary binder and a specified aggregate in a conventional hot-mix asphalt plant. The EPA Superfund Innovative Technology Evaluation program evaluated MatCon™ in 2003 with respect to permeability, flexural strength, durability, and cost (EPA 2003). EPA determined that the as-built permeability of <1E-07 cm/s was retained for at least 10 years with only minor maintenance, and MatCon™ had superior mechanical strength properties and durability. This technology is effective, technically implementable, commercially available, and is retained for further evaluation.

Flexible Membranes. Flexible membranes are single layers of relatively impermeable polymeric plastic [high-density polyethylene (HDPE) and others]. Flexible membranes are a component of a RCRA Subtitle C cover and, potentially, of other types and also may be used alone. Flexible membranes are laid out in rolls or panels and welded together. The resulting membrane cover essentially is impermeable to transmission of water unless breached. Flexible membranes can be sealed around infrastructure using adhesive sealants and flexible boots; however, constructability is improved by absence of surface infrastructure.

Flexible membranes must be protected from damage to remain impermeable. Flexible membranes are subject to damage and/or leakage due to puncturing or abrasion, exposure to excessive heat, freezing, temperature cycling, poor welds, tearing, shearing, ultraviolet or other radiation exposure, and chemical incompatibilities. This technology is effective, technically implementable, commercially available, and is retained for further evaluation.

Subsurface Horizontal Barriers

Subsurface horizontal barriers potentially may limit downward migration of contaminants in infiltrating water by formation of a physical barrier to flow. Surface barriers must be implemented with subsurface barriers to avoid "bathtubbing" (i.e., infiltrating water spilling over the sides). Several types of subsurface barriers are discussed below.

Freeze Walls. Frozen barrier walls, also called cryogenic barriers or freeze walls, are constructed by artificially freezing the soil pore water, resulting in decreased permeability and formation of a low-permeability barrier. The frozen soil remains relatively impermeable and migration of contaminants thereby is reduced. This technology has been used for groundwater control and soil stabilization in the construction industry and for strengthening walls at excavation sites for many years. This technology also has been identified for contamination and dust control during excavation of buried wastes.

Implementation of this technology requires installing pipes called thermoprobes into the ground and circulating refrigerant through them. As the refrigerant moves through the system, it removes heat from the soil and freezes the pore water. Implementation in arid regions requires injecting water to provide the moisture necessary to form the barrier or to repair the frozen wall. Systems can be operated actively or passively depending on air temperatures (EPA 1999a).

The thermoprobes can be placed at 45-degree angles along the sides of the area to be contained to form a V-shaped or conical barrier to provide subsurface containment. This technology is considered innovative and emerging for remediation, but is commercially available through the geotechnical construction industry.

Freeze wall containment potentially could eliminate vertical COC flux as long as the soil remains frozen and, therefore, would be effective only as a temporary containment measure. The technology is not practical as a permanent hydraulic barrier system and therefore is screened from further consideration.

Jet Grouting. Grout mixtures injected at high pressures and velocities into the pore spaces of the soil or rock have been used in civil construction for many years to stabilize subgrades and reduce infiltration of water. More recently, jet grouting has been tested as a potential means of creating a subsurface horizontal barrier, without disturbing overlying soils. Grouts typically are injected through drill rods. The jetted grout mixes with the soil to form a column or panel. Jet grouting can be used in soil types ranging from gravel to clay, but the soil type can alter the diameter of the grout column. Soil properties also are related to the efficiency. For instance, jet grouting in clay is less efficient than in sand (EPA 1999a).

V-shaped jet-grouted composite barriers were demonstrated at Brookhaven and the Hanford site (Dwyer 1994) and at Fernald in 1992 (Pettit *et al.* 1996) in attempts to completely isolate contaminated soils in field trials. At Hanford and Brookhaven, V-shaped grouted barriers were created by injecting grout through the drill strings of rotary/percussion directional drilling rigs. Next, a waterproofing polymer (AC-400) was placed as a liner between the waste form and the cement v-trough, forming a composite barrier. Technologies to determine the continuity and impermeability of the completed barrier are unavailable; therefore, the effectiveness of the completed barriers is uncertain. This technology is retained because of its potential applicability.

EarthSaw™. EarthSaw™ is an innovative emerging jet grouting technology for construction of barriers under and around buried waste without excavating or disturbing the waste. A deep vertical slurry trench is dug around the perimeter of a site and the trench is filled with high-specific-gravity grout sealant. A horizontal bottom pathway is cut at the base of the trench with a cable saw mechanism. The large density difference between the grout and the soil allows the severed block of earth to float. The grout then cures into a relatively impermeable barrier. After the grout has cured and hardened, a final surface covering may be applied, resulting in a completely isolated monolith. This technology has been demonstrated only at the proof-of-principle stage (DOE 2002a).

Overall, jet grouted subsurface horizontal barriers have not been successfully implemented for containment at full scale; therefore, effectiveness and implementability at the BGOU SWMUs cannot be assessed. Reliable monitoring methods to determine barrier continuity and permeability, including gas tracers, electrical resistance tomography, ground penetrating radar, and seismic or acoustic methods, have been tested with variable results and still are in development. Effectiveness and implementability of this technology type are uncertain, and these technologies are therefore screened from further consideration pending further technology development and demonstration.

Permeation Grout Barriers. Permeation grouting has been used extensively in construction and mining to stabilize soils and control movement of water. Low-viscosity grout is injected vertically or directionally at multiple locations into soil at sufficiently low pressure to avoid hydrofracturing while filling soil voids. Soil permeability may be reduced with minimal increase in soil volume using this method (EPA 1999a).

The extent of grout permeation is a function of the grout viscosity, grout particle size, and soil particle size distribution. A variety of materials can be used in permeation grouting, and it is essential to select a grout that is compatible with the soil matrix. Particulate grouts are applicable when the soil permeability is greater than 1E-01 cm/s. Chemical grouts can be used with soil permeabilities greater than 1E-03 cm/s (EPA 1999a). Permeation grouting has been tested at pilot scale, resulting in formation of subsurface layers of inconsistent coverage, thickness, and permeability.

Viscous liquid barriers are a variant of permeation grouting using low-viscosity liquids that gel after injection, forming an inert impermeable barrier. Field tests have resulted in formation of subsurface layers of inconsistent coverage, thickness, and permeability.

Permeation grouting is limited to soil formations with moderate to high permeabilities. Establishing and verifying a continuous, effective subsurface barrier is difficult or impossible in heterogeneous soils or in the presence of subsurface infrastructure.

The technical implementability of permeation grouting will require further evaluation for the BGOU SWMUs because of the heterogeneous soils and the low saturated hydraulic conductivity in zones containing COCs. This technology is retained for further consideration.

Soil Fracturing. Soil fracturing may be accomplished either pneumatically, using air, or hydraulically, using liquids. Pneumatic fracturing involves the injection of highly pressurized gas (nitrogen or air) into the soil via borings to extend existing fractures and create a secondary network of subsurface channels. Hydraulic fracturing (hydrofracturing) uses water or slurry instead of gas. Soil fracturing can extend the range of treatment when combined with other primary technologies such as bioremediation, chemical oxidation/reduction, or soil vapor extraction. Soil fracturing for these uses is discussed as a secondary technology in the discussion of the primary technology.

The horizontal subsurface barrier technology involves fracturing the soil matrix by creating stress points over a broad area (EPA 1999a). Soil tends to fracture preferentially along the horizontal plane. Air is injected into the boreholes at increasing pressures to cause the soil to fracture. After soil fracture formation, grouts or polymers can be injected into the fracture in an effort to create a low-permeability horizontal barrier. This technology was successfully demonstrated at the pilot scale level at the Savannah River Site, Aiken, SC, in 1996. Excavation of the test site showed the barrier to be continuous with a total diameter of 16 ft. This technique also may be used to create horizontal reactive barriers or to distribute chemical treatment amendments.

Fracturing potentially may mobilize nonaqueous-phase liquids (NAPLs) (ARS 2009). Recovery systems capable of capturing mobilized NAPL [i.e., soil vapor extraction (SVE) or dual-phase extraction (DPE)] are necessary to ensure NAPL containment during fracturing.

Pneumatic and hydraulic fracturing was evaluated in Hightower *et al.* (2001) and KRCEE (2005) as an adjunct technology for *in situ* chemical oxidation (ISCO) and SVE at PGDP DNAPL sites and was recommended for field testing. This technology is potentially implementable, but would require an on-site demonstration to determine feasibility and effectiveness. Due to the uncertainties associated with the effectiveness and implementability of soil fracturing, it is screened from further consideration.

Subsurface Vertical Barriers

Vertical barrier technologies can be used to isolate areas of soil contamination and to restrict groundwater flow into the contaminated area or underlying zones. Subsurface vertical barriers may be used to contain or divert contaminated groundwater flow. Subsurface vertical barrier technologies must be “keyed” into an underlying low permeability layer to avoid leakage around the barrier if complete containment is required (Deuren *et al.* 2002).

Given that flow is predominantly downward through the UCRS in the BGOU and that no continuous low permeability layer exists between the COC source areas and the RGA, vertical barriers are likely effective only as adjunct technologies for other primary technologies (e.g., removal or *in situ* treatment). The following is a discussion of several different types of subsurface vertical barriers.

Freeze Walls. This technology previously was screened as a subsurface horizontal barrier. The same principles apply as a subsurface vertical barrier, only the thermoprobes are installed vertically instead of on a 45 degree angle to prevent/contain the lateral flow of groundwater. Freeze wall containment potentially could eliminate lateral COC flux as long as the soil remains frozen and, therefore, would be effective only as a temporary containment measure. The technology is used in the construction industry to prevent the influx of groundwater into and/or stabilize the sidewalls of deep excavations. Although impractical as a permanent hydraulic barrier, the technology is potentially effective as an adjunct process option during excavation, is technically implementable, commercially available, and is retained for further evaluation.

Slurry Walls. Slurry walls are an established and commercially available technology. Slurry walls consist of vertically excavated trenches that are kept open by filling the trench with a low permeability slurry, generally bentonite and water. The slurry forms a very thin layer of fully hydrated bentonite that is impermeable. Soil (often excavated material) then is mixed with bentonite and water to create a soil-bentonite backfill with a hydraulic conductivity of approximately 1E-07 cm/s, which is used to backfill the trench, displacing the slurry. Trench excavation is commonly completed by a backhoe or a modified boom at depths of up to 60 ft. A drag line or clam shell may be used for excavations greater than 60 ft.

Alternatively, a cement, bentonite, and water slurry that is left in the trench to harden may be used. Concrete slurry walls may have a greater hydraulic conductivity than traditional slurry walls and the excavated soil that is not used as a backfill must be disposed of properly. This technology is technically implementable, commercially available, and is retained for further evaluation.

Sheet Pilings. Sheet pilings are an established and readily available technology. Sheet pilings are long structural steel sections with a vertical interlocking system that are driven into the ground to create a continuous subsurface wall. After the sheet piles have been driven to the required depth, they are cut off at the surface. Sheet pilings are commonly used in excavations for shoring and to reduce groundwater flow into the excavation and, therefore, are a potentially useful adjunct technology for soil removal. This technology is effective, technically implementable, commercially available, and is retained for further evaluation.

Permeable Reactive Barriers. Permeable reactive barriers (PRBs) are designed and constructed to permit the passage of water while immobilizing or destroying contaminants through the use of various reactive agents. PRBs are often used in conjunction with subsurface vertical barriers, such as sheet piling, to form a funnel and gate system that directs the groundwater flow through the PRB.

PRBs have been shown to be effective for the removal of TCE, and specific types are discussed in more detail. Some of these technologies also are evaluated as *in situ* treatments. Vertical PRBs would have the same constraints as other vertical barriers. They likely are effective only as adjunct technologies for other primary technologies (e.g., removal or *in situ* treatment) given that hydraulic gradients in the UCRS source areas are primarily downward, and no continuous confining layer exists into which to key vertical walls. PRBs may be constructed to depths of 60 ft bgs, but complexity and cost increase with depth (FRTR 2008).

Zero-valent iron (ZVI) is the most common reactive media used in PRBs. Halogenated hydrocarbons, such as TCE, are reductively dehalogenated by the iron, eventually reducing the compound to ethane and ethene that are amenable to biodegradation. The successful use of ZVI PRBs to remediate TCE is well documented and the technology is readily available (Tri-Agency 2002). This technology is technically implementable, commercially available, and is retained for further evaluation.

Oxidizing and reducing conditions can be generated in the subsurface by applying an electrical potential to permeable electrodes that are closely spaced to form a PRB panel. The electrical potential can be used to induce the sequential reduction of halogenated solvents. This technology was shown to reduce TCE flux rates by as much as 95% at the pilot-scale level at the F.E. Warren Air Force Base (Sale *et al.* 2005).

Mulch, when used as a PRB agent, acts as a source of carbon for aerobic bacteria that lowers the dissolved oxygen concentration and creates a redox potential in the barrier. The resulting anaerobic degradation byproducts of the organic mulch, which include hydrogen and acetate, may then be used by anaerobic bacteria to reductively dechlorinate TCE and other chlorinated VOCs. TCE also may be removed from the groundwater passing through the PRB via sorption and other biotic and abiotic processes. This technology was shown to successfully reduce TCE concentrations by 95% over a 2-year period at the Offutt Air Force Base (GSI 2004). This technology is technically implementable, commercially available, and is retained for further evaluation.

PRBs could not be effectively implemented for the treatment of DNAPL at the BGOU because hydraulic gradients in the UCRS are primarily downward and the construction depths required in the RGA exceed the practical limit of the technology. Therefore, the technology is not retained for further evaluation.

Jet Grouting. Although not considered an effective horizontal subsurface barrier, jet grouting is effective as a vertical subsurface barrier. Jet grouting can be used regardless of soil type, permeability, grain size distribution, etc. In theory, it is possible to stabilize most soils, from soft clays and silts to sands and gravel. Although it is possible to inject any type of binder, in practice, water/cement mixtures are normally used. Where it is required that the soil be impermeable, water/cement/bentonite mixes are typically utilized.

A subsurface slurry wall can be formed by sequentially jet grouting adjoining columns of soil. An advantage of jet grouting over other slurry wall techniques is it can be used to stabilize a wide range of soils ranging from gravel to heavy clays. A secondary advantage is that large diameter columns or panels can be created from relatively small diameter boreholes (http://www.recon-net.com/jet-grouting.html#jetgrouting). Waste soil and other material requiring management and disposal are less for jet grouting than for a conventional slurry wall and, therefore, jet grouting will be retained for consideration as a vertical subsurface barrier technology.

2.4.1.5 Treatment technologies

Treatment technologies may destroy, immobilize, or render contaminants less toxic. Treatment technologies may be implemented *in situ*, *ex situ*, or both. The following are treatment technologies potentially applicable to the BGOU SWMUs.

In situ Treatment

In situ treatments destroy, remove, or immobilize COCs without removing or extracting contaminated media. *In situ* treatment technologies may involve distributing fluids or gaseous amendments; applying thermal, pressure, or electrical potential gradients; manipulating subsurface conditions to promote biotic or abiotic contaminant degradation; or applying physical mixing in combination with other treatments. *In situ* treatments potentially applicable to the BGOU are discussed below.

Biological Technologies

Biodegradation of chlorinated ethenes in the subsurface occurs through one or more of three different pathways, which may occur simultaneously (ITRC 2005).

(1) The contaminant is used as an electron acceptor and is reduced by the microbe, but not used as a carbon source [i.e., the anaerobic reductive dechlorination (ARD) process].

(2) The contaminant is used as an electron donor and is oxidized by the microbe, which obtains energy and organic carbon from the contaminant.

(3) The contaminant is cometabolized; this is a process where an enzyme or other factor used by the microbe for some other purpose fortuitously destroys the contaminant while providing no benefit to the microbe itself. Cooxidation is a form of cometabolism.

Bioremediation acts on dissolved aqueous-phase VOCs and does not act directly on DNAPL. Instead, the technology relies on degradation and solubilization processes that occur near the water-DNAPL interface. The DNAPL contaminant mass must transfer into the aqueous phase before it can be subjected to the dechlorination or oxidation processes.

Biodegradation of dissolved-phase VOCs in DNAPL zones or VOCs sorbed to solids increases the rate of dissolution by maintaining a relatively high concentration gradient between the DNAPL, or sorbed phase, and the aqueous phase (i.e., maintaining contaminant concentrations in the aqueous phase as low as possible). Increased destruction of contaminant mass in the source area can be achieved by increasing the rate of contaminant dissolution. Even with increased dissolution rates, however, source areas at many sites are expected to persist for many decades, due to the large amount of DNAPL mass present and the difficulty of establishing conditions favorable for biodegradation throughout the contaminated areas. Despite variation in source area characteristics, enhancing the contaminant dissolution rate remains a key process objective for bioremediation of source areas. The following is a discussion of ARD and aerobic cooxidation.

Anaerobic Reductive Dechlorination. Enhanced anaerobic reductive dechlorination occurs through addition of an organic electron donor and nonindigenous dechlorinating microbes, as necessary, to facilitate the sequential transformation of chlorinated ethenes as follows:

PCE → TCE → *cis*-DCE → Vinyl Chloride → ethene

KRCEE (2008) noted that the presence of anaerobic TCE degradation products including *cis*-1,2-DCE observed in UCRS groundwater southwest of the C-400 Building and near RGA source areas is indicative of localized areas where ARD processes occur; however, rates and extent of ARD in the UCRS are not quantified.

Conditions favorable to ARD success, based on case studies, include (ITRC 2005) the following:

- Relatively low-strength residual sources characterized by nonaqueous-phase contaminants present primarily at residual saturation levels with no massive DNAPL pool;
- Relatively homogenous and permeable subsurface environment that would facilitate amendment injection and distribution throughout the contaminant zone;
- Sites with relatively long remedial time frames amenable to the achievable rate of contaminant mass destruction;
- Sites with sufficient access to facilitate the required amendment injections;
- Sites with sufficient hydraulic capture and/or downgradient buffer zone to ensure that the treatment effects, such as production of dissolvent metals and/or partial degradation products, such as vinyl chloride do not impact potential receptors; and
- Sites where cost is a major driver in the technology selection process.

The effectiveness and technical implementability of *in situ* bioremediation-anaerobic reductive dechlorination (ISB-ARD) at the BGOU SWMUs is uncertain in both the UCRS and RGA. The low lateral hydraulic conductivity, high soil heterogeneity, and variable extent of saturation in the UCRS soil limits its application in this zone. Technologies that rely on injection of substrates or chemicals into the subsurface are considered to be technically impractical for the UCRS. The lateral hydraulic conductivity of the UCRS is probably too low for practical implementation of technologies requiring *in situ* injection of substrates or chemicals. Injection of dissolved substrates is most applicable in soil with a lateral hydraulic conductivity of 3E-04 cm/s or greater and is considered to be impractical for soil with a lateral hydraulic conductivity less than 3E-06 cm/s (Parsons 2004). The only available data on hydraulic conductivity in the UCRS within the BGOU are for SWMUs 2 and 3 (DOE 2009). The most conductive layers within the UCRS are HU2A (18.5 to 26 ft bgs) and HU2B (34 to 40 ft bgs), comprised primarily of sand, gravel, and silt. The HU2A and HU2B layers have lateral hydraulic conductivities of 1E-05 and 5E-06 cm/s, respectively. These values are within, but on the lower end, of the practical range for injection. Although not reported, the lateral hydraulic conductivities of the HU2 silt and sand confining unit (26 to 34 ft bgs) and the HU3 silty clay layer (40 to 65 ft bgs) are presumably lower, as the vertical hydraulic conductivities of HU2 and HU3 are approximately an order of magnitude lower than HU2A and HU2B. Injection of chemicals into these layers likely would be impractical.

The effective implementation of ISB-ARD requires that anaerobic conditions be maintained within the treatment area. The dissolved oxygen (DO) and oxidation-reduction potential (ORP) of the UCRS groundwater indicate that the UCRS is primarily aerobic, although localized areas of reducing conditions have been or may be present within some of the burial cells where other organic wastes may be co-located (DOE 2009). RGA groundwater also is reported to be aerobic, as DO has been measured up to 6 mg/L, and ORP measurements range between 100 to 300 milliVolts. Although the introduction of sufficient carbon substrate into the aquifer will consume competing electron acceptors and drive the groundwater anaerobic, the influx of aerobic water through the treated area will provide a continuing source of competing electrons acceptors that can reduce the longevity of the injected carbon substrate, diminishing the cost-effectiveness of ISB-ARD. This is a particular and important concern for the RGA, because the high groundwater flow rate within the RGA in the area of the Southwest plume (typically 1 to 3 ft per day) could impose a significant demand on the injected substrate. A recirculation injection system, coupling groundwater extraction and reinjection with substrate amendment likely would be required to maintain anaerobic conditions in the RGA. A bioremediation pilot test would be required to confirm the effectiveness of such an approach. Establishing anaerobic conditions favorable for ARD also may inhibit ongoing existing natural aerobic degradation processes demonstrated to exist in the RGA (KRCEE 2008).

The available data indicate that the technical implementability of ISB-ARD is uncertain; however, the technology is retained for further evaluation.

<u>Aerobic Cometabolism</u>. TCE is not readily degraded aerobically as a primary substrate, but can be cometabolized. Cometabolism occurs when a microbe using an organic compound as a carbon and energy source produces enzymes that fortuitously degrade a second compound without deriving energy or carbon for growth from that compound. Microbes and microbial consortia of multiple species using methane as a substrate have been demonstrated to produce methane monooxygenase (MMO), which fortuitously oxidizes TCE. This conversion has been demonstrated to occur naturally in groundwater at many sites, including the PGDP, and is part of natural attenuation processes. Aerobic cometabolism has been demonstrated to occur in the RGA at the PGDP; however, evidence of cometabolism in the UCRS has not yet been developed (KRCEE 2008).

MMO inserts molecular oxygen into TCE, removing the carbon-carbon double bond, creating TCE epoxide. The epoxide is unstable in the aqueous environment outside the cell and breaks down to formate, chlorinated acids, glyoxylate, and carbon monoxide. Methanotrophs and/or heterotrophs then can metabolize these products into final products of carbon dioxide and cell mass.

Aerobic cometabolism acts only on dissolved aqueous-phase VOCs and only indirectly on DNAPL or sorbed phases by increasing the rate of dissolution, as does anaerobic reductive dechlorination. This technology has been applied successfully at field scale in the saturated zone at the Savannah River National Laboratory and other sites where methane gas is sparged into groundwater containing dissolved TCE. This technology has not been demonstrated for VOCs in the unsaturated zone.

Low-permeability and heterogeneous soils limit distribution of amendments. Implementability and effectiveness for VOCs in the UCRS are uncertain, and a field demonstration would be required prior to implementation. This technology is retained for further consideration.

<u>Phytoremediation</u>. Phytoremediation exploits plant processes, including transpiration and rhizosphere enzymatic activity, to uptake water and dissolved-phase contaminants or to transform contaminants *in situ*. TCE may be transpired to the atmosphere or degraded in the root zone. The depth of VOC

contamination at BGOU sites is greater than the root zone of plants capable of transpiring or degrading TCE. Phytoremediation is not technically implementable at the PGDP BGOU sites and therefore is screened from further consideration.

Physical/Chemical Technologies

Soil Vapor Extraction. SVE applies a vacuum to unsaturated soils to induce the controlled flow of air through contaminated intervals, thereby removing volatile and some semivolatile contaminants from the soil. SVE can increase the rate of volatilization from DNAPL, aqueous, and sorbed VOC phases by maintaining a high concentration gradient between these phases and the air filled soil porosity.

The gas leaving the soil may be treated to recover or destroy the contaminants, depending on local and state air discharge regulations. Vertical extraction wells typically are used at depths of 5 ft or greater and have been successfully applied as deep as 300 ft. Horizontal extraction vents installed in trenches or horizontal borings can be used as warranted by contaminant zone geometry, drill rig access, or other site-specific factors. SVE is defined by EPA as a presumptive remedy for VOCs in soil (EPA 2007).

The typical target contaminant groups for *in situ* SVE are VOCs and some fuels. The technology typically is applicable only to volatile compounds with a Henry's law constant greater than 0.01 or a vapor pressure greater than 0.5 mm Hg (0.02 inches Hg). Other factors, such as the moisture content, organic content, and air permeability of the soil, affect effectiveness.

Factors that may limit the applicability and effectiveness of the process include the following:

- Soil that has a high percentage of fines and a high degree of saturation will require higher vacuums (increasing costs) and hindering the operation of the *in situ* SVE system.
- Large screened intervals are required in extraction wells for soil with highly variable permeabilities or stratification, which otherwise may result in uneven delivery of gas flow from the contaminated regions.
- Soil that has high organic content or is extremely dry has a high sorption capacity of VOCs, which results in reduced removal rates.
- Exhaust air from the *in situ* SVE system may require treatment to meet discharge requirements.
- Off-gas treatment residuals (e.g., spent activated carbon) may require treatment/disposal.
- SVE is not effective in the saturated zone; however, groundwater pumping (dual-phase SVE) can expose more media to air flow.

Data requirements include the depth and areal extent of contamination, the concentration of the contaminants, depth to water table, and soil type and properties (e.g., structure, texture, permeability, and moisture content). Pilot studies should be performed to provide design information, including extraction well sizing, radius of influence, gas flow rates, optimal applied vacuum, and contaminant mass removal rates.

During full-scale operation, *in situ* SVE can be run intermittently (pulsed operation) after the mass removal rate has reached an asymptotic level. Pulsed operation can improve the cost-effectiveness of the system by facilitating extraction of higher concentrations of contaminants. After the contaminants are removed by *in situ* SVE, other remedial measures, such as biodegradation, can be investigated if RAOs have not been met.

The intrinsic permeability of the soil is the single most important factor in determining the effectiveness of SVE. SVE is generally effective in soil with an intrinsic permeability greater than 1E-08 cm^2. SVE is marginally effective to ineffective in soils with an intrinsic permeability of 1E-10 cm^2 or less. Soil with an intrinsic permeability between 1E-08 and 1E-10 cm^2 requires a pilot test to demonstrate the effectiveness of SVE (EPA 2004). There is no direct intrinsic permeability data for the UCRS soil at the BGOU, but intrinsic permeability may be estimated from hydraulic conductivity via the following equation (EPA 2004):

$$k = K * (\nu/\rho g),$$

where: k = intrinsic permeability (cm^2)
K = hydraulic conductivity (cm/s)
ν = viscosity of water (g/cm/s)
ρ = density of water (g/cm^3)
g = acceleration due to gravity (cm/s^2)

The factor ($\nu/\rho g$) is approximately 1E-05 cm/s at average groundwater temperature; therefore, SVE may be ineffective in soil with a hydraulic conductivity less than 1E-05 cm/s (intrinsic permeability < 1E-10). The only available data on hydraulic conductivity in the UCRS within the BGOU are for SWMUs 2 and 3 (DOE 2010). The hydraulic conductivity for UCRS soil at SWMU 2 ranges from 1E-05 (HU2A gravel) to 8E-07 (HU2 clayey silt). The hydraulic conductivity data for SWMU 2 indicate that SVE is unlikely to be effective in the UCRS, assuming that the SWMU 2 data is representative of the BGOU as a whole.

The heterogeneous natural of the soil within the UCRS further complicates the effective implementation of SVE. UCRS soil has layers of varying composition that will exhibit different intrinsic permeabilities. In stratified soil, the subsurface air flow induced by SVE will move preferentially through the layers with higher intrinsic permeability, with far less flow in the less permeable strata. This situation can result in uneven treatment and/or greatly extended treatment durations (EPA 2004).

Another limitation to the implementation of SVE within the UCRS is the high water table within the BGOU. Groundwater is typically encountered at about 5 ft bgs. SVE is not appropriate for sites with groundwater less than 3 ft bgs. Special controls, such as groundwater pumping to lower the water table, are required at sites with groundwater elevations between 3 to 10 ft bgs (EPA 2004). SVE would not be appropriate for the BGOU sites unless measures were implemented to lower the water table below the DNAPL zone.

A previous report that evaluated innovative technologies for applicability at PGDP (Hightower *et al*. 2001) identified high vacuum SVE as a potential technology for the treatment of VOC contamination in the UCRS unsaturated soil. The report stated that this technology can remove VOCs in soil with hydraulic conductivities in the range of 1E-06 to 1E-07 cm/s. The technology should be effective in portions of the UCRS, but the least permeable layers may still be resistant to complete treatment.

SVE would not be appropriate in the RGA because the soil in this unit is saturated.

The available data indicate that the effectiveness of SVE for the removal of VOCs in unsaturated soil in the UCRS is uncertain; however, the technology is retained for further evaluation.

Dual-phase Extraction. Impermeable covers often are placed over the soil surface during SVE operations to prevent short circuiting of air flow and to increase the radius of influence of the wells. Groundwater depression pumps may be used to reduce groundwater upwelling induced by the vacuum or to increase the depth of the vadose zone. This application, called dual-phase extraction (DPE), was evaluated and recommended by Hightower *et al.* (2001) as potentially effective and implementable for remediation of DNAPL TCE in saturated conditions in the UCRS at PGDP. Potential adjunct technologies to improve performance, including fracturing, active or passive air injection, air sparging, and ozone injection, are discussed separately.

Most guidance documents on DPE agree that the technology is most applicable in low to moderately permeable soil with a range of hydraulic conductivity from 1E-03 to 1E-05 cm/s (EPA 1996a; Suthersan 1997; EPA 1999c; COE 1999), although the use of high vacuum DPE can extend treatment to soil with hydraulic conductivities in the range 1E-06 to 1E-07 cm/s (Hightower *et al*. 2001). The hydraulic conductivity of UCRS soil ranges from 1E-05 to 8E-07 based on data from SWMU 2. In stratified soil, the subsurface air flow induced by DPE will move preferentially through the layers with higher intrinsic permeability, with much less flow in the less permeable strata. This situation can result in uneven treatment and/or greatly extended treatment durations (EPA 1995). The hydraulic conductivity data suggests that some layers of soil in the UCRS may be resistant to complete treatment using the technology.

DPE may be implementable in the RGA, although extraction of a significant volume of water may be required to depress the water table. The hydraulic conductivity of the RGA (5E-01 cm/s) is well above the target hydraulic conductivity range for DPE (1E-03 to 1E-05 cm/s).

The available data indicate that the technical implementability of DPE is uncertain. The technology may be more effectively implemented as an adjunct treatment process to another remedial technology, such as *in situ* heating; therefore, DPE is retained for further evaluation.

Air Sparging. Air sparging injects air into a contaminated aquifer. Injected air traverses horizontally and vertically in channels through the soil column, creating an underground stripper that removes contaminants by volatilization. This injected air helps to volatilize the contaminants up into the unsaturated zone, where they typically are removed by an SVE system. This technology is designed to operate at high flow rates to maintain increased contact between groundwater and soil and strip more groundwater by sparging. Air sparging can act on aqueous DNAPL and sorbed phase VOCs by promoting volatilization of VOCs into an air phase, although air sparging may not effectively treat DNAPL when present in amounts significantly above residual saturation (COE 2008).

Oxygen added to contaminated groundwater and vadose zone soils also can enhance biodegradation of contaminants below and above the water table. Ozone may be generated on-site and added to air injection or sparging systems to oxidize contaminants *in situ*. This application of sparging was recommended for evaluation by Hightower *et al.* (2001) for remediation of TCE sources in the UCRS unsaturated zone at the PGDP.

The target contaminant groups for air sparging are VOCs and fuels. Methane can be used as an amendment to the sparged air to enhance cometabolism of chlorinated organics.

Factors that may limit the applicability and effectiveness of the process include the following:

- Soil heterogeneity may cause some zones to be relatively unaffected or may result in uncontrolled movement of vapors, and

- Sparging tends to create preferential flowpaths that may bypass contaminated areas.

Characteristics that should be determined include vadose zone gas permeability, depth to water, groundwater flow rate, radial influence of the sparging well, aquifer permeability and heterogeneities, presence of low permeability layers, presence of DNAPLs, depth of contamination, and contaminant volatility and solubility. Additionally, it is often useful to collect air-saturation data in the saturated zone during an air sparging test, using a neutron probe.

This technology is demonstrated at numerous sites, though only a few sites are well documented. Air sparging has demonstrated sensitivity to minute permeability changes, which can result in localized stripping between the sparge and MWs (FRTR 2008). Air sparging has a medium to long duration that may last up to a few years.

Most air sparging technical guidance documents indicate that the effective lower limit of hydraulic conductivity in soil is between 1E-03 and 1E-05 cm/s for successful implementation of the technology (Battelle 2001; ITRC 2009; EPA 2004; AAEE 1998; COE 2008). Pulsed air sparging was effectively demonstrated at a site with hydraulic conductivities ranging from 3E-04 to 6E-07 cm/s (Kirtland and Aelion 2000). The hydraulic conductivity of UCRS soil ranges from 1E-05 to 8E-07 based on data from SWMU 2 (DOE 2010), so it is possible that air sparging could be effectively implemented in the UCRS soils. Soils with hydraulic conductivities ($K \geq$ 1E-01 cm/s) may require deeper air sparging wells and higher flow rates to be effective (ITRC 2009). The hydraulic conductivity of the RGA is approximately 2E-01 cm/s (DOE 2010).

The available data indicate that the technical implementability of air sparging is uncertain; however, the technology is retained for further evaluation.

Soil Flushing. *In situ* soil flushing is the extraction of contaminants from soil with water or other suitable aqueous solutions. Soil flushing is accomplished by passing the extraction fluid through in-place soils using an injection or infiltration process. Extraction fluids are recovered from the underlying aquifer and, when possible, they are recycled. Many soil flushing techniques are adapted from enhanced oil recovery methods used by the petroleum industry for many years. Soil flushing agents including cosolvents and surfactants are discussed here.

Cosolvent flushing involves injecting a solvent mixture (e.g., water plus a miscible organic solvent such as alcohol) into either the vadose zone, saturated zone, or both to extract contaminants through solubilization into the cosolvent. Cosolvent flushing is applied to soils to dissolve the source of contamination. It is not applicable to dissolved-phase plumes (ITRC 2003). The cosolvent mixture normally is injected upgradient of the contaminated source area, and the solvent with dissolved contaminants is extracted downgradient and treated aboveground.

Surfactant flushing acts by dissolving the contaminant or reducing the interfacial tension between the contaminant and either water or soil, thereby increasing the surface area for solubilization. Surfactant flushing can result in mobilization of COCs, and the process requires physical or hydraulic containment.

Recovered contaminated groundwater and flushing fluids may need treatment to meet appropriate discharge standards prior to recycling or releasing to receiving streams. Recovered fluids are reused in the flushing process to the extent practicable. The separation of surfactants from recovered flushing fluid, for reuse in the process, is a major factor in the cost of soil flushing. Treatment of the recovered fluids results in process sludges and residual solids, such as spent carbon and spent ion exchange resin, which must be appropriately treated before disposal. Air emissions of volatile contaminants from recovered flushing fluids should be collected and treated, as appropriate, to meet applicable requirements. Residual flushing additives in the soil may be a concern and should be evaluated on a site-specific basis.

The duration of soil flushing process generally is short- to medium-term. Costs are high relative to most other *in situ* treatments. Flushing solutions may alter the physical/chemical properties of the soil system.

Factors that may limit the applicability and effectiveness of the process include the following:

- Low permeability or heterogeneous soils are difficult to treat. Effectiveness and technical implementability of soil flushing at the PGDP BGOU sites are uncertain due to the heterogeneity and variable extent of saturation in the UCRS soils, resulting in difficult conditions for injecting and circulating liquid amendments.

- Surfactants can adhere to soil and reduce effective soil porosity.

- Reactions of flushing fluids with soil can reduce contaminant mobility.

- Control of mobilized fluids, in particular NAPLs, is critical to success. The technology should be used only where flushed contaminants and soil flushing fluid can be contained and recaptured.

- Aboveground separation and treatment costs for recovered fluids can drive the economics of the process.

Treatability tests are required to determine the feasibility of the specific soil-flushing process being considered. Physical and chemical soil characterization parameters that should be established include soil permeability, soil structure, soil texture, soil porosity, moisture content, total organic carbon, cation exchange capacity, pH, and buffering capacity.

Contaminant characteristics that should be established include concentration, solubility, partition coefficient, solubility products, reduction potential, and complex stability constants. Soil and contaminant characteristics will determine the flushing fluids required, flushing fluid compatibility, and changes in flushing fluids with changes in contaminants.

Soil flushing is a developing technology that has had limited use in the United States. Typically, laboratory and field treatability studies must be performed under site-specific conditions before soil flushing is selected as the remedy of choice. To date, the technology has been selected as part of the source control remedy at 12 Superfund sites. There has been very little commercial success with this technology (FRTR 2008).

Soil flushing has a low probability of success in the UCRS because of the low permeability of some soil layers in this zone; however, it may be more implementable in the RGA. The technology is retained for further evaluation.

<u>Electrokinetics</u>. The principle of electrokinetic remediation relies upon application of a low-intensity direct current through the soil between ceramic electrodes that are divided into a cathode array and an anode array. This mobilizes charged species, causing ions and water to move toward the electrodes. Metal ions, ammonium ions, and positively charged organic compounds move toward the cathode. Anions such as chloride, cyanide, fluoride, nitrate, and negatively charged organic compounds move toward the anode. The current creates an acid front at the anode and a base front at the cathode.

Two primary mechanisms, electromigration and electroosmosis, transport contaminants through the soil toward one or the other electrodes. In electromigration, charged particles are transported through the stationary soil moisture. In contrast, electroosmosis is the movement of the soil moisture containing ions relative to a stationary charged surface. The direction and rate of movement of an ionic species will depend on its charge, both in magnitude and polarity, as well as the magnitude of the electroosmosis-induced flow velocity. Non-ionic species, both inorganic and organic, also will be transported along with the electroosmosis-induced water flow. Electrokinetics can act on aqueous, DNAPL, and sorbed phase VOCs. Electroosmosis has been used for years in the construction industry to dewater low-permeability soils.

Two approaches are taken during electrokinetic remediation: "Enhanced Removal" and "Treatment without Removal." "Enhanced Removal" is achieved by electrokinetic transport of contaminants toward the polarized electrodes to concentrate the contaminants for subsequent removal and *ex situ* treatment. Removal of contaminants at the electrode may be accomplished by several means including electroplating at the electrode, precipitation or co-precipitation at the electrode, pumping of water near the electrode, or complexing with ion exchange resins. Enhanced removal is widely used in remediation of metals-contaminated soils.

"Treatment without Removal" is achieved by electroosmotic transport of contaminants through treatment zones placed between electrodes. The polarity of the electrodes is reversed periodically, which reverses the direction of the contaminants back and forth through treatment zones. The frequency with which electrode polarity is reversed is determined by the rate of transport of contaminants through the soil. This approach can be used on *in situ* remediation of soils contaminated with organic species.

Targeted contaminants for electrokinetics are heavy metals, anions, and polar organics, in soil, mud, sludge, and sediments. Concentrations that can be treated range from a few ppm to tens of thousands ppm. Electrokinetics is most applicable in low-permeability soils. Such soils typically are saturated and partially saturated clays and silt-clay mixtures that are not readily drained.

Factors that may limit the applicability and effectiveness of this process include the following:

- Effectiveness is sharply reduced for wastes with a moisture content of less than 10%. Maximum effectiveness occurs if the moisture content is between 14% and 18%.

- The presence of buried metallic or insulating material can induce variability in the electrical conductivity of the soil, therefore, the natural geologic spatial variability should be delineated. Additionally, deposits that exhibit very high electrical conductivity, such as ore deposits, cause the technique to be inefficient.

- Inert electrodes, such as carbon, graphite, or platinum, must be used so that no residue will be introduced into the treated soil mass. Metallic electrodes may dissolve as a result of electrolysis and introduce corrosive products into the soil mass.

- Electrokinetics is most effective in clays because of the negative surface charge of clay particles; however, the surface charge of the clay is altered by both charges in the pH of the pore fluid and the adsorption of contaminants. Extreme pH at the electrodes and reduction-oxidation changes induced by the process electrode reactions may inhibit electrokinetics effectiveness.

- Oxidation/reduction reactions can form undesirable products (e.g., chlorine gas).

In addition to identifying soil contaminants and their concentrations, information necessary for engineering electrokinetic systems to specific applications includes soil moisture content and classification, soil pH, bulk density, and cation-anion balance. Process-limiting characteristics such as pH or moisture content sometimes may be adjusted. In other cases, a treatment technology may be eliminated based upon the soil classification (e.g., particle-size distribution) or other soil characteristics.

The electrokinetic technology has been operated for test and demonstration purposes at the pilot scale and at full scale at a number of sites including the PGDP SWMU 91. The PGDP field test implemented the Lasagna™ process, a patented and trademarked “treatment without removal” electrokinetic soil treatment. The system uses a series of planar electrodes emplaced at the outer edge of a source zone, from 20 to 100 ft apart. Treatment zones for TCE consist of iron filings and clay emplaced between and parallel to the electrode zones. When the power is on, the soil is heated and pore water travels from the anode toward the cathode. TCE is broken down into nonhazardous compounds as it comes in contact with the iron particles in the treatment zones.

In 1994, PGDP SWMU 91, the Cylinder Drop Test Area, was selected for the demonstration of the Lasagna™ technology. TCE was present in UCRS soils and groundwater at concentrations indicative of residual saturation to a depth of approximately 45 ft bgs.

Phase I of the SWMU 91 Lasagna™ demonstration began in January 1995 and lasted for 120 days. The purpose of Phase I was to collect sufficient experience and information for site-specific design, installation, and operation of the Lasagna™ technology. Lasagna™ Phase IIa began in August 1996 and lasted 12 months. The purpose of Phase IIa was to perfect methods for installing treatment and electrode zones. During the technology demonstration, the average concentration of TCE in the target soil was reduced by approximately 95%.

Following the successful field-scale test, DOE issued the *Record of Decision for Remedial Action at Solid Waste Management Unit 91 of Waste Area Group 27 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* in 1998 (DOE 1998b). The ROD designated Lasagna™ as the selected remedial alternative for reducing the concentration of TCE in SWMU 91. Following installation, the Lasagna™ system was operated for two years to reduce the concentration of TCE in SWMU 91 soils to the RGs established in the SWMU 91 ROD (DOE 2002b).

This technology has been demonstrated at the PGDP to be effective, technically implementable, and commercially available for remediation of VOCs in soil. This technology is retained for further evaluation.

Soil Fracturing. Soil fracturing may be accomplished either pneumatically, using air, or hydraulically, using liquids. Pneumatic fracturing involves the injection of highly pressurized gas (nitrogen or air) into the soil via borings to extend existing fractures and create a secondary network of subsurface channels. Hydraulic fracturing (hydrofracturing) uses water or slurry instead of gas. Soil fracturing can extend the range of treatment when combined with other primary technologies such as bioremediation, chemical oxidation/reduction, or soil vapor extraction. Soil fracturing for these uses is discussed as a secondary technology in the discussion of the primary technology.

The horizontal subsurface barrier technology involves fracturing the soil matrix by creating stress points over a broad area (EPA 1999a). Soil tends to fracture preferentially along the horizontal plane. Air is injected into the boreholes at increasing pressures to cause the soil to fracture. After soil fracture formation, grouts or polymers can be injected into the fracture in an effort to create a low-permeability horizontal barrier. This technology was successfully demonstrated at the pilot scale level at the Savannah River Site, Aiken, SC, in 1996. Excavation of the test site showed the barrier to be continuous with a total diameter of 16 ft. This technique also may be used to create horizontal reactive barriers or to distribute chemical treatment amendments.

Fracturing potentially may mobilize NAPLs (ARS 2009). Recovery systems capable of capturing mobilized NAPL (i.e., SVE or DPE) are necessary to ensure NAPL containment during fracturing.

Pneumatic and hydraulic fracturing was evaluated in Hightower *et al.* (2001) and KRCEE (2005) as an adjunct technology for ISCO and SVE at PGDP DNAPL sites and was recommended for field testing. The technology is potentially implementable and is retained for further evaluation.

Soil Mixing. Several types of deep soil mixing systems are commercially available, including single- and dual-auger systems. Dual-auger soil mixing involves the controlled injection and blending of reagents into soil through dual overlapping auger mixing assemblies, consisting of alternate sections of auger flights and mixing blades that rotate in opposite directions to pulverize the soil and blend in the appropriate volumes of treatment reagents. Each auger mixing assembly is connected to a separate, hollow shaft (Kelly-bar) that conveys the treatment reagents to the mixing area, where the reagents are injected through nozzles located adjacent to the auger cutting edge. The mix proportions, volume, and injection pressures of the reagents are continuously controlled and monitored by an electronic instrumentation system. This technology has been widely used for grout injection and ground improvement in the civil and geotechnical construction industry for many years. *In situ* soil mixing is most effective at depths to 40 ft bgs; however, depths to 100 ft may be treated using smaller diameter augers (DOE 1996).

During the mixing operation, the dual auger flights break the soil loose allowing the mixing blades to blend the reagents and the soil into a homogeneous mixture. As the augers advance to a greater depth, the soil and reagent(s) are re-mixed by an additional set of augers and mixing blades located above the preceding set on each shaft. When the desired depth is reached, the augers are reversed and withdrawn and the mixing process is repeated on the way to the surface, leaving a homogeneously treated block of soil. Each treated block of soil is composed of two overlapping columns. The pattern of columns is extended laterally in rows of treated blocks, in a repetitive manner to encompass the total area of the required remediation. The depth of the columns encompasses the vertical extent of the remediation. A hood and filter system can be added to the dual auger soil mixing system, thereby eliminating the possibility of contaminants escaping into the atmosphere (ISF 2008).

Deep soil mixing can potentially reduce mass transfer limitations associated with UCRS soils, including low-permeability soils and partial saturation, by physically blending contaminated soils with amendments or heated air or water. Soil mixing can act on aqueous, DNAPL, and sorbed-phase VOCs. Deep soil mixing has been demonstrated to remove up to 95% of VOCs in soil, through ZVI injection, hot air/steam stripping, and injection of bioremediation reagents (ISF 2008). This technology likely would require a pilot demonstration at the PGDP prior to full-scale implementation. *In situ* mixing may not be a practical technology for burial sites that contain undocumented waste material, underground objects, or other hazards that could be encountered during operation of the augers.

The technical implementability of deep soil mixing is uncertain at BGOU burial sites where underground hazards may be encountered; however, the technology could be effective at sites that have been cleared of underground hazards or where underground hazards are not present. This technology is retained for further evaluation.

Thermal Technologies

Electrical Resistance Heating. Electrical resistance heating (ERH) uses electrical resistance heaters or electromagnetic/fiber optic/radio frequency heating to increase the volatilization rate of semivolatiles and facilitate vapor extraction. The vapor extraction component of ERH requires heat-resistant extraction wells, but is otherwise similar to SVE.

Contaminants in low-permeability soils such as clays and fine-grained sediments can be vaporized and recovered by vacuum extraction using this method. Electrodes are placed directly into the soil matrix and energized so that electrical current passes through the soil, creating a resistance that then heats the soil. The heat may dry out the soil causing it to fracture. These fractures make the soil more permeable allowing the use of SVE to remove the contaminants.

The heat created by ERH also forces trapped liquids, including DNAPLs, to vaporize and move to the steam zone for removal by SVE. ERH applies low-frequency electrical energy in circular arrays of three (three-phase) or six (six-phase) electrodes to heat soils. The temperature of the soil and contaminant is increased, thereby increasing the contaminant's vapor pressure and its removal rate. ERH also creates an *in situ* source of steam to strip contaminants from soil. Heating via ERH also can improve air flow in high moisture soils by evaporating water, thereby improving SVE performance. ERH can act on aqueous, DNAPL, and sorbed phase VOCs.

Six-phase heating (SPH) was evaluated and recommended by Hightower *et al.* (2001) for TCE DNAPL contamination in the saturated and unsaturated zones of the UCRS. A pilot study using SPH subsequently was conducted at PGDP between February and September of 2003. The heating array was 30 ft in diameter and reached a depth of 99 ft bgs. Baseline sampling results showed an average reduction in soil contamination of 98% and groundwater contamination of 99% (DOE 2003).

The following factors may limit the applicability and effectiveness of the process:

- Debris or other large objects buried in the media (e.g., conduit along the north side of SWMU 2) can cause operating difficulties;

- Low-permeability soils or soils with high moisture content have a reduced permeability to air, requiring more energy input to increase vacuum and temperature;

- Soils with a high organic content have a high VOC sorption capacity, which results in reduced removal rates;

- Air emissions may need to be regulated to eliminate possible harm to the public and the environment; and

- Residual liquids and spent activated carbon may require further treatment.

Data requirements include the depth and areal extent of contamination, the concentration of the contaminants, depth to the water table, and soil type and properties including structure, texture, permeability, organic carbon content, and moisture content.

Durations of thermally enhanced remediation projects are highly dependent upon the site-specific soil and chemical properties. The typical site consisting of 20,000 tons of contaminated media would require approximately nine months to remediate (FRTR 2008). This technology has been demonstrated at PGDP for removal of DNAPL TCE and its degradation products. This technology is retained for further evaluation.

Thermal Conduction Heating. Thermal conduction heating (TCH) is similar to ERH in that the physical processes of contaminant removal and collection are similar, but the two processes use different methods to heat the subsurface. TCH uses an array of heating elements placed in heater wells to raise the temperature of the subsurface by thermal conduction. Unlike ERH, it does not pass a current through the subsurface or rely on the electrical resistance of the soil to facilitate the heating process. TCH can generate subsurface temperatures above 100° C and is therefore effective at removing semivolatile organic compounds (SVOCs) such as PAHs, PCBs, pesticides, and dioxins. The maximum soil temperature achievable with ERH is 100° C and its application typically is limited to treatment of VOCs. Unlike ERH, buried metal objects are not a significant limitation to the implementation of TCH as long as the buried materials to not interfere with the construction of heater and heater/vacuum wells.

TCH is retained for further evaluation because of its potential applicability in treatment of TCE DNAPL, particularly in UCRS soil with buried metallic debris.

<u>Steam Stripping.</u> Hot air or steam is injected below the contaminated zone to heat contaminated soil and thereby enhance the release of VOCs and some VOCs from the soil matrix. Desorbed or volatilized VOCs are removed through SVE (FRTR 2008). Steam injection has been used to enhance oil recovery for many years and was investigated for environmental remediation beginning in the 1980s. Approximately 10 applications of this technology for recovery of fuels, solvents, and creosote are reported in EPA 2005, with varied results.

In situ steam stripping is commonly applied using soil mixing equipment to improve contact of steam with contaminated media. Steam stripping can act on aqueous, DNAPL, and sorbed-phase VOCs. This technology is retained for further evaluation.

Chemical Technologies

ISCO processes are *in situ* treatments whereby chemical compounds are injected to oxidize organic contaminants in the subsurface. Commercially available chemical oxidation technologies described in this section include the following:

- Permanganate
- Fenton's reagent
- ZVI
- Ozonation
- Persulfate
- Redox manipulation
- Surfactant-enhanced ISCO

ISCO has been used at many sites, and oxidants are available from a variety of vendors. Water-based oxidants can react only directly with the dissolved-phase of NAPL contaminants, since the two will not mix. This property limits their activity to the oxidant solution/DNAPL interface; however, significant mass reduction has been reported for application of ISCO at sites with dissolved-phase VOCs and DNAPL residual ganglia (EPA 2008). Off-gas control is often important during implementation of chemical oxidation technologies.

Data needs include heterogeneity of the site subsurface, soil oxidation demand, stability of the oxidant, and type and concentration of the contaminant. Effectiveness and technical implementability of ISCO at the PGDP BGOU sites is uncertain due to the relatively low permeability, heterogeneity, and variable extent of saturation in the UCRS soils, resulting in difficult conditions for injecting and circulating liquid amendments. The technology may be more implementable in the RGA.

Permanganate. Permanganate typically is provided as liquid or solid potassium permanganate (KMnO4), but also is available in sodium, calcium, or magnesium salts. The following equation represents the chemical oxidation of TCE using potassium permanganate:

$2KMnO_4 + C_2HCl_3 \rightarrow 2MnO_2 + 2CO_2 + 3Cl^- + H^+ + 2K^+$ (III-1)

The use of permanganate to degrade TCE causes the generation of salts and hydrogen or hydroxyl ions (acids or bases) with only minor pH shifts. The direct application of permanganate has commonly been used for contaminant levels up to 100 ppm to avoid off-gassing. It has only recently been applied to contaminant levels exceeding 1,000 ppm. Permanganate can be delivered to the contaminated zone by injection probes, soil fracturing, soil mixing, and groundwater recirculation (EPA 2004). Permanganate has an effective pH range of 3.5 to 12 (KRCEE 2005).

The effectiveness of permanganate injection in the UCRS is uncertain because of previously mentioned limitations (low soil permeability, soil heterogeneity and stratification, and variable extent of saturation). A bench-scale ISCO treatability study conducted on TCE-spiked RGA sediment concluded that potassium permanganate would not be an effective reagent to use on TCE DNAPL in the RGA because the reaction of permanganate with the contaminated soil was not exothermic enough to volatilize the TCE (DOE 1999a). Nevertheless, the technology is retained for further evaluation because permanganate oxidation may be effective when combined with other process options (e.g., coelution technologies).

Fenton's Reagent. Hydrogen peroxide (H_2O_2) was one of the first chemical oxidants to be used in industry and was commercialized in the early 1800s. Hydrogen peroxide works as a remedial chemical oxidant in two ways: (1) direct chemical oxidation as hydrogen peroxide and (2) in the presence of native or supplemental ferrous iron (Fe^{+2}), as Fenton's Reagent, which yields hydroxyl free radicals (OH^-). These strong, nonspecific oxidants can rapidly degrade a variety of organic compounds. Fenton's Reagent oxidation is most effective under very acidic pH and becomes ineffective under moderate to strongly alkaline conditions.

The most common field applications of chemical oxidation have been based on Fenton's Reagent. When peroxide is injected into the subsurface at concentrations of 10% to 35% in the presence of ferrous iron, the hydroxyl free radical oxidizes the VOCs to carbon dioxide (CO_2) and water. The residual hydrogen peroxide decomposes into oxygen and water, and the remaining iron precipitates (Jacobs and Testa 2003).

The oxidation reaction for TCE forms several unstable daughter products such as epoxides that break down to aldehydes and ketones, which then finally decompose to carbon dioxide, chloride ions, and water as shown in the following reaction (Jacobs and Testa 2003):

$4OH- + C_2HCl_3 \rightarrow 2CO2 + 3Cl- + 5H^+$ (III-6)

The pH of the surrounding medium increases as the reaction process continues; therefore, it is necessary to lower the pH with acids. Organic acids should be avoided since they have a tendency to increase side reactions. The optimal pH range is from 3.5 to 5.0. The exothermic nature of the oxidation process causes a rise in subsurface temperature which may decompose the peroxide. Field research has determined the optimal reaction temperature to be in the range of 35 to 41°C (Jacobs and Testa 2003).

The effectiveness of Fenton's reagent in the UCRS is uncertain due to previously mentioned limitations (low soil permeability, soil heterogeneity and stratification, and variable extent of saturation). A bench-scale *in situ* chemical oxidation treatability study conducted on TCE-spiked RGA sediment concluded that Fenton's reagent may be an effective technology to use on TCE DNAPL in the RGA (DOE 1999). The primary mechanism of TCE removal was via steam/vapor stripping caused by the exothermic reaction that occurs when large amounts of hydrogen peroxide injected into the soil (12 to 16 weight percent) undergo decomposition or react with the soil or TCE. Approximately 90 percent of the total TCE removed in the bench-scale tests was attributed to the stripping mechanism. The effective implementation of Fenton's reagent in the lab required co-injection of 0.1 to 1 percent iron in the form of iron sulfate and lowering the treatment zone pH to 2.0. Adjunct technologies, such as soil vapor extraction, dual phase extraction and aboveground treatment technologies would also be required to recover and/or destroy the mobilized TCE and hydraulically control the treatment area so that mobilized TCE did not migrate away from the treatment area. The ISCO bench-scale tests did not address a number of field-scale implementation issues, and there is still considerable uncertainty about the overall implementability and effectiveness of the technology at full-scale. The technology is retained for further evaluation.

Zero-Valent Iron. ZVI is conventionally used in conjunction with a permeable reactive barrier to dechlorinate chlorinated hydrocarbons in the subsurface; however, the technology also may be applied as direct injection of particulate iron, mixing of iron with clay slurries, or incorporating nanoscale ZVI into an oil emulsion prior to injection. A form of ZVI may be injected into the subsurface downgradient of the contaminant source to create a zone of treatment. This is an innovative/emerging technology that would require field demonstration prior to implementation. Technical implementability in the UCRS would be constrained by low-permeability soil layers and heterogeneity. This technology potentially is technically implementable and commercially available and is retained for further evaluation.

Ozonation. Ozone (O_3) is a strong oxidizer having an oxidation potential about 1.2 times that of hydrogen peroxide. Because of its instability, ozone typically is generated on-site and delivered to the contaminated zone through sparge wells. Air containing up to 5% ozone is injected through strategically placed sparge wells. Ozone dissolves in the groundwater and oxidizes the contaminant while decomposing to oxygen (O_2).

Ozone injection was evaluated and recommended by Hightower *et al.* (2001) for remediation of DNAPL TCE in the unsaturated zone of the UCRS at the PGDP. Pneumatic fracturing can be used to enhance ozone treatment effectiveness in low permeability soils (EPA 2004).

The effectiveness of ozone injection in the UCRS is uncertain because of previously mentioned limitations (low soil permeability, soil heterogeneity and stratification, and variable extent of saturation). Ozone may be more effective in the RGA. The technology is retained for further evaluation.

Sodium Persulfate. Persulfate is a strong oxidant with a higher oxidation potential than hydrogen peroxide and a potentially lower soil oxidant demand (SOD) than permanganate or peroxide. Persulfate reaction is slow unless placed in the presence of a catalyst, such as ferrous iron, or heated to produce sulfate free radicals that are highly reactive and capable of degrading many organic compounds or implemented at an elevated pH by co-injection with an alkaline agent such as sodium hydroxide. The ferrous iron catalyst, when used, will degrade with time and precipitate. Persulfate becomes especially reactive at temperatures above 40 °C (104 °F) and can degrade most organics (EPA 2008).

The effectiveness of sodium persulfate injection in the UCRS is uncertain because of previously mentioned limitations (low soil permeability, soil heterogeneity and stratification, and variable extent of saturation). Sodium persulfate may be more effective in the RGA. The technology is retained for further evaluation.

Redox Manipulation. *In situ* redox manipulation (ISRM) manipulates natural processes to change the mobility or form of contaminants in the subsurface. ISRM creates a permeable treatment zone by injection of chemical reagents, such as sodium dithionite and/or microbial nutrients into the subsurface downgradient of the contaminant source. The chemical reagent then reacts with iron naturally present in the aquifer sediments in the form of various minerals present as clays, oxides, or other forms. Redox sensitive metals that migrate through the reduced zone in the aquifer may become immobilized and organic species may be destroyed (DOE 2000b).

The effectiveness of ISRM in the UCRS is uncertain because of previously mentioned limitations (low soil permeability, soil heterogeneity and stratification, and variable extent of saturation). ISRM may be more effective in the RGA. The technology is retained for further evaluation.

<u>Surfactant-Enhanced ISCO.</u> Coelution technologies reduce the concentrations of organic contaminants such as TCE in soil. By combining surfactant and oxidant chemistries, a controlled dissolution and desorption process (by dilute surfactant mixtures) with concomitant biological or chemical destruction processes can be applied. This eliminates the need for removal of large quantities of contaminated soil and enables the design of treatments in place with custom surfactant/oxidant combinations that are environmentally safe and nonintrusive to the nearby community.

Coelution technologies such as surfactant-enhanced *in situ* chemical oxidation (S-ISCO®) provide treatment that enables the rapid removal of contaminants from soils and groundwater. The S-ISCO® process relies on injection pressure as the primary motive force to move chemicals that will destroy contaminants where they are located in the soil. The impact of the S-ISCO® process generally is limited to the injection zone with typical spacing of injection points on 10 ft centers and a radius of influence of 5 ft. Alternatively, in soils that have low permeability, the S-ISCO® process can be deployed using emplaced fracturing methodologies or direct-push injection. It requires no heavy equipment, no destruction of buildings, little odor control, and has very little community impact (VeruTEK 2009).

The effectiveness of S-ISCO® in the UCRS is uncertain because of previously mentioned limitations (low soil permeability, soil heterogeneity and stratification, and variable extent of saturation). It may be more effective in the RGA. S-ISCO® is an emerging technology with few full-scale field applications that have been subjected to peer review. The technology will be retained for further evaluation.

Monitored Natural Attenuation

Natural attenuation encompasses the naturally occurring soil and groundwater processes such as sorption, abiotic or biological degradation, and dilution, which immobilize, transform, or reduce concentrations of pollutants. Each natural attenuation process occurs under a range of conditions that must be extensively characterized and monitored over time to determine the effectiveness of the remedy.

The extent of sorption of VOCs in the UCRS and RGA at PGDP has been estimated using the organic carbon fraction of the geologic media and the K_{oc} of the individual VOCs to calculate partition coefficients. Biodegradation of TCE has been demonstrated to occur both aerobically and anaerobically in the UCRS and the RGA, and determination of rates and extents are ongoing (KRCEE 2008). Abiotic degradation has not been verified.

Natural attenuation alone is not expected to remediate DNAPL sources (EPA 1999b). Application of this technology in conjunction with source treatment, containment, or control potentially may be a cost-effective strategy. Review of Paducah site parameters suggests that few if any of the accepted natural attenuation processes are taking place in the groundwater aquifer to a large and quantifiable extent (Clausen *et al.* 1997).

Data needs for monitored natural attenuation are detailed in EPA 1998b and 1999a and include these:

- Soil and groundwater quality data

  — Three-dimensional distribution of residual-, free-, and dissolved-phase contaminants
  — Historical water quality data showing variations in contaminant concentrations through time
  — Chemical and physical characteristics of the contaminants
  — Geochemical data to assess the potential for biodegradation of the contaminants

- Location of potential receptors

  — Groundwater wells
  — Surface water discharge points

This technology is technically implementable and commercially available and is retained for further evaluation as a secondary technology.

***Ex situ* Treatment**

Ex situ treatment technologies may be applicable to treatment of source material and secondary wastes including recovered DNAPL TCE, excavated soils, extracted groundwater, or vapor. *Ex situ* treatment technologies potentially applicable to secondary wastes that may be generated during removal, treatment, or disposal of BGOU source areas are discussed here.

Physical/Chemical Technologies

Air Stripping. Air stripping removes volatile organics from extracted groundwater by greatly increasing the surface area of the contaminated water exposed to air. Air stripping is a presumptive technology for treatment of VOCs in extracted groundwater (EPA 1996b). Air stripping potentially may be applicable to secondary waste treatment from groundwater extraction, light NAPL recovery processes, or *in situ* treatment processes. Types of aeration methods include packed towers, diffused aeration, tray aeration, and spray aeration.

Air stripping involves the mass transfer of volatile contaminants from water to air. For groundwater remediation, this process typically is conducted in a tray aerator, packed tower, or aeration tank. Tray aerators stack a number of perforated trays vertically in an enclosure. Air is blown upward through the perforations as water cascades downward through the trays. Tray aerators occupy relatively little space, are easy to clean, and are highly efficient. Currently, the PGDP Northwest Plume Pump-and-Treat system includes low-profile tray air stripping for TCE removal.

Packed tower air strippers typically include a spray nozzle at the top of the tower to distribute contaminated water over the packing in the column, a fan to force air countercurrent to the water flow, and a sump at the bottom of the tower to collect decontaminated water. Auxiliary equipment that can be added to the basic air stripper includes an air heater to improve removal efficiencies; automated control systems with sump level switches and safety features, such as differential pressure monitors, high sump level switches, and explosion-proof components; and air emission control and treatment systems, such as activated carbon units, catalytic oxidizers, or thermal oxidizers. Packed tower air strippers are installed either as permanent installations on concrete pads or on a skid or a trailer.

Aeration tanks strip volatile compounds by bubbling air into a tank through which contaminated water flows. A forced air blower and a distribution manifold are designed to ensure air-water contact without the need for any packing materials. The baffles and multiple units ensure adequate residence time for stripping to occur. Aeration tanks typically are sold as continuously operated skid-mounted units. The advantages offered by aeration tanks are considerably lower profiles (less than 6 ft high) than packed towers (15 to 40 ft high) where height may be a problem, and the ability to modify performance or adapt to changing feed composition by adding or removing trays or chambers. The discharge air from aeration tanks can be treated using the same technology as for packed tower air discharge treatment.

Air strippers can be operated continuously or in a batch mode where the air stripper is intermittently fed from a collection tank. The batch mode ensures consistent air stripper performance and greater energy efficiency than continuously operated units because mixing in the storage tanks eliminates any inconsistencies in feed water composition.

Liquid and air effluents may require monitoring prior to release, but monitoring of the air effluent also may be necessary based on KY and EPA requirements. Data needs include influent flow rate, VOC concentrations, VOC chemical and physical properties, iron content, dissolved solids, total hardness, alkalinity, and pH. Air and water discharge limits also are required.

Air stripping is effective, technically implementable, and commercially available for removal of TCE and its degradation products from extracted groundwater. This technology is retained for further evaluation.

Ion Exchange. Ion exchange removes ions from the aqueous phase by exchanging cations or anions between the contaminants and the exchange medium. Ion exchange materials may consist of resins made from synthetic organic materials that contain ionic functional groups to which exchangeable ions are attached. Resins also may be inorganic and natural polymeric materials. After the resin capacity has been exhausted, resins can be regenerated for reuse. Wastewater is generated during the regeneration step, potentially requiring additional treatment and disposal.

These factors may affect the applicability and effectiveness of ion exchange (FRTR 2008):

- Oil and grease in the groundwater may clog the exchange resin;
- Suspended solids content greater than 10 ppm may cause resin blinding;
- The pH of the influent water may affect the ion exchange resin selection; and
- Oxidants in groundwater may damage the ion exchange resin.

VOCs are not removed by this method; however, removal of radionuclides including technetium-99 from extracted groundwater using ion exchange is effective, technically implementable, and commercially available. This technology is retained for further evaluation.

Granular-activated Carbon (Vapor Phase). Vapor-phase carbon adsorption removes pollutants including VOCs from extracted air by physical adsorption onto activated carbon grains. Carbon is “activated” for this purpose by processing the carbon to create porous particles with a large internal surface area (3,200 to 27,000 ft^2 per gram of carbon) that attracts and adsorbs organic molecules as well as certain metal and inorganic molecules.

Commercial grades of activated carbon are available for specific use in vapor-phase applications. The granular form of activated carbon typically is used in packed beds through which the contaminated air flows until the concentration of contaminants in the effluent from the carbon bed exceeds an acceptable level. Granular-activated carbon (GAC) systems typically consist of one or more vessels filled with carbon connected in series and/or parallel operating under atmospheric, negative, or positive pressure. The carbon then can be regenerated in place, regenerated at an off-site regeneration facility, or disposed of, depending upon economic considerations.

Carbon can be used in conjunction with steam reforming. Steam reforming is a technology designed to destroy halogenated solvents (such as carbon tetrachloride and chloroform) adsorbed on activated carbon by reaction with superheated steam.

GAC is effective, technically implementable, and commercially available for removal of VOCs from extracted air. This technology is retained for further evaluation.

Vapor Condensation. TCE and other VOCs in contaminated vapor streams can be cooled to condense the contaminants (EPA 2006b). The contaminant-laden vapor stream is cooled below the dew point of the contaminants (e.g., below about 99 °F for TCE), and the condensate can be collected for recycling or disposal. Methods used to cool the vapor stream may include the use of liquid nitrogen, mechanical chilling, or a combination of the two.

Condensation systems are most often used when the vapor stream contains concentrations of contaminants greater than 5,000 ppm or when it is economically desirable to recover the organic contaminant contained in the vapor stream for reuse or recycling. Other configurations of vapor condensation include adsorbing or otherwise concentrating compounds from low-concentration vapors using another technology (e.g., GAC) and then performing condensation for recovery for disposal or recycling.

Vapor condensation is potentially effective for removal of TCE and its degradation products from extracted air. This technology is retained for further evaluation.

Granular-activated Carbon (Liquid Phase). GAC also is widely used for removal of VOCs including TCE and its degradation products from aqueous streams, including pump-and-treat systems. Liquid-phase carbon adsorption removes dissolved pollutants by physical adsorption onto activated carbon grains, similar to gas-phase absorption as described previously. Sizing of the GAC bed is done based on effluent flow rate, face velocity, and residence time. Most GAC systems include a multiple bed configuration to optimize carbon utilization. To meet state and federal emission standards, it may be necessary to monitor the effluent prior to release to the environment. GAC currently is used as a polishing step after air stripping at the PGDP Northwest Plume Pump-and-Treat Facility.

GAC is effective, technically implementable, and commercially available for removal of TCE and its degradation products from extracted groundwater. This technology is retained for further evaluation.

Thermal Technologies

Catalytic Oxidation. Oxidation equipment (thermal or catalytic) can be used for destroying contaminants in the exhaust gas from air strippers and SVE systems. Thermal oxidation units typically are single chamber, refractory-lined oxidizers equipped with a propane or natural gas burner and a stack. Lightweight ceramic blanket refractory is used because many of these units are mounted on skids or trailers. Flame arrestors are installed between the vapor source and the thermal oxidizer. Burner capacities in the combustion chamber range from 0.5 to 2 million BTUs per hour. Operating temperatures range from 760 to 870 °C (1,400 to 1,600 °F), and gas residence times typically are one second or less.

Catalytic oxidation includes a catalyst bed that accelerates the rate of oxidation by adsorbing the oxygen and the contaminant on the catalyst surface where they react to form carbon dioxide, water, and hydrogen chloride gas. The catalyst enables the oxidation reaction to occur at much lower temperatures than required by a conventional thermal oxidation. VOCs are thermally destroyed at temperatures typically ranging from 320° to 540 °C (600° to 1,000 °F) by using a solid catalyst. First, the contaminated air is directly preheated (electrically or, more frequently, using natural gas or propane) to reach a temperature necessary to initiate the catalytic oxidation [310 to 370 °C (600 to 700 °F)] of the VOCs. Then the preheated VOC-laden air is passed through a bed of solid catalysts where the VOCs are rapidly oxidized. High chloride concentrations may require modification of the process to avoid corrosion.

Catalytic oxidation units are widely used for the destruction of VOCs and numerous vendors are available. As with the GAC adsorption units, it may be necessary to monitor effluent concentrations to determine compliance with state and federal emission standards.

Catalytic oxidation is effective, technically implementable, and commercially available for removal of VOCs from extracted groundwater. This technology is retained for further evaluation.

Thermal Desorption. Thermal desorption heats wastes *ex situ* to volatilize water and organic contaminants. A carrier gas or vacuum system transports volatilized water and organics to a gas treatment system where they are collected or oxidized to CO_2 and water (FRTR 2008).

Two common thermal desorption designs are the rotary dryer and thermal screw. Rotary dryers are horizontal cylinders that can be indirect- or direct-fired. The dryer is normally inclined and rotated. Thermal screw units transport the medium through an enclosed trough using screw conveyors or hollow augers. Hot oil or steam circulates through the auger to indirectly heat the medium.

Thermal desorption systems typically require treatment of the off-gas to remove particulates and destroy contaminants. Particulates are removed by conventional particulate removal equipment such as wet scrubbers or fabric filters. Contaminants may be removed through condensation followed by carbon adsorption or destroyed in a secondary combustion chamber or a catalytic oxidizer.

Thermal desorption processes can be categorized into two groups based on operating temperatures, high temperature thermal desorption (HTTD), and low temperature thermal desorption (LTTD). HTTD heats wastes to 320 to 560 °C (600 to 1,000 °F) and is frequently used in combination with incineration, solidification/stabilization, or dechlorination, depending upon site-specific conditions. The technology can produce a final contaminant concentration level below 5 mg/kg for the target contaminants identified.

LTTD heats wastes to between 90 and 320 °C (200 to 600 °F). Contaminant destruction efficiencies in the afterburners of these units are greater than 95%. Decontaminated soil retains its physical properties. Unless heated to the higher end of the LTTD temperature range, soil organic matter remains available to support future biological activity. The target contaminant groups for LTTD systems are nonhalogenated VOCs and fuels. The technology can be used to treat SVOCs at reduced effectiveness.

The target contaminants for HTTD are SVOCs, PAHs, PCBs, and pesticides. VOCs and fuels also may be treated, but treatment may be less cost-effective. Volatile metals may be removed by HTTD systems. The presence of chlorine can affect the volatilization of some metals, such as lead.

- The following factors may limit the applicability and effectiveness of the process:
- Particle size and materials handling requirements can affect applicability or cost at specific sites;
- Dewatering may be necessary to achieve acceptable soil moisture content levels;
- Highly abrasive feed potentially can damage the processor unit;
- Heavy metals in the feed may produce a treated solid residue that requires stabilization; and

- Clay and silty soils and high humic content soils increase reaction time as a result of binding of contaminants.

In addition to identifying soil contaminants and their concentrations, information necessary for engineering thermal systems to specific applications include soil moisture content and classification, determination of boiling points for various compounds to be removed, and treatability tests to determine the efficiency of thermal desorption for removing various contaminants at various temperatures and residence times. A sieve analysis is needed to determine the dust loading in the system to properly design and size the air pollution control equipment.

Most of the hardware components for thermal desorption systems are readily available off the shelf. Most *ex situ* soil thermal treatment systems employ similar feed systems consisting of a screening device to separate and remove materials greater than five centimeters (2 inches), a belt conveyor to move the screened soil from the screen to the first thermal treatment chamber, and a weight belt to measure soil mass. Occasionally, augers are used rather than belt conveyors, but either type of system requires daily maintenance and is subject to failures that can shut down the system. Soil conveyors in large systems seem more prone to failure than those in smaller systems. Size reduction equipment can be incorporated into the feed system, but its installation usually is avoided to minimize shutdown as a result of equipment failure.

Many vendors offer LTTD units mounted on a single trailer. Soil throughput rates typically are 13 to 18 metric tons (15 to 20 tons) per hour for sandy soils and less than 6 metric tons (7 tons) per hour for clay soils when more than 10% of the material passes a 200-mesh screen. Units with capacities ranging from 23 to 46 metric tons (25 to 50 tons) per hour require four or five trailers for transport and two days for setup. The approximate time to complete cleanup of a 20,000-ton site using HTTD is just over four months.

Soil storage piles and feed equipment generally are covered as protection from rain to minimize soil moisture content and material handling problems. Soils and sediments with water contents greater than 20% to 25% may require the installation of a dryer in the feed system to increase the throughput of the desorber and to facilitate the conveying of the feed to the desorber. Some volatilization of contaminants occurs in the dryer, and the gases are routed to a thermal treatment chamber (FRTR 2008).

Thermal desorption is potentially effective, technically implementable, and commercially available for *ex situ* removal of VOCs from soil. This technology is retained for further evaluation.

Ex situ Vitrification. Of all the common solidification methods, vitrification offers the greatest degree of containment. Most (but not all) of the resultant solids have an extremely low leach rate; however, the high energy demand and requirements for specialized equipment and trained personnel greatly limit the use of this method. Exposure to contaminants to the vitrification process results in several desirable results: (1) destruction of hazardous organics by pyrolytic decomposition and/or oxidation, (2) removal (partial or fully) of low-solubility, high-volatility, and high-solubility inorganics in the residual glass product, through chemical incorporation and/or encapsulation. The vitrification process may be carried out in either a separate location from the waste source itself.

In the *ex situ* method, the waste, together with other chemicals that produce the glassy product, are mixed and melted within a special furnace. Waste and glass- (or slag-) forming constituents are introduced into the heated zone of the furnace. These react to produce a molten mass while organic materials are decomposed or volatilized into a suitable scrubber system. The fused mass of insoluble materials can be cast into blocks or removed in a granular form depending on composition and intended disposal requirements.

While possessing several advantages, the process has not, to date, been demonstrated on a large full-scale waste pit. In the case of shallow waste pits spread out over a large area, the amount of waste to be processed by each “melt” is small enough that multiple placements of electrodes would be needed. This is accompanied by the need to place the melt areas closely enough together to consume all of the waste materials in between. Furthermore, the maximum effective depth is stated to be 19 or 20 ft. This technologically is implementable and will be retained for further consideration, but the large volumes of contaminated soils and wastes in the BGOU will contribute to high operating costs.

Metal Melting. There are large quantities of valuable scrap metals created during decommissioning and demolition of previously used nuclear processing facilities. These may be suitable for recycle into other uses. The key issue is the degree of radioactive contamination compared to the intended usage.

Programs have been initiated to find ways to reclaim valuable metal scrap (HPS 2000; NCRP Report 141). In some cases, the end use (such as containers for already-radioactive waste) would allow some radioactivity to remain in the reclaimed metal in its ultimate use location. There has been resistance on the part of the industry and the public to the release of slightly contaminated metals.

Another potential means of rendering the reclaimed metals useful is to decontaminate the surfaces of the metal thoroughly before it is further processed. This can be problematic. For instance, metals in contact with the uranium hexafluoride during the isotopic separation process can become coated with a tenacious layer of mixed oxide of uranium. To remove the coating, strong solubilizing agents would be needed. Such an operation adds to the cost and hazards of the reclamation procedures.

If the metal can be decontaminated to acceptable level or if there are allowable uses for the slightly contaminated metal, it can be melted to form feed metal forms for further processing. Ideally, decontamination has been sufficient to allow “free release” of the material. During the melting down of the scrap, some of the radioactive impurities may be removed by volatilization or oxidation into the slag waste. This can be an advantage of the process, although the new waste thus produced requires disposal in accordance with regulations for radioactive wastes.

Another advantage of going through a melt process during recovery is that the objects are destroyed to prevent unauthorized reuse.

Manufacturing Sciences Corporation (MSC) could not remove technetium-99 from volumetrically contaminated nickel from the former K-25 plant in Oak Ridge utilizing electro-refining approaches to levels that would allow the free release of nickel for commercial and industrial uses. The electro-refining methods employed by MSC resulted in nickel containing residual technetium-99. Residual technetium-99 in nickel purified by MSC’s electro-refining methods resulted in a moratorium being issued by the Secretary of DOE and congressional opposition to the release of nickel from the K-25 plant. Although there is interest in recovering the nickel and recycling it to the industrial sector, as indicated there are many regulatory issues associated with any use of such material outside of the nuclear industry (KRCEE 2007).

This technologically is implementable for metal recovery and/or volume reduction, and will be retained for further consideration; however, the large volumes of contaminated soils and wastes in the BGOU co-mingled with potentially recoverable metals will contribute to high operating costs. These costs are associated with cleaning and decontaminating the metals prior to the metal melting process.

2.4.1.6 Disposal technologies

Disposal technologies for recovered soil, groundwater, DNAPL, and secondary wastes produced during recovery and treatment are discussed.

Land Disposal. The PGDP is evaluating waste disposal options for waste generated from CERCLA projects. This evaluation includes as an alternative the construction of an on-site waste disposal facility (WDF). CERCLA waste types forecasted to be generated include low-level waste (LLW); waste defined under RCRA; waste defined under the Toxic Substance Control Act (TSCA); mixed wastes consisting of combinations of those waste types (e.g., LLW/RCRA, LLW/TSCA, LLW/RCRA/TSCA); and nonhazardous solid wastes. Some of the treatment and removal technologies described previously would generate solid waste. RCRA hazardous wastes could be treated on-site to remove the hazardous characteristics or sent to appropriate off-site facilities for treatment and disposal. LLW or mixed low-level waste could be disposed of at appropriate sites off-site or on-site. Nonhazardous soils or debris that meet the authorized limits could be disposed of at the existing PGDP C-746-U Landfill. Clean soils, as determined by analytical testing, could be returned to the excavation or otherwise used as fill. Materials for land disposal will require stockpiling and analytical characterization prior to determining the appropriate land disposal option. Analytical results for stockpiled materials must be evaluated to ensure that the waste acceptance criteria (WAC) for the respective land disposal facilities will be met prior to waste shipping and/or disposition.

Discharge of Wastewater. Wastewater collected or generated as part of this action will be sent to a wastewater treatment unit to be constructed as part of the remedial action. Ion exchange resins from groundwater treatment could be sent to a land disposal facility. GAC beds could be returned to the manufacturer for thermal regeneration and reused.

2.4.2 Evaluation of Technologies and Selection of Representative Technologies

Technologies retained following the initial screening in Section 2.4.1 are evaluated with respect to effectiveness, implementability, and cost in Table D.2 (see Appendix D). The objective of this evaluation is to provide sufficient information for subsequent selection of RPOs in Section 2.4.3.

Effectiveness is the most important criterion at this evaluation stage. The evaluation of effectiveness was based primarily on the following:

- The potential effectiveness of process options in handling the estimated areas or volumes of contaminated media and meeting the RAO;
- The potential impacts to worker safety, human health, and the environment during construction and implementation; and
- The degree to which the processes are proven and reliable with respect to the contaminants and conditions at the site.

The evaluation of implementability includes consideration of the following:

- The availability of necessary resources, skilled workers, and equipment to implement the technology;
- Site accessibility and interfering infrastructure;
- Potential public concerns regarding implementation of the technology; and

- The time and cost-effectiveness of implementing the technology in the physical setting associated with the waste unit.

A relative cost evaluation is provided for comparison among technologies. Relative capital and O&M costs are described as high, medium, or low. Capital costs for the technologies evaluated tend to increase with increasing complexity and number of process unit operations. O&M costs are estimated to be lower when an alternative may meet RGs and reduce or eliminate the need for long-term monitoring.

A technology that leaves waste in place is assumed to have a 30-year long-term monitoring program and is moderate in cost. A technology such as a RCRA cap that incorporates a long-term monitoring program, leachate collection and treatment system, and cap maintenance is estimated to have higher O&M costs. These costs are based on references applicable to the particular process option given at the end of this section, prior estimates, previous experience, and engineering judgment. The costs are not intended for budgeting purposes.

2.4.3 Representative Process Options

RPOs selected are listed in Table 2.5, based on the evaluation of process options for waste materials as well as VOCs and radionuclides and metals in UCRS soils and groundwater at the BGOU SWMUs. The RPOs selected were determined to be the most potentially effective and implementable of the process options considered for each technology type. The RPOs were selected as needed to formulate the remedial alternatives that are appropriate for each SWMU, as presented in Section 3. Not all technologies identified and retained as technically implementable in Table 2.4 will be developed into remedial process options in Table 2.5 or components of remedial alternatives presented in Section 3.

Technologies that have been demonstrated at the PGDP for treatment of DNAPL TCE in the UCRS, including ERH and electrokinetics using Lasagna™, have higher demonstrated effectiveness and implementability than other technologies within the same technology type and are preferred.

The RPOs selected also were determined to most effectively meet the RAOs for all phases of COCs potentially present in the BGOU source areas, as discussed in Section 1. These may include DNAPL TCE, and other VOCs sorbed to soil solids, dissolved in pore water, and present as vapor in pore space. RPO selection also was based on the ability of a technology to accommodate the range of contaminants and co-contaminants that might be present at a SWMU such as SVOCs including PAHs and PCBs; radionuclides in soil, including uranium and technetium-99; and other inorganic COCs and metals. Selection of treatment and disposal RPOs considered the technical and administrative feasibility of meeting discharge limits for effluents or disposal criteria for secondary wastes for these contaminants.

RPO selection considered the potential effectiveness and technical implementability in variable saturation in the UCRS, as described in Section 1.

Existing conditions and operations in the BGOU source areas also were considered in RPO selection. Some technologies were dismissed due to these conditions. Considerations included the ability to allow for ongoing operations in and around the BGOU SWMUs, ability to be implemented in areas with surface and subsurface infrastructure, and minimal effects on existing site uses. Use of existing infrastructure or programs (e.g., the C-746-U Landfill, and discharges to permitted outfalls) also were favored.

In some cases, more than one process option was selected for a technology type; for example, when two or more process options were considered to be sufficiently different in their performance that one would not adequately represent the other or if the processes are complementary or part of a treatment train. Innovative technologies were selected as RPOs only if they were judged to provide better treatment, had fewer or lower adverse effects, were implementable within a reasonable time period, or had lower costs than other established process options.

RPOs were not selected for every technology type based on lack of demonstrated effectiveness or implementability. These technologies were not screened out, but are available to be advanced to treatability studies or pilot demonstrations if the identified RPOs are considered inadequate. The initial selection of RPOs may be revised in the ROD based on public comment on the proposed plan, engineering data collected to support technology sizing, design, and optimization. or other considerations.

Table 2.5. Selection of Representative Process Options

General Response Actions	Technology Type	Representative Process Options	Basis for Selection
Land Use Controls	Institutional controls	Nonengineering, legal, or administrative controls intended to prevent or limit exposure to hazardous substances	Effective and implementable. Low costs.
Monitoring	Soil monitoring	Soil cores	Effective and implementable for Postremediation sampling; low to moderate cost.
	Groundwater monitoring	Sampling and analysis	Effective and implementable for monitoring; moderate cost.
Removal	Excavators	Backhoes, trackhoes	Demonstrated effectiveness to depths of 45 ft bgs; technically implementable at BGOU source areas. Moderate costs.
		Crane and clamshell	Demonstrated effectiveness to depths of 100 ft bgs; technically implementable at BGOU source areas. High costs.
Containment	Hydraulic containment	Recharge controls	Effective and implementable. Moderate costs.
		RCRA Landfill cover (Subtitle C or D as appropriate)	Effective and implementable. Prevents migration of residual contamination that cannot be effectively removed or destroyed by other means. Moderate cost.
		Soil cover	Effective and implementable. Prevents direct contact with contamination that cannot be effectively removed or destroyed by other means. Moderate cost.
	Subsurface horizontal barriers	Jet grouting	Adjunct technology for surface barrier technologies to prevent contaminant migration. Implementability uncertain. High cost.
		Permeation grouting	Adjunct technology for surface barrier technologies to prevent contaminant migration. Implementability uncertain. High cost.
	Subsurface vertical barriers	Sheet pilings	Adjunct technology for removal or surface barrier technologies; effective and implementable. High costs.

Table 2.5. Selection of Representative Process Options (Continued)

General Response Actions	Technology Type	Representative Process Options	Basis for Selection
Containment (Continued)	Subsurface vertical barriers (Continued)		
		Jet grouting	Adjunct technology for surface barrier technologies to prevent lateral infiltration or migration. Effective and implementable. High cost.
		Freeze Walls	Adjunct technology for removal technologies; effective and implementable. High cost.
Treatment	Physical/chemical	Soil vapor extraction	Adjunct technology for *in situ* thermal treatment technology; effective and implementable. Moderate cost.
		Dual-phase extraction	Adjunct technology for *in situ* thermal treatment technology; effective and implementable. Moderate cost.
		Air stripping-*ex situ*	Effective and implementable for *ex situ* removal of TCE from groundwater. Low costs. Currently implemented at Northwest Plume treatment plant.
		Ion exchange-*ex situ*	Effective and implementable for *ex situ* removal of ^{99}Tc from groundwater. Moderate costs.
		Granular activated carbon-*ex situ*	Effective and implementable for *ex situ* removal of organic chemicals from vapor and water waste streams. Moderate cost.
		Vapor condensation	Adjunct technology for *in situ* thermal treatment technology; effective and implementable for *ex situ* removal of water and organic chemicals from vapor streams. High cost.
	Thermal	Electrical resistance heating-*in situ*	Demonstrated effectiveness and implementability for all VOC phases in UCRS at PGDP; effective and implementable in variably saturated soils. Moderate costs.

Table 2.5. Selection of Representative Process Options (Continued)

General Response Actions	Technology Type	Representative Process Options	Basis for Selection
Treatment (Continued)	Thermal (Continued)	Thermal desorption-*ex situ*	Effective and implementable for all VOC phases as an adjunct technology for soil removal. High costs.
		Catalytic oxidation-*ex situ*	Effective and implementable treatment for thermal desorption, SVE or air stripper off-gas. High costs.
		Metal melting	This technology is effective in reducing volume of disposed metal and potentially allowing for reclamation and cost recovery of recycled metals. High costs.
Disposal	Land Disposal	Off-site disposal	Effective and implementable as an adjunct technology for soil removal. High costs.
		WDF	Effective as an adjunct technology for soil removal. Not currently implementable. Moderate costs.
		C-746-U on-site landfill	Effective and implementable for nonhazardous nonradioactive wastes, currently available. Wastes must meet WAC, including for PCBs. Low costs.
	Discharge of Wastewater	Wastewater treatment meeting substantive requirements of Kentucky surface water standards.	Effective and implementable for treated groundwater. Low costs.

THIS PAGE INTENTIONALLY LEFT BLANK

3. DEVELOPMENT AND SCREENING OF ALTERNATIVES

3.1 INTRODUCTION

The alternatives presented in the following sections were developed by combining the RPOs identified in Section 2.4 into a range of treatment strategies to meet the RAOs. The alternatives were formulated to create responses that vary in their extent of attainment of RAOs, implementability, and cost in order to meet EPA's expectation that the feasibility studies for source control actions provide "A range of alternatives in which treatment that reduces the toxicity, mobility, or volume of the hazardous substances, pollutants, or contaminants is a principal element" [40 *CFR* § 300.430(e)(1)(G)(3)(i)].

The demonstrated effectiveness of combined technologies was used to identify appropriate comprehensive alternatives. Media interactions, including effects of source actions on RGA groundwater during implementation, also were considered.

Alternatives are developed and discussed with the assumption that each would be applied to the various BGOU SWMUs. Decision makers could apply different alternatives to individual sites, depending on public response to the Proposed Plan. Sufficient information is provided to allow for this type of alternative selection in the Proposed Plan and ROD.

3.2 CRITERIA FOR THE DEVELOPMENT OF REMEDIAL ALTERNATIVES

The purpose of the FS and the overall remedy selection process is to identify remedial actions that eliminate, reduce, or control risks to human health and the environment and meet ARARs. The national program goal of the FS process, as defined in the NCP, is to select remedies that are protective of human health and the environment, that maintain protection over time, and that minimize untreated waste. The NCP defines certain expectations for developing remedial action alternatives to achieve these goals.

3.3 DEVELOPMENT OF ALTERNATIVES

The RPOs selected in Section 2 were combined to formulate a range of comprehensive remedial alternatives to satisfy the RAOs for BGOU source areas. Remedial technologies for both radioactive/inorganic and DNAPL source areas were evaluated and combined because the two types of sources may not be co-located (although they may overlap somewhat within the waste disposal cells) and different types of remedial technologies may be needed for each class of contaminant. Radioactive/inorganic source area alternatives are used to address non-DNAPL VOCs or SVOCs in near surface soil (i.e., within 20 ft of the surface) that are co-located with waste or soil containing radioactive or inorganic COCs at concentrations above the RGs. The alternatives were developed to combine appropriate RPOs for the combination of radioactive/inorganic source areas and DNAPL source areas that are reported to be present at the individual SWMUs. The primary elements that comprise each remedial alternative are summarized in Table 3.1. Effectiveness, implementability, and cost are criteria used to guide the development and screening of remedial alternatives.

The soil RGs developed in Section 2 for the COCs identified in the RI risk assessment (DOE 2010) were calculated using NAL concentrations based on cancer risk (ELCR) or noncancer hazard (HI) criteria to protect potential workers at the SWMU. Soil RGs were developed using MCL values or risk-based NALs to be protective of current and future residential groundwater users located off the PGDP property. The lower of these soil RGs developed for each COC is protective of those receptors and serve as the basis for

Table 3.1. Alternative Formulation for PGDP BGOU Source Areas

Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	Alternative 9
No Action	**Limited Action**	**Soil Cover and Long-Term Monitoring**	**Soil Cover combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring**	**RCRA Cover with Hydraulic Isolation and Long-Term Monitoring**	**Excavation and Disposal[1]**	**Excavation and Disposal combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring**	**Excavation and Disposal combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring**	***In situ* Containment and Long-Term Monitoring**
	Long-term groundwater monitoring Land use controls	Soil cover Long-term groundwater monitoring Land use controls	Partial excavation to remove debris, rubble, or metallic waste that could interfere with the installation or operation of the *in situ* DNAPL source treatment system, if necessary. *In situ* DNAPL source treatment Process monitoring Postremediation sampling Soil cover Long-term groundwater monitoring Land use controls	Vertical subsurface hydraulic isolation barrier RCRA cover Long-term groundwater monitoring Land use controls	Sheet pilings to shore excavation Excavation Treat or dispose of residual groundwater, as indicated by sampling Postremediation and WAC sampling and analysis Physical/chemical waste treatment Transportation to disposal facility Backfill with clean soil	Sheet pilings to shore excavation Excavation Treat or dispose of residual groundwater, as indicated by sampling Postremediation and WAC sampling and analysis Physical/chemical waste treatment Transportation to disposal facility Backfill with clean soil *In situ* source treatment for DNAPL Process monitoring Postremediation sampling Long-term groundwater monitoring	Sheet pilings to shore excavation Excavation Treat or dispose of residual groundwater, as indicated by sampling Postremediation and WAC sampling and analysis Physical/chemical waste treatment Transportation to disposal facility Backfill with clean soil Vertical barrier to protect deep excavation Deep excavation of DNAPL source area *Ex situ* source treatment for DNAPL Process monitoring WAC sampling of treated soil Postremediation sampling Backfill with clean, decontaminated soil Long-term groundwater monitoring	Construct subsurface horizontal barrier Construct subsurface vertical barrier Construct structure Long-term groundwater monitoring Land use controls.

BGOU = Burial Grounds Operable Unit; PGDP = Paducah Gaseous Diffusion Plant; RCRA = Resource Conservation and Recovery Act; RD = Remedial Design; WAC = waste acceptance criteria
[1] Metal melting, an option associated with SWMU 5 only, includes treatability study, sorting and size reduction, cleaning of metal surfaces, and melting and casting of cleaned metal for reuse.

developing and evaluating remedial alternatives. The final determination of successful remediation will be based on a demonstration that the target concentrations for COCs have been met and that RAOs have been achieved. (Target concentrations are those concentrations that meet RAOs and acceptable risk criteria for the specific COCs present. They differ from RGs in that they consider cumulative risk of actual COCs present in samples at time of sampling.)

In order to develop remedial costs for each alternative, assumptions were made about the area, depth, and volume of the contaminant source areas. These assumptions were based on the available characterization data and site history.

A detailed RD will be developed after an alternative is chosen as the selected remedy. Engineering data will be collected as part of the RD to support technology sizing, design, and optimization.

3.4 ALTERNATIVES FOR BGOU SOURCE AREAS

3.4.1 Alternative 1—No Action

Formulation of a No Action alternative is required by the NCP [40 *CFR* § 300.430(e)(6)]. The No Action alternative serves as a baseline for evaluation of other remedial action alternatives and is generally retained throughout the FS process. As defined in CERCLA guidance (EPA 1988), a No Action alternative may include environmental monitoring; however, actions taken to reduce exposure, such as site fencing, are not included as a component of the No Action alternative. Alternative 1 includes no actions and no costs.

3.4.2 Alternative 2—Limited Action

The Limited Action alternative will consist of installation of strategically placed wells, one upgradient, three downgradient, screened in both the UCRS and RGA, sampled quarterly for a full suite of SWMU-related analytes for five years; semiannually for the next five years; and annually for years 11-30. This alternative will consist of the following as necessary:

- Remedial design
- Well installation and long-term groundwater monitoring
- LUCs

This alternative combines process options from GRAs of monitoring and LUCs. The goal of the Limited Action alternative is to monitor any changes in SWMU status or condition that may warrant a response or action in the future.

3.4.3 Alternative 3—Soil Cover and Long-Term Monitoring

An engineered soil cover would be designed to provide a protective barrier over surface soils containing residual contamination. The cover would do the following:

- Reduce rainwater infiltration and contact with residual contamination,
- Prevent wind transport of contaminants, and
- Protect humans and wildlife from coming into direct contact with the contaminated material.

This alternative combines process options from GRAs of monitoring, LUCs, and containment, and includes the following:

- Remedial design
- Construction of a surface soil cover
- Long-term groundwater monitoring
- LUCs

3.4.3.1 Remedial design

Detailed remedial design will be performed for this remedial alternative. Engineering data collection to support technology sizing, design and optimization would be performed as necessary during the RD. The data collection would be based on an approach to be developed in the RAWP.

3.4.3.2 Soil cover construction

A surface soil cover will be constructed over the unit. The cover will consist of 18 inches of 10^{-5} cm/sec or less permeable material (typically clay) and 6 inches of topsoil. The cover will be mulched and grassed. It will be armored where erosion may occur. The cover will be contoured to promote runoff and will reduce potential direct exposure to the surface soil hazardous and radioactive contamination.

3.4.3.3 Long-term groundwater monitoring

A long-term groundwater monitoring program comparable to that described under Alternative 2 would be implemented. The monitoring program would utilize existing PGDP MWs and additional groundwater MWs, as necessary, to monitor upgradient and downgradient groundwater contaminant levels.

3.4.3.4 Land use controls

LUCs as described in Section 2.4.1.1 would be implemented for units where waste remains in place (E/PP program).

3.4.4 Alternative 4—Soil Cover with *In situ* DNAPL Source Treatment and Long-Term Monitoring

Alternative 4 was evaluated for SWMUs where DNAPL reportedly is present in the soil below the buried waste, but RI data and waste disposal records indicate that the buried wastes does not pose a threat to human health or the environment. Alternative 4 consists of a soil cover as described for Alternative 3, but also contains the contingency to implement *in situ* DNAPL source treatment if engineering data collected to support technology sizing, design, and optimization of the *in situ* DNAPL source treatment system confirm the presence of DNAPL.

A partial excavation above the DNAPL source area where waste was buried would be performed, if necessary, to remove disposed construction rubble, debris, or metallic waste that could interfere with the installation or operation of the DNAPL source treatment system. Upon completion of the DNAPL treatment phase, a soil cover would be installed over the SWMU. An engineered soil cover would be designed to provide a protective barrier over surface soils containing residual contamination as described for Alternative 3.

This alternative combines process options from GRAs of monitoring, LUCs, containment, and treatment, and consists of the following:

- Remedial design
- Partial excavation, if necessary, to remove debris, rubble, or metallic waste that could interfere with installation of the DNAPL source treatment system
- Installation of *in situ* DNAPL source treatment
- Off-gas treatment, if necessary
- Process monitoring
- Postremediation sampling
- Construction of a soil cover
- Well installation and long-term groundwater monitoring
- LUCs

This alternative would reduce the mass of the DNAPL source in the UCRS, reduce recharge through the UCRS and thereby mitigate the secondary release mechanism, and eliminate risks to receptors by eliminating the exposure pathways. Requirements and conceptual designs for each element of Alternative 4 are discussed here in detail. The source treatment system design would include measures to reduce the potential for mobilization of DNAPL during treatment.

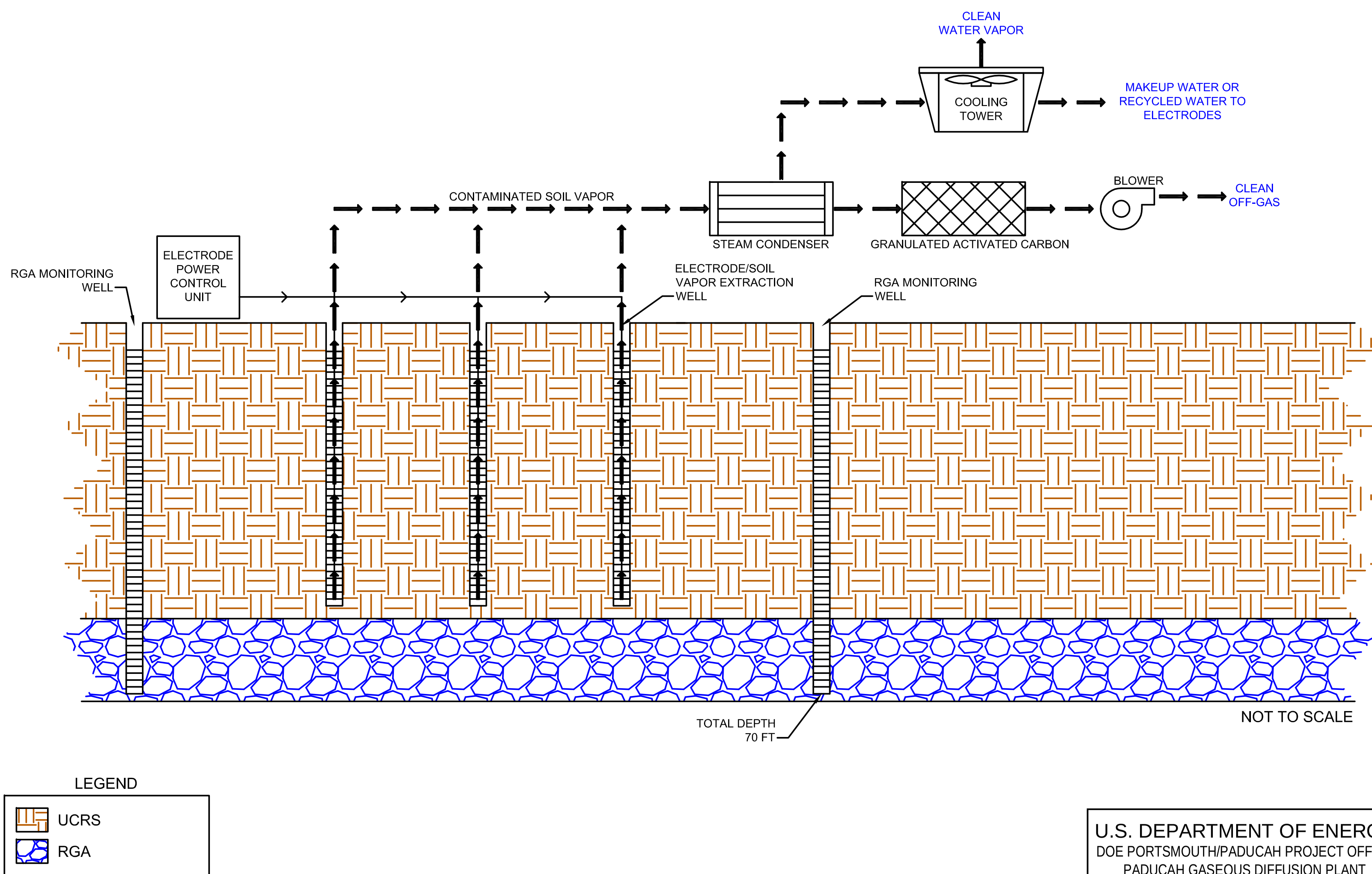
The conceptual design of the Alternative 4 DNAPL treatment process is based on the design of the C-400 ERH treatment system. ERH has been determined to be effective at PGDP and, therefore, serves as the representative DNAPL source removal technology and the basis for the cost estimate for implementation of Alternative 4. The treatment system design would include measures to ensure that DNAPL was not mobilized during treatment. Details for each element of Alternative 4 are discussed below. A schematic view of the representative ERH technology and treatment process is provided in Figure 3.1.

3.4.4.1 Remedial design

Detailed remedial design will be performed for this remedial alternative. Engineering data collection to support technology sizing, design, and optimization would be performed as necessary during the RD. The data collection would be based on an approach to be developed in the RAWP.

3.4.4.2 Partial excavation to remove debris, rubble, or metallic objects

At some SWMUs where construction debris and rubble were disposed of, it may be necessary to remove enough of this disposed material to allow the *in situ* DNAPL source treatment system to be constructed and operated. The goal of this excavation is to facilitate construction of the treatment system, not to remediate buried material present at the SWMU. Regardless, excavated material will have to be managed and disposed of properly in accordance with its composition and degree of contamination, if any.



U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Figure 3.1. Schematic View of ERH System - Representative Technology for *In situ* DNAPL Source Treatment

3.4.4.3 *In situ* DNAPL source treatment

The details for the *in situ* DNAPL source treatment system will be developed during the remedial design. For the purpose of this FS and to establish a basis for a cost estimate, the conceptual design will be based on application of ERH to include power electrodes with co-located vapor recovery wells, an electrical power control unit, a blower for steam and vapor recovery, pressure and temperature monitoring systems, and contaminant vapor and water treatment systems. The active treatment period for a DNAPL source area is estimated at approximately six months.

3.4.4.4 Process monitoring

The C-400 ERH process monitoring system and procedures would be scaled and modified, if necessary, for application to the BGOU SWMU DNAPL source areas.

Air samples will be collected weekly from the influent of the primary GAC.

Subsurface temperatures and electrical usage would be monitored during implementation of the ERH system.

3.4.4.5 Postremediation sampling

Confirmatory sampling in the treatment area would be required to determine posttreatment TCE soil concentrations. A postremediation sampling plan would be prepared during RAWP development. The conceptual design for postremediation sampling includes soil coring using direct push technology (DPT) and analysis for VOCs. Depths and locations of coring would be determined based on the results of data collected during the remedial design.

3.4.4.6 Soil cover construction

A soil cover as described under Alternative 3 would be constructed over the unit upon completion of active DNAPL source treatment.

3.4.4.7 Long-term groundwater monitoring

A long-term groundwater monitoring program comparable to that described under Alternative 2 would be implemented. The monitoring program will utilize existing PGDP MWs and additional groundwater MWs, as necessary, to monitor upgradient and downgradient groundwater contaminant levels.

3.4.4.8 Land use controls

LUCs as described in Section 2.4.1.1 would be implemented for units where waste remains in place (E/PP Program).

3.4.5 Alternative 5—RCRA Cover, Hydraulic Isolation, and Long-Term Monitoring

Alternative 5 is to install a secure RCRA landfill cover to contain waste. This alternative combines process options from GRAs of monitoring, LUCs, and containment and includes the following:

- Remedial design
- Vertical subsurface hydraulic isolation barrier
- RCRA cover

- Well installation and long-term groundwater monitoring
- LUCs

This alternative would reduce risk to receptors by limiting contaminant migration via the exposure pathways. Covering also will limit infiltration and greatly reduce and/or eliminate the leaching of contaminants from the waste cells. This remedial alternative consists of physical containment mechanisms to prevent future releases of contaminants from the buried waste and allows restrictions, which would be included to prevent future disturbance of buried wastes left in place; these actions would satisfy all three RAOs (i.e., protect industrial workers from radiological hazards in surface soil, protect industrial workers from direct exposure to the buried waste, and protect off-site residential receptors from unacceptable TCE concentrations in the RGA). The containment components include installing a low-permeability cap to prevent infiltration of precipitation, preventing direct contact with surficial contamination, reducing external penetrating radiation, and preventing erosion of contaminated surficial soils and vertical subsurface barriers installed around the perimeter of the buried waste to mitigate lateral migration of contaminants. The vertical subsurface barriers would be extended into the HU 3 confining clay layer to mitigate downward migration of contaminants. The cap, vertical subsurface barriers, and the underlying clay acting as a horizontal subsurface barrier would be connected together to effectively contain and isolate the buried waste.

Groundwater monitoring would be continued to monitor the effectiveness of the containment actions.

A schematic conceptual representation of a low-permeability cover is presented in Figure 3.2. Details for each element of the alternative are presented below.

3.4.5.1 Remedial design

Detailed remedial design will be performed for this remedial alternative. Engineering data collection to support technology sizing, design, and optimization would be performed as necessary during the RD. The data collection would be based on an approach to be developed in the RAWP.

3.4.5.2 Vertical subsurface hydraulic isolation barrier

A vertical isolation barrier will be installed to prevent lateral migration of contaminants and inflow of groundwater. The details of the vertical barrier will be developed during the RD. For the purpose of this FS and to establish a basis for a cost estimate, the conceptual design will be based on developing a barrier by jet grouting. Jet grouting involves first drilling to the plan depth using small diameter drill rods. Next, a large, powerful pump is connected to the drill rod, which pumps the high pressure jet grout through the drill rods and horizontally into the soil. The drill rods are slowly rotated and raised creating columns of soil-cement. Typical column diameters are 2 to 6 ft. (http://www.geo-solutions.com/construction-technologies/jet-grouting.php)

3.4.5.3 Installation of RCRA cover

The cover or cap will be designed to eliminate direct exposure to the waste and cover areas where surface water could penetrate and leach COCs, causing them to be transported into lower soil layers. The capping activity will include the following:

- Contouring of surface soils, as needed, to support the structural cap per established requirement, and

- Placement of the capping materials in accordance with RCRA or other applicable requirements.

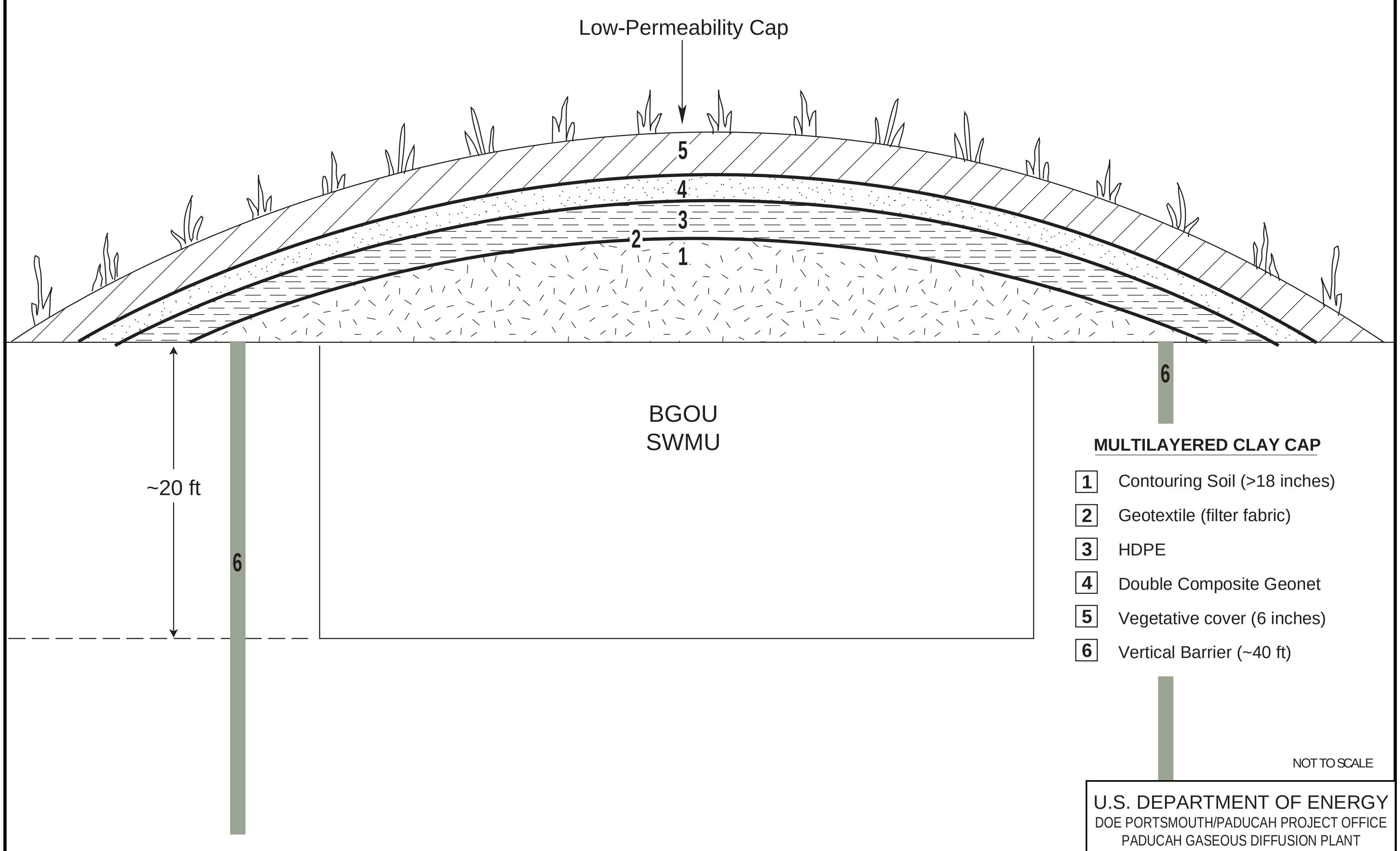


Figure 3.2. Schematic View of Low-Permeability Cap

3.4.5.4 Long-term groundwater monitoring

Long-term groundwater monitoring would be consistent with the approach described for Alternative 2 (Limited Action). Actual monitoring requirements (analytical parameters, frequency of monitoring, etc.) will be documented in a long-term monitoring plan to be prepared during the RD.

3.4.5.5 Land use controls

LUCs as described in Section 2 would be implemented for units where waste remains in place (E/PP program).

3.4.6 Alternative 6—Excavation and Disposal

Alternative 6 is to excavate the waste for disposal. Emphasis will be placed on limiting the excavation to only those areas of the SWMU that are impacted by previously disposed wastes. This remedial alternative consists of removing or excavating the buried waste and soils to satisfy all three RAOs.

Contaminants in the excavated waste potentially could include VOCs, PCBs, metals, and radionuclides; therefore, an *ex situ* treatment train would be required to separate and treat the contaminants prior to disposing of any of the excavated waste. Depending upon the contaminant concentrations, some excavated soil and wastes may not require treatment prior to storage and disposal. Liquids generated during the excavation activities are anticipated to contain similar contaminants as those identified in the soil, and these extracted liquids also would require appropriate treatment. Several concerns currently exist regarding excavation of wastes that contain potentially pyrophoric uranium. The excavation and disposal alternative is presented in Figure 3.3.

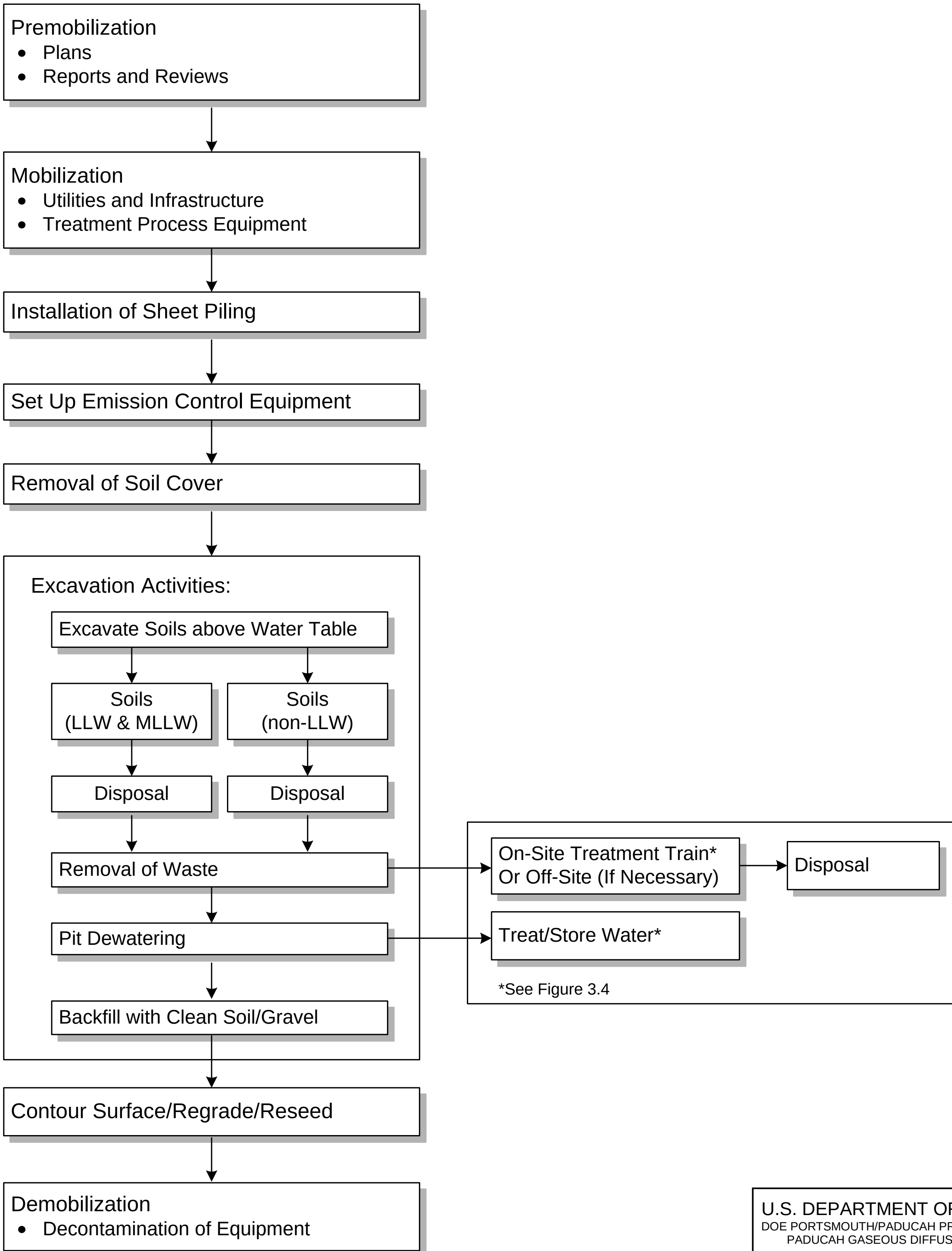
This alternative combines process options from GRAs of removal, treatment and disposal, and includes the following:

- Remedial design
- Install sheet pilings to shore the excavation walls and minimize groundwater intrusion
- Excavate waste and source area soils contaminated with COCs above target concentrations
- Treat or dispose of residual groundwater, if necessary, as indicated by sampling results
- Postremediation and WAC sampling and analysis
- Treat the waste and soil, if necessary, for transportation and/or disposal
- Transport and dispose of waste
- Backfill with clean or uncontaminated soil

The primary components of this alternative would be the following:

- The buried waste materials and associated contaminated soils would be excavated. Unit operations for dewatering, stabilization of potentially reactive wastes (e.g., pyrophoric uranium), segregation of waste types, and a temporary storage facility may be required. Accommodations will be made for management of intact drums containing wastes, in the unlikely event they are encountered.

- Sampling and analysis would be required to determine if the wastes would be classified as meeting the C-746-U Landfill WAC, LLW, RCRA waste, or mixed waste.



U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Figure 3.3. Excavation Alternative Flow Chart

- If wastes are to be disposed of at an existing or planned on-site PGDP disposal facility, they would have to meet the disposal facility WAC. Wastes not meeting the WAC for the WDF would require appropriate treatment prior to disposal. Wastes shipped off-site for disposal would require pretreatment only if they could not meet the disposal facility WAC.

- Water collected during dewatering activities also would require testing to determine if treatment would be necessary prior to discharge.

- The wastes would be stored/disposed of in compliance with substantive requirements of applicable standards.

The primary disposal option considered in this alternative would consist of off-site disposal at an appropriate facility. The PGDP C-746-U Landfill would be utilized for disposal of waste that meets the landfill's WAC. Soil identified as clean, analyzed, and determined suitable for reuse may be used as backfill. The PGDP is evaluating the construction of an on-site cell for disposal of CERCLA project wastes. A cost estimate for disposal of excavated materials in the WDF also is provided as an option for Alternatives 6, 7, and 8 for waste materials that typically would go off-site for disposal.

This alternative combines process options from GRAs of removal, treatment, and disposal. It removes the risk to receptors by transporting and securely disposing of all soil and waste cell contents that do not meet target concentrations. The removed material would be placed in a disposal facility that will reduce or eliminate the risk to potential receptors. The open excavation will be backfilled with clean or uncontaminated soil to the existing site grade.

A large volume of waste would be generated as a result of implementing this alternative. In addition, dewatering likely would be required to conduct excavation activities. This alternative includes construction of a treatment system on-site to treat the extracted water. Cost for this system has been included in the corresponding cost estimates. It is possible that there will be capacity available at the existing on-site water treatment facility. Use of the existing on-site facility would reduce the cost for this alternative, as shown in the break out for the treatment system in the cost estimates in Appendix E. Potential treatment mechanisms include precipitation/coagulation, air stripping, ion exchange, and carbon adsorption. Treatability testing may be required to optimize treatment of wastes and/or extracted groundwater. Appropriate precautions would be taken during the excavation phase to prevent adverse effects to workers and the surrounding environment. This alternative would address or eliminate long-term risks to the environment and could be conducted in accordance with ARARs.

3.4.6.1 Remedial design

Detailed remedial design will be performed for this remedial alternative. Engineering data collection to support technology sizing, design, and optimization would be performed as necessary during the remedial design. The data collection would be based on an approach to be developed in the RAWP.

3.4.6.2 Sheet pilings

Excavation is assumed to extend through SADA Layer 3 of the buried waste, approximately 20 ft bgs. Because the SWMUs are located in areas of PGDP with limited accessibility, sheet piles will be required to excavate the waste cell material to the anticipated depth. It has been assumed the soil will be unstable, requiring shoring, and there is some potential for UCRS groundwater inflows to the excavation. Steel sheet pilings will be driven to the required depth to retain the surrounding soil before the waste cell and contaminated soil are removed. (The artificial groundwater mounding influences of the C-616 lagoons will be considered, as necessary, during remedial design.)

Installation of sheet piles around the perimeter of the waste trench will be performed prior to beginning excavation. Sheet piles will be installed to help minimize the infiltration of groundwater into the waste area and to provide shoring and stability to the side slopes during excavation. The sheet piles would be installed to a depth that would allow penetrating an existing underlying clay layer. The waste trench contained by the sheet piles and clay zone base will help relieve the waste area of groundwater intrusion. During excavation, dewatering would be required to remove groundwater trapped within the confines of the sheet piles. At the area of initial excavation, a sump pump will be placed at the base of the trench to pump out any collected water. This water will be collected and transported to the designated staging area for proper treatment and then discharged in accordance with the substantive requirements of Kentucky surface water standards.

3.4.6.3 Excavation

Soil containing COCs above their target concentrations will be removed from the identified SWMUs, to a depth of 20 ft in accordance with Figure 2.3. The method of waste excavation, staging, stabilization, and loading are complex and site specific; therefore, only a general approach is presented. A number of factors and variables are considered part of the general excavation approach including, but not limited to field lighting; site controls and monitoring; cameras to monitor for hazards as they are encountered; controls for fugitive emissions; weather protection; combustibles monitoring, and fire suppression. A detailed description of the excavation methodology will be presented in the SWMU-specific RAWP.

(1) The waste material will be excavated with mechanized equipment. Equipment such as backhoes and trackhoes is anticipated if the excavation does not exceed their depth limits. Vacuum excavation is possible for depths up to about 30 ft. A crane with a clamshell can be used to excavate to depths of 100 ft or more. It is unlikely that excavations at the BGOU will exceed 20 ft.

(2) Depending on how the material is to be characterized to meet the disposal facility WAC, the soil either will be temporarily staged at the PGDP or loaded directly into the waste containers.

(3) The material will be segregated based on physical, chemical, and radioactive characteristics, as determined by field observation, testing, and monitoring.

(4) The waste and soil will be treated to meet WAC requirements. A uranium chip roaster[4] or other appropriate technology would be required to treat any pyrophoric uranium encountered during excavation. Soils containing organic contaminants (e.g., VOCs or PCBs potentially present at SWMU 2) that exceed land disposal restrictions may be subjected to thermal treatment prior to disposal. A representation of a process flow scenario for treatment and disposal of excavated soil and associated excavation by-products and residues is presented in Figure 3.4. Not all SWMU excavation scenarios would require all the elements represented in this schematic diagram.

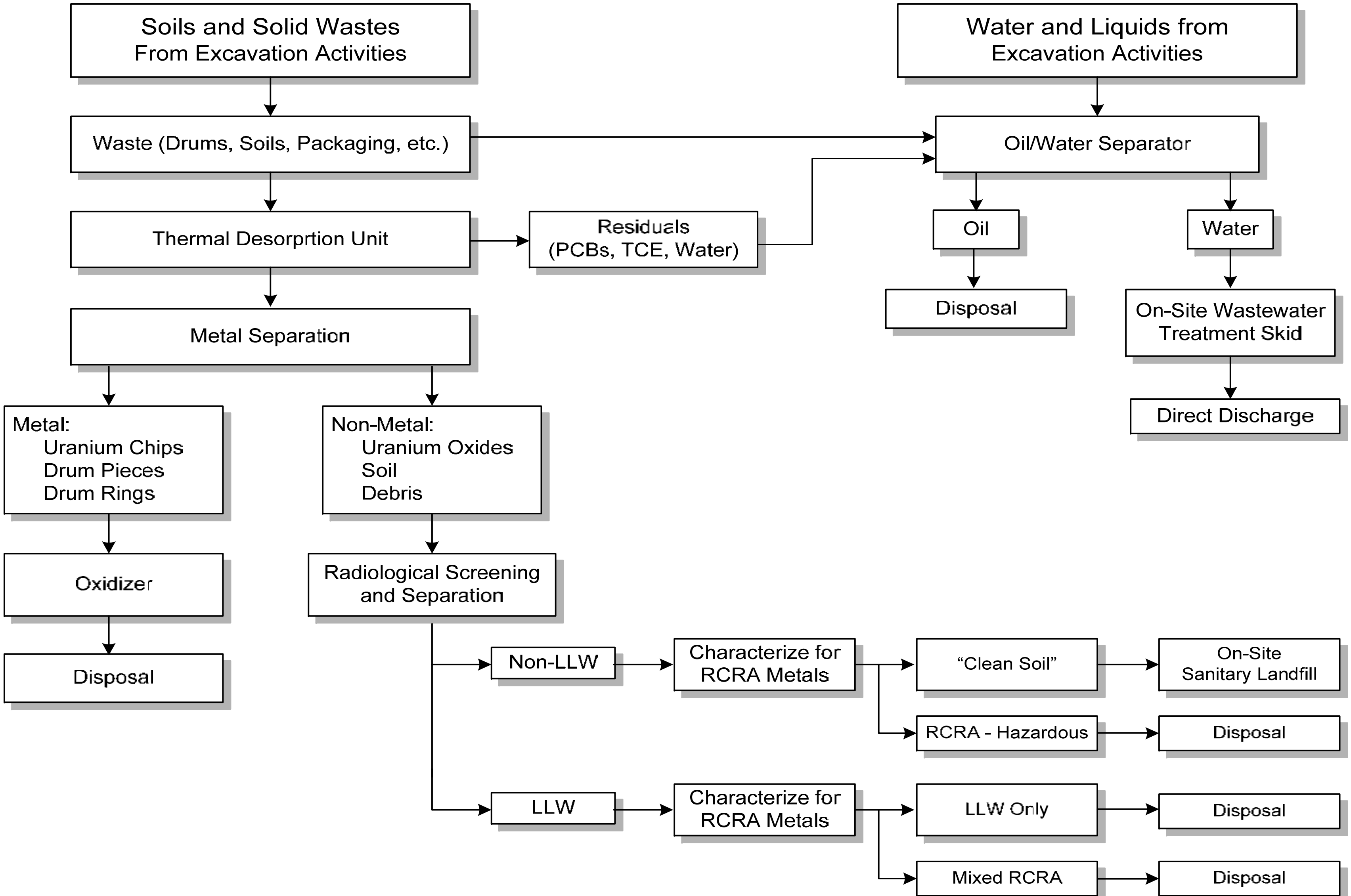
(5) The material will be loaded into the proper shipping container and transported for treatment or disposal.

(6) If the material is determined by analytical testing to be nonhazardous, does not exceed the target concentrations, and meets PGDP guidance for clean backfill (PRS 2010), it will be set aside and considered for use as backfill. This procedure will be documented in the RAWP.

(7) As required, air containment and monitoring will be implemented. This may include a temporary (soft sided) structure that maintains air containment by negative pressure during excavation.

---

[4] Depleted uranium chips are burned to an oxide (a more stable form) under controlled conditions in a chip roaster.



U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Figure 3.4. Excavation Alternative Treatment Flow Chart

The excavation alternative includes the removal of all visible waste, with no prescribed restriction on excavation depth, although the cost estimates assume that no visible waste would be encountered below 20 ft. Excavation will progress as described in Section 2 until visible wastes have been removed and the appropriate target concentrations are met. It is anticipated that target concentrations would be met before reaching a depth of approximately 16 ft, a depth that also corresponds with typical maximum depths for utility installations at PGDP (and therefore protective of industrial and outdoor worker). Excavations may be advanced to 20 ft, if necessary, in an effort to meet groundwater protective RGs. In the absence of visible waste, excavation below 20 ft to meet groundwater protective RGs will be at DOE's discretion and communicated to the regulators. The bottom and sidewalls of an excavation would be characterized and the conditions documented. (Based on the BGOU CSM, DNAPL constituents are the only contaminants that potentially might remain at levels above their respective groundwater protective RGs at depths of 20 ft or greater, and they would be addressed by employing DNAPL remedial technology.)

Equipment and Preparation. Excavation of contaminated soil and the removal of buried waste drums and other types of packaged debris can be accomplished using conventional excavation techniques and equipment. Excavation equipment will consist of a trackhoe, rubber-tired backhoe, and/or front-end loader. The excavator bucket will be equipped with teeth fabricated from material that minimizes spark-potential while handling drums containing depleted uranium. Because of the potential hazardous nature of the contents of the barrels, the backhoe should be fitted with a transparent, protective shield. This shield should be in place during the excavation of soil as well as during the removal of the barrels. To insure worker safety and to minimize fugitive emissions in the case of a fire, a vacuum hood and smoke extraction unit will be fully prepared and located on-site. This negative-pressure, emission control equipment, operated by a movable crane, will control dust, vapors, and air flow through the work area (and prevention of potential fires of the pyrophoric uranium at SWMU 2).

A second backhoe, outfitted with a drum grappler, could be used to exhume the drums of waste and place them directly into overpacks adjacent to the excavation. Drums covered with mud that cannot be placed into an overpack will be placed in an open area with containment where a determination will be made if a drum should be opened and its contents transferred to another container or treated with foam or other fixing agent. During this operation, the waste material within the exhumed drums could be sampled. The track excavator will work with the drum removal operation to excavate loose waste and backfill material at and around the drums. Other waste such as decayed drums, packaging, and soil will be placed in dewatering roll-off containers to collect any saturation drainage from the excavated material. Water collected from the dewatering process will be characterized, classified and, if necessary, transported to the designated treatment area, treated, and then properly discharged. When the water has completely drained from the containers, the containers filled with solid waste material then will be transferred to the waste treatment areas.

Drums that are still intact will be removed from the excavation individually in order to minimize exposure to workers and the environment. Site controls will be utilized for both intact and degraded drums, as specified in the Health and Safety Plan (HASP). Standard fire prevention and suppression techniques will be utilized. Additional extinguishing agents for the potentially pyrophoric uranium at SWMU 2 will be located immediately adjacent to the excavation site and ready for use. A boom-mounted extinguisher on the excavator will be used accurately to target the burning material in an emergency response effort. Soils, drums, and debris will be moved in bins, roll-offs, or by similar transport to a staging area for immediate treatment, if needed.

During drum and soil handling activities, dust minimization techniques, such as water-based spray solutions, may be used, if needed, to minimize suspension of particulate. Air emission control equipment, such as a movable unit supporting a mobile high-efficiency particulate air (HEPA) filtration vacuum hood or similar system, will be used for dust control under normal conditions or emergency response as needed.

When the excavation is inactive, such as downtime or the end of work shifts, exposed drums in the trench will be covered with soil and potentially pyrophoric materials will be contained in a fire-safe configuration.

Pyrophoric Uranium Waste (SWMU 2 only). Excavation activities will be performed in accordance with a HASP designed for handling pyrophoric uranium. The excavation and handling of this uranium presents challenges for the remedial action contractor.

During milling, grinding, and turning operations, uranium shavings were cooled and protected from oxidation by a metalworking oil. Metal fines were stored in oil to prevent oxidation and combustion, allowing them to cool. The uranium shavings have been placed in drums underground, stored in the original metalworking coolant, along with a variety to waste oils, for a period of about 40 years. It is reasonable to expect that many of the drums have degraded enough to have lost the oils or liquids covering the shavings. Uranium shavings that have been exposed to air in the drum are expected to be oxidized. Other drums still may be intact and may contain the waste oils covering the shavings. Uranium shavings within intact drums still covered by coolant are expected to be partially oxidized from the presence of water in the coolant. It is unlikely that fresh surfaces of small particle-size material have remained intact for the period of burial. Oxidation of uranium by water has the potential of producing hydrogen gas and build-up in the drums is possible if the drums still are intact and airtight. Hydrogen atoms are small and lighter than air, however, and will tend to diffuse upward out of the drums and soil. Nonetheless, suspected intact drums could be pierced and vented with nonsparking tools in the roll-off containers prior to removal from the excavation area.

Uranium will undergo combustion if the oxide layer on the fines is disturbed in the presence of air and the metal is above its spontaneous ignition temperature of about 49°C (120 °F). Any handling is capable of disturbing this oxide layer. The combustion usually resembles smoldering and produces a heavy smoke that likely would settle in the immediate vicinity. Unless local conditions produce a plume that might escape the excavation, the uranium usually may be covered with dirt and allowed to self-extinguish. Excavation conditions can be controlled by water-based spray solutions to control dust. Emissions can be controlled by a mobile vacuum hood equipped with the capability to provide HEPA filtration as needed, and supported by an all-terrain crane so that it can be placed to capture smoke or fumes from a possible fire.

Water generally is acceptable for use as an extinguishing or cooling agent for fires involving uranium. The preferred extinguishing agent is a sodium chloride-based powder such as MET-L-X. This dry powder is noncombustible and does not produce secondary fires as a result of its application to burning metal. Sodium chloride-based extinguishers and sodium chloride-based powder will be available at the site.

Staging/Segregation of Contaminated Materials. Excavation, sorting, sampling, and treatment procedures will be explained in detail in the remedial design phase.

In addition to normal plant air monitoring, air quality should be monitored as part of the health and safety program, and corrective measures initiated during the excavation and removal process, if necessary, to minimize or eliminate any health hazards. At least two additional monitoring stations will be placed near the excavation. Because of the known radioactive materials buried in some SWMUs, radiation levels should also be monitored.

Bins or roll-offs from the excavation face will be moved to a staging/segregation area. The bins will collect drums, drum fragments, debris, and waste materials. Historic waste materials reports for the BGOU included uranium metal, uranium oxides, uranium tetrafluoride solution, zirconium-bearing scrap, sandblast grit, crucible burnout materials, cleanup debris, and radioactive sources. The RAWP and HASP will address measure to be taken to monitor for potentially explosive airborne particulate mixtures of combustible metals. Liquids and sludges, when encountered, will be segregated and managed appropriately.

Soils from the surface and at depth will be segregated in roll-off bins. This material will be segregated and managed appropriately based on levels of radioactivity and other forms of contamination, such as RCRA- or TSCA–mixed wastes.

Soils and waste drums from below the surface will be segregated into bins and roll-off containers. Drums that are found intact in the excavation face will be placed in separate bins. Once in the bins, the drums will be punctured to vent any built-up hydrogen or other gasses and to drain the liquids or waste oils from the drums. Decayed drums, soils, and other waste materials will separated into dewatering roll-off containers. This material can then be immediately transported to on-site treatment and appropriate waste management.

Miscellaneous debris is expected to include compatible materials such as waste personal protective equipment (PPE), concrete, roofing materials, cleanup debris, and radioactive sources. In addition to radiation and volatile organic screening, these items will be visually inspected for stains or discoloration to help identify hazardous materials. In general, these items are anticipated to be LLW material unless RCRA hazardous characteristics or the presence of PCBs or other TSCA regulated materials are indicated.

Materials that cannot be immediately identified will be containerized and sampled to identify the contents. Once the materials are identified, they will be disposed of properly.

The excavated containers will be inspected for labels, markings, or other information that may indicate their contents. If the physical state of the drum contents cannot be determined, the material will be sampled to determine its characteristics. If the liquids/sludges cannot be identified, they will be screened for radiological and volatile organic contamination and will be repackaged, if required, in order to assure container integrity. Once container integrity is assured, the liquids will be stored within secondary containment. Based on known information, screening information, or if necessary, sampling data, the characteristics of the liquid/sludge will be used to determine the appropriate disposal site.

Treatment of Soils and Waste Debris. Figures 3.3 and 3.4 present flowcharts that graphically represent this remedial alternative. Soils excavated directly from the disposal plots may contain waste drums, pieces of drums, debris, etc., and may possess hazardous or radioactive characteristics. Visual indicators may include miscellaneous debris and particulate mixed in with soils, staining and discoloration, odors, or other indications from field instruments that indicate the soils may be contaminated. Soils that appear stained or discolored or appear to possess chemical or radioactive contamination automatically will be segregated as suspect-contaminated to ensure waste minimization. These will be placed in roll-off containers.

The excavation rate will be determined by the speed of batch treatment to keep a minimum amount [determined by HASP and sampling and analysis plan (SAP)]of material staged prior to treatment. During the excavation, soils from different depths will be handled appropriately for the suspect contaminants.

Waste material will be sized, scanned, and segregated for magnetic/metallic materials. These materials will then be scanned and segregated for radioactive contamination. (Such a segregation step actually may reduce the volume of soils that would have to be sent off as LLW.) Soils and debris that fail the radioactive segregation will be disposed as LLW.

Material determined to require on-site treatment will be transported to the on-site treatment facility where it will be handled in one of these ways:

- Reduced in size and blended,
- Treated in a low-temperature thermal desorption unit,
- Screened and separated by metal detection,
- Segregated according to its level of radioactivity,
- Disposed of properly according to its final characterization.

Each of these elements is discussed in the following sections.

Shredders and waste blenders. Shredders and waste blenders may be purchased separately or may come as part of the thermal desorption unit package. These two steps are necessary pretreatment steps before the waste enters the thermal desorption unit. Separate shredders may be used for soils and other solid debris.

Low-temperature thermal desorption. LTTD systems are physical separation processes that are designed to treat organically contaminated soils, sludges, and solids, but not to destroy organics. Wastes are heated from 90°C to 320°C (194 °F to 608 °F) to volatilize water and organics while a carrier gas and vacuum system are used to transport the gasses to a gas treatment system. The LTTD bed temperatures and residence times are designed to volatilize selected contaminants, but not oxidize them. A proven full-scale technology, LTTD is currently used to remediate all types of soils contaminated with petroleum hydrocarbons. Most of these units are transportable.

Two common thermal desorption designs are the rotary dryer and the thermal screw. Wastes are reduced in size and blended to allow easier materials handling and more uniform drying properties. Rotary dryers are horizontal cylinders (normally inclined) that can be indirectly heated or direct-fired. Thermal screw units are screw conveyors that transport wastes through an enclosed trough where hot oil or steam circulating through a hollow auger indirectly heats the medium. All thermal desorption systems require off-gas treatment to remove particulates and capture or destroy the contaminants. Particulates are typically removed by conventional particulate removal equipment, such as wet scrubbers or fabric filters. Volatilized contaminants can be removed through condensation followed by carbon adsorption or destroyed in a secondary combustion chamber.

Metal detection/separation system. A metal detection/separation system is a commonly used, proven technology that will screen out nonoxidized (and, therefore, pyrophoric) uranium as well as drums, pieces of drums, and metal components.

Segmented gate system. A segmented gate system was used to scan radioactive soils at the DOE Formerly Utilized Sites Remedial Action Program site in New Brunswick, New Jersey. This gate system separates radiologically contaminated soils from the below action level soils. This process reduces the total amount of contaminated soils that requires treatment. It provides 100 percent assay of all soils processed for radioactive contamination and produces no secondary waste.

Waste disposition. Waste disposition will occur at appropriate facilities.

Additional Treatment of Wastes and Soils. A stabilization process may be utilized as appropriate to encapsulate radioactively contaminated soils and other low-level radioactive debris recovered from the disposal plots. Stabilization involves mixing the wastes with a stabilization agent to form a solid monolith. Encapsulation within the monolith isolates depleted uranium pieces from oxygen and moisture, rendering them stable and non reactive. Stabilization techniques can be sensitive to the presence of oils or solvents. If these materials are detected, the stabilization mixture may be modified, or the oils/solvents may be separated and containerized. Following stabilization, the monolith will be sampled to support off-site disposal WAC and will include analysis by the EPA Toxicity Characteristic Leaching Procedure for metals, VOCs, and reactivity. These activities may be conducted within a temporary, pre-engineered containment structure, as mentioned previously.

On-Site Storage. Waste may be stored in containers such as 208-liter (55-gal) drums; 1,325-liter (350-gal polyliners); 1,585-kg (3,500-lb) steel boxes; or 19-m^3 (25-yd^3) roll-off containers.

3.4.6.4 Treatment or disposal of residual groundwater

Postremediation samples will be collected to determine the effectiveness of remediation and when excavation is complete. The eventual evaluation of soil concentrations will be based on a cumulative ELCR and cumulative HI calculation using postremediation sampling results. There may, however, be contaminated groundwater entering the excavation. If groundwater is entering the excavation during and after removal waste and contaminated soils, the groundwater will be treated and/or disposed of appropriately based on the nature of the contamination and the levels present in the groundwater.

Treatment of Wastewater. An on-site wastewater treatment unit will be required to treat wastewater generated from pit dewatering, solid/liquid separation in the roll-offs and bins, and thermal desorption processes. The wastewater treatment unit will be designed as part of the remedial action to treat the COCs to meet the substantive requirements of Kentucky surface water standards for discharge of this water. A temporary confinement structure or existing decontamination pad will provide a controlled environment for performing treatment operations.

Secondary wastes. Secondary wastes, such as PPE and spent bag filters, generated as part of the proposed action, will be characterized based on process knowledge and radiological screening. High-efficiency particulate air filters (if any are used) may contain low-levels of radioactivity and will be managed on-site until they can be sent off-site to an approved disposal facility. Waste identified as nonradiological and nonhazardous will be disposed of in the PGDP C-746-U Landfill. Wastes identified as hazardous or low-level/low-level-mixed will be stored on-site pending shipment off-site to an appropriate disposal facility.

All wastes will be managed, recycled, treated, and/or disposed of in accordance with applicable federal, state, and local laws and regulations, and on-site activities will be in accordance with ARARs.

3.4.6.5 Sampling and analysis

Several types of sampling and analysis efforts will be performed during the excavation phase. As required, one set of samples will be collected to characterize the excavated material to meet WAC requirements. Periodic sampling and analysis will occur throughout the course of excavating the SWMU to monitor progress. Excavation will continue to the desired depth or until material above the target concentrations no longer is encountered. A final set of samples will be collected from the bottom and sides of the excavation to confirm that the material above the target concentrations has been removed. The excavation will be backfilled after this is confirmed.

3.4.6.6 Transportation and disposal

The exact mode of transportation will be chosen based on material characteristics and disposal facility requirements. The shipping container requirements and transportation method(s) will be described in detail in the RAWP. The transportation requirements will be more accurately determined after the SWMU wastes are characterized. It is anticipated that the wastes will be transported either by rail cars in appropriate containers or by truck utilizing closed containers such as intermodals or roll-offs. Waste of sufficiently high radioactivity may require transport in steel drums or B-25 boxes. The waste may require the addition of absorbent material or stabilization prior to being transported and dispositioned.

Off-Site Shipment to a Disposal Facility. This option assumes that the waste would be shipped off-site to an existing federal or commercial facility. Shipments would require manifesting and would occur in accordance with local, state, and federal regulations. The excavated waste would undergo treatment, if necessary, to meet the WAC of the facility and RCRA land disposal restrictions.

The excavated waste would be loaded and transported by rail or truck to the disposal facility. The roll-off containers used at the site could be loaded onto the rail cars, assuming the existing rail spur can be repaired/modified if needed and used for transportation of the waste off-site for disposal.

Any radioactively or chemically contaminated solid waste generated during remedial actions would be collected and placed in containers acceptable for transportation or combined with bulk contaminated soils for shipment off-site. The rail cars or trucks used to haul contaminated materials would undergo safety inspection before use. All containers would be checked for surface contamination and decontaminated, if necessary, before being loaded onto the rail cars or trucks. Containers would be manifested according to the applicable requirements for shipments of radioactive and chemically hazardous waste materials. As required, predesignated routes would be traveled and an emergency response program would be developed for responding to any accidents. Off-site transportation of radioactively and chemically contaminated materials would comply with all applicable state and federal regulations.

Department of Energy Disposal Facilities. An evaluation of the feasibility of constructing an on-site disposal facility for CERCLA waste is underway. Should such a facility be constructed and available within a reasonable time frame for use, it would provide the option for cost-effective implementation of this alternative.

3.4.6.7 Backfill

Upon completion of excavation and receipt of acceptable postremediation sample results, clean or uncontaminated fill material will be placed in the excavation. (Drainage structures or long-term monitoring equipment and sampling points may need to be installed in the excavation prior to backfill.) The fill material will be placed in the excavation in lifts and compacted as described in the RAWP. The excavation will be backfilled and graded to return the location to its original condition. If confirmed clean, soil from the upper layer of each SWMU that has been set aside will be combined with soil from elsewhere on the facility. All backfill material used will be confirmed clean prior to placement, in accordance with DOE protocol (PRS 2010). The cost estimate for this alternative assumes clean soil is obtained from off-site sources to be used for backfill.

3.4.6.8 Metal recovery (optional for SWMU 5, which contains recoverable metals)

Metal melting provides an opportunity to recover and recycle commodity metals. Metal melting is an option for SWMU 5 only and will be evaluated for its cost effectiveness should excavation be implemented. Contamination levels are unknown on these metals. Decontamination may be cost prohibitive to achieve levels appropriate for free release. Metal melting would be integrated into the excavation process described above, with the addition of the following process elements:

- Treatability study
- Sorting and size reduction of metal

- Water cleaning of metal surfaces
- Melting and casting of cleaned metal for reuse, recycle, or disposal

The metal melting option extends the excavation and disposal alternative because the waste may include discrete metal objects in the buried material that require special handling. These objects will range from metal shavings to very large width dimensions of approximately 3 to 6 ft. They may be of various metals and alloys; however, nickel is a metal of special interest because of the potential for recycle and reuse. Because of the interest in nickel, the waste material will be inspected as it is being removed, and potentially recoverable metals will be segregated. Provisions will be made for a separate lifting vehicle to place the shaped objects in a special holding location that is enclosed to prevent viewing of the objects.

Because the metal objects may be too large to feed directly, the metal melting operation that is to follow may require size reduction so the material is suitable as feed material. During development of the RAWP, it will be evaluated to determine whether mechanical cutting, flame cutting, or compaction is the most effective method for size reduction. The method evaluation will address control of potentially radioactive or toxic dust and fumes generated by the process.

3.4.6.9 Treatability study—Metal melting

Because of the unknowns associated with these metals, treatability studies may be required to evaluate the most cost effective method for removing the radioactive coating (presumably oxide/fluoride salts of uranium) on the metal. It is assumed that the treatability testing will require actual samples of contaminated metal for testing. Water is the planned cleaning agent, but other potential cleaning agents also may be evaluated during the treatability study. Because of the anticipated costs associated with the required cleaning, and the potential that the metal cannot be cleaned, the treatability study must be carried out using pieces of metal segregated from the waste material.

3.4.6.10 Sorting and size reduction

Prior to melting, various mechanical, thermal, chemical, and magnetic techniques are used to separate contaminants and extraneous materials from scrap metal and to segregate metals of various types and composition. The specific technologies will be developed during remedial design, based on results of the treatability study.

3.4.6.11 Cleaning of the metal surfaces for metal melting

To minimize the amount of radioactive material that is carried into the metal melting process, an effective method for cleaning is required. The method of cleaning, such as blasting, dipping, or spraying, can be determined when the data from the treatability study are complete. An effective procedure for removing contamination cannot be developed until treatability testing is completed. The waste residual from surface cleaning may be a RCRA-hazardous or mixed waste. Residual cleaning waste will be treated and disposed of appropriately.

3.4.6.12 Melting and casting of cleaned metal for reuse

Once the condition and size of the cleaned pieces of metal are known, the exact configuration of the metal melting furnace can be established. There are several commercially available units of various sizes and capacities that can be selected once this is determined. This decision will become part of the project planning and documented in the RAWP, if this is a selected alternative.

3.4.7 Alternative 7—Excavation and Disposal Combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring

Alternative 7 is identical to the excavation and disposal alternative described for Alternative 6, except this alternative is coupled with *in situ* DNAPL source treatment to remediate potential DNAPL that remains post-excavation at depths greater than 20 ft bgs.

This alternative combines process options from GRAs of monitoring, removal, treatment and disposal, and consists of the following:

- Remedial design
- Excavation and disposal in accordance with Alternative 6
- *In situ* DNAPL source treatment
- Off-gas treatment, as necessary
- Process monitoring
- Postremediation sampling
- Well installation and long-term groundwater monitoring

This alternative would reduce the mass of the DNAPL source in the UCRS and the RGA, reduce recharge through the UCRS and thereby mitigate the secondary release mechanism and eliminate risks to receptors by eliminating the exposure pathways. Requirements and conceptual designs for each element of Alternative 7 are discussed here in detail.

The conceptual design of the Alternative 7 DNAPL treatment process is based on the design of the C-400 ERH treatment system. The source treatment system design would include measures to ensure that DNAPL was not mobilized during treatment. Details for each element of Alternative 7 are discussed below. A schematic view of an ERH system, a representative DNAPL source treatment process, is provided in Figure 3.1.

3.4.7.1 Remedial design

Detailed remedial design will be performed for this remedial alternative. Engineering data collection to support technology sizing, design, and optimization would be performed as necessary during the remedial design. The data collection would be based on an approach to be developed in the RAWP.

3.4.7.2 Treatment

The ERH treatment system conceptual design includes power electrodes with co-located vapor recovery wells, an electrical power control unit, a blower for steam and vapor recovery, pressure and temperature monitoring systems, and contaminant vapor and wastewater treatment systems. The active treatment period for a DNAPL source area is estimated at approximately six months.

3.4.7.3 Process monitoring

The C-400 ERH process monitoring system and procedures would be scaled and modified, if necessary, for application to the BGOU SWMU DNAPL source areas.

Air samples will be collected weekly from the influent of the primary GAC.

Subsurface temperatures and electrical usage would be monitored during implementation of the ERH system.

3.4.7.4 Postremediation sampling

Confirmatory sampling in the treatment area would be required to determine posttreatment TCE soil concentrations. A postremediation sampling plan would be prepared during RAWP development. The conceptual design for postremediation sampling includes soil coring using DPT and analysis for VOCs. Depths and locations of coring would be determined based on the results of remedial design data collection.

A long-term groundwater monitoring program comparable to that described under Alternative 2 would be implemented. The monitoring program will utilize existing PGDP MWs and additional groundwater MWs as necessary to monitor upgradient and downgradient groundwater contaminant levels.

3.4.8 Alternative 8—Excavation and Disposal Combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring

Alternative 8 is essentially a two-phase remedial action. In the first phase, buried waste and contaminated soil are removed in accordance with the approach outlined for Alternative 6. Postremediation samples will be collected after the buried waste is excavated. If these samples indicate the presence of a secondary DNAPL source residing below the primary waste disposal pit, then the Alternative 8 remedial action for DNAPL will be implemented. This action may include deep excavation of the potential DNAPL source areas and *ex situ* treatment of the DNAPL-contaminated soil.

The assumption being made for Alternative 8 in this FS is that the excavated burial pit will be backfilled with clean soil prior to initiating the DNAPL excavation. This approach is taken because of the estimated depth for the DNAPL excavation and the need to shore the DNAPL excavation for safety, minimizing the surface area impacted by remediation, operating within space constraints of the SWMU, and preventing groundwater intrusion.

Neither the exact nature of the buried waste nor the exact dimension of any potential DNAPL source is known. Excavating the buried waste prior to pursuing the DNAPL contamination removes the challenges associated with drilling through unknown buried waste to emplace shoring for the deep excavation, excavating through buried waste to access DNAPL contamination, and working on top of buried waste that has not been fully characterized. It may be determined during the RD that the excavation can be terraced and the burial pit remain open for the excavation of the DNAPL source.

The estimated dimensions for the volumes of potential DNAPL-contaminated soil to be excavated at SWMUs 2, 4, and 7 are shown in Table 3.2.

Table 3.2. Estimated Soil Excavation Dimensions at SWMUs 2, 4, and 7

SWMU No.	Estimated Dimensions of Treatment Surface Area, ft x ft	Estimated Depth Interval of Treatment, ft bgs to ft bgs
SWMU 2	75 x 75	20 to 59
SWMU 4	85 x 150 and 150 x 160	20 to 90
SWMU 7	75 x 75	20 to 59

Note: bgs = below ground surface

This alternative combines process options from GRAs of removal, treatment, and disposal. The primary elements that Alternative 8 may include are summarized below and in Figure 3.5.

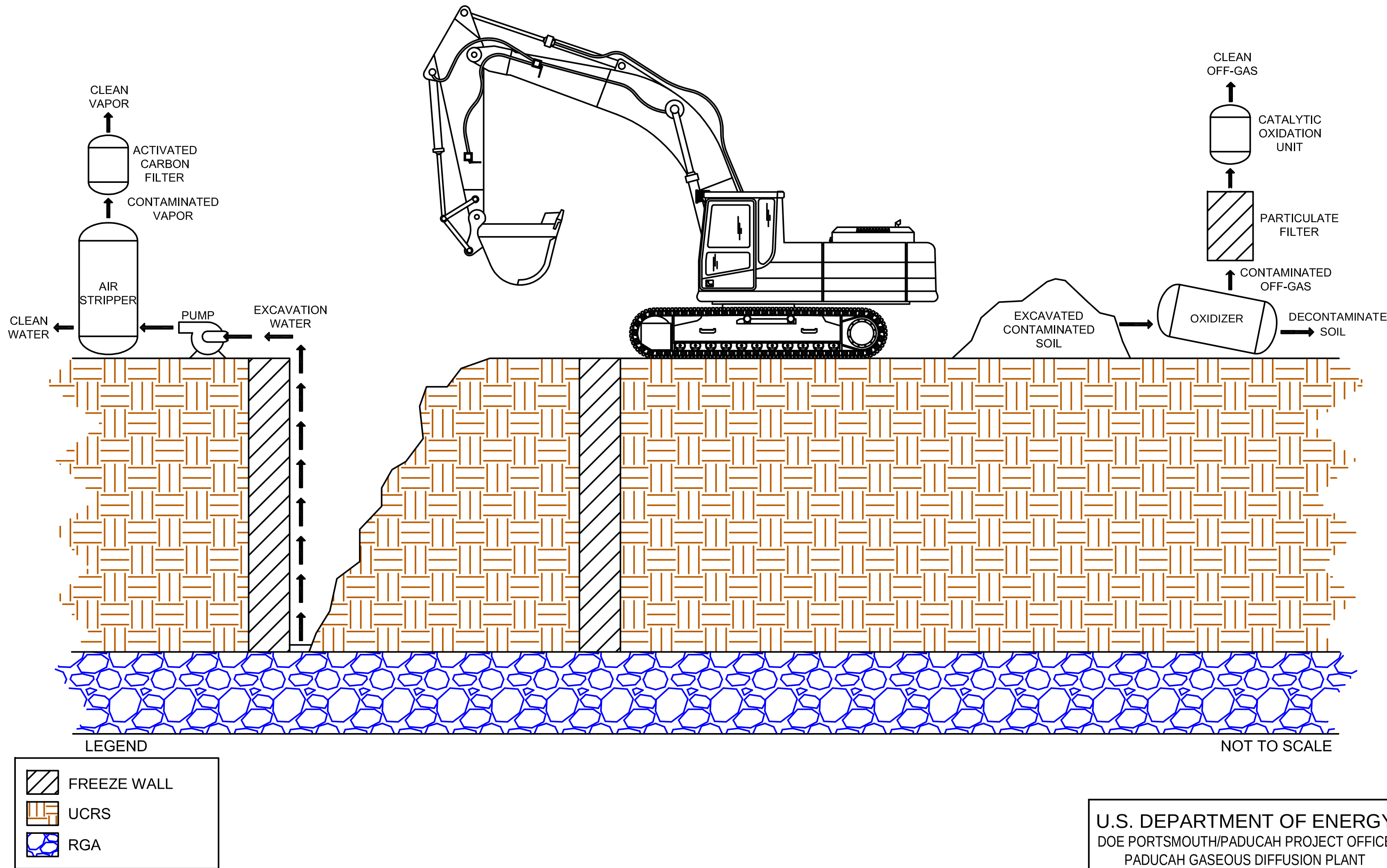


Figure 3.5. Schematic View of *Ex situ* DNAPL Source Treatment

The previously described elements of Alternative 6 that are part of Alternative 8 include the following:

- Shore the excavation walls and minimize groundwater intrusion;
- Excavate waste and source area soils contaminated with COCs above target concentrations;
- Treat or dispose of residual groundwater, if necessary, as indicated by sampling results;
- Postremediation and WAC sampling and analysis;
- Treat the waste and soil, if necessary, for transportation and/or disposal;
- Transport and dispose of waste; and
- Backfill with clean or uncontaminated soil.

In addition, Alternative 8 will include elements for removal and treatment of potential DNAPL-contaminated soils present below the waste disposal zone remediated by excavation and disposal:

- Deep excavation of the source area
- Continuous dewatering of the excavation
- Treating or disposing of residual groundwater, if necessary, as indicated by sampling results
- *Ex situ* treatment of the waste and soil, if necessary
- Postremediation and WAC sampling and analysis
- Backfilling with clean, decontaminated soil
- Well installation and long-term groundwater monitoring

This alternative would remove the mass of the DNAPL source in the UCRS and the RGA, mitigate the secondary release mechanism, and eliminate risks to receptors by eliminating the exposure pathways. The detailed requirements for excavation and disposal of waste and contaminated soils in a burial pit are described in detail under Alternative 6. The additional requirements and conceptual design for removal and treatment of DNAPL-contaminated soils by Alternative 8 are discussed in the following sections.

3.4.8.1 Shoring

Deep excavation requires shoring either by conventional means (e.g., benching and sheet piling) or by applying innovative technologies (e.g., soil freezing). The maximum depth of excavation using sheet piling is typically 40 ft; below that requires benching which significantly expands the excavation footprint and increases cost. Sheet piling is discussed in greater detail under Alternative 6.

Soil freezing is another technology used for shoring excavations and has been proposed for containing waste at Hanford Nuclear Reservation. Case studies include ground freezing at Mill Creek, Ohio, for installing a 32 ft diameter by 140 ft deep concrete shaft designed for storm and sewer water diversion. Installation includes encircling the treatment area with bore holes approximately 3 ft apart, installation of injection piping down the boreholes, and circulating cold brine (-30 degrees C) through the piping to the bottom of each boring and back to the surface. The brine is returned to a chiller for cooling. Circulating the chilled brine creates a frozen cylinder around the treatment zone within months. Soil freezing provides complete groundwater cutoff, ability to go around buried utilities, no ground vibration during installation, and can be installed in all soil types. Frozen soil is approximately two times stronger than concrete, impermeable, and cost competitive with conventional shoring techniques.

3.4.8.2 Excavation

Shallower DNAPL-contaminated soils would be removed using long reach track hoes; deeper excavations would require a clam shell excavating system.

3.4.8.3 *Ex situ* DNAPL source treatment

DNAPL-contaminated soil removed from the excavation would be transferred to a staging area for material sampling and testing, temporary storage, and processing for *ex situ* treatment. Aggressive treatment such as oxidation or thermal destruction may result in soil that can be returned to the excavated area. Other *ex situ* methods that can be applied to the contaminated soil include soil vapor extraction (with or without heat assistance) and bioremediation depending on the type and level of contamination. This soil likely would be disposed of off-site. For the purpose of this FS and to establish a basis for a cost estimate, the conceptual design will be based on oxidation for treatment of DNAPL-contaminated soil, and returning the decontaminated soil to the excavation.

Ex situ treatment usually requires a shorter amount of time to complete than *in situ* treatment. Remediation of the contaminated soils identified for treatment is accomplished with a greater degree of confidence because of the known quantities and increased level of control. There is uniformity of treatment because of the ability to homogenize, screen, and continuously mix the soil. There is a degree of uncertainty associated with identifying and excavating all the contaminated soil for DNAPL treatment.

3.4.8.4 Dewatering

Dewatering would be required during excavation since depth to groundwater is approximately 10 ft. The removed water likely would require on-site treatment employing a wastewater treatment unit designed for the remedial action followed by direct discharge. Treatment at the SWMU may include as necessary, based on the contaminants that are present, oil/water separation, green sand filtration, air stripping, carbon adsorption, or ion exchange.

A long-term groundwater monitoring program comparable to that described under Alternative 2 would be implemented. The monitoring program will utilize existing PGDP MWs and additional groundwater MWs, as necessary, to monitor upgradient and downgradient groundwater contaminant levels.

3.4.9 Alternative 9—*In situ* Containment with Long-Term Monitoring

This alternative uses *in situ* grouting, soil mixing, or a combination of related technologies to hydraulically isolate the buried waste from the aquifer. An engineered horizontal layer is installed beneath the buried waste (and shallow DNAPL source, if applicable) in the SWMU to limit any further downward migration of contaminants from the waste. A vertical hydraulic barrier tied into the horizontal subsurface barrier will limit groundwater intrusion and lateral migration. A structure will control infiltration of precipitation or surface water into the waste.

Alternative 9 is formulated as follows for screening, analysis, and cost estimating in this FS. Horizontal drilling combined with jet grouting will be used to establish the subsurface horizontal barrier beneath the buried waste. Jet grouting will be used install a vertical barrier that ties into the horizontal barrier to isolate the waste and limit lateral migration of contaminants. A building with a roof will be constructed over the SWMU to provide the final containment barrier to control infiltration of precipitation into and through the waste. Long-term monitoring and LUCs will be components of this alternative, as well as leachate collection and treatment if required.

This alternative combines process options from GRAs of monitoring, LUCs, and containment and includes the following:

- Remedial design
- Construction of a subsurface horizontal barrier

- Construction of vertical hydraulic barrier
- Construction of a structure
- Well installation and long-term groundwater monitoring
- LUCs

3.4.9.1 Remedial design

Detailed remedial design will be performed for this remedial alternative. Engineering data collection to support technology sizing, design, and optimization would be performed as necessary during the RD. The data collection would be based on an approach to be developed in the RAWP.

3.4.9.2 Construction of subsurface horizontal barrier

A jet-grouted horizontal subsurface barrier (i.e., laminar diaphragm or membrane) would be constructed underground using special jet-grouting techniques as shown conceptually in Figure 3.6. By jetting grout into the soil through properly spaced drill holes, a continuous low-permeability barrier will be constructed to limit the passage of water or other fluids that may contain toxic, hazardous, or radioactive chemicals.

Drill holes will be spaced according to the RAWP. Directional drilling will be required for the drill holes to follow the shape of the waste disposal area so that the barrier will be placed beneath the waste site.

The jet-grouting method will use special grout nozzles to create a grout sheet of controlled width and thickness from each drilled grout hole. This sheet will be approximately 4 to 6 inches thick, 6 to 10 ft wide, and any desired length. The width of the sheet in one pass can go up to approximately 10 ft. Actual lateral soil penetration of the grout jets is a function of the nature of the soil, the type of equipment used, the skill of the operator, and other factors.

This technology for construction of a horizontal subsurface barrier was nominated for the 1994 NOVA Award. It was commercialized and implemented at the industry level. Experimental laminar diaphragm construction was conducted under the sponsorship of the DuPont Corporation and DOE. Other experimental and successful construction was completed in Germany to contain leaching of hazardous and aggressive chemical refuses in waste lagoons (http://rebar.ecn.purdue.edu/ECT/Links/technologies/other/jetgrdia.aspx).

3.4.9.3 Construction of vertical hydraulic barrier

The construction of the vertical barrier also will employ jet grouting technology. The jet grouting process consists of drilling a borehole to the desired depth. Once at depth, the drilling fluid is diverted from the drill bit to the jetting nozzles and the pumping of the desired slurry begins. The pump pressure and flow rate then are increased to the desired specifications. Once at pressure, the drill string is withdrawn at a predetermined rate without rotating the drill string. As the jet grouting process proceeds, excess soils and slurry will be expelled at the surface through the annulus of the borehole and the drill string. The walls are emplaced using high pressure jetting of slurry into native soils to create low permeable zones by jetting through two relatively horizontal and opposing nozzles as the drill string is extracted (Landis 2001).

3.4.9.4 Construction of a structure

A structure will be placed over the contained volume to control infiltration of stormwater runoff and precipitation. The structure would be a prefabricated building installed to completely enclose the contained area, and engineered to divert stormwater away from the building.

3.4.9.5 Long-term groundwater monitoring

A long-term groundwater monitoring program comparable to that described under Alternative 2 would be implemented. The monitoring program would utilize existing PGDP MWs and additional groundwater MWs, as necessary, to monitor upgradient and downgradient groundwater contaminant levels.

Leachate collection or treatment will be implemented, if required, under this alternative.

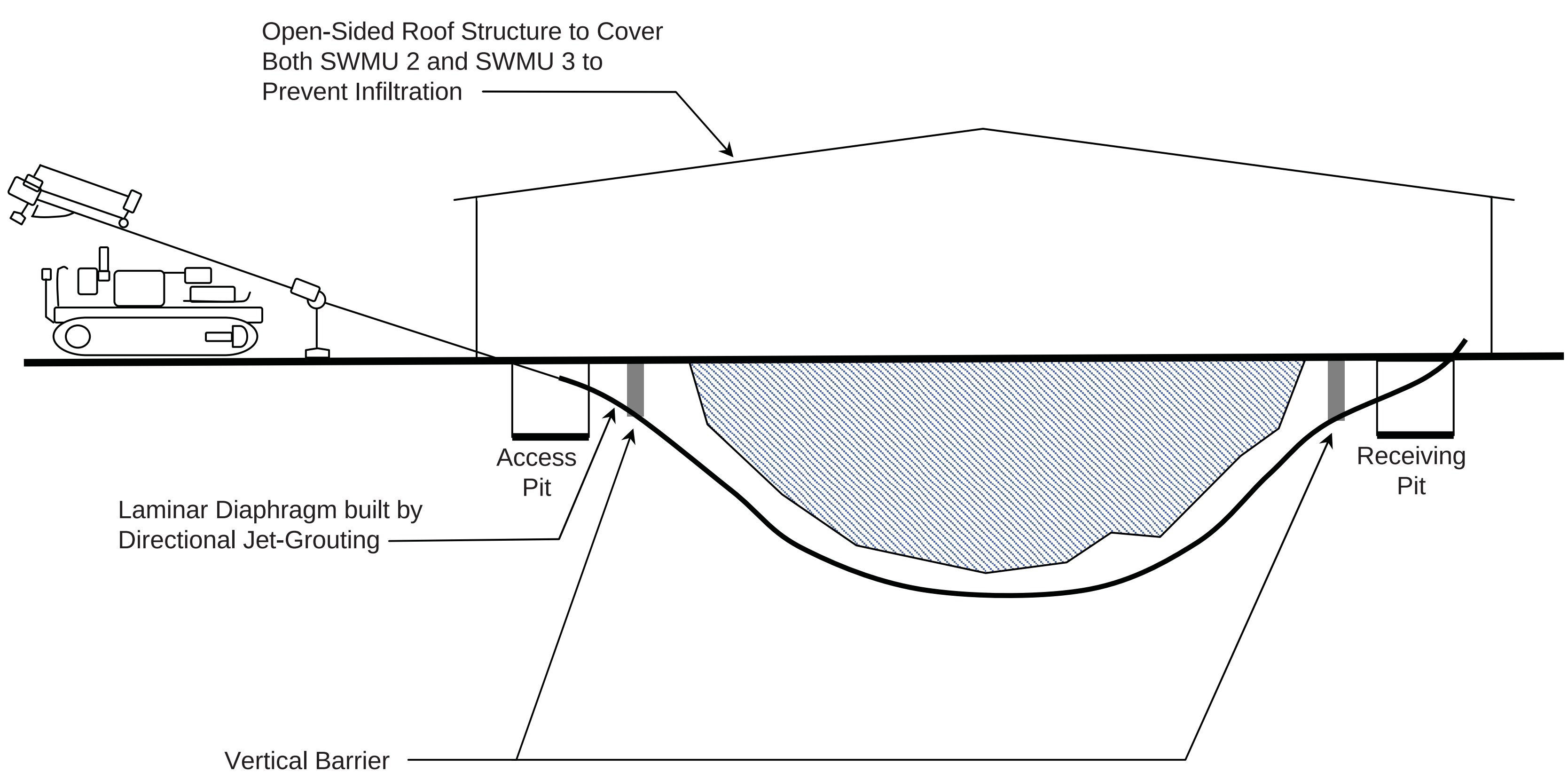
3.4.9.6 Land use controls

LUCs, as described in Section 2, would be implemented for units where waste remains in place (E/PP program).

3.5 SCREENING OF ALTERNATIVES

Alternatives are screened using the process described in EPA (1988) and the NCP to reduce the number of alternatives carried forward to detailed analysis. Defined alternatives are evaluated against the short and long-term aspects of three broad criteria: effectiveness, implementability, and cost. Because the purpose of the screening evaluation is to reduce the number of alternatives that will undergo a more thorough and extensive analysis, alternatives are evaluated more generally in this phase than during the detailed analysis.

The evaluation of effectiveness considers reductions in toxicity, mobility, and volume of COCs. The long-term aspect evaluates effectiveness and permanence of the alternative, while the short-term aspect evaluates alternatives with respect to their effects on human health and the environment during construction and implementation of the remedial action. The evaluation of implementability considers technical feasibility criteria, including the ability to construct, operate, and maintain the remedy, as well as administrative feasibility criteria, including the availability of treatment, storage, and disposal capacity. Evaluation of cost for the alternatives is based on the capital and O&M costs for the primary technologies utilized. Alternatives with the best combinations of effectiveness and implementability and the lowest costs are retained for detailed analysis and comparative analysis. The screening evaluation along with detailed and comparative analyses of alternatives for each BGOU SWMU is presented in the SWMU-specific sections to follow. A summary of the alternatives retained for detailed and comparative analysis at each SWMU is presented in Table 3.3.



U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Figure 3.6. BGOU FS Alternative 9

Table 3.3. BGOU SWMU Remedial Action Alternative Summary

Alternative	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Alternative Description	**No Action**	**Limited Action**	**Soil Cover and Long-Term Monitoring**[a]	**Soil Cover combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring**	**RCRA Cover with Hydraulic Isolation and Long-Term Monitoring**	**Excavation and Disposal**	**Excavation and Disposal combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring**[b]	**Excavation and Disposal combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring**[c]	***In situ* Containment and Long-Term Monitoring**
SWMU No.									
2	X				X		X	X	X
3[d]	X[e]	X[f]				X[g]			X
4[h]	X						X	X	
5	X		X			X[i]			
6	X	X							
7	X			X[j]			X	X	
30	X		X			X			
145	X		X			X[k]			

X-Indicates an alternative that was analyzed in detail for a particular SWMU.
[a] A soil cover was evaluated for those SWMUs where surface contact with the waste management unit is to be prevented and infiltration resulting from precipitation does not appear to pose any threat to human health or groundwater.
[b] *In situ* treatment is evaluated as a contingency alternative at SWMUs 2 and 7 if DNAPL is present upon completion of the excavation.
[c] *Ex situ* treatment is evaluated as a contingency alternative at SWMUs 2 and 7 if DNAPL is present upon completion of the excavation.
[d] SWMU 3 is a closed RCRA landfill lined with compacted soil, covered with a RCRA Subtitle C cap, equipped with a leachate collection system and managed under a RCRA postclosure permit.
[e] No action would be taken at SWMU 3 under the CERCLA program, but it would continue to be managed under the RCRA program.
[f] This alternative is for long-term monitoring based on results of the demonstration required under 40 *CFR* § 294.90(f)(1) and (2), but performed under the CERCLA program.
[g] SWMU 3 was evaluated for excavation of the documented waste disposal volume. No further action is required for the ditch at SWMU 3 under the BGOU.
[h] DNAPL at SWMU 4 is assumed to extend to sufficient depth to be present in both the UCRS and RGA.
[i] Metal melting is evaluated as a supplementary technology to excavation at SWMU 5 for metal recovery/recycle.
[j] A soil cover combined with *in situ* source treatment was evaluated for SWMU 7 where radioactive/inorganic contamination is limited to the surface. *In situ* treatment was evaluated to remediate DNAPL reported potentially to be present at SWMU 7.
[k] Excavation at SWMU 145 will be limited to course of the former North-South Diversion Ditch. Soil cover will be placed over uncovered portions, if necessary.

4. DETAILED AND COMPARATIVE ANALYSES OF ALTERNATIVES

Remedial alternatives were developed in Section 3. A determination about whether to retain each alternative for detailed analysis at each individual SWMU occurs in the SWMU-specific sections that follow for each of the BGOU SWMUs. The purpose and approach for performing the detailed analysis for alternatives retained at each SWMU are discussed here in Section 4. Results of the detailed analysis will form the basis for comparing alternatives. The general approach for performing the comparative analysis of alternatives also is presented here in Section 4. The detailed and comparative analyses of each alternative retained for consideration is presented in the respective sections for each SWMU. The results of the detailed and comparative analyses ultimately will be used for preparing the Proposed Plan for the BGOU.

4.1 DETAILED ANALYSIS

4.1.1 Purpose of the Detailed Analysis

The remedial action alternatives developed in Section 3 and retained after screening are analyzed in detail against the seven CERCLA threshold and balancing criteria to form the basis for selecting a final remedial action. The intent of this analysis is to present sufficient information for selection of an appropriate remedy.

Alternatives are evaluated with respect to the seven CERCLA threshold and balancing criteria outlined in 40 *CFR* § 300.430(e)(9)(iii) and as discussed in Section 4.1.2. This evaluation is the basis for determining the ability of a remedial action alternative to satisfy CERCLA remedy selection requirements.

4.1.2 Overview of the CERCLA Evaluation Criteria

The CERCLA evaluation criteria include technical, administrative, and cost considerations; compliance with specific statutory requirements; and state and community acceptance. Overall protection of human health and the environment and compliance with ARARs (in the absence of a CERCLA waiver) are categorized as threshold criteria that any viable alternative must meet. Long-term effectiveness and permanence; reduction of toxicity, mobility, and volume through treatment; short-term effectiveness; implementability; and cost are considered balancing criteria upon which the detailed analysis is primarily based. State and community acceptance is evaluated following a public comment period on the Proposed Plan, as well as when a final decision is made and the ROD is prepared. Each criterion is described here.

4.1.2.1 Overall protection of human health and the environment

Alternatives will be assessed to determine whether they can adequately protect human health and the environment in both the short- and long-term from unacceptable risks posed by contaminants present at the BGOU source areas by eliminating, reducing, or controlling exposures as established during the development of RAOs consistent with 40 *CFR* § 300.430(e)(2)(I). Overall protection of human health and the environment draws on the assessments of the other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs (in the absence of a CERCLA waiver).

4.1.2.2 Compliance with ARARs

ARARs include substantive federal or more stringent state environmental or facility siting laws/regulations. They do not include occupational safety or worker radiation protection requirements. Additionally, per 40 *CFR* § 300.400(g)(3), other advisories, criteria, or guidance may be considered in determining remedies (TBC category). CERCLA § 121(d)(4) provides several ARAR waiver options that may be invoked, provided that human health and the environment are protected. Activities conducted on-site must comply with the substantive, but not administrative requirements. Administrative requirements include applying for permits, recordkeeping, consultation, and reporting. Activities conducted off-site must comply with both the substantive and administrative requirements of applicable laws. Measures required to meet ARARs will be incorporated into the design phase and implemented during the construction and operation phases of the remedial action.

ARARs typically are divided into three categories: (1) chemical-specific, (2) location-specific, and (3) action-specific. Chemical-specific ARARs provide health- or risk-based concentration limits or discharge limitations in various environmental media (i.e., surface water, groundwater, soil, or air) for specific hazardous substances, pollutants, or contaminants. Location-specific ARARs establish restrictions on permissible concentrations of hazardous substances or establish requirements for how activities will be conducted because they are in special locations (e.g., floodplains or historic districts). Action-specific ARARs include operation, performance, and design of the preferred alternative based on waste types and/or media to be addressed, and removal/remedial activities to be implemented.

There are no chemical-specific ARARs for remediation of the contaminated soils at the source areas. Kentucky drinking water standards, however, were used for calculation of soil RGs. DOE Order 5400.5, *Radiation Protection of the Public and Environment*, is TBC for operation of a DOE facility. The order requires that all exposure pathways, including those presented from remedial activities, not result in radiation exposures to members of the general public greater than an EDE of 100 mrem/year. Exposure to the general public also must be maintained as low as reasonable achievable. ARARs are further identified in each alternative.

Alternatives are assessed to determine whether they meet ARARs identified for each alternative. If ARARs will not be met at the end of an action, an evaluation will occur to determine when a basis exists for invoking one of the ARAR waivers cited in 40 *CFR* § 300.430(f)(l)(ii)(c) that are listed as follows:

(1) The alternative is an interim measure and will become part of a total remedial action that will attain the federal or state ARARs.

(2) Compliance with the requirement will result in greater risk to human health and the environment than other alternatives.

(3) Compliance with the requirement is technically impracticable from an engineering perspective.

(4) The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method or approach.

(5) With respect to a state requirement, the state has not consistently applied, or demonstrated the intention to consistently apply, the promulgated requirement in similar circumstances at other remedial actions within the state.

4.1.2.3 Long-term effectiveness and permanence

Long-term effectiveness and permanence are an assessment of the risk remaining at the site after RAOs have been met and the effectiveness and reliability of controls required to manage the risk posed by untreated waste or treatment residuals. Alternatives will be assessed for the long-term effectiveness and permanence they afford, along with the degree of certainty that the alternative will prove successful. These are factors that may be considered in this assessment:

- The magnitude of residual risk from untreated waste or treatment residuals remaining at the conclusion of the remedial activities, including their volume, toxicity, and mobility.

- The adequacy and reliability of controls such as containment systems necessary to manage treatment residuals and untreated waste. For example, this factor addresses uncertainties associated with land disposal for providing long-term protection from residuals; the assessment of the potential need to replace technical components of the alternative, such as a cover or treatment system; and the potential exposure pathways and risks posed should the remedial action need replacement.

4.1.2.4 Reduction of toxicity, mobility, or volume through treatment

The degree to which the alternatives employ treatment or recycling that reduces toxicity, mobility, or volume will be assessed, including how the treatment is used to address the principal threats posed by the release sites. Factors that will be considered, as appropriate, include these:

- Treatment or recycling processes that the alternatives employ and the materials that they will treat;

- The amount of hazardous substances, pollutants, or contaminants that will be destroyed or recycled;

- The degree of expected reduction in toxicity, mobility, or volume of the waste because of the treatment or recycling and the specification of which reductions are occurring;

- The degree to which the treatment is irreversible;

- The type and quantity of residuals that will remain following treatment, taking into consideration the persistence, toxicity, mobility, and propensity to bioaccumulate such hazardous substances and their constituents; and

- The degree to which treatment reduces the inherent hazards posed by the principal threats at the release sites.

4.1.2.5 Short-term effectiveness

Short-term effects during implementation of the remedial action will be assessed, including the following:

- Short-term risks that might be posed to the community;
- Potential risks or hazards to workers and the effectiveness and reliability of protective measures;
- Potential environmental effects and the effectiveness and reliability of mitigative measures; and
- Time until protection is achieved.

4.1.2.6 Implementability

The ease or difficulty of implementing the alternatives will be assessed by considering the following types of factors, as appropriate:

- Technical feasibility, including the technical difficulties and unknowns associated with constructing and operating the technology, reliability of the technology, ease of undertaking additional remedial actions, and ability to monitor the effectiveness of the remedy;

- Administrative feasibility, including the availability of treatment, storage, and disposal capacity; and

- Availability of required materials and services.

4.1.2.7 Cost

Supporting calculations for conceptual designs including cost estimates are provided in Appendix E. These are the types of costs assessed:

- RD and construction documentation costs, including RD, construction management and oversight, remedial design and remedial action document preparation, project/program management and oversight, and reporting costs;

- Construction costs, including capital equipment, general and administrative costs, and construction subcontract fees;

- Operating and maintenance costs;

- Equipment replacement costs; and

- Surveillance and monitoring costs.

EPA guidance distinguishes between scope contingency and bid contingency costs (EPA 2000). Scope contingency costs represent risks associated with incomplete design and include contributing factors such as limited experience with technologies, additional requirements because of regulatory or policy changes, and inaccuracies in defining quantities or characteristics. Bid contingency costs are unknown costs at the time of estimate preparation that become known as remedial action construction proceeds. They represent reserves for quantity overruns, modifications, change orders, and claims during construction. Although EPA guidance allows for contingency based on the complexity and size of the project and the inherent uncertainties related to the remedial technologies, no contingency was applied to the cost estimates prepared for this FS.

Life-cycle costs are presented as Net Present Worth, and in escalated dollars, for capital, O&M, and periodic costs for each alternative. Escalation was applied as directed by DOE Order 430.1A, "Life Cycle Asset Management." Guidance was provided by DOE Headquarters, Office of Project and Fixed Asset Management; "Departmental Price Change Index, FY 99 Guidance; Anticipated Economic Escalation Rates," January 1997 update.

Detailed total costs for implementing each alternative at the appropriate BGOU source areas are presented in Appendix E. Summary costs for implementing each alternative at the individual source areas are presented in the sections for the individual SWMUs that follow.

The alternative cost estimates are for comparison purposes only and are not intended for budgetary, planning, or funding purposes. Estimates were prepared to meet the -30% to +50% range of accuracy recommended in CERCLA guidance EPA (1988).

4.1.2.8 State acceptance

This assessment evaluates the technical and administrative issues and concerns KDEP may have regarding each of the alternatives. This criterion will be addressed in the Proposed Plan and ROD after KDEP comments on the FS are received.

4.1.2.9 Community acceptance

This assessment evaluates the issues and concerns the public may have regarding each of the alternatives. This criterion will be addressed in the ROD after public comments on the Proposed Plan are received.

4.1.3 Federal Facility Agreement and NEPA

Specific requirements of the FFA and NEPA, consistent with the DOE's Secretarial Policy Statement on NEPA in June of 1994, are considered in the FS.

4.1.3.1 Otherwise required permits under the FFA

When DOE proposes a response action, Section XXI of the FFA further requires that DOE identify each state and federal permit that otherwise would have been required in the absence of CERCLA Section 121(e)(1) and the NCP. DOE identifies the permits that otherwise would be required, the standards, requirements, criteria, or limitations necessary to obtain such permits and provide an explanation of how the proposed action will meet the standards, requirements, criteria, or limitations identified.

An evaluation of alternatives presented in the FS determined that the otherwise required permits may include the KPDES; RCRA Treatment, Storage, and Disposal Facility; and Solid Waste Landfill permits. Jurisdictional wetlands have been identified on PGDP and will be delineated, as necessary, prior to the remedial action.

PGDP currently operates under KPDES Permit No. KY0004049, Hazardous Waste Facility Operating Permit No. KY8-890-008-982, and Solid Waste Permit No. 07300045, which define the applicable standards, requirements, criteria, or limitations. In the absence of the existing permits, the substantive requirements of the otherwise required permits are identified in the ARARs provided for each alternative.

4.1.3.2 NEPA values

The following NEPA values also are considered in this FS to the extent practicable, consistent with DOE policy.

- Land use
- Air quality and noise
- Geologic resources and soils
- Water resources
- Wetlands and floodplains
- Ecological resources
- T&E species
- Migratory birds

- Cultural and archeological resources
- Socioeconomics, including environmental justice and transportation

Alternatives selected for detailed analysis would have no identified short-term or long-term impacts on geological resources, migratory birds, cultural resources, or socioeconomics. Upon final selection of the alternative, the absence of any short- and long-term impacts to these values will be verified.

No long-term impacts to air quality or noise would result from implementation of the remedial action alternatives evaluated. Remedial actions should not result in generation of air pollutants above regulatory limits, and noise levels should be similar to current background levels.

None of the remedial alternatives would have any impacts on geologic resources, and construction activities would have only short-term impacts on soils. Site clearing, excavation, grading, and contouring would alter the topography of the construction area, but the geologic formations underlying those sites should not be affected. Construction would disturb existing soils, and some topsoil might be removed in the process. Soil erosion impacts during construction would be mitigated through the use of best management practices control measures (e.g., covers and silt fences). No conversion of prime farmland soils is expected to occur. Any alternative that would create disturbances also would include restoration to these areas.

None of the activities associated with the remedial alternatives would be conducted within a floodplain. Wetlands were identified during the 1994 COE environmental investigation for the area surrounding the PGDP. This investigation identified five acres of potential wetlands inside the fence at PGDP (COE 1994). The COE made the determination that these areas are jurisdictional wetlands (COE 1995).

As stated in the regulations, construction activities must avoid or minimize adverse impacts on wetlands and act to preserve and enhance their natural and beneficial values [Executive Order 11990 and 10 *CFR* § 1022]. These applicable requirements include avoiding construction in wetlands, avoiding (to the extent practicable) long- and short-term adverse impacts to floodplains and wetlands, avoiding degradation or destruction of wetlands, and avoiding discharge of dredge and fill material into wetlands. In addition, the protection of wetlands shall be incorporated into all planning documents and decision making as required by 10 *CFR* § 1022.3.

No long- or short-term impacts have been identified to archeological or cultural resources. DOE developed the CRMP (BJC 2006) to define the preservation strategy for PGDP and direct efficient compliance with the NHPA and federal archaeological protection legislation at PGDP. No archaeological or historical resources have been identified within the vicinity of the BGOU SWMUs; however, should portions of the project remove soils that previously have been undisturbed, an archaeological survey will be conducted in accordance with the CRMP. If archaeological properties are located that will be affected adversely, then appropriate mitigation measures will be employed.

Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations," requires agencies to identify and address disproportionately high and adverse human health or environmental effects their activities may have on minority and low-income populations. There is a disproportionately high percentage of minority and low-income populations within 50 miles of the PGDP site (DOE 2004), but since there are no potential impacts from these alternatives, there would be no disproportionate or adverse environmental justice impacts to these populations associated with this alternative.

No long- or short-term adverse transportation impacts are expected to result from implementation of remedial alternatives. During construction activities there would be a slight increase in the volume of truck traffic in the vicinity of the BGOU SWMUs, but the affected roads are capable of handling the additional truck traffic. Any wastes transferred off-site or transported in commerce along public rights-of-way will meet the packaging, labeling, marking, manifesting, and placarding requirements for hazardous materials at 49 *CFR* Parts 107, 171-174, and 178; however, transport of wastes along roads within the PGDP site that are not accessible to the public would not be considered “in commerce.”

In addition, CERCLA § 121(d)(3) provides that the off-site transfer of any hazardous substance, pollutant, or contaminant generated during CERCLA response actions be sent to a treatment, storage, or disposal facility that complies with applicable federal and state laws and has been approved by the EPA for acceptance of CERCLA waste. Accordingly, DOE will verify with the appropriate EPA regional contact that any needed off-site facility is acceptable for receipt of CERCLA wastes before transfer.

4.1.3.3 Natural Resources Damage Assessment

As part of the overall FS process, a preliminary analysis was conducted of each alternative’s impact on natural resources, including each alternative’s potential to avoid, mitigate, compensate for, or cause a natural resource injury. This initial evaluation found that no alternative is expected to cause damage to natural resources. Furthermore, the analysis revealed that all alternatives, with the exception of alternatives one and two (no action and limited action), are expected to have a positive impact on natural resources. The most significant positive impact to natural resources offered by the alternatives is either the mitigation or the removal of existing sources of groundwater contamination; six of the nine alternatives offer this advantage. Another positive implication is that five alternatives would lead to a state in which native vegetation or timber could be reestablished. Table 4.1 summarizes the results of the analysis. Further integration may be included in subsequent documents, as appropriate.

4.2 COMPLIANCE WITH ARARS

An alternative must meet this threshold criterion (or obtain a CERCLA waiver) to be eligible for selection. The ARARs in this FS are tailored to the scope of the FS, which does not include groundwater or surface water remediation. ARARs for each of the remedial alternatives retained for detailed and comparative analysis at one or more of the SWMUs are listed in Appendix F.

No ARARs have been identified for Alternative 1, the No Action alternative.

4.3 COMPARATIVE ANALYSIS

The PGDP BGOU source area remedial action alternatives, which were developed in Section 3 and analyzed in detail as described previously in this section, then are subjected to comparative analysis. The comparative analysis identifies the relative advantages and disadvantages of each alternative, so that the key tradeoffs that risk managers must balance can be identified. The comparative analysis provides a measure of the relative performance of the alternatives against each evaluation criterion.

Alternatives are compared based on two of the three CERCLA categories including threshold criteria and primary balancing criteria. The third category, modifying criteria, including state and community acceptance, will not be addressed until the Proposed Plan has been issued for public review. These modifying criteria will be addressed in the responsiveness summary and the ROD, which will be prepared following the public comment period.

Table 4.1. Remedial Alternatives and the Relative Impacts on Natural Resources

Natural Resources	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	Alternative 9
	No Action	Limited Action	Soil Cover	Soil Cover and Source Treatment	RCRA Cover and Hydraulic Barrier	Excavation and Dispose	Excavation and *In situ* Treatment	Excavation and *Ex situ* Treatment	Isolation
Ground Water	Neutral	Neutral	Positive	Positive	Positive	Positive	Positive	Positive	Positive
Surface Water	Neutral	Neutral	Neutral	Positive	Positive	Positive	Positive	Positive	Positive
Air	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
Biological	Neutral	Neutral	Neutral	Neutral	Neutral	Positive	Positive	Positive	Neutral
Geological	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral

Threshold criteria are of greatest importance in the comparative analysis because they reflect the key statutory mandates of CERCLA, as amended. The threshold criteria that any viable alternative must meet are as follows:

- Overall protection of human health and the environment, and
- Compliance with ARARs (in the absence of a CERCLA waiver).

The primary balancing criteria to which relative advantages and disadvantages of the alternatives are compared include the following:

- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, and volume through treatment;
- Short-term effectiveness;
- Implementability; and
- Cost.

The first and second balancing criteria address the statutory preference for treatment as a principal element of the remedy and the bias against off-site land disposal of untreated material. Together with the third and fourth criteria, they form the basis for determining the general feasibility of each potential remedy. The final criterion addresses whether the costs associated with a potential remedy are proportional to its overall effectiveness, considering both the cleanup period and O&M requirements during and following cleanup, relative to other alternatives. Key tradeoffs among alternatives most frequently will relate to one or more of the balancing criteria.

The comparative analyses for remedial alternatives are presented the SWMU-specific sections that follow.

In addition to evaluating each SWMU individually in the following sections, an option for grouping SWMUs for remediation also was evaluated. Emphasis was placed on opportunities to improve effectiveness of remediation, efficiency of implementation, and schedule. The discussion of SWMU grouping is presented in Appendix G.

THIS PAGE INTENTIONALLY LEFT BLANK

5. SWMU 2

5.1 SWMU 2 HISTORY AND BACKGROUND

The C-749 Uranium Burial Ground (SWMU 2) is located within the west-central portion of the plant. SWMU 2 encompasses an area of approximately 32,000 ft^2, with approximate dimensions of 160 ft by 200 ft. Records indicate that when the burial grounds was in use, pits were excavated to an estimated depth of 7 to 17 ft. After the burial ground no longer was in use, the area was covered with a 6-inch-thick clay cap and an 18-inch-thick soil layer covered with vegetation (DOE 1995b). Figure 5.1 illustrates the documented disposal at SWMU 2 (Union Carbide 1975).

SWMU 2 was used from 1951 to 1977 for the disposal of uranium and uranium-contaminated wastes. Disposal records for SWMU 2 indicate that 270 tons of uranium, 59,000 gal of oils, and 450 gal of TCE were disposed of in the unit (DOE 1999b). Disposal records also indicate that drummed wastes buried in the unit consist primarily of uranium metal from machine shop turnings, shavings, and sawdust. Other wastes at the unit consist of drummed uranyl fluoride and TCE. The most likely scenario is that the uranium buried at PGDP is in the metallic state or is coated with uranium (IV) oxide. Neither of these forms of uranium is very susceptible to leaching. The kinetics of dissolution of the buried metal and uranium (IV) oxide is controlled by the amount of oxygen and carbon dioxide that leaches through the waste.

Because small pieces of uranium metal may be pyrophoric (spontaneously burn in air), operating practices of that time required placing the material in drums and submerging the material in petroleum-based oil and synthetic oil to avoid contact with air. It is possible that the oils used may have included some PCB-contaminated oils. Such oils are resistant to chemical and biological degradation and from leaching by percolating waters. In addition, oils, as they slowly degrade, consume oxygen, which lowers the oxidation-reduction potential. Under such conditions, uranium dissolution is negligible (ORNL 1998).

No documentation of technetium-99 disposal at SWMU 2 exists; however, during the years of feed plant operation from 1953 to 1964 and from 1968 intermittently through 1977, recycled uranium feed material from nuclear reactors was reprocessed through the feed plant, resulting in the introduction of reactor-produced radioactive impurities, such as technetium-99, into the enrichment process. It is possible that a portion of the uranium-contaminated wastes disposed of in burial grounds at PGDP contains technetium-99 from reprocessing activities (DOE 1994b).

The BGOU RI reviewed both data collected during the RI along with historical data. The RI Report states that the most prevalent metals detected above background level in subsurface soil samples at SWMU 2 are arsenic, thallium, and uranium. Arsenic and thallium are commonly associated with uranium. Arsenic was detected above the screening levels throughout the depth of the angled borings (60 ft) installed during the RI. The areas that exceed the background level for metals are in the shallow soils on the eastern side of the SWMU and an isolated area at 45 ft bgs on the western side (the 60 ft sample at this location was less than background). Because this is a relatively small SWMU, these two zones may be connected spatially. The highest concentrations of uranium were found at shallow depths on the western side of the burial ground. TCE and its degradation products *cis*-1,2- DCE and vinyl chloride were detected at high levels (140 mg/kg, 130 mg/kg, and 1.4 mg/kg, respectively) at a depth of 12 ft bgs on the eastern side of the burial unit. Although PCBs were suspected to be associated with the waste buried in SWMU 2, PCBs were detected above 1 ppm in only one subsurface soil sample below a depth of 6 ft (the approximate depth of the top of buried waste). The highest activities of the uranium isotopes were found at shallow depths on the western side of the burial ground. The distribution of the uranium isotopes are very similar to that of uranium.

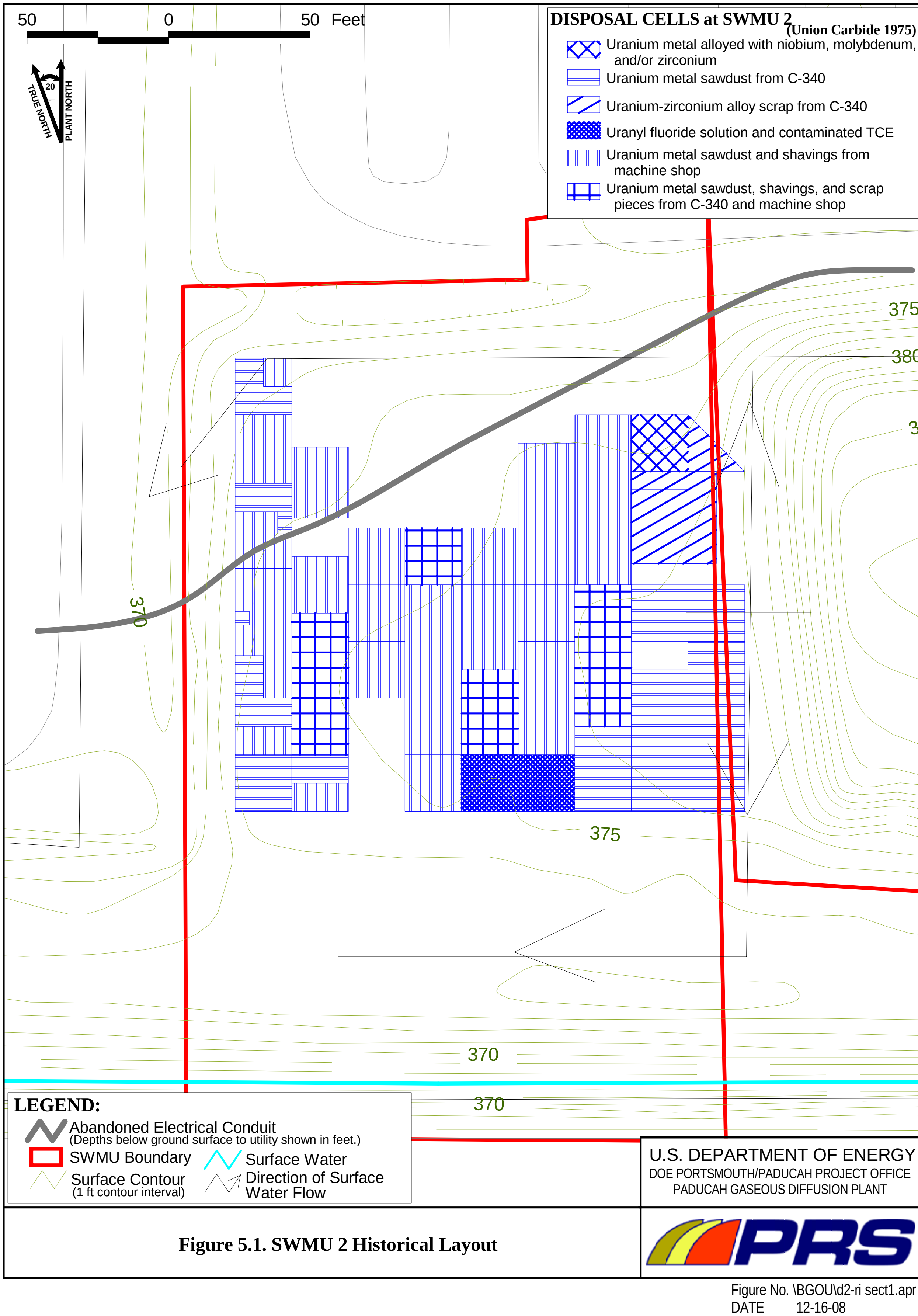


Figure 5.1. SWMU 2 Historical Layout

Groundwater samples were attempted at the two angled borings installed at SWMU 2 as part of the BGOU RI; however, none was collected (even where the UCRS is saturated, the low hydraulic conductivity of the unit restricts groundwater yield). A review of historical data indicates uranium and the uranium isotopes exceeded screening criteria in the horizon of the burial cells. Additionally, beryllium, manganese, and vanadium, TCE and its degradation products, and uranium isotopes occurred at levels that exceeded RI screening criteria throughout the UCRS interval below the waste pits.

The RGA contained several metals that exceeded RI screening criteria including beryllium, iron, manganese, uranium, vanadium (also identified as UCRS contaminants), arsenic, and cadmium. TCE was the most widely detected organic contaminant in RGA groundwater at SWMU 2. Another VOC, 1,1-DCE, showed high levels in one RGA historical boring. RGA groundwater samples from one historical location contained uranium-234 above screening criteria; and samples from two historical locations contained uranium-238 above screening criteria.

The hydrogeological assessment of the SWMUs 2 and 3 area (PRS 2007) determined that an upgradient source is responsible for the high TCE levels in the area. It is difficult to separate any potential impacts to the RGA from SWMU 2 due to the migration of contamination from upgradient areas.

5.1.1 Hydrogeologic Interpretation

The study area geology and hydrogeology is summarized below as documented in the BGOU RI (DOE 2010). Because SWMUs 2 and 3 are adjacent to each other, their hydrogeologic interpretation is discussed as one.

Stratigraphy. The burial cells of SWMU 2 are excavated into the HU1 loess member (silt with some clay) of the Upper Continental Deposits. Some waste cells likely extend to near the base of the HU1 unit, at a depth of 18.5 ft. The underlying HU2 interval consists of upper and lower sand and gravel horizons, separated by an intervening clayey silt unit, to a depth of 40 ft. A nine-ft-thick silty clay interval (HU3) separates the HU2 sand and gravel horizons from the basal HU4 sand and the sands and gravels of the Lower Continental Deposits (HU5). SWMU 3 rests upon the top of the Upper Continental Deposits.

UCRS Groundwater Flow and Hydraulic Potential. The SWMU 2 Data Summary and Interpretation Report (DOE 1997) documents the depth and gradient of the water table using measurements from shallow MWs and piezometers. Four rounds of measurements of water level during a one-week period in August 1996, consistently demonstrate that the water table occurred within 10 ft of land surface, sloping toward a ditch on the west side. Most of the buried waste at SWMU 2 is saturated. The westward slope of the water table below SWMU 2 indicates that the water table must be equally shallow beneath SWMU 3.

The governing parameters determining the groundwater flow paths are the higher hydraulic conductivity corridors in the RGA marked by the Southwest Plume and the Northwest Plume to the south and north of SWMU 3, respectively, and the RGA potentiometric surface, which declines to the north. Edges of the Southwest Plume and Northwest Plume approximate boundaries of higher hydraulic conductivity in the HU5 sediments, through which the majority of groundwater flow occurs. Pumping tests of the RGA in the area of the main contaminant plumes on-site (Terran 1992; LMES 1996) have determined the representative hydraulic conductivity to be 1,200 to 1,300 ft/day, which contrasts with the hydraulic conductivity of the RGA beneath SWMU 3, measured as 100 ft/day in a previous pumping test (Terran 1990).

The northward groundwater flow beneath SWMU 3 is an intermediate flow path between the hydraulic conductivity “expressways” delineated by the Southwest Plume (to the south of SWMU 3) and the Northwest Plume (to the north of SWMU 3) and is related to seasonal variations in potentiometric head.

Average RGA groundwater flow velocity in the areas of the contaminant plumes is commonly 1 to 3 ft/day. Hydraulic potential gradients to the north and to the west are commonly similar in the SWMU 3 area. The northward groundwater flow rate beneath SWMU 3 is likely 0.1 to 0.3 ft/day, in step with the order-of-magnitude reduction in hydraulic conductivity beneath SWMU 3.

5.2 SWMU-SPECIFIC RAOS

RAOs that are specific to SWMU 2 were developed based on the findings and observations forthcoming the BGOU RI Report. The SWMU-specific RAOs generally are directed toward conditions related to the waste materials, the surface soils, and the subsurface soils at the SWMU. A brief statement of the specific problem associated with the SWMU is followed by bulleted RAOs developed to address the problem.

Wastes in the burial pits (including potentially pyrophoric uranium) and constituents in surrounding subsurface soil present an unacceptable direct exposure risk to an outdoor worker.

- Prevent future contaminant migration to the environment such that it does not present unacceptable risks to future receptors or groundwater.

- Prevent exposure from subsurface soil metals and radionuclides within the SWMU boundary to approximately 16 ft bgs that would cause an unacceptable cumulative risk to future outdoor worker.

Constituents in surface soil present cumulative ELCR to current and future industrial workers, respectively, exceeding an ELCR=1E-06. This is confined to the area of the burial pits and locations adjacent to the SWMU boundary to 1 ft bgs.

- Prevent exposure from surface soil metals and radionuclides within the SWMU administrative boundary, excluding the drainage ditch in the southern portion of the SWMU, that would cause an unacceptable cumulative risk to future industrial workers.

Constituents in subsurface soils are predicted to result in a future risk to a current and future off-site residential groundwater user exceeding an ELCR=1E-06 and HI=1.

- Prevent migration of radionuclides, VOCs, and metals in soil in the source areas to the RGA groundwater to the extent they do not contribute contamination exceeding MCLs, or in the absence of an MCL, a risk-based concentration.

The FS process began with the full list of COCs identified in the RI Report. A detailed evaluation of the sample results for commonly occurring elements identified in the RI Report as COCs was performed by comparing field sample results against the PGDP site background concentrations. A number of COCs identified in the RI Report were eliminated from further consideration in the FS because they were below background levels. A discussion of the evaluation that was performed and its results are presented in detail in Section 1. The final list of COCs for the SWMU and their preliminary RGs for surface soil and subsurface soil are provided in Appendix C, Tables C.2 and C.3, respectively. Preliminary RGs for the SWMU meet the target cumulative ELCR and HI criteria for both surface and subsurface soil.

5.3 SCREENING OF ALTERNATIVES

Alternatives are screened in this section, using the process described in EPA (1988) and the NCP to reduce the number of alternatives carried forward to detailed analysis. Alternatives are screened with respect to effectiveness, implementability, and cost. The evaluation of effectiveness considers reductions in toxicity, mobility, and volume of COCs. The evaluation of implementability considers technical feasibility criteria, including the ability to construct, operate, and maintain the remedy, and administrative feasibility criteria, including the availability of treatment, storage, and disposal capacity. Evaluation of cost for the alternatives is based on the relative capital and O&M costs for the primary technologies utilized. Alternatives with the best combinations of effectiveness and implementability and the lowest costs are retained for detailed analysis and comparative analysis.

Surface area estimates and waste mass and volume estimates for cover and excavation alternatives, respectively, are developed and discussed in Appendix E. These area, mass, and volume estimates were used to support development of the cost estimates for the alternatives that also appear in Appendix E. The conceptual location of the radioactive/inorganic treatment area is presented on Figure 5.2.

The presence of DNAPL at SWMU 2 is suspected, but not defined. As indicated previously in Section 1, DNAPL appears to be limited to a depth of less than 20 ft bgs at this SWMU. If an excavation alternative were to be implemented at SWMU 2, it is probable that any DNAPL source would be removed as part of the excavation; therefore, alternatives that include RPOs for remediation of DNAPL at SWMU 2 are presented as contingency components of the alternatives. An alternative that incorporates DNAPL remediation RPOs would be fully implemented only if the engineering data or postremediation samples from an excavation confirmed the presence of a DNAPL source at SWMU 2.

The estimated volume of potentially DNAPL-contaminated soils to be remediated at the SWMU was developed in Section 1. The conceptual location of the DNAPL treatment area at the SWMU is presented on Figure 5.3.

Potentially pyrophoric uranium metal shavings were deposited over 30 years ago in SWMU 2. It is improbable that the drums in which the uranium was disposed are still intact. Uranium may corrode (oxidize) through a number of processes (e.g., galvanic corrosion, crevice corrosion, pitting corrosion), the majority of which are controlled by the local chemical environment in which the uranium resides. For example, corrosion may occur in air, water or in contact with the water- and air-filled porosity of soils and sediments (Royal Society 2002). The contents of these drums likely have been in contact with groundwater in the UCRS, causing some portion of the uranium to oxidize and no longer to possess the characteristic of pyrophoricity. The low solubility of uranium makes it essentially immobile. In the event that the uranium is pyrophoric, it could spontaneously react if exposed to air. The screening and evaluation of alternatives will consider the risk of removing the uranium, will include proper precautions to manage pyrophoric uranium, and will qualitatively assess the comparative potential risk of excavating the waste relative to containing it in place.

5.3.1 Alternative Screening for SWMU 2 Source Areas

Table 5.1 summarizes the results of alternative screening for source areas at SWMU 2. Alternatives that were screened out at this step for this SWMU are shaded grey on the table. Alternative 1 (no action) is not effective but is retained for further consideration in the detailed analysis as a baseline alternative to which all other alternatives are compared, as required by CERCLA.

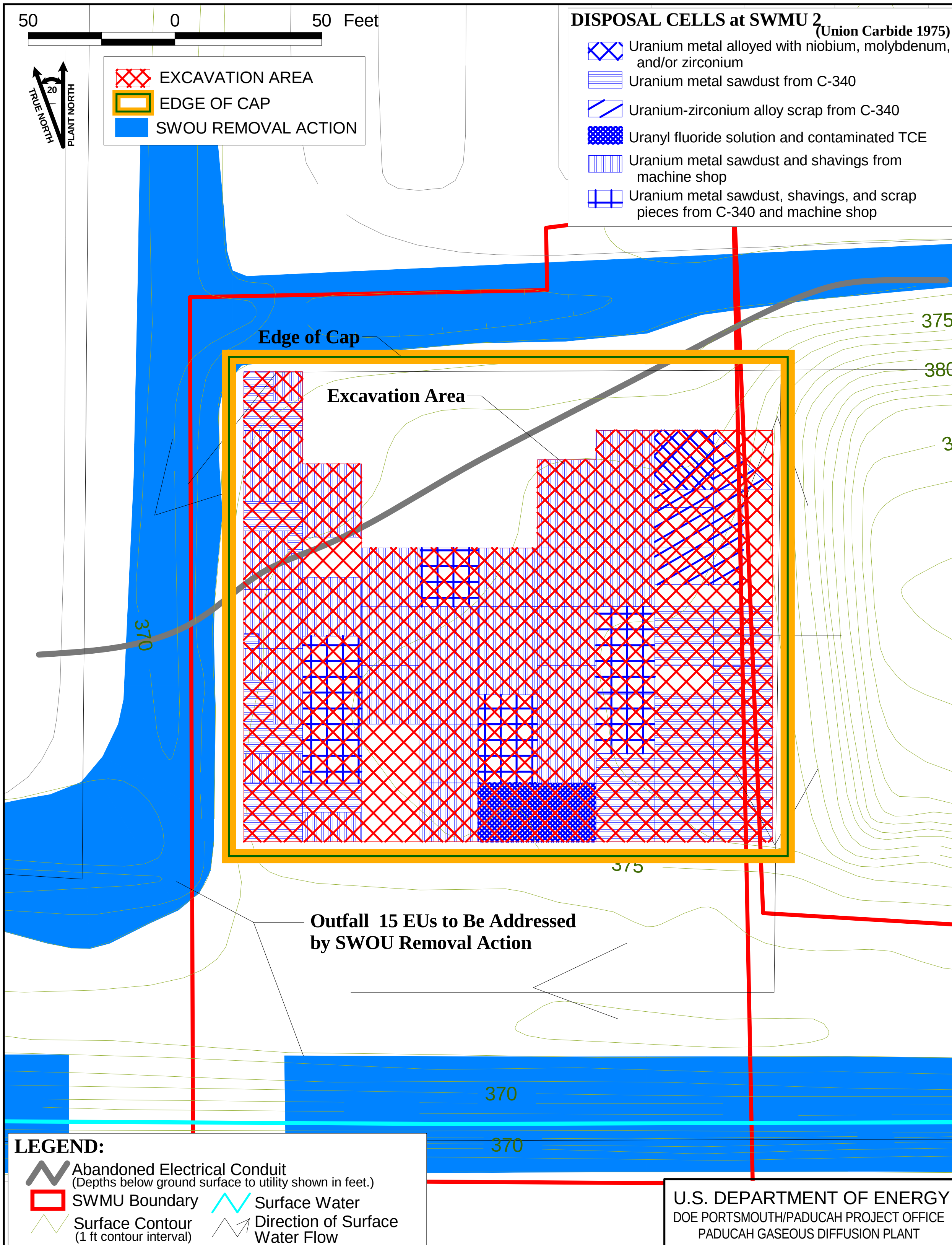


Figure 5.2. SWMU 2 Treatment Area

Figure No. \BGOU\FS_2-EXCR2.apr
DATE 09-17-09

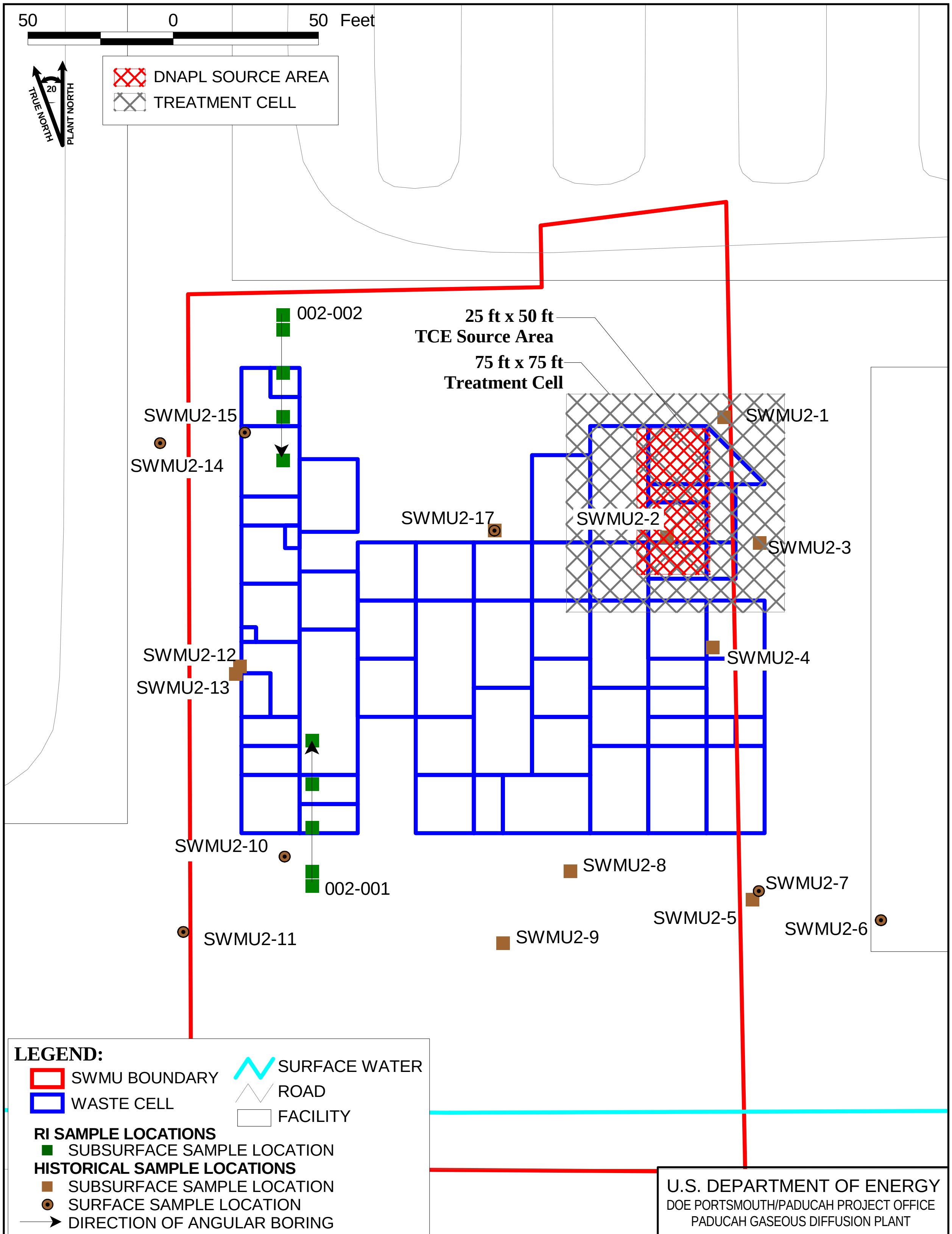


Figure 5.3. Location of SWMU 2 Potential DNAPL Source Area and Treatment Cell

Figure No. \BGOU\FS_2-VOCR1.apr
DATE 09-23-09

Table 5.1. Source Area Alternative Screening Summary for SWMU 2

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	Alternative 9
Screening Criteria	**No Action**	**Limited Action**	**Soil Cover and Long-Term Monitoring**	**Soil Cover with *In situ* DNAPL Source Treatment and Long-Term Monitoring**	**RCRA Cover with Hydraulic Isolation and Long-Term Monitoring**	**Excavation and Disposal**	**Excavation and Disposal combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring[1]**	**Excavation and Disposal combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring[1]**	***In situ* Containment and Long-Term Monitoring**
Overall Effectiveness	NA	NA	NA[2]	NA[3]	Moderate to High[4]	NA[5]	High	Low to Moderate	Moderate to High
Short-term	NA	NA	NA	NA	High	NA	Moderate	Low	Moderate
Long-term	NA	NA	NA	NA	Moderate	NA	High	High	Moderate to High
Overall Implementability	NA	NA	NA	NA	Moderate to High	NA	Moderate	Low to Moderate	Moderate
Technical	NA	NA	NA	NA	Moderate to High	NA	Moderate[6]	Moderate[6]	Moderate
Administrative	NA	NA	NA	NA	Moderate	NA	Moderate	Low	Moderate
Overall Cost	NA	NA	NA	NA	Moderate	NA	High	High	Moderate
Capital	NA	NA	NA	NA	Moderate	NA	High	High	Moderate
Operation and maintenance	NA	NA	NA	NA	High	NA	Low to Moderate	Low to Moderate	Moderate

NA—Not applicable based on-site conditions or nature of contamination present at the SWMU.
[1] Both *in situ* and *ex situ* DNAPL source treatment is a contingency at SWMU 2 in the event DNAPL is present after excavation.
[2] Not effective in remediating buried radioactive and inorganic materials. Provides no contingency for remediation of potential DNAPL source.
[3] Not effective in remediating buried radioactive and inorganic materials.
[4] Effective for containing buried radioactive and inorganic contaminants; moderately effective for containing potential DNAPL confined to UCRS.
[5] Provides no contingency for remediation of potential DNAPL source.
[6] Proximity to SWMU 3 and potential for encountering pyrophoric uranium may make technical implementation more challenging.
NOTE: Alternatives shaded grey were screened out at this step.

5.3.1.1 Alternative 2—Limited action

Alternative 2, which consists of long-term groundwater monitoring only, is screened from further consideration at SWMU 2. The RI Report documents the presence of uranium, which may be pyrophoric, and also cites the potential presence of DNAPL contamination at the SWMU. Alternative 2 provides no protection from these contaminants.

5.3.1.2 Alternative 3—Soil cover and long-term monitoring

Alternative 3, soil cover and long-term monitoring, is screened from further consideration for SWMU 2 because the data in the RI Report indicate that buried wastes at the SWMU are in contact with the water table, and construction of a soil cover may not prevent the continued leaching of contaminants to groundwater. The RI report indicates that the water table within the BGOU ranges from 5 to 10 ft bgs and intrudes into buried wastes at the SWMU. Although this alternative would not treat or remove the potentially pyrophoric uranium that is present, it provides limited protection against direct contact and infiltration of water from the surface.

5.3.1.3 Alternative 4—Soil cover with *in situ* DNAPL source treatment and long-term monitoring

Although this alternative is capable of remediating a potential DNAPL source at SWMU 2, Alternative 4 is screened from further consideration for SWMU 2 because the data in the RI Report indicate that buried waste at the SWMU is in contact with the water table. Construction of a soil cover without any mechanism to reduce lateral flow will provide only limited reduction in leaching of radioactive and inorganic contaminants to groundwater.

5.3.1.4 Alternative 6—Excavation and disposal

Alternative 6 is screened from further consideration at SWMU 2 because it does not incorporate contingency RPOs for remediation of a potential DNAPL source at SWMU 2, should it exist.

5.3.2 Summary of Alternatives Retained for Detailed Analysis

The following alternatives are carried forward for detailed analysis at SWMU 2.

- Alternative 1: No action
- Alternative 5: RCRA cover, hydraulic isolation, and long-term monitoring
- Alternative 7: Excavation and disposal combined with *in situ* DNAPL source treatment and long-term monitoring
- Alternative 8: Excavation and disposal combined with *ex situ* DNAPL source treatment and long-term monitoring
- Alternative 9: *In situ* containment and long-term monitoring

Comparative analyses of these alternatives are performed following the detailed analyses.

5.4 DETAILED ANALYSIS OF ALTERNATIVES

5.4.1 Alternative 1—No Action

The No Action alternative is defined in accordance with CERCLA and provides a baseline to which other alternatives can be compared. Under this alternative, no action would be taken to implement remedial activities for SWMU 2 or to reduce the potential hazard to human or ecological receptors.

5.4.1.1 Overall protection of human health and the environment

This alternative would not be protective of groundwater Potentially pyrophoric uranium would not be treated, removed, or contained at SWMU 2. The results of the risk-based evaluation of the No Action alternative indicate a possible threat to human health via the groundwater pathways presented in Figure 2.1. No additional controls would be implemented to protect site workers or the public. Not all of the RAOs, particularly protection of groundwater, would be met because no action would be implemented.

Alternative 1 would not meet this threshold criterion for a DNAPL source. A potential DNAPL source would not be treated or removed, risks to potential receptors would not be reduced, and the RAOs would not be met because no action would be implemented.

5.4.1.2 Compliance with ARARs

No ARARs have been identified for Alternative 1, the No Action alternative.

5.4.1.3 Long-term effectiveness and permanence

Alternative 1 provides no long-term effectiveness or permanence. Future potential leaching of contaminants to the RGA may result in concentrations above their MCL or risk-based value. Alternative 1 leaves the risk or hazard from radioactive or inorganic COCs at current levels at the SWMU. Over time, this alternative would not prevent future migration of contaminants. Alternative 1 would leave the risk or hazard from a DNAPL source, if one exists, at an unacceptable level at SWMU 2. The alternative does not provide any long-term remedy to manage residual risk at this SWMU.

5.4.1.4 Reduction of toxicity, mobility, or volume through treatment

Treatment would not be implemented with Alternative 1. Reduction of toxicity, mobility, or volume through treatment would not be applicable to the No Action alternative because it does not include treatment. The No Action alternative would not result in any reduction in the toxicity, mobility, or volume of contaminants other than those attributable to natural processes, such as degradation, dilution, or dispersion.

5.4.1.5 Short-term effectiveness

No actions would be implemented under Alternative 1; therefore, no risks to remediation and site workers, the public, or the environment would be incurred. There would be no change to existing conditions. RAOs would not be met over any reasonable time period.

5.4.1.6 Implementability

The No Action alternative can be implemented readily. If future remedial action is necessary, this alternative would not impede its implementation.

The ongoing public awareness program would require regular coordination with DOE, KY, and possibly with other governmental agencies.

5.4.1.7 Cost

The preliminary cost estimates for Alternative 1 serve as a baseline for comparison of the other remedial alternatives. These cost estimates are based upon FS-level scoping and are intended to aid with selection of a preferred alternative. There are no capital or O&M costs associated with Alternative 1.

5.4.2 Alternative 5—RCRA Cover, Hydraulic Isolation, and Long-Term Monitoring

Implementation of Alternative 5 consists of the following three components: (1) continuation/expansion of environmental media monitoring to track contaminant migration from the unit and determine the effectiveness of remedial actions implemented at the SWMU; (2) construction of a low-permeability cap to prevent exposure to contaminated surficial soils and minimize infiltration to mobilize residual subsurface contamination; and (3) construction of a vertical subsurface barrier system to prevent mobilization of subsurface contaminants that could degrade water quality in the RGA. In addition, it has been assumed that groundwater collection and treatment will be required for Alternative 5, with volumes dependent on the effectiveness of the cover and vertical barriers in preventing surface water and groundwater inflows into the contained volume.

5.4.2.1 Overall protection of human health and the environment

Alternative 5 would meet this threshold criterion for SWMU 2. A cover provides a physical barrier between receptors and contaminated surface soils, thus preventing direct contact and the associated risk. A cover provides a direct reduction in mobility of surface contamination and a reduction in migration of subsurface vadose zone contamination by preventing infiltration. A cover designed to reduce infiltration by 90% will reduce the migration of contaminants sufficiently to meet MCLs or risk-based values at the UCRS–RGA boundary beneath the SWMU and hence meet the RAO for groundwater protection. Estimated infiltration reduction rates necessary to meet the RAO for groundwater protection are presented in Appendix B. Construction of a vertical subsurface barrier would further prevent migration of contaminants to the RGA. Both uranium and the potential DNAPL source at SWMU 2 would be contained. LUCs (Section 2.4.1.1) protect current and future site workers and the public.

5.4.2.2 Compliance with ARARs

Alternative 5 would meet this threshold criterion for SWMU 2. ARARs for this alternative are summarized in Appendix F.

5.4.2.3 Long-term effectiveness and permanence

Installation of a low-permeability cap would provide direct protection against exposure to residual surface contamination, diminish external penetrating radiation, and indirectly prevent exposure to residual subsurface waste and contamination. The cap would be placed over the surficial contamination, thereby eliminating the exposure pathway, and would limit the amount of infiltration of precipitation and its effect of mobilizing the waste. Long-term effectiveness is dependent upon a number of factors, including construction materials, construction methods, and maintenance of the cap.

Installation of a vertical subsurface barrier system would provide direct protection against exposure to subsurface waste and contamination; the barrier would be placed around the residual contamination and waste mass, thereby minimizing contaminant migration to the RGA. The ability to maintain effective near surface groundwater control is challenging because the barrier system has no ability to control vertical release from the waste. The vertical barriers should be designed to key into the low-permeability HU3 unit, located approximately 12 m (40 ft) below grade in the vicinity of the unit, which will be utilized as a horizontal barrier.

Alternative 5 is designed to limit exposure to surface and subsurface contamination and minimize the contribution of contaminants to the RGA. After implementation of Alternative 5, wastes would remain at the unit; however, the waste would be managed effectively.

5.4.2.4 Reduction of toxicity, mobility, or volume through treatment

Alternative 5 does not include any treatment or removal technologies; therefore, a reduction in toxicity, or volume through treatment would not be achieved. However, a direct reduction in the mobility of the subsurface contamination would be achieved by constructing a vertical subsurface barrier system. Additionally, an indirect reduction in the mobility of subsurface contamination would be achieved through limiting infiltration by constructing a low-permeability cap over the SWMU.

5.4.2.5 Short-term effectiveness

Implementation of Alternative 5 has low potential for remediation worker exposure to surficial soil contamination and residual subsurface contamination through construction of vertical subsurface barriers and cover. Exposure to contaminated surface soils, subsurface soils, and groundwater during environmental sampling is also low. Potential exposure pathways include inhalation of dust containing surficial soils, dermal contact with surficial and subsurface soils, exposure to external penetrating radiation associated with buried waste, and dermal contact with contaminated groundwater. While estimated risks associated with these exposures are greater than Alternative 1, they are much less than excavation and are considered manageable because LUCs (E/PP Program) protect current site workers.

No ecological impacts at the BGOU are anticipated under this alternative. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archaeological or historical sites or T&E species would be impacted by this alternative. Risk assessment and mitigation for ecological receptors in nearby drainage ditches are within the scope of the Surface Water OU.

The RAOs for SWMU 2 will be met when the vertical barriers are in place and the cap construction is completed.

5.4.2.6 Implementability

Implementation of the remedial action components of Alternative 5 is technically feasible, and the alternative consists of demonstrated technologies, standard construction methods, materials, and equipment that are available from vendors and contractors. Groundwater flow is predominantly downward in the UCRS, but there will be some minor lateral flow due to heterogeneities in the shallow soils that may impact the implementation of hydraulic isolation technology.

5.4.2.7 Cost

O&M costs for Alternative 5 are considered high because, in addition to long-term monitoring costs, there are potential continuing costs for dewatering and water treatment, as well as cover inspection and maintenance.

5.4.3 Alternative 7—Excavation and Disposal Combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring

This alternative is comprised of excavation to remove waste and contaminated soil, followed by a contingency RPO for *in situ* DNAPL source treatment to remove residual DNAPL that may remain after excavation. The excavation component of this alternative includes the following: installation of sheet piles around the perimeter of the waste unit; excavation of all buried materials and contaminated soils; operation of emission control equipment; cover soil and waste disposal characterization sampling; excavation pit dewatering; and segregation, bulking, and consolidation of compatible waste groups. In addition, treatment of excavated materials may include the following: *ex situ* thermal desorption to drive off VOCs and SVOCs; metal detection/magnetic separation of metallic materials (decayed drums and uranium for stabilization/solidification); and radiological separation. For the treatment and segregation operations, short-term storage would be required for the excavated waste and for treated materials awaiting shipment to the disposal site. Disposal options include off-site disposal facilities, as well as the WDF. The contingency RPO for potential residual DNAPL is *in situ* DNAPL source treatment, assumed to be ERH for the purpose of cost estimation. A detailed description of this alternative is presented in Section 3.4.

5.4.3.1 Overall protection of human health and the environment

Alternative 7 would meet this threshold criterion. Potential short-term risks to remediation workers may include direct contact with the waste material, fire, and inhalation hazards. Potential risks to the public and the environment as a result of uranium fires and potential shipping and handling concerns should be considered for off-site shipments. These concerns are greatly reduced for disposal in the WDF.

Waste and contaminated soil will be physically removed from the SWMU and disposed of in one or more appropriate disposal facilities, including the WDF, thus meeting all RAOs for waste in the former burial pits.

In situ DNAPL source treatment for potential DNAPL at SWMU 2 would meet the RAO for treating waste by removing the potential DNAPL source as vapor and destroying it *ex situ*. It also would meet the RAOs for groundwater protection and worker protection based on previous demonstrations. The C-400 SPH Study (DOE 2003) determined that over 98% of TCE was removed from soil in less than six months, and similar performance would be expected at SWMU 2. LUCs (E/PP Program) protect current site workers.

5.4.3.2 Compliance with ARARs

Alternative 7 would meet this threshold criterion. ARARs for this alternative are summarized in Appendix F.

5.4.3.3 Long-term effectiveness and permanence

Complete excavation offers maximum control of contaminant migration, since no wastes or associated contaminated soils would remain in the SWMU; therefore, this alternative offers a high degree of risk reduction. Complete treatment processes manage or remove hazardous characteristics, or destroy the COCs.

Alternative 7 reduces or eliminates the potential long-term risks associated with contaminants, including those posed by the presence of disposed uranium. Risks associated with direct contact with waste and surface soils will be eliminated since the primary source and associated contaminated soils will be removed; therefore, Alternative 7 allows for a maximum reduction of uncertainties associated with these soils in terms of continued contributions to the hydrogeologic system.

Residual VOCs, in the form of contaminated soils, may remain after excavation; however, the concentrations are not anticipated to result in concentrations at the UCRS-RGA interface that would exceed the MCL or risk-based value. A contingency *in situ* DNAPL source treatment component is incorporated into Alternative 7 for DNAPL removal for this SWMU in the event postremediation samples indicate residual DNAPL after the excavation is completed.

The long-term effectiveness and permanence of Alternative 7 for DNAPL remediation is high because much of the DNAPL in the source areas at SWMU 2 would be removed by *in situ* DNAPL source treatment. VOCs in the extracted vapor would be condensed. Overall removal efficiency is estimated at up to 98% over approximately six months, based on results of the C-400 SPH Study (DOE 2003). The estimated degradation rate for TCE upon completion of active remediation is presented in Appendix B. *In situ* DNAPL source treatment should greatly reduce DNAPL levels in soil, protecting the future site worker and current and future off-site residential groundwater user, thereby reducing site risks to acceptable levels.

5.4.3.4 Reduction of toxicity, mobility, or volume through treatment

This alternative reduces or eliminates the mobility and volume of contaminants from the unit. The toxicity of the treatment residuals also would be drastically reduced and/or eliminated. The removal and disposition of waste and contaminated soil from an unlined burial cell containing COCs to an appropriate disposal facility prevents those contaminants from migrating to the groundwater.

Should it be determined after the excavation is complete that DNAPL is present, this alternative would remove and recondense most of the DNAPL. Overall removal efficiency is estimated at up to 98% over approximately six months, based on results for the C-400 SPH Study (DOE 2003). The *in situ* DNAPL source treatment system design would include measures to reduce the potential for mobilization of DNAPL during treatment. Secondary wastes would include condensed VOC liquids, spent GAC, treated condensate, drill cuttings produced during electrode/vapor recovery well installation, PPE, and decontamination fluids. For cost-estimating purposes, drill cuttings, PPE, and decontamination fluids were assumed to be dewatered, sampled, and analyzed prior to bulk transport to off-site disposal. Actual disposal requirements would be determined during RD and by sampling of containerized soils. Condensed VOCs would be shipped off-site for recycling or destruction. Spent GAC would be shipped off-site for regeneration. It is assumed that treated condensate would be discharged directly.

5.4.3.5 Short-term effectiveness

Short-term risks to the community resulting from excavation activities at the SWMU would not be expected; however, there is a potential that pyrophoric uranium at SWMU 2 could combust, creating health concerns for remediation workers, the surrounding public, and the environment. Alternative 7 incorporates measures to prevent or mitigate such an event. Potential risks resulting from migration of contaminants to off-site locations would be controlled by the on-site vacuum hood and HEPA filtration system. Alternative 7 includes a potential risk to the public from transportation of the LLW or hazardous wastes/liquids to off-site disposal and/or treatment facilities. This risk would be greatly reduced by disposing of waste in the WDF.

Short-term exposures of remediation workers to COCs during implementation of Alternative 7 could occur. Potential exposure pathways include direct contact with soil (ingestion, inhalation) and exposure to external penetrating radiation. Worker risks are not expected to exceed acceptable limits because exposure frequency and duration are less than those evaluated in the baseline risk assessment. The pyrophoric nature of the buried waste at SWMU 2 presents additional hazards to remediation workers during excavation. Typically, risks from handling waste/contaminated soils would be minimized through adherence to health and safety protocols. To protect workers, PPE, ambient conditions monitoring, decontamination protocols, and fire suppression measures would be used in accordance with an approved, site-specific HASP.

The short-term effectiveness of Alternative 7 is moderate to high. The alternative includes *in situ* DNAPL source treatment process as a contingency remedial component to remediate a DNAPL source if one is discovered. Installation of electrode/vapor recovery wells and monitoring equipment would encounter contaminated soils. Soil cuttings produced during installation of electrode/vapor recovery wells would be managed in accordance with the HASPs, Waste Characterization Plan (WCP), and Waste Management Plan (WMP) prepared during the RD/RAWP. Installation and operation of the *in situ* DNAPL source treatment system would be conducted by trained personnel in accordance with procedures. Site preparation and *in situ* DNAPL source treatment system operation is expected to require less than one year.

Excavation and disposal would be conducted by trained personnel in accordance with standard radiological, engineering, and operational procedures, documented safety analyses (DSAs), HASPs, and safe work practices to maintain a work environment that minimizes injury or exposure to risks to human health or the environment.

No ecological impacts at the BGOU are anticipated under this alternative. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archaeological or historical sites or T&E species would be impacted by this alternative. Risk assessment and mitigation for ecological receptors in nearby drainage ditches is within the scope of the Surface Water OU.

The RAOs for radioactive and inorganic contaminants would be achieved following completion of excavation. The goal would be to remove as much DNAPL as practicable by the end of the treatment period, but any low-level contaminant residues remaining after a reasonable period of treatment will be remediated by natural attenuation processes.

5.4.3.6 Implementability

Alternative 7 is considered to be technically and administratively feasible and implementable. The equipment and technologies associated with implementation of this alternative have been proven to be technically feasible and are available from contractors or vendors. Treatability testing may be required for waste treatment processes including *ex situ* thermal desorption for excavated soils and uranium oxidation. The implementability of construction-related activities during excavation and backfilling at SWMU 2 subject to Alternative 7 is very similar to that carried out routinely at other sites. Likewise, sampling, analysis, transportation, and disposal at an approved location are routinely performed and, if properly implemented, are proven to be safe. Some excavated waste materials may be radioactive, RCRA hazardous, PCB-contaminated, or a combination. Treatment of wastes with multiple regulatory classifications is more complex and may require more than one treatment process to make the waste suitable for transportation and/or land disposal. On-site treatment processes will comply with ARARs. Care must be exercised in the implementation of any excavation alternative at SWMU 2 to avoid negatively impacting the existing RCRA cap and its performance at adjacent SWMU 3. The proximity of SWMU 3 to SWMU 2 makes the logistics of excavation challenging.

Overall implementability of Alternative 7 for DNAPL is moderate to high. Waste material will be removed during excavation that could interfere with underground construction of the *in situ* DNAPL source treatment system.

Equipment, personnel, and services required to implement this alternative are readily commercially available. No additional development of these technologies would be required. Contractors possessing the required skills and experience are available.

Implementation of Alternative 7 for DNAPL remediation is administratively feasible. The electrode/vapor extraction wells would be constructed and abandoned according to the substantive requirements of KY regulations. Recovered vapor would be treated to meet allowable emission levels prior to discharge.

An option for disposal of waste and residuals at the WDF was considered under Alternative 7. The primary difference would be the elimination of waste leaving the PGDP, related off-site transportation issues, and the cost for disposal. At this time, no capacity for disposal of these wastes exists at PGDP. The following discussion assumes that future capacity to treat and dispose of the mixed and/or LLW at PGDP is available.

The PGDP disposal facility WAC would provide the basis for determining if waste sent to that facility is acceptable.

Wastes would be loaded into trucks and transported to the on-site disposal facility at the PGDP. Wastes would be placed in the disposal facility so that the potential for releases, danger from the mixing of incompatible or unstable outdated materials, and environmental and personal exposures are minimized.

5.4.3.7 Cost

Costs were estimated for transportation and disposal of wastes at an off-site facility as well as for an option to dispose of waste at the WDF. O&M costs are dependent upon the status of the SWMU upon completion of excavation. Cost will be low if SWMU closure can be achieved upon completion of excavation and a long-term monitoring program is minimal or unnecessary. Alternative 7 also includes cost for implementation of a contingency remediation of DNAPL employing *in situ* DNAPL source treatment.

5.4.4 Alternative 8—Excavation and Disposal Combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring

This alternative is comprised of excavation to remove waste and contaminated soil, followed by a contingency RPO for *ex situ* DNAPL source treatment to remove DNAPL that potentially may remain after excavation of the buried wastes and long-term monitoring to confirm no further impacts to groundwater. The buried waste excavation component of this alternative includes the following: shoring around the perimeter of the waste unit; excavation of all buried materials and contaminated soils; operation of emission control equipment; cover soil and waste disposal characterization sampling; excavation pit dewatering; and segregation, bulking, and consolidation of compatible waste groups. In addition, treatment of excavated materials may include the following: *ex situ* thermal desorption to drive off VOCs and SVOCs (TCE and PCBs); metal detection/magnetic separation of metallic materials (decayed drums and uranium for stabilization/solidification); and radiological separation. For the treatment and segregation operations, short-term storage would be required for the excavated waste and for treated materials awaiting shipment to the disposal site. Disposal options include off-site disposal facilities, as well as the WDF.

The contingency RPO for potential residual DNAPL is *ex situ* DNAPL source treatment. It consists of excavation of the DNAPL source and treatment, which is assumed to be oxidation for the purpose of cost estimation. A detailed description of this alternative is presented in Section 3.4.

5.4.4.1 Overall protection of human health and the environment

Alternative 8 would meet this threshold criterion. Potential short-term risks to remediation workers may include direct contact with the waste material, fire, and inhalation hazards and are greater than for any of the other alternatives evaluated for this SWMU. The greatest considerations for off-site shipments are the potential risks to the public and the environment as a result of uranium fires and shipping and handling. These concerns are greatly reduced for disposal in the WDF.

Waste and contaminated soil will be physically removed from the SWMU and disposed of in one or more appropriate disposal facilities, including the WDF, thus meeting all RAOs for waste in the former burial pits.

Ex situ DNAPL source treatment for potential DNAPL at SWMU 2 would meet the RAO for treating waste by removing the potential DNAPL source and destroying it *ex situ*. It also would meet the RAOs for groundwater protection and worker protection. Long-term monitoring will verify that target concentrations are met after the action is complete.

5.4.4.2 Compliance with ARARs

Alternative 8 would meet this threshold criterion. ARARs for this alternative are summarized in Appendix F.

5.4.4.3 Long-term effectiveness and permanence

Complete excavation offers maximum control of contaminant migration, since no wastes or associated contaminated soils would remain in the SWMU; therefore, this alternative offers a high degree of risk reduction. Complete treatment processes manage or remove hazardous characteristics or destroy the COCs.

Alternative 8 reduces or eliminates the potential long-term risks associated with contaminants, including those posed by the presence of disposed uranium. Risks associated with direct contact with waste and surface soils will be eliminated since the primary source and associated contaminated soils will be removed; therefore, Alternative 8 allows for a maximum reduction of uncertainties associated with these soils in terms of continued contributions to the hydrogeologic system.

Residual VOCs, in the form of contaminated soils, may remain after excavation; however, the concentrations are not anticipated to result in concentrations at the UCRS-RGA interface that would exceed the MCL or risk-based value. A contingency *ex situ* DNAPL source treatment component is incorporated into Alternative 8 for DNAPL removal for this SWMU in the event postremediation samples indicate residual DNAPL after the excavation is completed.

The long-term effectiveness and permanence of Alternative 8 for DNAPL remediation is high because the DNAPL in the source areas at SWMU 2 would be removed and treated. VOCs in the vapor from the thermal desorber would be captured and/or condensed. In the event that some TCE contaminated soils remain, the estimated degradation rate for TCE upon completion of active remediation is presented in Appendix B. *Ex situ* DNAPL source treatment will remove DNAPL contaminated soil, thereby reducing or eliminating site risks. Long-term monitoring will be implemented as part of this alternative to verify target concentrations have been met. Long-term groundwater monitoring will be conducted to confirm no further impacts to groundwater.

5.4.4.4 Reduction of toxicity, mobility, or volume through treatment

This alternative reduces or eliminates the mobility and volume of contaminants from the unit. The toxicity of the treatment residuals also would be drastically reduced and/or eliminated. The removal and disposition of waste and contaminated soil from an unlined burial cell containing COCs to an appropriate disposal facility prevents those contaminants from migrating to the groundwater.

Should it be determined after the excavation of buried waste is complete that DNAPL is present, this alternative would remove and capture or condense most of the DNAPL at the SWMU. The *ex situ* DNAPL source treatment system design would include measures to reduce the potential for mobilization of DNAPL during treatment. Secondary wastes may include condensed VOC liquids, spent GAC, treated condensate, treated soil, and PPE. For cost-estimating purposes, treated soil, PPE, and decontamination fluids were assumed to be dewatered, sampled, and analyzed prior to bulk transport to off-site disposal. Actual disposal requirements would be determined during RD and by sampling of containerized soils. Condensed VOCs would be shipped off-site for recycling or destruction. Spent GAC would be shipped off-site for regeneration. It is assumed that treated condensate would be discharged. It is assumed that DNAPL-contaminated soils treated by oxidation will be sufficiently decontaminated to be returned to the excavation. If not, the soils should pass the WAC and be disposed of at the C-746-U Landfill; otherwise, these soils would be disposed of in the WDF or shipped to an off-site disposal facility.

5.4.4.5 Short-term effectiveness

Short-term risks to the community resulting from excavation activities at the SWMU would not be expected; however, there is a potential that pyrophoric uranium at SWMU 2 could combust, creating health concerns for remediation workers, the surrounding public, and the environment. Alternative 8 incorporates measures to prevent or mitigate such an event. Potential risks resulting from migration of contaminants to off-site locations would be controlled by the on-site vacuum hood and HEPA filtration system. Alternative 8 includes a potential risk to the public from transportation of the LLW or hazardous wastes/liquids to off-site disposal and/or treatment facilities. This risk would be greatly reduced by disposing of waste in the WDF.

Short-term exposures of remediation workers to COCs during implementation of Alternative 8 could occur. Potential exposure pathways include direct contact with soil (ingestion, inhalation) and exposure to external penetrating radiation. Worker risks are not expected to exceed acceptable limits because exposure frequency and duration are less than those evaluated in the BHHRA. The pyrophoric nature of the buried waste at SWMU 2 presents additional hazards to remediation workers during excavation. Typically, risks from handling waste/contaminated soils would be minimized through adherence to health and safety protocols. To protect workers, PPE, ambient conditions monitoring, decontamination protocols, and fire suppression measures would be used in accordance with an approved, site-specific HASP.

The short-term effectiveness of Alternative 8 is low. The alternative includes *ex situ* DNAPL source treatment as a contingency remedial component to remediate a DNAPL source if one is discovered. Risk to remediation workers would be higher than other alternatives because of the depth of excavation, the nature of equipment and activities associated with excavation, and the volumes of waste and contaminated soils to be handled. There is a higher potential for fugitive dust and vapors. Transportation issues are fewer for on-site disposal because waste will not leave PGDP property. Soil for treatment would be managed in accordance with the HASPs, WCP, and WMP prepared during the RD/RAWP.

Installation and operation of the *ex situ* DNAPL source treatment system would be conducted by trained personnel in accordance with procedures.

Excavation and disposal would be conducted by trained personnel in accordance with standard radiological, engineering, and operational procedures including, DSAs, HASPs, and safe work practices to maintain a work environment that minimizes injury or exposure to risks to human health or the environment.

No ecological impacts at the BGOU are anticipated under this alternative. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archaeological or historical sites or T&E species would be impacted by this alternative. Risk assessment and mitigation for ecological receptors in nearby drainage ditches is within the scope of the Surface Water OU.

The RAOs for radioactive and inorganic contaminants would be achieved following completion of excavation. The goal would be to remove as much DNAPL as practicable by the end of the treatment period, but any low-level contaminant residues remaining after a reasonable period of treatment will be remediated by natural attenuation processes.

5.4.4.6 Implementability

Alternative 8 is considered to be technically and administratively feasible, but its overall ease of implementation is low to moderate. The equipment and technologies associated with implementation of this alternative have been proven to be technically feasible and are available from contractors or vendors. Treatability testing may be required for waste treatment processes including *ex situ* thermal desorption for excavated soils, and uranium oxidation of potentially pyrophoric uranium. The implementability of construction-related activities during excavation and backfilling at SWMU 2 subject to Alternative 8 is very similar to that carried out routinely at other sites. Likewise, sampling, analysis, transportation, and disposal at an approved location are routinely performed and, if properly implemented, are proven to be safe. Some excavated waste materials may be radioactive, RCRA hazardous, PCB-contaminated, or a combination. Treatment of wastes with multiple regulatory classifications is more complex and may require more than one treatment process to make the waste suitable for transportation and/or land disposal. On-site treatment processes will comply with ARARs. Care must be exercised in the implementation of any excavation alternative at SWMU 2 to avoid negatively impacting the existing RCRA cap and its performance at adjacent SWMU 3. The proximity of SWMU 3 to SWMU 2 makes the logistics of excavation challenging, particularly when considering the overall excavation depths to remove potentially DNAPL-contaminated soil.

Overall implementability of Alternative 8 for DNAPL is low to moderate. DNAPL-contaminated soils will be removed during excavation and treated *ex situ*.

Equipment, personnel, and services required to implement this alternative are readily commercially available. No additional development of these technologies would be required. Contractors possessing the required skills and experience are available, although the space constraints, depth of waste, and potential for groundwater intrusion into the excavation add complexity to the action.

Implementation of Alternative 8 for DNAPL remediation is administratively feasible; however, requirements for control and monitoring of air emissions may be greater than for other alternatives. Recovered vapor would be treated to meet allowable emission levels prior to discharge.

An option for disposal of waste and residuals at the WDF was considered under Alternative 8. The primary difference would be the elimination of waste leaving the PGDP, related off-site transportation issues, and the cost for disposal. At this time, no capacity for disposal of these wastes exists at PGDP. The following discussion assumes that future capacity to treat and dispose of the mixed and/or LLW at PGDP is available.

The PGDP disposal facility WAC would provide the basis for determining if waste sent to that facility is acceptable.

Wastes would be loaded into trucks and transported to the WDF. Wastes would be placed in the disposal facility so that the potential for releases, danger from the mixing of incompatible or unstable outdated materials, and environmental and personnel exposures are minimized.

5.4.4.7 Cost

Costs were estimated for transportation and disposal of wastes at an off-site facility as well as for an option to dispose of waste at the WDF. O&M costs are dependent upon the status of the SWMU upon completion of excavation. Cost will be low if target concentrations are achieved upon completion of excavation and a long-term monitoring program is minimal or unnecessary. Alternative 8 also includes cost for implementation of a contingency remediation of DNAPL employing *ex situ* DNAPL source treatment.

5.4.5 Alternative 9—*In situ* Containment and Long-Term Monitoring

Implementation of Alternative 9 consists of the following three components: (1) a subsurface horizontal barrier; (2) vertical hydraulic barrier; and (3) a structure.

5.4.5.1 Overall protection of human health and the environment

Alternative 9 would meet this threshold criterion for SWMU 2. A structure provides a physical barrier between receptors and contaminated surface soils, thus limiting direct contact and the associated risk. A structure provides a direct reduction in mobility of surface contamination and a reduction in migration of subsurface vadose zone contamination by limiting infiltration. A structure designed to reduce infiltration by 90% will reduce the migration of contaminants sufficiently to meet MCLs or risk-based values at the UCRS–RGA boundary beneath the SWMU and hence meet the RAO for groundwater protection. Estimated infiltration reduction rates necessary to meet the RAO for groundwater protection are presented in Appendix B. Construction of a vertical subsurface barrier would further limit migration of contaminants to the RGA. Both uranium and the potential shallow DNAPL sources at SWMU 2 would be contained by the subsurface horizontal barrier. Long-term monitoring, LUCs (see Section 2.4.1.1), and leachate collection and treatment, if required, protect current and future site workers and the public.

5.4.5.2 Compliance with ARARs

Alternative 9 would meet this threshold criterion for SWMU 2. ARARs for this alternative are summarized in Appendix F.

5.4.5.3 Long-term effectiveness and permanence

Installation of a structure would provide direct protection against exposure to residual surface contamination, diminish external penetrating radiation, and indirectly limit exposure to residual subsurface waste and contamination. The structure would be placed over the unit, thereby eliminating the exposure pathway; this would limit infiltration of precipitation and its effect of mobilizing the waste. Long-term effectiveness is dependent upon a number of factors, including construction materials, construction methods, and maintenance of the structure.

Installation of a vertical subsurface barrier system would provide direct protection against exposure to subsurface waste and contamination; the barrier would be placed around the residual contamination and waste mass, thereby minimizing contaminant migration to the RGA. The ability to maintain effective near surface groundwater control is challenging because the barrier system has no ability to control vertical release from the waste. The vertical barriers would be designed to key into the low-permeability horizontal barrier.

Construction of the horizontal subsurface barrier should limit the downward migration of water or fluids and associated contaminants present in buried wastes. To be effective for years into the future, the constructed barrier must be continuous beneath the waste area, with no breaks or voids that might compromise the integrity of the barrier.

Alternative 9 is designed to limit exposure to surface and subsurface contamination and minimize the contribution of contaminants to the RGA. After implementation of Alternative 9, wastes would remain at the unit; however, they would be fully contained.

5.4.5.4 Reduction of toxicity, mobility, or volume through treatment

Alternative 9 does not include any treatment or removal technologies; therefore, a reduction in toxicity or volume through treatment would not be achieved; however, a direct reduction in the mobility of the subsurface contamination would be achieved by constructing both horizontal and vertical subsurface barrier systems. Additionally, construction of a structure would reduce the mobility of subsurface contamination by limiting infiltration.

5.4.5.5 Short-term effectiveness

Implementation of Alternative 9 has low potential for remediation worker exposure to surficial soil contamination and residual subsurface contamination through construction of vertical subsurface barriers and an overhead structure. Exposure to contaminated surface soils, subsurface soils, and groundwater during environmental sampling also is low. Potential exposure pathways include inhalation of dust containing surficial soils, dermal contact with surficial and subsurface soils, exposure to external penetrating radiation associated with buried waste, and dermal contact with contaminated groundwater. While estimated risks associated with these exposures are greater than Alternative 1, they are much less than excavation and are considered manageable because of LUCs (E/PP Program).

Construction of the barrier could be complicated by factors such as the following:

- The existence of subsurface obstructions or obstacles;
- The need for frequently varying construction alignments;
- Underpassing environmentally contaminated areas;
- The need for protective measures and for special control of jetted effluents when working in hazardous conditions; and
- The need to use grout mixes that are not destroyed by chemicals in the ground.

It is also difficult to determine if the constructed barrier is continuous beneath the waste area with no breaks or voids that might make the barrier less impermeable.

The ability to use relatively light construction machinery makes the system versatile for construction in difficult conditions or tight geometries. The construction can be implemented relatively quickly and essentially anywhere it is needed.

No ecological impacts at the BGOU are anticipated under this alternative. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archaeological or historical sites or T&E species would be impacted by this alternative. Risk assessment and mitigation for ecological receptors in nearby drainage ditches are within the scope of the Surface Water OU.

The RAOs for SWMU 2 will be met when the horizontal and vertical barriers are in place and the structure construction is completed.

5.4.5.6 Implementability

Implementation of the remedial action components of Alternative 9 is technically feasible, and the alternative consists of demonstrated technologies, standard construction methods, materials, and equipment that are available from vendors and contractors. The most challenging element of this alternative is construction of the subsurface horizontal barrier and confirming its integrity. Groundwater flow is predominantly downward in the UCRS, but there will be some minor lateral flow due to heterogeneities in the shallow soils that may impact the implementation of hydraulic isolation technology.

5.4.5.7 Cost

Capital costs are considered moderate for Alternative 9. O&M costs for Alternative 9 are considered high because there will be long-term groundwater monitoring, routine structure inspection and maintenance, and, if required, leachate collection and treatment.

5.5 COMPARATIVE ANALYSIS OF ALTERNATIVES

A comparative analysis summary for contaminated source area alternatives for SWMU 2 is presented in Table 5.2, and the corresponding costs for the alternatives are presented in Table 5.3.

5.5.1 Threshold Criteria

Source area remedial alternatives are compared with respect to the threshold criteria in the following sections.

5.5.1.1 Overall protection of human health and the environment

Alternative 1 does not meet the threshold criterion of overall protection of human health and the environment. Alternative 1 would not treat, contain, or remove waste.

Table 5.2. Summary of Comparative Analysis of Source Area Alternatives SWMU 2

	Threshold Criteria			Primary Balancing Criteria		
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 1: No Action	Does not meet the threshold criterion because no action would be taken. Although it is unlikely that disposed uranium is pyrophoric, it would remain untreated. Potential DNAPL source would remain untreated other than through natural processes. No protection for future off-site groundwater users.	No actions implemented; no ARARs identified.	No long-term effectiveness or permanence.	Low. No direct treatment or containment provided.	High. RAOs would not be met. No actions implemented; therefore, no change to existing conditions.	High. No action would be implemented. High technical and administrative implementability.
Alternative 5: RCRA Cover, Hydraulic Isolation, and Long-Term Monitoring	Moderate. Meets this criterion. More protective than Alternative 1, but less protective than Alternative 7. Prevents direct contact with waste and reduces migration potential by containing uranium and potential DNAPL. Land use controls protect current and future site workers and the public.	High. Complies with ARARs and potential TBCs.	Moderate. Protects against direct contact. Significantly reduces potential for contaminant migration to RGA. Reliability is dependent upon proper design and O&M.	Moderate. No reduction of toxicity or volume. Mobility is greatly reduced through containment. Some potential for contaminated waste generation during construction of vertical barrier.	High. No negative impacts to community. Potential exposure to remediation workers during installation of vertical barrier and cover is much less than for excavation. More short term risk to workers during implementation than Alternative 1, but much less than Alternative 7. Could be completed in months.	High. Proven, reliable technologies that are readily available. While groundwater flow is predominantly downward in the UCRS, there will be some minor lateral flow due to heterogeneities in the shallow soils that may impact the implementation of hydraulic isolation technology.

Table 5.2. Summary of Comparative Analysis of Source Area Alternatives SWMU 2 (Continued)

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 7: Excavation and Disposal combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring	High. Threshold criterion met. Removal of contaminated waste offers the highest degree of overall protection and achievement of RAOs. Potential DNAPL source would be treated in UCRS. Significant reduction in DNAPL mass should be achieved by treatment. Remaining TCE DNAPL would be remediated over time by natural processes. Soil target concentrations should be attained based on results of C-400 Six-Phase Heating (SPH) Study.	High. Threshold criterion met. Complies with ARARs and potential TBCs. Should provide groundwater protection based on results of C-400 SPH Study.	High. Contaminant sources removed. Most adequate overall level of protection to humans and the environment. Long-term monitoring will not be required after action is complete and DNAPL is removed to level that is protective of groundwater.	High. Excavation, treatment and disposal would eliminate mobility of radionuclides, reduce or destroy toxicity of organics and DNAPL, and remove the pyrophoric characteristic from uranium.	Moderate. Potential negative impacts to community from waste excavation (if pyrophoric uranium present) and transportation for off-site disposal. Risk to remediation workers much higher than non-intrusive alternatives but can be managed by applying appropriate health and safety procedures. Improves to high for on-site disposal. Transportation issues become negligible since waste will not leave PGDP property. Implementation could take years.	Moderate. Excavation and associated technologies are readily implementable, although presence of potentially pyrophoric uranium may increase the complexity of excavation procedures in some areas. Proximity to SWMU 3 makes logistics challenging. Some excavated waste materials or soil may have multiple regulatory classifications, increasing the complexity of treatment required for transportation and/or disposal. An on-site waste disposal facility (WDF) is being evaluated as part of the waste disposal option project, and a ROD has not been issued.

Table 5.2. Summary of Comparative Analysis of Source Area Alternatives SWMU 2 (Continued)

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 8: Excavation and Disposal combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring	High. Threshold criterion met. Removal of contaminated waste offers the highest degree of overall protection and achievement of RAOs. Potential DNAPL source would be treated in UCRS. Removal of DNAPL mass should be achieved by excavation and treatment. Soil target concentrations should be attained. Long-term monitoring would verify that target concentrations are met after action is complete.	High. Threshold criterion met. Complies with ARARs and potential TBCs. Should provide groundwater protection.	High. Contaminant sources removed; therefore, no residual risks should remain. Long-term monitoring conducted to confirm no further impacts to groundwater.	High. Excavation, treatment and disposal would remove contamination sources.	Low. Potential negative impacts to community from waste excavation (if pyrophoric uranium present) and from waste transportation for off-site disposal. Risk to workers higher than other alternatives because depth of excavation, and volumes of waste and contaminated soils to be handled. Higher potential for fugitive dust and vapors because of the volumes being treated. Transportation issues less for on-site disposal because waste will not leave PGDP property. Implementation could take years.	Low. Presence of potentially pyrophoric uranium may increase the complexity of excavation procedures in some areas. Proximity to SWMU 3 and overall depth of excavation makes logistics challenging. Some excavated waste materials or soil may have multiple regulatory classifications, increasing the complexity of treatment, transportation and/or disposal. WDF is being evaluated as part of the waste disposal option project. and a ROD has not been issued.
Alternative 9: *In situ* Containment and Long-Term Monitoring	Moderate to high. Meets this criterion. More protective than Alternative 5, but less protective than Alternative 7. Prevents direct contact with waste and reduces migration potential by containing uranium and potential DNAPL. Land use controls protect current and future site workers and the public.	High. Complies with ARARs and potential TBCs.	Moderate to high. Protects against direct contact. Significantly reduces potential for contaminant migration to RGA. Effectiveness and reliability are primarily dependent upon proper design and construction to ensure integrity of horizontal barrier.	Moderate. No reduction of toxicity or volume. Mobility is greatly reduced through containment. Some potential for contaminated waste generation during construction of horizontal and vertical barriers.	Moderate. Negative impacts to community from construction can be controlled. Potential for exposure to contaminated soil and slurry by remediation workers during construction of horizontal and vertical barriers. Potentially more short-term risk to workers during implementation than Alternative 5, but less than Alternative 7. Could be completed in months.	Moderate. Mostly proven, reliable technologies that are readily available. The construction of horizontal subsurface barriers and verifying their integrity are less proven than the other construction elements. While groundwater flow is predominantly downward in the UCRS, there will be some minor lateral flow due to heterogeneities in the shallow soils that may impact the implementation of hydraulic isolation technology.

Table 5.3. SWMU 2 Remedial Alternatives Cost Estimate Summary

			PRESENT WORTH[1]		ESCALATED	
Alternative Description	**Annual Time Period, yrs**	**Capital $ (2010 Constant Dollars)**	**Total Annual $**	**Total $ (Capital and Annual)**	**Alternative Description**	**Annual Time Period, yrs**
Alternative 1—No Action	0	$0	$0	$0	Alternative 1—No Action	0
Alternative 5—RCRA Cover with Hydraulic Isolation and Long-Term Monitoring	30	$8,337,000	$5,914,000	$14,251,000	Alternative 5—RCRA Cover with Hydraulic Isolation and Long-Term Monitoring	30
Alternative 7a—Excavation and Disposal	0	$37,177,000	$0	$37,177,000	Alternative 7a—Excavation and Disposal	0
Alternative 7b—Excavation and Disposal (at Proposed On-Site WDF)	0	$28,994,000	$0	$28,994,000	Alternative 7b—Excavation and Disposal (at Proposed On-Site WDF)	0
Contingency for Alternative 7—Combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring	30	$8,556,000	$733,000	$9,289,000	Contingency for Alternative 7—Combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring	30
Alternative 8a—Excavation and Disposal	0	$37,177,000	$0	$37,177,000	Alternative 8a—Excavation and Disposal	0
Alternative 8b—Excavation and Disposal (at the WDF)	0	$28,994,000	$0	$28,994,000	Alternative 8b—Excavation and Disposal (at the WDF)	0
Contingency for Alternative 8—Combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring	30	$25,510,000	$739,000	$26,249,000	Contingency for Alternative 8—Combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring	30
Alternative 9—*In situ* Containment with Long-Term Monitoring	30	$13,695,000	$3,767,000	$17,462,000	Alternative 9—*In situ* Containment with Long-Term Monitoring	30

[1] Not used for budgeting or planning purposes because value is based on investing funds for outyear expenditures.

Alternative 5, RCRA cover (designed to provide > 90% reduction in infiltration), would meet the threshold criterion by containing wastes and TCE in soil at the SWMU. No waste would be treated or removed, but placement of a cover in conjunction with a vertical barrier would control surface infiltration as well as lateral infiltration to reduce or prevent further migration of contamination to groundwater. LUCs (see Section 2.4.1.1) would protect current and future site workers and the public. The modeling approach and results that support this prediction are presented in Appendix B. While the short-term risks associated with excavation can be mitigated by proper engineering precautions in achieving long-term risk reduction, the trade-offs of removing risks that can be managed at the unit for risks during excavation and removal are significant factors that favor Alternative 5.

Alternative 7, excavation and disposal combined with *in situ* DNAPL source treatment, meets the threshold criterion by removing waste and contaminated soil from the SWMU. This alternative would treat uranium chips, turnings, and fines in waste and contaminated soil to remove the reactive (pyrophoric) characteristic from the material. This alternatives could remove enough waste and contaminated soil so that the remaining soil at the SWMU would meet soil target concentrations and attain MCLs or risk-based values in RGA groundwater at the UCRS-RGA boundary beneath the SWMU.

Should residual DNAPL remain upon completion of excavation, implementation of the *in situ* DNAPL source treatment component of Alternative 7 will remove DNAPL in soil. Based on the maximum observed concentration of TCE at SWMU 2 and modeling based on 98% removal of TCE DNAPL observed during the C-400 SPH Study (DOE 2003), the results were estimated for DNAPL removal after operating the system for less than one year. The time frames for reaching the maximum TCE concentration, and the risk-based target concentrations necessary to meet the MCL beneath the SWMU. There is minimal benefit to operating the *in situ* DNAPL source treatment system for a longer than one year. The modeling approach and results are presented in Appendix B.

Alternative 8, which excavates buried waste and provides a contingency for excavation and *ex situ* treatment of DNAPL, if it is determined to be present, meets this threshold criterion by removing waste and contaminated soil. This alternative is at least as, if not more protective than, Alternative 7.

Alternative 9, *in situ* containment (designed to provide > 90% reduction in infiltration), would meet this threshold criterion by containing wastes and TCE DNAPL in soil at the SWMU. No waste would be treated or removed, but placement of a structure, in conjunction with both horizontal and vertical barriers, would control surface infiltration as well as lateral infiltration to reduce or limit future migration of contamination to groundwater. LUCs (see Section 2.4.1.1) would protect current and future site workers and the public. The modeling approach and results that support this prediction are presented in Appendix B. While the short-term risks associated with excavation can be mitigated by proper engineering precautions in achieving long-term risk reduction, the trade-offs of removing risks that can be managed at the unit for risks during excavation and removal are significant factors that favor Alternative 9.

5.5.1.2 Compliance with ARARs

No ARARs have been identified for Alternative 1, the No Action alternative.

Alternative 5 would meet this threshold criterion. It would contain waste and contaminated soil and reduce or prevent migration of contaminants to RGA groundwater at the UCRS-RGA boundary beneath the SWMU. This alternative is expected to meet all location- and action-specific ARARs through design and planning during preparation of the RD/RAWP. Monitoring environmental media would further assure compliance with ARARs for this alternative.

Alternative 7 would meet this threshold criterion. This alternative could remove enough waste and contaminated soil so that the remaining soil at the SWMU would meet soil target concentrations and attain MCLs or risk-based values in RGA groundwater at the UCRS-RGA boundary beneath the SWMU. Should residual DNAPL remain upon completion of excavation, Alternative 7 would remove a large portion of the residual DNAPL mass in soil during the period of operation of the *in situ* DNAPL source treatment system, and natural processes would, in time, prevent further degradation of RGA groundwater from SWMU 2. This alternative is expected to meet all location- and action-specific ARARs through design and planning during preparation of the RD/RAWP.

Alternative 8 would meet this threshold criterion as well or better than Alternative 7.

Alternative 9 would meet this threshold criterion. It would contain waste and contaminated soil and reduce or limit migration of contaminants to RGA groundwater at the UCRS-RGA boundary beneath the SWMU. This alternative is expected to meet all location- and action-specific ARARs through design and planning during preparation of the RD/RAWP. Monitoring environmental media would further assure compliance with ARARs for this alternative.

5.5.2 Balancing Criteria

Source area alternatives are compared with respect to the balancing criteria in the following sections.

5.5.2.1 Long-term effectiveness and permanence

Alternative 1 would not be effective. The risk posed by waste material and COCs in soil would remain unabated.

Alternative 5 provides a moderate degree of long-term effectiveness and permanence. Residual risk would remain, but it would be contained. This alternative would reduce or prevent contaminant migration so that COCs remaining in place at levels above their target concentrations would make only a minor contribution to contamination of RGA groundwater.

Alternative 7 provides a high degree of long-term effectiveness and permanence. Residual risk should be the lowest under this alternative. Long-term controls may not be required under this alternative provided that waste material and contaminated soil can be removed to attain soil target concentrations. Should residual DNAPL remain upon completion of excavation, *in situ* DNAPL source treatment should be effective at removing the majority of the mass of DNAPL from the UCRS, with the remainder being remediated by natural processes. Residual risk would be the lowest under this alternative.

The long-term effectiveness and permanence of Alternative 8 would be as good as, or better than Alternative 7.

Alternative 9 provides a moderate to high degree of long-term effectiveness and permanence. Residual risk would remain, but it would be contained. This alternative would reduce or limit contaminant migration so that COCs remaining in place at levels above their target concentrations would make only a minor contribution to contamination of RGA groundwater.

5.5.2.2 Reduction of toxicity, mobility, and volume through treatment

Alternative 1 would not reduce the toxicity, mobility, or volume of COCs in waste or soil at SWMU 2.

Alternative 5 does not reduce the toxicity or volume of waste, but it does prevent its migration. A cover prevents surface water infiltration and vertical migration of contaminants. A vertical barrier prevents the lateral migration of contaminants.

Alternative 7 reduces toxicity by removal, treatment, and disposal of wastes. This alternative would treat metallic uranium chips, turnings, and fines to remove the reactive (pyrophoric) characteristic and make it suitable for transportation and land disposal. Other waste materials and soil would be treated on-site as needed to allow excavated materials to be readied for transport or disposal. Volume is similarly reduced. The relocation of waste and contaminated soil from an unlined burial cell that has COCs in direct contact with groundwater to an appropriate disposal facility will reduce the mobility of those contaminants in the environment. Removal of source material and surrounding contaminated soils will prevent future migration of contaminants at the SWMU.

If residual DNAPL is present at SWMU 2, the *in situ* DNAPL source treatment component of Alternative 7 would remove most of the DNAPL mass from the UCRS. It would remove DNAPL from the subsurface to be condensed by aboveground equipment. VOC-contaminated water condensed from the extracted vapor stream would be air stripped to remove VOCs. The VOCs in the air stripper emissions would be condensed and either recycled or destroyed off-site. Residual VOCs in air stripped water would be removed by adsorption on activated carbon. The spent carbon would be managed off-site, likely by thermal regeneration or incineration.

Alternative 8 also reduces toxicity by removal, treatment, and disposal of wastes the same as Alternative 7. There is even less likelihood that DNAPL will remain after active treatment than in the case of Alternative 7 because the DNAPL-contaminated soil, if present, will be excavated and treated. There is a degree of uncertainty associated with identifying and excavating all the contaminated soil for DNAPL treatment.

Alternative 9 does not reduce the toxicity or volume of waste, but it does limit migration of contaminants by containing the waste. A structure limits infiltration of precipitation and surface water to significantly reduce vertical migration of contaminants. A vertical barrier limits the lateral migration of contaminants. A subsurface horizontal barrier limits leaching and migration of contaminants from the waste.

5.5.2.3 Short-term effectiveness

The short-term effectiveness of Alternative 1 is low because RAOs would not be attained over any reasonable time frame.

Alternative 5 is moderately effective. There is minimal risk to remediation workers during installation of the subsurface vertical barrier and cover. Risk to the community is low during this period.

The short-term effectiveness of Alternative 7 is moderate because of the increased potential for contact to workers and the community during excavation. The option to dispose of excavated waste in the WDF would improve the short-term effectiveness by eliminating risks associated with wastes leaving the site. The *in situ* DNAPL source treatment component of Alternative 7 for DNAPL remediation has a high degree of short-term effectiveness. Active remedial action could be completed in a period of less than one year. Alternative 7 potentially could expose workers to chemical hazards during well drilling, installation of electrodes, and operation of the aboveground treatment system. Workers also could be exposed to thermal and electrical hazards due to installation and operation of electrodes. The ERH system is technically complex, but site workers will have gained valuable experience with the technology during the C-400 Remedial Action, so the associated health and safety issues should be effectively managed. The potential risks to the community are negligible from Alternative 7 during the remedial action period for DNAPL.

The short-term effectiveness for Alternative 8 is potentially low. Greater depths of excavation, larger volumes of contaminated soil, potentially larger volumes of wastewater, increased requirements and size for treatment unit operations, and associated emissions significantly increase the risks and are all factors that contribute negatively to the short-term effectiveness of Alternative 8.

Alternative 9 is moderately effective. There is some risk of exposure to remediation workers during installation of the subsurface horizontal and vertical barriers. Risk to the community is low during this construction.

5.5.2.4 Implementability

Alternative 1 would be the most readily implementable alternative because no construction or invasive action would be taken.

The implementability of Alternative 5 is moderate to high as the technology is proven and readily available.

Alternative 7 is considered to be technically and administratively feasible and implementable. The presence of potentially pyrophoric uranium may increase the complexity of the excavation process. For the DNAPL remediation components of the alternative, the SPH Study at C-400 established system design parameters and the range of operating conditions. Subsurface objects that could interfere with construction of the underground components of the *in situ* DNAPL source treatment system would be removed prior to construction. Equipment, personnel, and services required to implement this alternative are readily available. Equipment replacement should be minimal during the remedial action period at any SWMU because RAOs should be achieved within less than one year of operation. The treatment system would generate several waste residuals that would require management, including condensed VOCs, treated water, and VOC-contaminated activated carbon.

Alternative 8 is technically feasible, but there are challenges. The main technical challenges are associated with the depth of excavation and shoring, groundwater control treatment.

The implementability of Alternative 9 is moderate, as the technology is reasonably well proven and readily available.

5.5.2.5 Cost

Capital and O&M costs for alternatives at SWMU 2 are presented in Table 5.3.

5.5.3 Summary of Comparative Analysis of Alternatives

Alternative 1 does not meet the threshold criterion of overall protection of human health and the environment. Alternative 1 would not treat or remove waste. Risk to current and future off-site residential groundwater users from the migration of COCs to RGA groundwater could reach unacceptable levels.

Alternative 5, RCRA cover, would meet the threshold criterion by containing waste and soil contaminated above target concentrations at the SWMU. No waste would be treated or removed, but placement of a cover in conjunction with a vertical barrier would control surface infiltration as well as lateral infiltration to prevent migration of contamination to groundwater. LUCs (see Section 2.4.1.1) would protect current and future site workers and the public. Alternative 5 avoids the potential of encountering pyrophoric uranium during excavation and the possible short-term risks associated with mitigating and controlling its impacts. There would be long-term monitoring and O&M costs and responsibilities associated with Alternative 5.

Alternative 7, excavation and disposal with *in situ* DNAPL source treatment, meets the threshold criteria by removing waste and contaminated soil from the SWMU. This alternative would treat uranium chips, turnings, and fines in waste and contaminated soil to remove the reactive (pyrophoric) characteristic from the material. This alternative would remove enough waste and contaminated soil so that the remaining soil at the SWMU likely would meet soil target concentrations and attain MCLs or risk-based values in RGA groundwater at the UCRS-RGA boundary beneath the SWMU. All ARARs defined for Alternative 7 would be met.

For DNAPL source areas, Alternative 7 provides a high degree of long- and short-term effectiveness. Alternative 7 also provides a high reduction in toxicity, mobility, and volume of contamination through treatment.

Alternative 8 is comparable in long-term effectiveness to Alternative 7, but its short-term effectiveness is less. Alternative 8 is also more challenging to implement than Alternative 7.

Alternative 9, *in situ* containment, would meet the threshold criteria by containing waste and soil contaminated above target concentrations at the SWMU. No waste would be treated or removed, but placement of a structure would control surface infiltration. Construction of both horizontal and vertical barriers limits lateral infiltration of groundwater and provides a low-permeability barrier to limit vertical migration of contamination to groundwater. There are uncertainties associated with construction of a horizontal barrier and being able to verify its continuity and integrity. LUCs (see Section 2.4.1.1) would protect current and future site workers and the public. Alternative 9 avoids the potential of encountering pyrophoric uranium during excavation and the possible short-term risks associated with mitigating and controlling its impacts. There would be long-term monitoring and maintenance costs and responsibilities associated with Alternative 9.

THIS PAGE INTENTIONALLY LEFT BLANK

6. SWMU 3

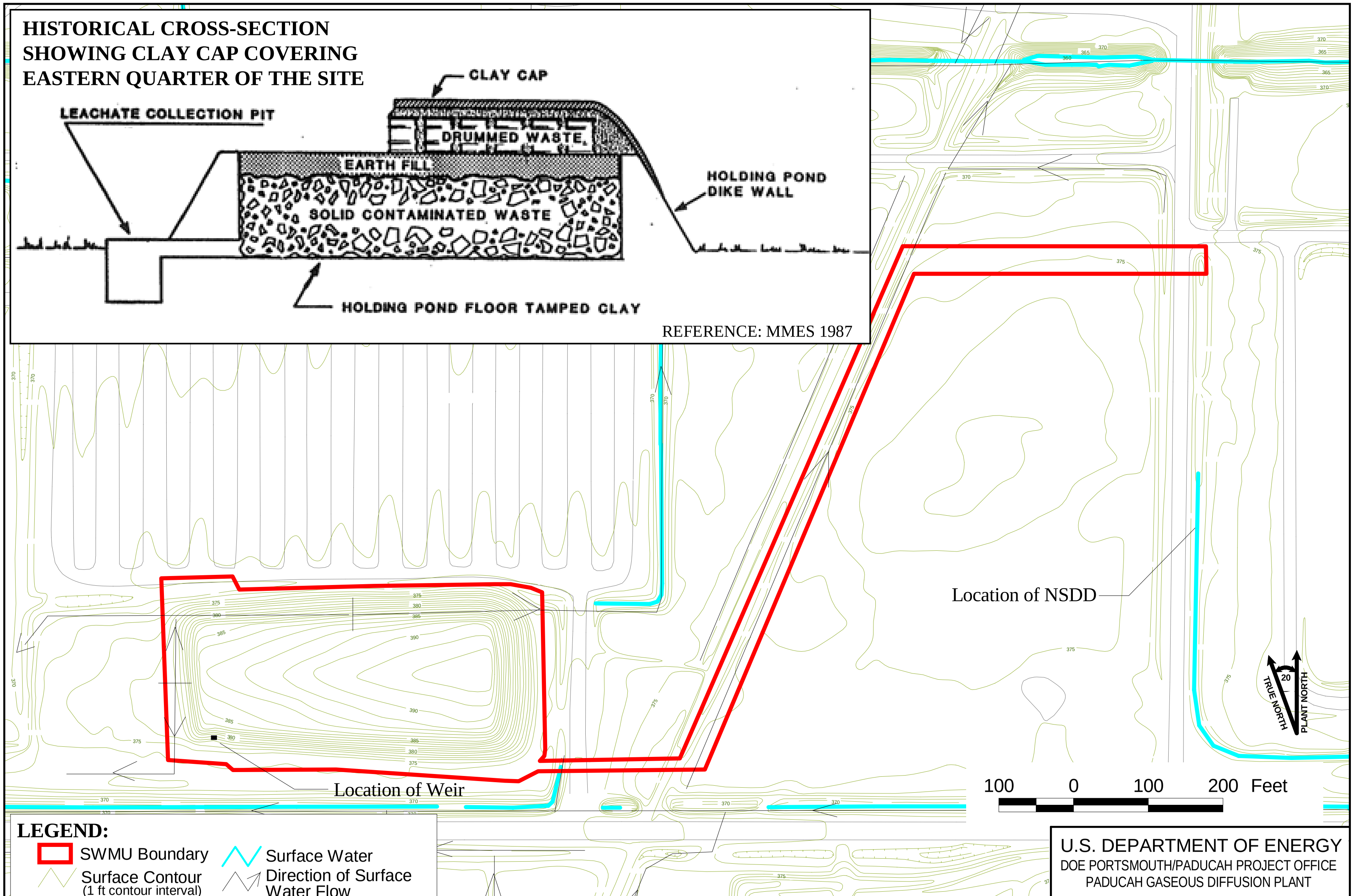
6.1 SWMU 3 HISTORY AND BACKGROUND

The C-404 Low-Level Radioactive Waste Burial Ground (SWMU 3) is 1.2 acres located in the west-central portion of the secured area. The unit originally was constructed as a rectangular, aboveground surface impoundment measuring 387 ft by 137 ft, with a floor area of approximately 53,000 ft^2. The floor of the surface impoundment was constructed of well-tamped earth and clay dikes to a height of 6 ft. The C-404 impoundment was designed with an overflow weir at its southwest corner. From the weir, the surface impoundment effluent flowed west in a ditch (not the NSDD) and eventually discharged through what is now KPDES Outfall 015. Figure 6.1 shows C-404 along with a schematic of this design. Historic effluent/leachate discharges later were rerouted to the NSDD via what is now an abandoned pipeline leading from the northeast corner of the landfill.

SWMU 3 operated as a surface impoundment from approximately 1952 until early 1957. During this time, all influents to the impoundment originated from C-400. In 1957, the C-404 surface impoundment was converted to a solid WDF for solid uranium-contaminated wastes. The waste consists of uranium precipitated from aqueous solutions, uranium tetrafluoride, uranium metal, uranium oxides, degreasing sludge, and radioactively contaminated trash. There are no records documenting the cleanout of sludges and sediments from the pond when it was converted to a landfill. When the C-404 impoundment was converted into a disposal facility, a sump was installed at the weir. Leachate was pumped from the sump through an underground transfer line. The transfer line discharged into a northeast-southwest ditch just east of C-404. From this ditch, the leachate flowed into the NSDD. NSDD historically carried PGDP effluents north to Little Bayou Creek. The date of termination of the leachate discharge through the underground transfer line into the NSDD has not been determined. It is known that, prior to landfill closure in 1986, this underground transfer line to the NSDD was not in operation, and leachate from the C-404 Landfill was being collected in the sump for treatment at the C-400-D Lime Precipitation Unit in the C-400 Facility. At some time following closure of the C-404 Landfill, treatment of leachate from C-404 at C-400 was discontinued, and treatment of the leachate was transferred to the C-752 Remedial Action Waste Holding Facility. Some of the constituents found in the leachate and their ranges have included fluoride (4.8–10mg/L), TCE (1–22 mg/L), PCBs (0.41–1.18 µg/L), neptunium-237 (0.42–11.7 pCi/L), technetium-99 (90.6–365 pCi/L), and uranium-235 (2,160–37,900 pCi/L).

The upper tier of waste within C-404 contains drummed waste similar to that collected in the impoundment plus smelter furnace liners and drums of extraction-procedure, characteristically hazardous, waste [RCRA waste codes D006 (for cadmium), D008 (for lead), and D010 (for selenium)]. The drums of extraction-procedure were produced in C-400 during treatment of wastes including sodium bisulfate solution, hydrochloric acid, chromic acid, nickel stripper solution, miscellaneous acids and alkalis, and aqueous solutions containing metals. A partial clay cap was installed on the eastern end of the landfill in 1982 (DOE 1987).

Approximately 6,615,000 lb of uranium-contaminated waste was disposed at SWMU 3. The total volume is approximately 260,000 ft^3. Some uranium contaminated waste also is contaminated with TCE, radionuclides, and metals. In 1986, the disposal of waste at C-404 Landfill was halted, and a portion of the disposed waste was found to be RCRA-hazardous. The landfill was covered with a RCRA multilayered cap and certified closed in 1987. It currently is regulated under RCRA as a land disposal unit, and compliance is required by a RCRA postclosure permit issued in 1992. The closure plan required continued groundwater monitoring (DOE 1989). A permit modification was submitted in May 2008, revising the MW network for the unit to add a new upgradient well, MW420 (DOE 2008). MW420 is screened in the upper RGA. The permit conditions are summarized in Appendix H.



U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Figure 6.1. SWMU 3 Historical Layout

Figure No. \BGOU\d2-ri sect1.apr
DATE 01-05-09

The most prevalent metal detected above its background values in subsurface soil at SWMU 3 is uranium, followed by antimony. Uranium contamination has migrated to a depth of 10 to 15 ft under C-404 (both as a metal and as a radionuclide) and as much as 10 ft under the former discharge ditch (as a metal). The higher concentrations are found in shallow soils on the western side of the unit. Uranium was not detected above screening levels in the 15-ft samples along the former discharge ditch. Antimony contamination is limited to a depth of 5 to 10 ft along the former discharge ditch. Cesium-137 was detected above screening in one sample at a depth of 5 ft along the former discharge ditch.

For UCRS groundwater, RI and historical data identified levels of at least one metal (arsenic, iron, lead, manganese, molybdenum, and uranium), TCE, technetium-99, and uranium-238 that exceed screening criteria at all sampling locations. Arsenic and uranium are the only UCRS groundwater contaminants that also are SWMU 3 subsurface soil contaminants.

RGA groundwater contaminants exceeding screening levels for SWMU 3 are metals (arsenic, iron, manganese, and uranium); organics (1,1-DCE, chloroform, and TCE), and radionuclides (uranium-234 and uranium-238).

The hydrogeological assessment of SWMUs 2 and 3 that was completed as part of the BGOU RI (PRS 2007) documents that an upgradient source accounts for the high TCE levels. Because the 1,1-DCE detects occurred only in upgradient wells, it also appears to be related to an upgradient source.

Groundwater monitoring under the RCRA permit for the unit, however, has shown statistically significant increases of TCE above background in one of three downgradient compliance wells in the upper RGA (MW84). *C-404 Landfill Source Demonstration, Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (PRS 2007), related the increase in TCE levels to trends in the Southwest Plume and does not indicate that SWMU 3 is the contributor.

6.1.1 Hydrogeologic Interpretation

The study area geology and hydrogeology is summarized below as documented in the BGOU RI (DOE 2010). Because SWMUs 2 and 3 are adjacent to each other, their hydrogeologic interpretation is discussed as one.

Stratigraphy. The burial cells of SWMU 2 are excavated into the HU1 loess member (silt with some clay) of the Upper Continental Deposits. Some waste cells likely extend to near the base of the HU1 unit, at a depth of 18.5 ft. The underlying HU2 interval consists of upper and lower sand and gravel horizons, separated by an intervening clayey silt unit, to a depth of 40 ft. A 9-ft-thick silty clay interval (HU3) separates the HU2 sand and gravel horizons from the basal HU4 sand and the sands and gravels of the LCD (HU5). SWMU 3 rests upon the top of the UCD.

UCRS Groundwater Flow and Hydraulic Potential. The SWMU 2 Data Summary and Interpretation Report (DOE 1997) documents the depth and gradient of the water table in the vicinity of SWMU 3 using measurements from shallow MWs and piezometers. Four rounds of measurements of water level during a one-week period in August 1996 consistently demonstrate that the water table occurred within 10 ft of land surface, sloping toward a ditch on the west side. The westward slope of the water table below SWMU 2 indicates that the water table must be equally shallow beneath SWMU 3. Because SWMU 3 is an aboveground facility with a RCRA multilayered cap, the actual saturation level within the waste is unknown; however, with the shallow water table and generation of leachate, it is assumed that all but the base of the landfill wastes are likely unsaturated.[5]

RGA Groundwater Flow and Hydraulic Potential. The BGOU RI includes a hydrogeological assessment of SWMU 3 (PRS 2007), which documents the primary groundwater pathways in the area RGA. Contaminant trends associated with the Southwest Plume demonstrate convincingly that the dominant groundwater pathway immediately south of SWMU 3 is to the northwest, in agreement with the larger Southwest Plume trend, which passes beneath the south end of SWMU 2. Beneath SWMU 3, the groundwater pathway veers northward.

The governing parameters determining the groundwater flow paths are the higher hydraulic conductivity corridors in the RGA marked by the Southwest Plume and the Northwest Plume to the south and north of SWMU 3, respectively, and the RGA potentiometric surface, which declines to the north. Edges of the Southwest Plume and Northwest Plume approximate boundaries of higher hydraulic conductivity in the HU5 sediments, through which the majority of groundwater flow occurs. Pumping tests of the RGA in the area of the main contaminant plumes on-site (Terran 1992; LMES 1996) have determined the representative hydraulic conductivity to be 1,200 to 1,300 ft/day, which contrasts with the hydraulic conductivity of the RGA beneath SWMU 3, measured as 100 ft/day in a previous pumping test (Terran 1990).

The northward groundwater flow beneath SWMU 3 is an intermediate flow path between the hydraulic conductivity “expressways” delineated by the Southwest Plume (to the south of SWMU 3) and the Northwest Plume (to the north of SWMU 3) and is related to seasonal variations in potentiometric head.

Average RGA groundwater flow velocity in the areas of the contaminant plumes is commonly 1 to 3 ft/day. Hydraulic potential gradients to the north and to the west are commonly similar in the SWMU 3 area. The northward groundwater flow rate beneath SWMU 3 is likely 0.1 to 0.3 ft/day, in step with the order-of-magnitude reduction in hydraulic conductivity beneath SWMU 3.

6.2 SWMU-SPECIFIC RAOS

RAOs that are specific to SWMU 3 were developed based on the findings and observations forthcoming from the BGOU RI Report. The SWMU-specific RAOs generally are directed toward conditions related to the waste materials, the surface soils, and the subsurface soils at the SWMU. A brief statement of the specific problem associated with the SWMU is followed by bulleted RAOs developed to address the problem.

Approximately 6,615,000 pounds of uranium-contaminated waste and wastes in buried drums present a potential future contamination source to soil and groundwater.

- Prevent future contaminant migration to the environment such that it does not present unacceptable risks to future receptors or groundwater.

- Prevent exposure from subsurface soil metals and radionuclides within the SWMU boundary to approximately 16 ft bgs that would cause an unacceptable cumulative risk to future outdoor worker.

---

[5]The continuing recovery of leachate from the facility indicates that some infiltration occurs and the base of the disposal cell must be saturated.

Radionuclides and metals in surface soil present a cumulative ELCR to future industrial workers and an ELCR to current industrial workers, exceeding an ELCR of 1E-06.

- Prevent exposure from surface soil metals and radionuclides that would cause an unacceptable cumulative risk to future industrial workers.

Metals and radionuclides in subsurface soil also exceed concentration criteria for potential threat to a current and future off-site residential groundwater user, exceeding an ELCR=1E-06 and HI=1.

- Prevent migration of radionuclides, VOCs, and metals in soil in the source areas to the RGA groundwater to the extent they do not contribute contamination exceeding MCLs, or in the absence of an MCL, a risk-based concentration.

The FS process began with the full list of COCs identified in the RI Report. A detailed evaluation of the sample results for commonly occurring elements identified in the RI Report as COCs was performed by comparing field sample results against the PGDP site background concentrations. A number of COCs identified in the RI Report were eliminated from further consideration in the FS because they were below background levels. A discussion of the evaluation that was performed and its results are presented in detail in Section 1. The final list of COCs for the SWMU and their preliminary RGs for surface soil and subsurface soil are provided in Appendix C, Tables C.2 and C.3, respectively. Preliminary RGs for the SWMU meet the target cumulative ELCR and HI criteria for both surface and subsurface soil.

The northeast-southwest ditch just east of C-404 that is part of SWMU 3 was assessed independently after the RI for its risk to human health and the environment, and it was determined not to require any further action. The risk assessment for the ditch at SWMU 3 is presented in Appendix I.

6.3 SCREENING OF ALTERNATIVES

Alternatives are screened in this section, using the process described in EPA (1988) and the NCP to reduce the number of alternatives carried forward to detailed analysis. Alternatives are screened with respect to effectiveness, implementability, and cost. The evaluation of effectiveness considers reductions in toxicity, mobility, and volume of COCs. The evaluation of implementability considers technical feasibility criteria, including the ability to construct, operate, and maintain the remedy, and administrative feasibility criteria, including the availability of treatment, storage, and disposal capacity. Evaluation of cost for the alternatives is based on the relative capital and O&M costs for the primary technologies utilized. Alternatives with the best combinations of effectiveness and implementability and the lowest costs are retained for detailed analysis and comparative analysis.

Surface area estimates and waste mass and volume estimates for cover and excavation alternatives, respectively, are developed and discussed in Appendix E. These area, mass, and volume estimates were used to support development of the cost estimates for the alternatives that also appear in Appendix E. The conceptual location of the treatment area is presented on Figure 6.2.

The unique circumstances of SWMU 3, the C-404 Landfill, as a closed RCRA land disposal unit subject to postclosure monitoring and care requirements were considered in the screening of alternatives. RCRA regulations and the permit establish a process for groundwater monitoring and postclosure care for RCRA-regulated units. The C-404 Landfill currently is in a groundwater detection monitoring status.

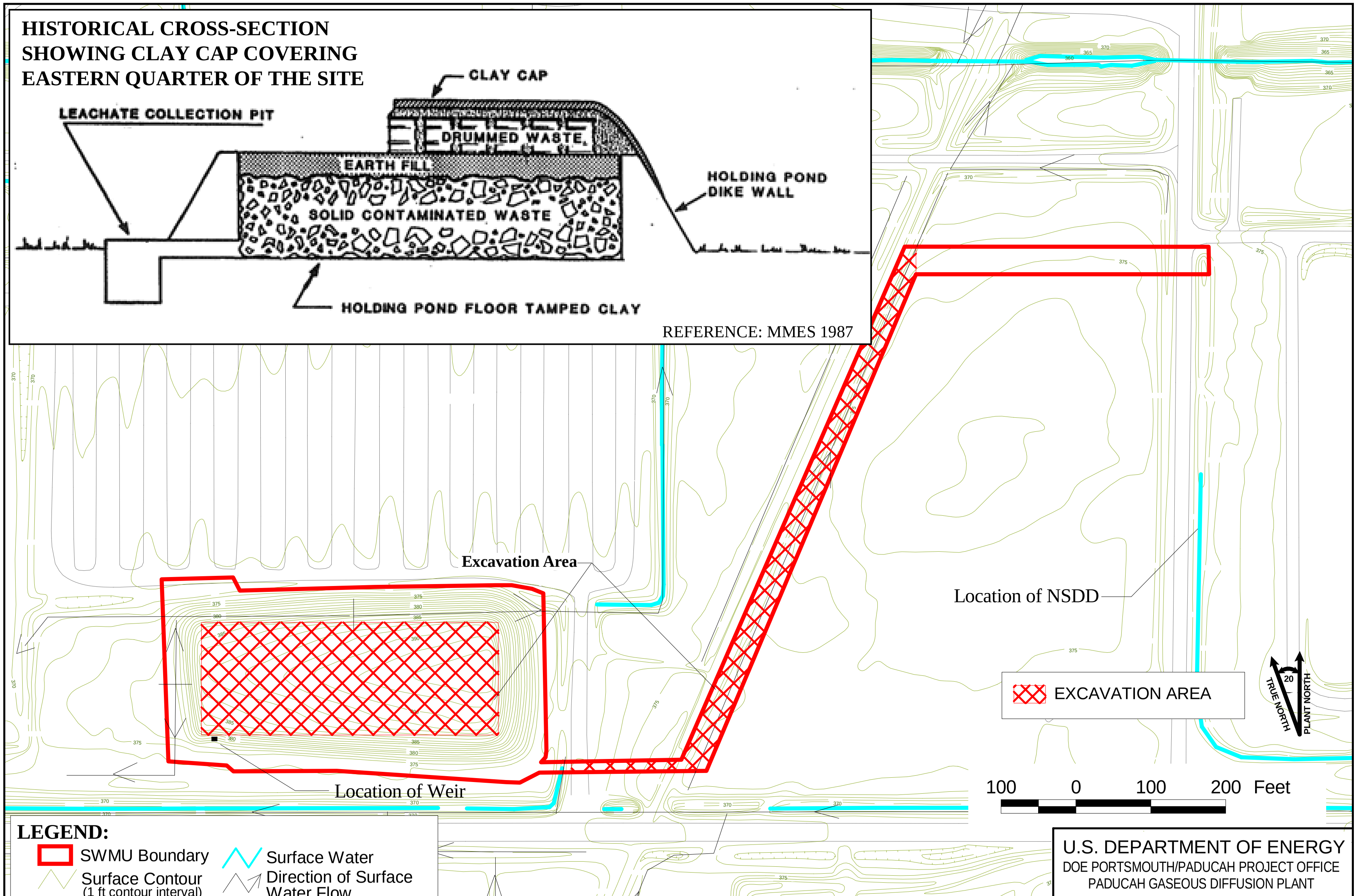


Figure 6.2. SWMU 3 Treatment Area

Figure No. \BGOU\FS_2-EXC.apr
DATE 07-08-09

In the mid-1990s, DOE expressed concern to KY that groundwater releases from C-404 potentially were commingled with releases from adjacent SWMUs and, as such, groundwater contamination at PGDP should be addressed on a sitewide basis using the CERCLA process. C-404 subsequently was included in the BGOU under the FFA, but has continued along a parallel path under RCRA for postclosure monitoring in accordance with the permit.

On October 22, 1998, EPA promulgated a regulation giving the regulators discretion to allow operators to comply with postclosure/corrective action for RCRA-regulated units through alternate approaches when RCRA regulated-units are situated among SWMUs with releases [40 *CFR* § 264.90 (f)(1) and (2)].

6.3.1 Alternative Screening for SWMU 3 Source Areas

Table 6.1 summarizes the results of alternative screening for source areas for SWMU 3. Alternatives that were screened out at this step are shaded grey on the table.

6.3.1.1 Alternative 1—No action

Alternative 1 (No Action) is retained for further consideration in the detailed analysis as a baseline alternative to which all other alternatives are compared, as required by CERCLA.

6.3.1.2 Alternative 3—Soil cover and long-term monitoring

Alternative 3, soil cover and long-term monitoring, is screened from further consideration for SWMU 3 because the SWMU is a closed RCRA facility managed under a RCRA postclosure permit. A RCRA cover has been constructed at SWMU 3. Alternative 3 would provide no additional protection or benefit at this SWMU.

6.3.1.3 Alternative 4—Soil cover with *in situ* DNAPL source treatment and long-term monitoring

Alternative 4, soil cover with *in situ* DNAPL source treatment and long-term monitoring, is screened from further consideration for SWMU 3 because the SWMU is a closed RCRA facility managed under a RCRA postclosure permit. A RCRA cover has been constructed at SWMU 3. There is no DNAPL contamination present at SWMU 3. The *in situ* DNAPL source treatment component of Alternative 4 is unnecessary at this SWMU.

6.3.1.4 Alternative 5—RCRA cover, hydraulic isolation and long-term monitoring

Alternative 5, RCRA cover with hydraulic isolation and long-term monitoring, is screened from further consideration for SWMU 3. SWMU 3 is a closed RCRA facility managed under a RCRA postclosure permit. A RCRA cover already has been constructed at SWMU 3. Because the waste disposed at SWMU 3 is abovegrade, the hydraulic isolation component of Alternative 5 would provide no additional protection or benefit at this SWMU.

6.3.1.5 Alternative 7—Excavation and disposal combined with *in situ* DNAPL source treatment and long-term monitoring

Alternative 7 is screened from further consideration at SWMU 2 because it incorporates contingency RPOs for remediation of DNAPL sources. There are no DNAPL sources at SWMU 3.

Table 6.1. Source Area Alternative Screening Summary for SWMU 3

Screening Criteria	Alternative 1 No Action	Alternative 2 Limited Action	Alternative 3 Soil Cover and Long-Term Monitoring	Alternative 4 Soil Cover with *In situ* DNAPL Source Treatment and Long-Term Monitoring	Alternative 5 RCRA Cover with Hydraulic Isolation and Long-Term Monitoring	Alternative 6 Excavation and Disposal	Alternative 7 Excavation and Disposal combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring	Alternative 8 Excavation and Disposal combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring	Alternative 9 *In situ* Containment and Long-Term Monitoring
Overall Effectiveness	Moderate[1]	Moderate[2]	NA[3]	NA[3]	NA[3]	High	NA[4]	NA[4]	Moderate to High
Short-term	High	High	NA	NA	NA	Moderate to High	NA	NA	Moderate
Long-term	Moderate	Moderate	NA	NA	NA	High	NA	NA	Moderate to High
Overall Implementability	High	Moderate	NA	NA	NA	Moderate	NA	NA	Moderate
Technical	High	High	NA	NA	NA	Moderate	NA	NA	Moderate
Administrative	High	Moderate	NA	NA	NA	Moderate	NA	NA	Moderate
Overall Cost	NA	Low	NA	NA	NA	High	NA	NA	Moderate
Capital	NA	Low	NA	NA	NA	High	NA	NA	Moderate
Operation and maintenance	NA	Moderate	NA	NA	NA	None	NA	NA	Moderate

NA—Not applicable based on-site conditions or nature of contamination present at the SWMU.
[1] Remedial alternative for SWMU 3 of continued postclosure monitoring under RCRA Permit.
[2] For long-term monitoring based on results of the demonstration required under 40 CFR § 294.90(f)(1) and (2), but performed under the CERCLA program.
[3] SWMU 3 is already capped.
[4] DNAPL source treatment not applicable because no DNAPL present at SWMU 3.
NOTE: Alternatives shaded grey were screened out at this step.

6.3.1.6 Alternative 8—Excavation and disposal combined with *ex situ* DNAPL source treatment and long-term monitoring

Alternative 8 is screened from further consideration at SWMU 2 because it incorporates contingency RPOs for remediation of DNAPL sources. There are no DNAPL sources at SWMU 3.

6.3.2 Summary of Alternatives Retained for Detailed Analysis

The following alternatives for radioactive/inorganic source areas are carried forward for detailed analysis.

- Alternative 1: No action
- Alternative 2: Limited action
- Alternative 6: Excavation and disposal
- Alternative 9: *In situ* containment and long-term monitoring

Comparative analyses are performed following detailed analyses.

6.4 DETAILED ANALYSIS OF ALTERNATIVES

6.4.1 Alternative 1—No Action

The No Action alternative is defined in accordance with CERCLA and provides a baseline to which other alternatives can be compared. A RCRA Subtitle C cap and a leachate collection system have been installed at SWMU 3, which is a closed RCRA unit under the jurisdiction of the Kentucky RCRA program. Under this alternative, SWMU 3 will continue to be monitored and managed in accordance with the requirements of the RCRA permit. A summary of the current postclosure care requirements of the RCRA permit are summarized in Appendix H.

6.4.1.1 Overall protection of human health and the environment

This alternative is protective of human health and the environment. Waste would not be treated or removed at SWMU 3. No additional controls would be implemented to protect site workers or the public. The results of the risk-based evaluation of the No Action alternative do not indicate an imminent threat to human health via the groundwater pathway. Thus, these elements of the RAO are achieved by the No Action alternative. All of the RAOs would be met if no action is implemented.

6.4.1.2 Compliance with ARARs

ARARs are not relevant to Alternative 1, the No Action alternative, because requirements for postclosure monitoring and care are implemented under the RCRA permit.

6.4.1.3 Long-term effectiveness and permanence

Existing site controls prevent exposure to the waste and drinking water. The potential for leaching of contaminants to the RGA would be reduced or prevented by the existing RCRA cover, clay liner, and leachate collection system. Alternative 1 leaves the risk or hazard from COCs at current levels at SWMU 3. Over time, with proper O&M under the RCRA program, this alternative should prevent future migration of contaminants. The alternative does not provide any long-term controls to manage residual risk at this SWMU.

6.4.1.4 Reduction of toxicity, mobility, or volume through treatment

Treatment would not be implemented with Alternative 1. Reduction of toxicity, mobility, or volume through treatment would not be applicable to the No Action alternative because it does not include treatment; however, the existing RCRA cover and leachate collection system do provide a reduction in contaminant mobility. The No Action alternative would not result in any reduction in the toxicity or volume of contaminants other than those attributable to natural processes, such as degradation, dilution, or dispersion.

6.4.1.5 Short-term effectiveness

No actions would be implemented under Alternative 1; therefore, no additional risks to workers, the public, or the environment would be incurred.

6.4.1.6 Implementability

The No Action alternative is highly implementable. If future monitoring in accordance with the postclosure permit indicates that additional remedial action is necessary, this alternative would not impede implementation of other remedial activities in the future.

The ongoing public awareness program would require regular coordination with the DOE, KY, and possibly with other governmental agencies.

6.4.1.7 Cost

The preliminary cost estimates for Alternative 1 serve as a baseline for comparison of the other remedial alternatives. These cost estimates are based upon FS-level scoping and are intended to aid with selection of a preferred alternative. There are no additional capital or O&M costs associated with Alternative 1 beyond those already committed at this SWMU under the RCRA program.

6.4.2 Alternative 2—Limited Action

Alternative 2 will require implementing an alternative for long-term monitoring based on results of a determination under 40 *CFR* § 264.90(f)(1) and (2) under the CERCLA process. A RCRA permit modification is necessary for DOE to transfer standards for long-term monitoring and care from the postclosure permit to a CERCLA remedial action document. CERCLA authority covers both RCRA hazardous constituents and radionuclides. This approach will streamline and simplify current and future management of SWMU 3.

6.4.2.1 Overall protection of human health and the environment

Same as Alternative 1, but LUCs (see Section 2.4.1.1) would be implemented under CERCLA because waste would remain in place.

6.4.2.2 Compliance with ARARs

Alternative 2 would be compliant with the substantive requirements of a groundwater monitoring program approved under CERCLA.

6.4.2.3 Long-term effectiveness and permanence

Same as Alternative 1, but LUCs (see Section 2.4.1.1) would be implemented under CERCLA because waste would remain in place.

6.4.2.4 Reduction of toxicity, mobility, or volume through treatment

Same as Alternative 1.

6.4.2.5 Short-term effectiveness

No actions would be implemented under Alternative 2; therefore, no additional risks to workers, the public, or the environment would be incurred.

6.4.2.6 Implementability

Obtaining the determination under 40 *CFR* § 264.90(f)(1) and (2) and approval of a RCRA permit modification may have some additional impact on administrative implementability of Alternative 2 as compared to Alternative 1.

6.4.2.7 Cost

The monitoring and O&M costs incurred under Alternative 2 would be low to moderate.

6.4.3 Alternative 6—Excavation and Disposal

Excavation of SWMU 3 includes the following: installation of sheet piles around the perimeter of the waste unit; excavation of all buried materials and contaminated soils; emission control equipment; cover soil and waste disposal characterization sampling; excavation pit dewatering; and segregation, bulking, and consolidation of compatible waste groups. In addition, treatment of excavated materials may include the following: *ex situ* thermal desorption to drive off VOCs and SVOCs; metal detection/magnetic separation of metallic materials (decayed drums and uranium for stabilization/solidification); and radiological separation. This alternative is described in detail in Section 3. A contingency would be planned for SWMU 3 for the likelihood that buried drums at the SWMU still may be intact (since the burial area is above the water table) and require handling/management. For the treatment and segregation operations, short-term storage would be required for the excavated waste and for treated materials awaiting shipment to the disposal site. Disposal options include off-site disposal facilities, as well as the WDF.

6.4.3.1 Overall protection of human health and the environment

Alternative 6 would meet this threshold criterion. Potential short-term risks to remediation workers due to direct contact with the waste material and inhalation hazards are much larger than any of the other alternatives. In addition, potential risks to the public and the environment as a result of potential shipping and handling concerns should be considered for off-site shipments. These concerns are greatly reduced for disposal in the WDF.

Waste and contaminated soil will be physically removed from the SWMU and disposed of in one or more appropriate disposal facilities, including the WDF, thus meeting all RAOs for waste in the former burial pits.

6.4.3.2 Compliance with ARARs

Alternative 6 would meet this threshold criterion. ARARs for this alternative are summarized in Appendix F.

6.4.3.3 Long-term effectiveness and permanence

Complete excavation offers maximum control of contaminant migration, since no wastes or associated contaminated soils would remain in the SWMU; therefore, this alternative offers a high degree of risk reduction. Complete treatment processes manage or remove hazardous characteristics or destroy the COCs.

Alternative 6 allows for potential risks associated with contaminants to be reduced or eliminated. Risks associated with direct contact with waste and surface soils will be eliminated since the primary source and associated contaminated soils will be removed. Alternative 6 allows for a maximum reduction of uncertainties associated with these soils in terms of continued contributions to the hydrogeologic system.

6.4.3.4 Reduction of toxicity, mobility, or volume through treatment

This alternative reduces or eliminates the mobility and volume of contaminants from the unit. The toxicity of the treatment residuals also would be drastically reduced and/or eliminated. The removal and disposition of waste and contaminated soil from a burial cell containing COCs to an appropriate disposal facility prevents those contaminants from migrating to the groundwater.

6.4.3.5 Short-term effectiveness

Short-term risks to the community resulting from excavation activities at the SWMU would not be expected. Potential risks resulting from migration of contaminants to off-site locations would be controlled by the on-site vacuum hood and HEPA filtration system. Alternative 7, however, includes a potential risk to the public from transportation of the LLW or hazardous wastes/liquids to off-site disposal and/or treatment facilities. This risk would be greatly reduced by disposing of waste in the WDF.

Short-term exposures of workers to COCs could occur during implementation of Alternative 6. Potential exposure pathways include direct contact with soil (ingestion, inhalation) and exposure to external penetrating radiation. Worker risks are not expected to exceed acceptable limits because exposure frequency and duration are less than those evaluated in the baseline risk assessment. Typically, risks from handling waste/contaminated soils would be minimized through adherence to health and safety protocols. To protect workers, PPE, ambient conditions monitoring, and decontamination protocols would be used in accordance with an approved, site-specific HASP.

Time until RAO is achieved. The remedial action objective would be achieved immediately following excavation. Excavation, treatment, and disposal of residuals could be accomplished in approximately three years.

Excavation and disposal would be conducted by trained personnel in accordance with standard radiological, engineering, and operational procedures, DSAs, HASPs, and safe work practices to maintain a work environment that minimizes injury or exposure to risks to human health or the environment.

No ecological impacts at the BGOU are anticipated under this alternative. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archaeological or historical sites or T&E species would be impacted by this alternative.

The RAOs for COCs identified at SWMU 3 would be achieved following completion of excavation.

6.4.3.6 Implementability

Alternative 6 is considered to be technically and administratively feasible and implementable. The equipment and technologies associated with implementation of this alternative have been proven to be technically feasible and are available from contractors or vendors. Treatability testing may be required for waste treatment processes including *ex situ* thermal desorption for excavated soils and uranium oxidation. The implementability of construction-related activities during excavation and backfilling at SWMU 3 subject to Alternative 6 is very similar to that carried out routinely at other sites, so it is considered high. Likewise, sampling, analysis, transportation, and disposal at an approved location are routinely performed and, if properly implemented, are proven to be safe. Some excavated waste materials may be radioactive, RCRA hazardous, or mixed. Treatment of wastes with multiple regulatory classifications is more complex and may require more than one treatment process to make the waste suitable for transportation and/or land disposal. On-site treatment processes will comply with ARARs.

An option for disposal of waste and residuals at the WDF was considered under Alternative 6. The primary difference would be the elimination of waste leaving the PGDP, related off-site transportation issues, and the cost for disposal. At this time, no capacity exists at PGDP for disposal of these wastes.

6.4.3.7 Cost

Costs were estimated for transportation and disposal of wastes at an off-site facility as well as for an option to dispose of waste at the WDF. Costs are provided for excavation and disposal of SWMU 3. O&M costs are dependent upon the status of the SWMU upon completion of excavation. Cost will be low if SWMU closure can be achieved upon completion of excavation, and a long-term monitoring program is minimal or unnecessary.

6.4.4 Alternative 9—*In situ* Containment and Long-Term Monitoring

Implementation of Alternative 9 consists of the following three components: (1) a subsurface horizontal barrier; (2) vertical hydraulic barrier; and (3) a structure.

6.4.4.1 Overall protection of human health and the environment

Alternative 9 would meet this threshold criterion for SWMU 3. A structure provides a physical barrier between receptors and contaminated surface soils, thus limiting direct contact and the associated risk. A structure provides a direct reduction in mobility of surface contamination and a reduction in migration of subsurface vadose zone contamination by limiting infiltration. A structure designed to reduce infiltration by 90% will reduce the migration of contaminants sufficiently to meet MCLs or risk-based values at the UCRS–RGA boundary beneath the SWMU and hence meet the RAO for groundwater protection. Estimated infiltration reduction rates necessary to meet the RAO for groundwater protection are presented in Appendix B. Construction of a vertical subsurface barrier would further limit migration of contaminants to the RGA. Uranium at SWMU 3 would be contained. Installation of subsurface horizontal barrier would fully contain the wastes buried in SWMU 3. LUCs (see Section 2.4.1.1) protect current and future site workers and the public.

6.4.4.2 Compliance with ARARs

Alternative 9 would meet this threshold criterion for SWMU 3. ARARs for this alternative are summarized in Appendix F.

6.4.4.3 Long-term effectiveness and permanence

Installation of a structure would provide direct protection against exposure to residual surface contamination, diminish external penetrating radiation, and indirectly limit exposure to residual subsurface waste and contamination. The structure would be placed over the unit, thereby eliminating the exposure pathway, and would limit infiltration of precipitation and its effect of mobilizing the waste. Long-term effectiveness is dependent upon a number of factors, including construction materials, construction methods, and maintenance of the structure.

Installation of a vertical subsurface barrier system would provide direct protection against exposure to subsurface waste and contamination; the barrier would be placed around the residual contamination and waste mass, thereby minimizing contaminant migration to the RGA. The ability to maintain effective near surface groundwater control is challenging because the barrier system has no ability to control vertical release from the waste. The vertical barriers would be designed to key into the low-permeability horizontal barrier.

Construction of the horizontal subsurface barrier should limit the downward migration of water or fluids and associated contaminants present in buried wastes. To be effective for years into the future, the constructed barrier must be continuous beneath the waste area with no breaks or voids that might compromise the integrity of the barrier. There are uncertainties associated with construction of a horizontal barrier and being able to verify its continuity and integrity.

Alternative 9 is designed to limit exposure to surface and subsurface contamination and minimize the contribution of contaminants to the RGA. After implementation of Alternative 9, wastes would remain at the unit; however, the waste would be fully contained.

6.4.4.4 Reduction of toxicity, mobility, or volume through treatment

Alternative 9 does not include any treatment or removal technologies; therefore, a reduction in toxicity or volume through treatment would not be achieved; however, a direct reduction in the mobility of the subsurface contamination would be achieved by constructing both horizontal and vertical subsurface barrier systems. Additionally, construction of a structure would reduce the mobility of subsurface contamination by limiting infiltration.

6.4.4.5 Short-term effectiveness

Implementation of Alternative 9 has low potential for remediation worker exposure to surficial soil contamination and residual subsurface contamination through construction of vertical subsurface barriers and an overhead structure. Exposure to contaminated surface soils, subsurface soils, and groundwater during environmental sampling also is low. Potential exposure pathways include inhalation of dust containing surficial soils, dermal contact with surficial and subsurface soils, exposure to external penetrating radiation associated with buried waste, and dermal contact with contaminated groundwater. While estimated risks associated with these exposures are greater than Alternative 1, they are much less than excavation and are considered manageable because LUCs (E/PP Program) provide worker protection.

Construction of the barrier could be complicated by factors like the following:

- The existence of subsurface obstructions or obstacles;
- The need for frequently varying construction alignments;
- Underpassing environmentally contaminated areas;
- The need for protective measures and for special control of jetted effluents when working in hazardous conditions; and
- The need to use grout mixes that are not destroyed by chemicals in the ground.

It also is difficult to determine if the constructed barrier is continuous beneath the waste area, with no breaks or voids that might make the barrier less impermeable.

The ability to use relatively light construction machinery makes the system versatile for construction in difficult conditions or tight geometries. The construction can be implemented relatively quickly and essentially anywhere it is needed.

No ecological impacts at the BGOU are anticipated under this alternative. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archaeological or historical sites or T&E species would be impacted by this alternative.

The RAOs for SWMU 3 will be met when the horizontal and vertical barriers are in place. Construction of a structure would further enhance the containment at SWMU 3.

6.4.4.6 Implementability

Implementation of the remedial action components of Alternative 9 is technically feasible, and the alternative consists of demonstrated technologies, standard construction methods, materials, and equipment that are available from vendors and contractors. The most challenging element of this alternative is construction of the subsurface horizontal barrier and confirming its integrity. Groundwater flow is predominantly downward in the UCRS, but there will be some minor lateral flow due to heterogeneities in the shallow soils that may impact the implementation of hydraulic isolation technology.

6.4.4.7 Cost

Capital costs are considered moderate for Alternative 9. O&M costs for Alternative 9 are considered high because there will be long-term groundwater monitoring, routine structure inspection and maintenance, and, if required, leachate collection and treatment.

6.5 COMPARATIVE ANALYSIS OF ALTERNATIVES

A comparative analysis summary for source area alternatives for SWMU 3 is presented in Table 6.2, and the corresponding costs for the alternatives are presented in Table 6.3.

6.5.1 Threshold Criteria

Source area remedial alternatives are compared with respect to the threshold criteria in the following sections.

6.5.1.1 Overall protection of human health and the environment

Alternatives 1 and 2 meet the threshold criterion of overall protection of human health and the environment. They would not treat or remove waste, but the existing RCRA cover reduces or prevents migration of contaminants. There would be no additional protection beyond that provided by the cover for future industrial workers. There is some risk to future off-site groundwater users from the migration of COCs to RGA groundwater reaching unacceptable levels, but the risk is managed by containment. While the short-term risks associated with excavation can be mitigated by proper engineering precautions in achieving long-term risk reduction, the trade-offs of removing risks that can be managed at the unit for risks during excavation and removal are significant factors that favor Alternatives 1 and 2.

Alternative 2 streamlines and simplifies current and future management of SWMU 3. It provides LUCs to protect current and future site workers and the public.

Alternative 6 would meet this threshold criterion. This alternative could remove enough waste and contaminated soil to meet soil target concentrations and prevent contamination exceeding MCLs or risk-based values in RGA groundwater at the UCRS-RGA boundary beneath the SWMU.

Alternative 9, *in situ* containment (designed to provide > 90% reduction in infiltration), would meet this threshold criterion by containing wastes and TCE DNAPL in soil at the SWMU. No waste would be treated or removed, but placement of a structure in conjunction with both horizontal and vertical barriers would control surface infiltration as well as lateral infiltration to reduce or limit future migration of contamination to groundwater. Industrial workers would be protected in several ways. The physical barrier of the structure would limit direct contact and, additionally, LUCs (see Section 2.4.1.1) would be in place. The public would be protected by site procedures to monitor and ensure the integrity of the containment. The modeling approach and results that support this prediction are presented in Appendix B. While the short-term risks associated with excavation can be mitigated by proper engineering precautions in achieving long-term risk reduction, the trade-offs of removing risks that can be managed at the unit for risks during excavation and removal are significant factors that favor Alternative 9.

6.5.1.2 Compliance with ARARs

ARARs are not relevant to Alternative 1; however, Alternative 1 does meet the regulatory requirements implemented through the existing RCRA permit. Alternative 2 will meet the substantive requirements in ARARs. Alternative 1 would be continued management under and compliance with the existing RCRA postclosure permit, Alternative 2 would meet the substantive requirements for monitoring and postclosure care, but would be conducted under the CERCLA program.

Alternative 6 will meet all location- and action-specific ARARs through design and planning during preparation of the RD/RAWP.

Alternative 9 would meet this threshold criterion. It would contain waste and contaminated soil and reduce or limit migration of contaminants to RGA groundwater at the UCRS-RGA boundary beneath the SWMU. This alternative is expected to meet all location- and action-specific ARARs through design and planning during preparation of the RD/RAWP. Monitoring environmental media would further assure compliance with ARARs for this alternative.

Table 6.2. Summary of Comparative Analysis of Source Area Alternatives SWMU 3

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 1: No Action. SWMU 3 is a closed RCRA facility that is managed under a RCRA postclosure permit. No Action for SWMU 3 is continued postclosure care under the RCRA Permit	Moderate. Existing RCRA cap meets this threshold criterion. Provides continued protection for future on-site industrial workers and off-site groundwater users.	High. Compliance with regulatory requirements in RCRA permit.	Moderate. RCRA cap provides containment of buried waste. Leachate collection system in place. Groundwater monitoring data indicate that contaminants are not migrating from SWMU 3.	Moderate. No treatment provided. Existing cap minimizes surface infiltrations and is equipped with a leachate collection system that further reduces contaminant mobility. Approximately 2,500 gal/yr of leachate are collected and treated on-site. Results are reported to the Kentucky RCRA program.	High. Cap appears to be effective. No actions implemented; therefore, no impact to workers or the surrounding community.	High. No action would be implemented. Continued O&M under the RCRA permit.
Alternative 2: Limited Action. Modify RCRA permit to allow use of alternative requirements for monitoring pursuant to 40 *CFR* § 264.90(f) and implement postclosure care under a CERCLA remedial action document	Moderate. Provides continued groundwater monitoring in accordance with substantive requirements of ARARS. Land use controls protect current and future site workers and the public.	High. Provides continued groundwater monitoring in accordance with substantive requirements of ARARs.	Moderate. RCRA cap provides containment of buried waste. Leachate collection system in place. Groundwater monitoring data indicate that contaminants are not migrating from SWMU 3.	Moderate. No treatment provided. Existing cap minimizes surface infiltrations and is equipped with a leachate collection system that further reduces contaminant mobility. Approximately 2,500 gal/yr of leachate is collected and treated on-site.	High. Cap appears to be effective. No actions implemented; therefore, no impact to workers or the surrounding community.	Moderate. Requires approval of a RCRA permit modification to obtain an enforceable document (e.g., CERCLA remedial action document) with alternative requirements for monitoring and corrective action. Postclosure O&M would be performed under CERCLA.

Table 6.2. Summary of Comparative Analysis of Source Area Alternatives SWMU 3 (Continued)

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 6: Excavation and Disposal	High. Removal of contaminated waste offers the highest degree of overall protection with respect to RAOs.	High. Complies with ARARs and potential TBCs.	High. Contaminant sources removed. Most adequate overall level of protection to humans and the environment.	High. Excavation, waste treatment and disposal would reduce or eliminate mobility of radionuclides and inorganic COCs, and reduce or eliminate toxicity of organics.	Moderate to High. Potential negative impacts to community from waste transportation to off-site disposal facility. Potential impacts reduced greatly if waste disposed at the WDF. Risk to workers higher than other alternatives but can be managed through site procedures during implementation. Implementation could take years.	Moderate to high. Excavation and associated technologies are readily implementable. Some excavated waste materials or soil may have multiple regulatory classifications, increasing the complexity of treatment required for transportation and/or disposal. WDF is being evaluated as part of the waste disposal option project, and a ROD has not been issued.
Alternative 9: *In situ* Containment and Long-Term Monitoring	Moderate to high. Meets this criterion. More protective than Alternative 2 because subsurface horizontal barrier constructed, but less protective than Alternative 6. Provides greater protection against direct contact with waste by constructing a building over the RCRA cap and further reduces migration potential by containing buried waste on all sides. Land use controls protect current and future site workers and the public.	High. Complies with ARARs and potential TBCs.	Moderate to high. Protects against direct contact. Reduces potential for contaminant migration to RGA. Increased effectiveness and reliability are primarily dependent upon proper design and construction to ensure integrity of horizontal barrier.	Moderate. No reduction of toxicity or volume. Mobility is further reduced through additional containment. Some potential for contaminated waste generation during construction of horizontal and vertical barriers.	Moderate. Negative impacts to community from construction can be controlled. Potential for exposure to contaminated soil and slurry by remediation workers during construction of horizontal and vertical barriers. More short-term risk to workers during implementation than Alternative 2, but much less than Alternative 6. Could be completed in months.	Moderate. Mostly proven, reliable technologies that are readily available. The construction of horizontal subsurface barriers and verifying their integrity are less proven than the other construction elements. While groundwater flow is predominantly downward in the UCRS, there will be some minor lateral flow due to heterogeneities in the shallow soils that may impact the implementation of hydraulic isolation technology.

Table 6.3. SWMU 3 Remedial Alternatives Cost Estimate Summary

			PRESENT WORTH[1]		ESCALATED	
Alternative Description	**Annual Time Period, yrs**	**Capital $ (2010 Constant Dollars)**	**Total Annual $**	**Total $ (Capital and Annual)**	**Alternative Description**	**Annual Time Period, yrs**
Alternative 1—No Action	0	$0	$0	$0	Alternative 1—No Action	0
Alternative 2—Limited Action	30	$0	$1,944,000	$1,944,000	Alternative 2—Limited Action	30
Alternative 6a—Excavation and Disposal	0	$88,358,000	$0	$88,358,000	Alternative 6a—Excavation and Disposal	0
Alternative 6b—Excavation and Disposal (at the WDF)	0	$62,438,000	$0	$62,438,000	Alternative 6b—Excavation and Disposal (at the WDF)	0
Alternative 9—*In situ* Containment with Long-Term Monitoring	30	$16,094,000	$4,362,000	$20,456,000	Alternative 9—*In situ* Containment with Long-Term Monitoring	30

[1] Not used for budgeting or planning purposes because value is based on investing funds for outyear expenditures.

6.5.2 Balancing Criteria

Source area alternatives are compared with respect to the balancing criteria in the following sections.

6.5.2.1 Long-term effectiveness and permanence

Alternatives 1 and 2 would be effective because of the existing RCRA cover. The risk posed by waste material and COCs in soil would remain unchanged.

Alternative 6 provides a high degree of long-term effectiveness and permanence. Residual risk should be the lowest under this alternative. Long-term controls may not be required under this alternative, provided that waste material and contaminated soil can be removed to attain soil target concentrations.

Alternative 9 provides a moderate to high degree of long-term effectiveness and permanence. Residual risk would remain, but it would be contained. This alternative would reduce or limit contaminant migration so that COCs remaining in place at levels above their target concentrations would make only a minor contribution to contamination of RGA groundwater.

6.5.2.2 Reduction of toxicity, mobility, and volume through treatment

Alternatives 1 and 2 would not reduce the toxicity, mobility, or volume of COCs in waste or soil at SWMU 3.

Alternative 6 reduces toxicity by removal, treatment, and disposal of wastes. Waste materials and soil would be treated on-site as needed to allow excavated materials to be readied for transport or disposal. Volume is similarly reduced. Removal of source material and surrounding contaminated soils will prevent future migration of contaminants at the SWMU.

Alternative 9 does not reduce the toxicity or volume of waste, but it does limit migration of contaminants by containing the waste. A structure limits infiltration of precipitation and surface water to significantly reduce vertical migration of contaminants. A vertical barrier limits the lateral migration of contaminants. A subsurface horizontal barrier limits leaching and migration of contaminants from the waste.

6.5.2.3 Short-term effectiveness

The short-term effectiveness of Alternatives 1 and 2 is high because the action is immediate without any additional risk to site workers or the community. The RCRA cover at the site presently is effective in containing waste and preventing exposure to site workers.

The short-term effectiveness of Alternative 6 is moderate to high. Disposal at the WDF would result in higher overall short-term effectiveness by eliminating risks associated with wastes leaving the site.

Alternative 9 is moderately effective. There is some risk of exposure to remediation workers during installation of the subsurface horizontal and vertical barriers. Risk to the community is low during this construction.

6.5.2.4 Implementability

Alternatives 1 and 2 both would be readily implementable because no construction or invasive action would be taken. Alternative 2 may be more administratively challenging because of the strategy to conduct monitoring under the CERCLA process based on results of the demonstration required under 40 *CFR* § 264.90(f)(1) and (2) and successful modification of the RCRA permit.

Alternative 6 is considered to be technically and administratively feasible and implementable.

The implementability of Alternative 9 is moderate, as the technology is reasonably well proven and readily available.

6.5.2.5 Cost

Capital and O&M costs for alternatives at SWMU 3 are presented in Table 6.3. Costs were estimated for transportation and disposal of wastes at an off-site facility as well as for an option to dispose of waste at the WDF. Costs are provided for excavation and disposal of SWMU 3.

6.5.3 Summary of Comparative Analysis of Alternatives

SWMU 3 is a closed SWMU under the jurisdiction of the Kentucky RCRA program. The existing RCRA cover at SWMU 3 already provides protection to site workers, contains the waste in the SWMU, and minimizes migration of contamination by means of infiltration control and a leachate collection system. Compliance with the long-term monitoring and care requirements of the postclosure permit or substantive requirements of RCRA under Alternatives 1 and 2, respectively, can be considered effective alternatives at SWMU 3.

Alternative 6 is the most effective alternative, but the large additional costs associated with this alternative may not be justified because the SWMU already is contained effectively.

Alternative 9, *in situ* containment, would meet the threshold criteria by containing waste and soil contaminated above target concentrations at the SWMU. No waste would be treated or removed, but placement of a structure would control surface infiltration. Construction of both horizontal and vertical barriers limit lateral infiltration of groundwater and provide a low-permeability barrier to limit vertical migration of contamination to groundwater. There are uncertainties associated with construction of a horizontal barrier and being able to verify its continuity and integrity. LUCs (see Section 2.4.1.1) would protect current and future site workers and the public. Alternative 9 avoids the potential of encountering waste during excavation and the possible short-term risks associated with mitigating and controlling those impacts. There would be long-term monitoring and maintenance costs and responsibilities associated with Alternative 9.

7. SWMU 4

7.1 SWMU 4 HISTORY AND BACKGROUND

The C-747 Contaminated Burial Yard and the C-748-B Burial Area (SWMU 4) are located in the western section of the PGDP secured area. SWMU 4 (which covers an area of approximately 286,700 ft^2) is bounded on the north, east, and west by plant roads and on the south by an active railroad spur. This SWMU is an open field that, at one time, was used for the burial and disposal of various waste materials in designated burial cells. A short, narrow, gravel road that enters from the west 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 typically is mowed 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. There is an elevation difference of approximately 10 ft between the highest point in the SWMU to the adjacent drainage swales. The entire burial yard was covered with 2 to 3 ft of soil material, and a 6-inch clay cap was placed over the area in 1982 (Figure 7.1) (DOE 1998c).

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 Uranium Hexafluoride (UF_6) Feed Plant. The area originally consisted of two pits covering an area of approximately 8,300 ft^2 (50 ft by 15 ft and 50 ft by 150 ft) (Union Carbide 1978).

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.

The C-748-B Burial Area, located on the west side of C-747, is identified as a Proposed Chemical Landfill Site in the 1973 Union Carbide document on waste disposal. The original SWMU Assessment Report dated August 24, 1987, for SWMU 4 included only the C-747 Contaminated Burial Yard. The C-748-B Burial Area was incorporated into various descriptions of SWMU 4 starting in the mid-1990s as a result of a geophysical survey. As a result of this addition, the area of the SWMU was changed from 8,300 ft^2 to 286,700 ft^2 (DOE 2007b).

SWMU 4 also may have received sludges designated for disposal at the C-404 Burial Ground. The source of these sludges is unknown, but the WAG 3 RI Work Plan (DOE 1998c) indicated that the sludges potentially included uranium-contaminated solid waste and technetium-99-contaminated magnesium fluoride. The total volume of material disposed at this SWMU is unknown. Potential contaminants associated with this SWMU include uranium, technetium-99, metals, and TCE.

Beryllium is the most widely detected metal in subsurface soils above background (52 of 126 analyses). Most of the higher concentrations (> 1 mg/kg) occur in a horizon at 40 to 55 ft bgs. Iron and vanadium are the most common metals to exceed both PGDP background (in 7 of 126 analyses for both) and the NAL (in 126 of 126 analyses of iron and 125 of 126 analyses of vanadium). Manganese exceeds PGDP background in 6 of 126 analyses and exceeds the NAL in 92 of 126 analyses. The iron and vanadium exceedances are well distributed across SWMU 4. Most of the exceedances occur at depths of 20 to 55 ft.

TCE is widely present (47 of 314 analyses) in subsurface soil samples from borings located within burial pits. Highest levels (up to 41 mg/kg) are commonly found in the soils below the large southern burial pit, with levels as high as 25 mg/kg at the maximum depth of the soil samples (61 ft). A potential DNAPL source is suspected in the UCRS at SWMU 4 near the southern burial pit. Subsurface soil analyses also document the TCE degradation product vinyl chloride above screening levels in 3 of 318 subsurface

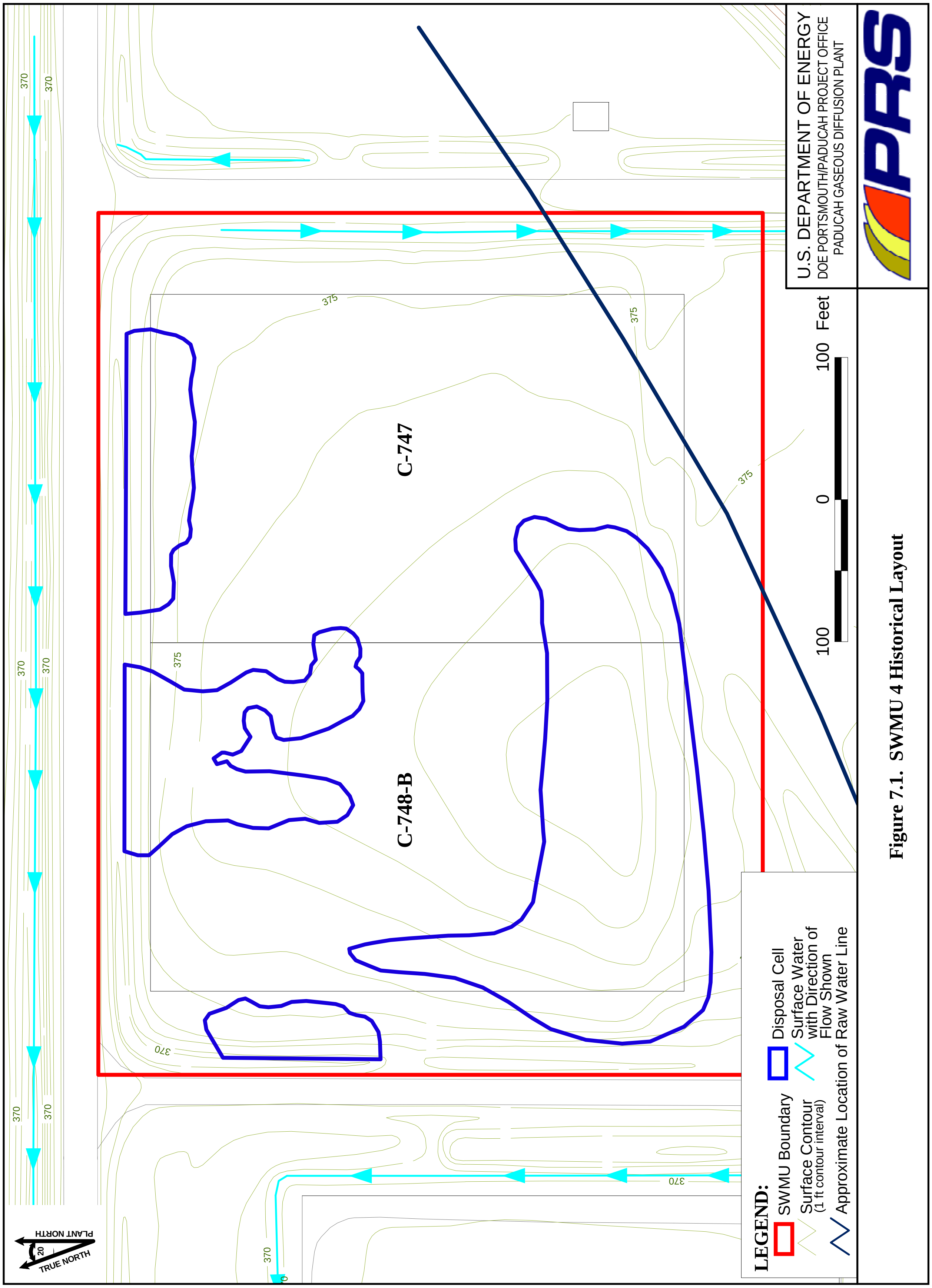


Figure 7.1. SWMU 4 Historical Layout

samples from borings within the area of the large southern burial pit. The highest levels of PCBs cluster around the east end of the southern burial pit (in soils of 6 ft depth or less).

Dissolved TCE trends indicate that a potential TCE DNAPL source is present in the UCRS at SWMU 4, related to the elevated soil concentrations found in the southern burial area. A discrete DNAPL zone, less than 200 ft wide, also may be present at the base of the RGA as evidenced by a discrete area with TCE concentrations greater than 10,000 µg/L in the lower RGA immediately downgradient of the SWMU. The evidence of the potential UCRS DNAPL presence is markedly higher dissolved TCE levels (commonly 1,000 to 4,000 µg/L) in the RGA on the west (downgradient) side of the SWMU. The area of higher TCE levels spans the entire west side of SWMU 4, suggestive of a diffuse source of DNAPL contamination in the UCRS soils underlying the Burial Grounds (DOE 2007a).

The most common radionuclides with activities that exceed background and the outdoor worker NAL are the uranium isotopes uranium-234 and uranium-238. These detections are commonly limited to soils less than 10 ft deep and occur across the SWMU. Uranium levels decrease quickly below a depth of 10 ft.

The metals arsenic, iron, lead, and manganese frequently exceeded screening levels in both the UCRS and RGA groundwater. VOCs also were common contaminants of the UCRS and RGA associated with SWMU 4. TCE levels exceeded the MCL in 43 of 45 analyses in the RGA. TCE degradation products, notably 1,1-DCE and *cis*-1,2-DCE, also frequently exceeded MCLs. Other VOCs present at SWMU 4 include carbon tetrachloride and chloroform.

7.1.1 Hydrogeologic Interpretation

The study area geology and hydrogeology is summarized below as documented in the BGOU RI (DOE 2010).

Stratigraphy. Like SWMU 2, the burial cells of SWMU 4 penetrate into the HU1 loess member (predominately silt) of the Upper Continental Deposits. These burial cells likely extend to near the base of HU1, at a depth of 15 to 20 ft. Lithologic logs of wells MW415 and MW417 document the presence of an upper and lower HU2 sand horizon, separated by an intervening silt member beneath SWMU 4. The HU2 occurs over the approximate depths of 20 to 40 ft. This, in turn, is underlain by the HU3 silt interval down to a depth of 50 ft. The HU4 sand is approximately 15 ft thick at SWMU 4. Sand and gravelly sand members of the Lower Continental Deposits (HU5) extend down to a depth of approximately 100 ft. The underlying McNairy Formation consists of fine sands and clays.

UCRS Groundwater Flow and Hydraulic Potential. The depth to the water table at SWMU 4 is uncertain since there are no direct measurements of the depth of the water table beneath SWMU 4. Because the stratigraphy and hydrogeology is comparable to that of SWMUs 2 and 3, and SWMU 4 is in close proximity to those SWMUs, it is reasonable to assume a similar depth to water in the UCRS (10 to 15 ft bgs). The water table likely extends up into the waste burial pits.

RGA Groundwater Flow and Hydraulic Potential. The northwest flow direction demonstrated for the immediate area to the south of SWMU 3 and the general west-northwest trend of the Southwest Plume define the dominant flow paths in the RGA beneath SWMU 4. It is anticipated that the hydraulic conductivity of the RGA is similar to that of other on-site areas containing the main contaminant plumes, 1,200 to 1,300 ft/day. Average RGA groundwater flow velocity in the areas of the contaminant plumes is commonly 1 to 3 ft/day.

7.2 SITE-SPECIFIC RAOS

RAOs that are specific to SWMU 4 were developed based on the findings and observations forthcoming from the BGOU RI Report. The site-specific RAOs generally are directed toward conditions related to the waste materials, the surface soils, and the subsurface soils at the SWMU. A brief statement of the specific problem associated with the SWMU is followed by bulleted RAO(s) developed to address the problem.

Buried waste materials present a risk to a future outdoor worker and a potential future contribution to RGA groundwater and subsurface soils.

- Prevent future contaminant migration from buried waste to the environment such that it does not present unacceptable direct exposure risks to future receptors or migration to groundwater.

Radionuclides and metals in surface soil present a cumulative ELCR and an HI to future industrial workers, exceeding an ELCR=1E-06 and an HI=1.

- Prevent exposure from surface soil metals and radionuclides that would cause an unacceptable cumulative risk to future industrial workers.

Constituents in subsurface soil present a cumulative ELCR and an HI to future outdoor worker, exceeding an ELCR=1E-06 and an HI=1.

- Prevent exposure to subsurface soil metals, radionuclides, and SVOCs within the SWMU boundary to 16 ft bgs that would cause an unacceptable cumulative risk to a future outdoor worker.

VOCs in the subsurface constitute a DNAPL continuing source to groundwater and represent a PTW. COCs are TCE, VC, and *cis*-1,2-DCE. TCE and degradation products underlie the southern burial area and the western boundary of the SWMU from a depth of 20 to 90 ft bgs.

- Remove or treat DNAPL so that contributions to RGA groundwater do not exceed MCLs.

Metals, radionuclides, and VOCs in subsurface soil exceed concentration criteria for an acceptable cumulative risk to a potential future residential groundwater user.

- Prevent migration of metals, radionuclides, and VOCs in soil in the source areas to the RGA groundwater to the extent they do not contribute contamination exceeding MCLs, or in the absence of an MCL, a risk-based concentration.

The FS process began with the full list of COCs identified in the RI Report. A detailed evaluation of the sample results for commonly occurring elements identified in the RI Report as COCs was performed by comparing field sample results against the PGDP site background concentrations. A number of COCs identified in the RI Report were eliminated from further consideration in the FS because they were below background levels. A discussion of the evaluation that was performed and its results are presented in detail in Section 1. The final list of COCs for the SWMU and their preliminary RGs for surface soil and subsurface soil are provided in Appendix C, Tables C.2 and C.3, respectively. Preliminary RGs for the SWMU meet the target cumulative ELCR and HI criteria for both surface and subsurface soil.

7.3 SCREENING OF ALTERNATIVES

Alternatives are screened in this section, using the process described in EPA (1988) and the NCP to reduce the number of alternatives carried forward to detailed analysis. Alternatives are screened with respect to effectiveness, implementability, and cost. The evaluation of effectiveness considers reductions in toxicity, mobility, and volume of COCs. The evaluation of implementability considers technical feasibility criteria, including the ability to construct, operate, and maintain the remedy, and administrative feasibility criteria, including the availability of treatment, storage, and disposal capacity. Evaluation of cost for the alternatives is based on the relative capital and O&M costs for the primary technologies utilized. Alternatives with the best combinations of effectiveness and implementability and the lowest costs are retained for detailed analysis and comparative analysis.

Surface area estimates and waste mass and volume estimates for cover and excavation alternatives, respectively, are developed and discussed in Appendix E. These area, mass, and volume estimates were used to support development of the cost estimates for the alternatives that also appear in Appendix E. The conceptual location of the radioactive/inorganic treatment area is presented on Figure 7.2.

The estimated volume of soils that potentially are contaminated with DNAPL that are to be remediated at the SWMU was developed in Section 1. The conceptual location of the DNAPL treatment area at the SWMU is presented on Figure 7.3.

7.3.1 Alternative Screening for SWMU 4 Source Areas

Table 7.1 summarizes the results of alternative screening for source areas at SWMU 4. Alternatives that were screened out at this step for this SWMU are shaded grey on the table. Alternative 1 (no action) is not effective, but is retained for further consideration in the detailed analysis as a baseline alternative to which all other alternatives are compared, as required by CERCLA.

7.3.1.1 Alternative 2—Limited action

Alternative 2, which consists of long-term groundwater monitoring only, is screened from further consideration at SWMU 4. The RI Report documents the presence of DNAPL contamination at the SWMU. Alternative 2 provides no effective reduction or remediation of DNAPL.

7.3.1.2 Alternative 3—Soil cover and long-term monitoring

Alternative 3 is screened from further consideration for SWMU 4 because the data in the RI Report indicate that buried wastes at SWMU 4 are in contact with the water table and construction of a soil cover may not prevent the continued leaching of contaminants to groundwater. The RI Report indicates that the water table within the BGOU ranges from 5 to 10 ft bgs and intrudes into buried wastes at the SWMU.

7.3.1.3 Alternative 4—Soil cover with *in situ* DNAPL source treatment and long-term monitoring

Although this alternative is capable of remediating the potential DNAPL source at SWMU 4, Alternative 4 is screened from further consideration for SWMU 4 because the data in the RI Report indicate that buried wastes at the SWMU are in contact with the water table, and construction of a soil cover may not prevent the continued leaching of radioactive and inorganic contaminants to groundwater.

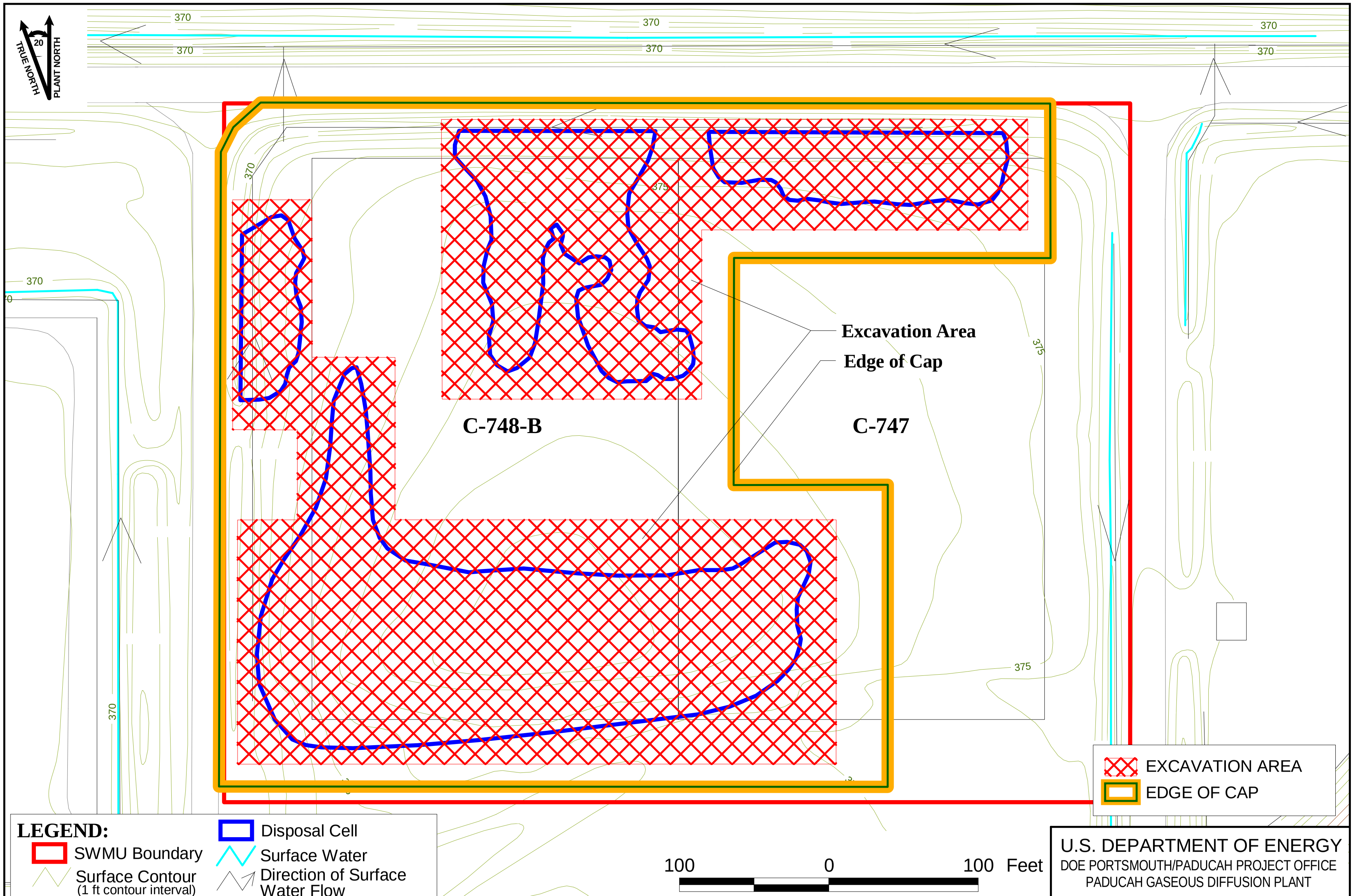


Figure 7.2. SWMU 4 Treatment Area

Figure No. \BGOU\FS_2-EXC.apr
DATE 07-08-09

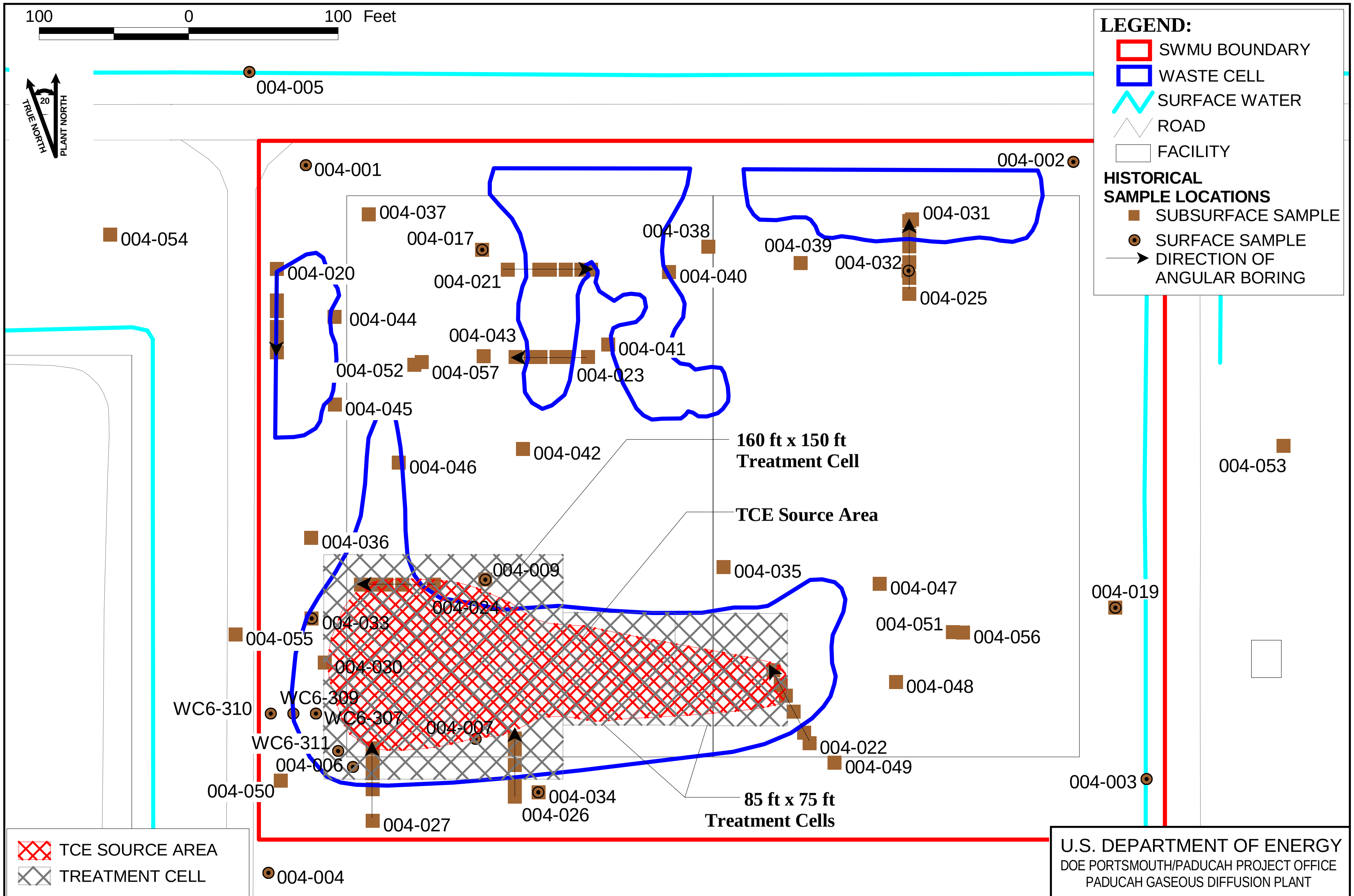


Figure 7.3. Location of SWMU 4 DNAPL Source Area and Treatment Cells

Figure No. \BGOU\FS_2-VOC.apr
DATE 07-06-09

Table 7.1. Source Area Alternative Screening Summary for SWMU 4

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	Alternative 9
Screening Criteria	**No Action**	**Limited Action**	**Soil Cover and Long-Term Monitoring**	**Soil Cover with *In situ* DNAPL Source Treatment and Long-Term Monitoring**	**RCRA Cover with Hydraulic Isolation and Long-Term Monitoring**	**Excavation and Disposal**	**Excavation and Disposal combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring**	**Excavation and Disposal combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring**	***In situ* Containment and Long-Term Monitoring**
Overall Effectiveness	NA	NA	NA[1]	NA[2]	NA[3]	NA[4]	High	Moderate	NA
Short-term	NA	NA	NA	NA	NA	NA	Moderate to High	Low	NA
Long-term	NA	NA	NA	NA	NA	NA	High	High	NA
Overall Implementability	NA	NA	NA	NA	NA	NA	Moderate	Low to Moderate	NA
Technical	NA	NA	NA	NA	NA	NA	Moderate	Low to Moderate	NA
Administrative	NA	NA	NA	NA	NA	NA	Moderate	Low	NA
Overall Cost	NA	NA	NA	NA	NA	NA	High	High	NA
Capital	NA	NA	NA	NA	NA	NA	High	High	NA
Operation and maintenance	NA	NA	NA	NA	NA	NA	Low to Moderate	Low to Moderate	NA

NA—Not applicable based on-site conditions or nature of contamination present at the SWMU.
[1] Not effective in remediating buried radioactive and inorganic materials, or DNAPL extending into RGA.
[2] Not effective in remediating buried radioactive and inorganic materials.
[3] Not effective in containing DNAPL extending into the RGA.
[4] Provides no remedial process option for remediating DNAPL in UCRS and RGA.
NOTE: Alternatives shaded grey were screened out at this step.

7.3.1.4 Alternative 5—RCRA cover with hydraulic isolation and long-term monitoring

Alternative 5 is screened from further consideration for SWMU 4 because the data in the RI Report indicate that there is a potential DNAPL source that extends through the UCRS into the RGA. A RCRA cover would not be effective in containing DNAPL in the RGA.

7.3.1.5 Alternative 6—Excavation and disposal

Alternative 6 is screened from further consideration at SWMU 4 because it does not incorporate RPOs for remediation of the potential DNAPL source at SWMU 4.

7.3.2 Summary of Alternatives Retained for Detailed Analysis

The following alternatives are carried forward for detailed analysis.

- Alternative 1: No action
- Alternative 7: Excavation and disposal combined with i*n situ* DNAPL source treatment and long-term monitoring
- Alternative 8: Excavation and disposal combined with *ex situ* DNAPL source treatment and long-term monitoring

Comparative analyses are performed following the detailed analyses.

7.4 DETAILED ANALYSIS OF ALTERNATIVES

7.4.1 Alternative 1—No Action

The No Action alternative is defined in accordance with CERCLA and provides a baseline to which other alternatives can be compared. Under this alternative, no action would be taken to implement remedial activities for SWMU 4 or to reduce the potential hazard to human or ecological receptors.

7.4.1.1 Overall protection of human health and the environment

This alternative would not be protective of groundwater. No additional controls would be implemented to protect site workers or the public. The results of the risk-based evaluation of the No Action alternative indicate a possible threat to human health via the groundwater pathway at this SWMU via the groundwater pathways presented in Figure 2.1. Not all of the RAOs, particularly protection of groundwater, would be met because no action would be implemented.

Alternative 1 would not meet this threshold criterion for a potential DNAPL source. A DNAPL source would not be treated or removed, risks to potential receptors would not be reduced, and the RAOs would not be met because no action would be implemented.

7.4.1.2 Compliance with ARARs

No ARARs have been identified for Alternative 1, the No Action alternative.

7.4.1.3 Long-term effectiveness and permanence

Alternative 1 provides no long-term effectiveness or permanence. Future potential leaching of contaminants to the RGA may result in concentrations above their MCL or risk-based value. Alternative 1 leaves the risk or hazard from radioactive or inorganic COCs at an unacceptable level at SWMU 4. Over time, this alternative would not prevent future migration of contaminants. Alternative 1 would leave the risk or hazard from a DNAPL source at an unacceptable level at SWMU 4. The alternative does not provide any long-term remedy to manage residual risk at this SWMU.

7.4.1.4 Reduction of toxicity, mobility, or volume through treatment

Treatment would not be implemented with Alternative 1. Reduction of toxicity, mobility, or volume through treatment would not be applicable to the No Action alternative because it does not include treatment. The No Action alternative would not result in any reduction in the toxicity, mobility, or volume of contaminants other than those attributable to natural processes, such as degradation, dilution, or dispersion.

7.4.1.5 Short-term effectiveness

No actions would be implemented under Alternative 1; therefore, no additional risks to workers, the public, or the environment would be incurred. There would be no change to existing conditions. RAOs would not be met over any reasonable time period.

7.4.1.6 Implementability

The No Action alternative can be implemented readily. If future remedial action is necessary, this alternative would not impede implementation of such action in the future.

The ongoing public awareness program would require regular coordination with DOE, KY, and possibly with other governmental agencies.

7.4.1.7 Cost

The preliminary cost estimates for Alternative 1 serve as a baseline for comparison of the other remedial alternatives. These cost estimates are based upon FS-level scoping and are intended to aid with selection of a preferred alternative. There are no capital or O&M costs associated with Alternative 1.

7.4.2 Alternative 7—Excavation and Disposal Combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring

This alternative is comprised of excavation to remove waste and contaminated soil, followed by *in situ* DNAPL source treatment to remove DNAPL that potentially may remain after excavation. The excavation component of this alternative includes the following: installation of sheet piles around the perimeter of the waste unit; excavation of all buried materials and contaminated soils; operation of emission control equipment; cover soil and waste disposal characterization sampling; excavation pit dewatering; and segregation, bulking, and consolidation of compatible waste groups. In addition, treatment of excavated materials may include the following: *ex situ* thermal desorption to drive off VOCs and SVOCs; metal detection/magnetic separation of metallic materials (decayed drums and uranium for stabilization/solidification); and radiological separation. For the treatment and segregation operations, short-term storage would be required for the excavated waste and for treated materials awaiting shipment to the disposal site. Disposal options include off-site disposal facilities, as well as WDF. The RPO for potential residual DNAPL is *in situ* DNAPL source treatment, assumed to be ERH for the purpose of cost estimation. A detailed description of this alternative is presented in Section 3.4.

7.4.2.1 Overall protection of human health and the environment

Alternative 7 would meet this threshold criterion. Waste and contaminated soil will be physically removed from the SWMU and disposed of in one or more appropriate disposal facilities, including the WDF, thus meeting all RAOs for waste in the former burial pits.

In situ DNAPL source treatment for potential DNAPL at SWMU 4 would meet the RAO for treating waste by removing the suspected DNAPL source as vapor and destroying it *ex situ*. It also would meet the RAOs for groundwater protection and worker protection based on previous demonstrations. The C-400 SPH Study (DOE 2003) determined that over 98% of TCE was removed from soil in less than six months, and similar performance would be expected at SWMU 4.

7.4.2.2 Compliance with ARARs

Alternative 7 would meet this threshold criterion. ARARs for this alternative are summarized in Appendix F.

7.4.2.3 Long-term effectiveness and permanence

Complete excavation offers maximum control of contaminant migration, since no wastes or associated contaminated soils would remain in the SWMU; therefore, this alternative offers a high degree of risk reduction. Complete treatment processes manage or remove hazardous characteristics or destroy the COCs.

Alternative 7 allows for potential risks associated with contaminants in the SWMU to be reduced or eliminated. Risks associated with direct contact with waste and surface soils will be eliminated since the primary source and associated contaminated soils will be removed; therefore, Alternative 7 allows for a maximum reduction of uncertainties associated with these soils in terms of continued contributions to the hydrogeologic system.

Secondary sources of DNAPL, in the form of contaminated soils remaining after excavation, likely will continue to release these contaminants. *In situ* DNAPL source treatment is incorporated into Alternative 7 for DNAPL removal for this SWMU in the event postremediation samples indicate the presence of DNAPL after the excavation is completed.

The long-term effectiveness and permanence of Alternative 7 for DNAPL remediation is high because much of the DNAPL in the source areas at SWMU 4 would be removed by *in situ* DNAPL source treatment. VOCs in the extracted vapor would be condensed. Overall removal efficiency is estimated at up to 98% over approximately six months, based on results of the C-400 SPH Study (DOE 2003). The estimated degradation rate for TCE upon completion of active remediation is presented in Appendix B. *In situ* DNAPL source treatment should greatly reduce DNAPL levels in soil.

7.4.2.4 Reduction of toxicity, mobility, or volume through treatment

This alternative reduces or eliminates the mobility and volume of contaminants from the unit. The toxicity of the treatment residuals also would be drastically reduced and/or eliminated. The removal and disposition of contaminated soil from an unlined burial cell containing COCs to an appropriate disposal facility prevents those contaminants from migrating to the groundwater.

This alternative would remove and recondense most of the DNAPL potentially present at the SWMU. Overall removal efficiency is estimated at up to 98% over approximately six months, based on results for the C-400 SPH Study (DOE 2003). The *in situ* DNAPL source treatment system design would include measures to reduce the potential for mobilization of DNAPL during treatment. Secondary wastes would include condensed VOC liquids, spent GAC, treated condensate, drill cuttings produced during electrode/vapor recovery well installation, PPE, and decontamination fluids. For cost-estimating purposes, drill cuttings, PPE, and decontamination fluids were assumed to be dewatered, sampled, and analyzed prior to bulk transport to off-site disposal. Actual disposal requirements would be determined during RD and by sampling of containerized soils. Condensed VOCs would be shipped off-site for recycling or destruction. Spent GAC would be shipped off-site for regeneration. It is assumed that treated condensate would be discharged to a permitted outfall.

7.4.2.5 Short-term effectiveness

Short-term risks to the community resulting from excavation activities at the SWMU would not be expected. Potential risks resulting from migration of contaminants to off-site locations would be controlled by the on-site vacuum hood and HEPA filtration system. Alternative 7, however, includes a potential risk to the public from transportation of the LLW or hazardous wastes/liquids to off-site disposal and/or treatment facilities. This risk would be greatly reduced by disposing of waste in the WDF.

Short-term exposures of workers to COCs during implementation of Alternative 7 could occur. Potential exposure pathways include direct contact with soil (ingestion, inhalation) and exposure to external penetrating radiation. Worker risks are not expected to exceed acceptable limits because exposure frequency and duration are less than those evaluated in the baseline risk assessment. Typically, risks from handling waste/contaminated soils would be minimized through adherence to health and safety protocols. To protect workers, PPE, ambient conditions monitoring, and decontamination protocols would be used in accordance with an approved, site-specific HASP.

The short-term effectiveness of Alternative 7 is moderate to high. The alternative includes *in situ* DNAPL source treatment process to remediate a DNAPL source if one is discovered. Installation of electrode/vapor recovery wells and monitoring equipment would encounter contaminated soils. Soil cuttings produced during installation of electrode/vapor recovery wells would be managed in accordance with the HASPs, WCP, and WMP prepared during the RD/RAWP. Installation and operation of the *in situ* DNAPL source treatment system would be conducted by trained personnel in accordance with procedures. Site preparation and *in situ* DNAPL source treatment system operation is expected to require less than one year.

Excavation and disposal would be conducted by trained personnel in accordance with standard radiological, engineering, and operational procedures, DSAs, HASPs, and safe work practices to maintain a work environment that minimizes injury or exposure to risks to human health or the environment.

No ecological impacts at the BGOU are anticipated under this alternative. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archaeological or historical sites or T&E species would be impacted by this alternative. Risk assessment and mitigation for ecological receptors in nearby drainage ditches are within the scope of the Surface Water OU.

The RAOs for radioactive and inorganic contaminants would be achieved following completion of excavation. The goal would be to remove as much DNAPL as practicable by the end of the treatment period, but any low-level contaminant residues remaining after a reasonable period of treatment will be remediated by natural attenuation processes.

7.4.2.6 Implementability

Alternative 7 is considered to be technically and administratively feasible and implementable. The equipment and technologies associated with implementation of this alternative have been proven to be technically feasible and are available from contractors or vendors. Treatability testing may be required for waste treatment processes, including *ex situ* thermal desorption for excavated soils and uranium oxidation. The implementability of construction-related activities during excavation and backfilling at SWMU 4 subject to Alternative 7 is very similar to that carried out routinely at other sites. Likewise, sampling, analysis, transportation, and disposal at an approved location are routinely performed and, if properly implemented, are proven to be safe. Some excavated waste materials may be radioactive, RCRA hazardous, or mixed. Treatment of wastes with multiple regulatory classifications is more complex and may require more than one treatment process to make the waste suitable for transportation and/or land disposal. On-site treatment processes will comply with ARARs.

An option for disposal of waste and residuals at the WDF was considered under Alternative 7. The primary difference would be the elimination of waste leaving the PGDP, related off-site transportation issues, and the cost for disposal. At this time, no capacity for disposal of these wastes exists at PGDP.

Overall implementability of Alternative 7 for DNAPL is moderate. Waste material will be removed during excavation that could interfere with underground construction of the *in situ* DNAPL source treatment system.

Equipment, personnel, and services required to implement this alternative are readily commercially available. No additional development of these technologies would be required. Contractors possessing the required skills and experience are available.

Implementation of Alternative 7 for DNAPL remediation is administratively feasible. The electrode/vapor extraction wells would be constructed and abandoned according to the substantive requirements of KY regulations. Recovered vapor would be treated to meet allowable emission levels prior to discharge.

7.4.2.7 Cost

Costs were estimated for transportation and disposal of wastes at an off-site facility as well as for an option to dispose of waste at the WDF. O&M costs are dependent upon the status of the SWMU upon completion of excavation. Cost will be low if SWMU closure can be achieved upon completion of excavation and a long-term monitoring program is minimal or unnecessary.

7.4.3 Alternative 8—Excavation and Disposal Combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring

This alternative is comprised of excavation to remove waste and contaminated soil, followed by *ex situ* DNAPL source treatment to remove DNAPL that potentially may remain after excavation of the buried wastes and long-term monitoring to confirm no further impacts to groundwater. The buried waste excavation component of this alternative includes the following: shoring around the perimeter of the waste unit; excavation of all buried materials and contaminated soils; operation of emission control equipment; cover soil and waste disposal characterization sampling; excavation pit dewatering; and segregation, bulking, and consolidation of compatible waste groups. In addition, treatment of excavated materials may include the following: *ex situ* thermal desorption to drive off VOCs and SVOCs; metal detection/magnetic separation of metallic materials (decayed drums and uranium for stabilization/solidification); and radiological separation. For the treatment and segregation operations, short-term storage would be required for the excavated waste and for treated materials awaiting shipment to the disposal site. Disposal options include off-site disposal facilities, as well as the WDF.

The RPO for DNAPL-contaminated soils following excavation of buried waste is *ex situ* DNAPL source treatment. It consists of excavation of the DNAPL source, oxidation of contaminated soil, and returning the decontaminated soil to the excavation for the purpose of cost estimation. A detailed description of this alternative is presented in Section 3.4.

7.4.3.1 Overall protection of human health and the environment

Alternative 8 would meet this threshold criterion. Potential short-term risks to remediation workers due to direct contact with the waste material and inhalation hazards are much larger than any of the other alternatives evaluated in this FS. In addition, potential risks to the public and the environment as a result shipping and handling should be considered for off-site shipments. These concerns are greatly reduced for disposal in the WDF.

Waste and contaminated soil will be physically removed from the SWMU and disposed of in one or more appropriate disposal facilities, including the WDF, thus meeting all RAOs for waste in the former burial pits.

Ex situ DNAPL source treatment for DNAPL at SWMU 4 would meet the RAO for treating waste by removing the DNAPL source and destroying it *ex situ*. It also would meet the RAOs for groundwater protection and worker protection. Long-term monitoring will verify that target concentrations are met after the action is complete.

7.4.3.2 Compliance with ARARs

Alternative 8 would meet this threshold criterion. ARARs for this alternative are summarized in Appendix F.

7.4.3.3 Long-term effectiveness and permanence

Complete excavation offers maximum control of contaminant migration, since no wastes or associated contaminated soils would remain in the SWMU; therefore, this alternative offers a high degree of risk reduction. Complete treatment processes manage or remove hazardous characteristics or destroy the COCs.

Alternative 8 reduces or eliminates the potential risks associated with contaminants. Risks associated with direct contact with waste and surface soils will be eliminated since the primary source and associated contaminated soils will be removed; therefore, Alternative 8 allows for a maximum reduction of uncertainties associated with these soils in terms of continued contributions to the hydrogeologic system.

Secondary sources of TCE, in the form of contaminated soils, potentially may remain after excavation of buried waste; however, the residual concentrations are not anticipated to result in concentrations at the UCRS-RGA interface that would exceed the MCL or risk-based value. An *ex situ* DNAPL source treatment component is incorporated into Alternative 8 for DNAPL removal for this SWMU in the event postremediation samples indicate residual DNAPL after the excavation is completed.

The long-term effectiveness and permanence of Alternative 8 for DNAPL remediation is high because the DNAPL in the source areas at SWMU 4 would be removed and treated. In the event that some TCE contaminated soils remain, the estimated degradation rate for TCE upon completion of active remediation is presented in Appendix B. *Ex situ* DNAPL source treatment will remove DNAPL levels in soil, protecting the future site worker and current and future off-site residential groundwater user, thereby reducing or eliminating site risks. Long-term monitoring will be conducted to confirm no further impacts to groundwater.

7.4.3.4 Reduction of toxicity, mobility, or volume through treatment

This alternative reduces or eliminates the mobility and volume of contaminants from the unit. The toxicity of the treatment residuals also would be drastically reduced and/or eliminated. The removal and disposition of waste and contaminated soil from an unlined burial cell containing COCs to an appropriate disposal facility prevents those contaminants from migrating to the groundwater.

This alternative would remove and capture or condense most of the DNAPL present at the SWMU. The *ex situ* DNAPL source treatment system design would include measures to reduce the potential for mobilization of DNAPL during treatment. Secondary wastes may include condensed VOC liquids, spent GAC, treated condensate, treated soil, and PPE. For cost-estimating purposes, treated soil, PPE, and decontamination fluids were assumed to be dewatered, sampled, and analyzed prior to bulk transport to off-site disposal. Actual disposal requirements would be determined during RD and by sampling of containerized soils. Condensed VOCs would be shipped off-site for recycling or destruction. Spent GAC would be shipped off-site for regeneration. It is assumed that treated condensate would be discharged. It is assumed that DNAPL-contaminated soils treated by oxidation will be sufficiently decontaminated to be returned to the excavation. If not, they should pass the WAC and be disposed of at the C-746-U Landfill; otherwise, they would be disposed of in the WDF or shipped to an off-site disposal facility.

7.4.3.5 Short-term effectiveness

Short-term risks to the community resulting from excavation of buried waste would not be expected. Potential risks resulting from migration of contaminants to off-site locations would be controlled by the on-site vacuum hood and HEPA filtration system. Alternative 8, however, includes a potential risk to the public from transportation of the LLW or hazardous wastes/liquids to off-site disposal and/or treatment facilities. This risk would be greatly reduced by disposing of waste in the WDF.

Short-term exposures of workers to COCs during implementation of Alternative 8 could occur. Potential exposure pathways include direct contact with soil (ingestion, inhalation) and exposure to external penetrating radiation. Worker risks are not expected to exceed acceptable limits because exposure frequency and duration are less than those evaluated in the baseline risk assessment. Typically, risks from handling waste/contaminated soils would be minimized through adherence to health and safety protocols. To protect workers, PPE, ambient conditions monitoring, decontamination protocols, and fire suppression measures would be used in accordance with an approved, site-specific HASP.

The short-term effectiveness of Alternative 8 is low. The alternative includes *ex situ* DNAPL source treatment as a remedial component to remediate a DNAPL source if one is discovered. Risk to workers would be higher than other alternatives because of the depth of excavation and volumes of waste and contaminated soils to be handled. There is a higher potential for fugitive dust and vapors to the public because of the volumes being treated. Transportation issues are fewer for on-site disposal because waste will not leave PGDP property. Soil for treatment would be managed in accordance with the HASPs, WCP, and WMP prepared during the RD/RAWP. Installation and operation of the *ex situ* DNAPL source treatment system would be conducted by trained personnel in accordance with procedures.

Excavation and disposal would be conducted by trained personnel in accordance with standard radiological, engineering, and operational procedures, DSAs, HASPs, and safe work practices to maintain a work environment that minimizes injury or exposure to risks to human health or the environment.

No ecological impacts at the BGOU are anticipated under this alternative. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archaeological or historical sites or T&E species would be impacted by this alternative. Risk assessment and mitigation for ecological receptors in nearby drainage ditches is within the scope of the Surface Water OU.

The RAOs for radioactive and inorganic contaminants would be achieved following completion of excavation. The goal would be to remove as much DNAPL as practicable by the end of the treatment period, but any low-level contaminant residues remaining after a reasonable period of treatment will be remediated by natural attenuation processes.

7.4.3.6 Implementability

Alternative 8 is considered to be technically and administratively feasible, but its overall ease of implementation is low to moderate. The equipment and technologies associated with implementation of this alternative have been proven to be technically feasible and are available from contractors or vendors. Treatability testing may be required for waste treatment processes including *ex situ* thermal desorption for excavated soils. The implementability of construction-related activities during excavation and backfilling at SWMU 4 subject to Alternative 8 is very similar to that carried out routinely at other sites. Likewise, sampling, analysis, transportation, and disposal at an approved location are routinely performed and, if properly implemented, are proven to be safe. Some excavated waste materials may be radioactive, RCRA hazardous, or mixed. Treatment of wastes with multiple regulatory classifications is more complex and may require more than one treatment process to make the waste suitable for transportation and/or land disposal. On-site treatment processes will comply with ARARs.

Overall implementability of Alternative 8 for DNAPL is low to moderate. DNAPL-contaminated soils will be removed during excavation and treated *ex situ*.

Equipment, personnel, and services required to implement this alternative are readily commercially available. No additional development of these technologies would be required. Contractors possessing the required skills and experience are available, although the space constraints, depth of waste, and potential for groundwater intrusion into the excavation add complexity to the action.

Implementation of Alternative 8 for DNAPL remediation is administratively feasible; however, requirements for control and monitoring of air emissions may be greater than for other alternatives. Recovered vapor would be treated to meet allowable emission levels prior to discharge.

An option for disposal of waste and residuals at the WDF was considered under Alternative 8. The primary difference would be the elimination of waste leaving the PGDP, related off-site transportation issues, and the cost for disposal. At this time, no capacity for disposal of these wastes exists at PGDP. The following discussion assumes that future capacity to treat and dispose of the mixed and/or LLW at PGDP is available.

The PGDP disposal facility WAC would provide the basis for determining if waste sent to that facility is acceptable.

Wastes would be loaded into trucks and transported to the on-site disposal facility at the PGDP. Wastes would be placed in the disposal facility so that the potential for releases, danger from the mixing of incompatible or unstable outdated materials, and environmental and personnel exposures are minimized.

7.4.3.7 Cost

Costs were estimated for transportation and disposal of wastes at an off-site facility as well as for an option to dispose of waste at the WDF. O&M costs are dependent upon the status of the SWMU upon completion of excavation. Cost will be low if target concentrations are achieved upon completion of excavation and a long-term monitoring program is minimal or unnecessary. Alternative 8 includes cost for implementation of a remedial action for DNAPL employing *ex situ* DNAPL source treatment.

7.5 COMPARATIVE ANALYSIS OF ALTERNATIVES

A comparative analysis summary for contaminated source area alternatives for SWMU 4 is presented in Table 7.2 and the corresponding costs for the alternatives are presented in Table 7.3.

7.5.1 Threshold Criteria

Source area remedial alternatives are compared with respect to the threshold criteria in the following sections.

7.5.1.1 Overall protection of human health and the environment

Alternative 1 does not meet the threshold criterion of overall protection of human health and the environment. Alternative 1 would not treat, contain, or remove waste.

Alternative 7, excavation and disposal combined with *in situ* DNAPL source treatment, meets the threshold criterion by removing waste and contaminated soil from the SWMU. This alternatives could remove enough waste and contaminated soil so that the remaining soil at the SWMU would meet soil target concentrations and attain MCLs or risk based values in RGA groundwater at the UCRS-RGA boundary beneath the SWMU.

Should residual DNAPL remain upon completion of excavation, implementation of the *in situ* DNAPL source treatment component of Alternative 7 will remove DNAPL in soil. Based on the maximum observed concentration of TCE at SWMU 4 and modeling based on 98% removal of TCE DNAPL observed during the C-400 SPH Study (DOE 2003), the results for DNAPL removal after operating the system for less than one year were estimated. The time frames for reaching the maximum TCE concentration and the risk-based target concentrations necessary to meet the MCL beneath the SWMU were predicted by modeling. There is minimal benefit to operating the *in situ* DNAPL source treatment system for a longer than one year. The modeling approach and results are presented in Appendix B.

Alternative 8, which excavates buried waste and follows up with excavation and *ex situ* treatment of DNAPL, meets this threshold criterion by removing waste and contaminated soil. This alternative is at least as, if not more protective than, Alternative 7.

7.5.1.2 Compliance with ARARs

No ARARs have been identified for Alternative 1, the No Action alternative.

Table 7.2. Summary of Comparative Analysis of Source Area Alternatives SWMU 4

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 1: No Action	Does not meet the threshold criterion. Waste would remain untreated. Potential DNAPL source would remain untreated other than through natural processes. No protection for future off-site groundwater users.	No actions implemented; no ARARs identified.	No long-term effectiveness or permanence.	Low. No direct treatment or containment provided.	High. No actions implemented; therefore, no change to existing conditions.	High-No action would be implemented. High technical and administrative implementability.
Alternative 7: Excavation and Disposal with *In situ* DNAPL Source Treatment and Long-Term Monitoring	High. Threshold criterion met. Removal of contaminated waste offers the highest degree of overall protection and achievement of RAOs. Potential DNAPL source would be treated in UCRS and RGA. Significant reduction in DNAPL mass should be achieved by treatment. Remaining TCE DNAPL would be remediated over time by natural processes. Soil target concentrations should be attained based on results of C-400 SPH Study.	High. Threshold criterion met. Complies with ARARs and potential TBCs. Should provide groundwater protection based on results of C-400 SPH Study.	High. Contaminant sources removed; therefore, residual risks are negligible. Most adequate overall level of protection to humans and the environment.	Moderate to high. Excavation, treatment and disposal would reduce mobility of radionuclides, reduce or destroy toxicity of organics and VOCs. DNAPL source at SWMU 4 extends to RGA.	Moderate to High. Potential negative impacts to community from waste transportation for off-site disposal. Risk to workers higher than other alternatives but can be managed by applying appropriate health and safety procedures. Improves to high for on-site disposal. Transportation issues become negligible since waste will not leave PGDP property. Implementation could take years.	Moderate. Excavation and associated technologies are readily implementable Some excavated waste materials or soil may have multiple regulatory classifications, increasing the complexity of treatment required for transportation and/or disposal. WDF is being evaluated as part of the waste disposal option project, and a ROD has not been issued.

Table 7.2. Summary of Comparative Analysis of Source Area Alternatives SWMU 4 (Continued)

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 8: Excavation and Disposal combined with *Ex Situ* DNAPL Source Treatment and Long-Term Monitoring	High. Threshold criterion met. Removal of contaminated waste offers the highest degree of overall protection and achievement of RAOs. DNAPL source would be treated in the UCRS and the RGA. Removal of DNAPL mass should be achieved by excavation and treatment. Soil target concentrations should be attained. Long-term monitoring would verify that target concentrations are met after action is complete.	High. Threshold criterion met. Complies with ARARs and potential TBCs. Should provide groundwater protection.	High. Contaminant sources removed; therefore, no residual risks should remain. Long-term monitoring conducted to confirm no further impacts to groundwater.	High. Excavation, treatment and disposal would remove contamination sources.	Low. Potential negative impacts to community from waste transportation for off-site disposal. Risk to workers higher than other alternatives because depth of excavation, and volumes of waste and contaminated soils to be handled Higher potential for fugitive dust and vapors because of the volumes being treated. Transportation issues less for on-site disposal because waste will not leave PGDP property. Implementation could take years.	Low. Some excavated waste materials or soil may have multiple regulatory classifications, increasing the complexity of treatment, transportation and/or disposal. Excavation to remove DNAPL extending into RGA may be impractical depending on its depth. WDF is being evaluated as part of the waste disposal option project, and a ROD has not been issued.

Table 7.3. SWMU 4 Remedial Alternatives Cost Summary

			PRESENT WORTH[1]		ESCALATED	
Alternative Description	**Annual Time Period, yrs**	**Capital $ (2010 Constant Dollars)**	**Total Annual $**	**Total $ (Capital and Annual)**	**Total Annual $**	**Total $ (Capital and Annual)**
Alternative 1—No Action	0	$0	$0	$0	$0	$0
Alternative 7a—Excavation and Disposal	0	$146,328,000	$0	$146,328,000	$0	$155,239,000
Alternative 7b—Excavation and Disposal (at the WDF))	0	$82,605,000	$0	$82,605,000	$0	$87,636,000
Contingency for Alternative 7—*In situ* DNAPL Source Treatment and Long-Term Monitoring	30	$80,876,000	$733,000	$81,609,000	$2,283,000	$88,084,000
Alternative 8a—Excavation and Disposal	0	$146,328,000	$0	$146,328,000	$0	$155,239,000
Alternative 8b—Excavation and Disposal (at the WDF))	0	$82,605,000	$0	$82,605,000	$0	$87,636,000
Contingency for Alternative 8—*Ex situ* DNAPL Source Treatment and Long-Term Monitoring	30	$99,652,000	$739,000	$100,391,000	$2,296,000	$108,017,000

[1] Not used for budgeting or planning purposes because value is based on investing funds for outyear expenditures.

Alternative 7 would meet this threshold criterion. This alternative could remove enough waste and contaminated soil so that the remaining soil at the sites would meet soil target concentrations and attain MCLs or risk-based values in RGA groundwater at the UCRS-RGA boundary beneath the SWMU. Should residual DNAPL remain upon completion of excavation, Alternative 7 would remove a large portion of the residual DNAPL mass in soil during the period of operation of the *in situ* DNAPL source treatment system, and natural processes would, in time, prevent further degradation of RGA groundwater from SWMU 4.This alternative is expected to meet all location- and action-specific ARARs through design and planning during preparation of the RD/RAWP.

Alternative 8 would meet this threshold criterion as well or better than Alternative 7.

7.5.2 Balancing Criteria

Source area alternatives are compared with respect to the balancing criteria in the following sections.

7.5.2.1 Long-term effectiveness and permanence

Alternative 1 would not be effective. The risk posed by waste material and COCs in soil would remain unabated.

Alternative 7 provides a high degree of long-term effectiveness and permanence. Residual risk should be the lowest under this alternative. Long-term controls may not be required under this alternative provided that waste material-and contaminated-soil can be removed to attain soil target concentrations. Should residual DNAPL remain upon completion of excavation, *in situ* DNAPL source treatment should be effective at removing most of the mass of DNAPL from both the UCRS and RGA, with the remainder being remediated by natural processes. Residual risk would be the lowest under this alternative.

The long-term effectiveness and permanence of Alternative 8 would be as good as or better than Alternative 7.

7.5.2.2 Reduction of toxicity, mobility, and volume through treatment

Alternative 1 would not reduce the toxicity, mobility, or volume of COCs in waste or soil at the SWMU.

Alternative 7 reduces toxicity by removal, treatment, and disposal of wastes. Waste materials and soil would be treated on-site as needed to allow excavated materials to be readied for transport or disposal. Volume is similarly reduced. The relocation of waste and contaminated soil from an unlined burial cell that has COCs in direct contact with groundwater, to an appropriate disposal facility will reduce the mobility of those contaminants in the environment. Removal of source material and surrounding contaminated soils will prevent future migration of contaminants at the SWMU.

If residual DNAPL is present at SWMU 4, the *in situ* DNAPL source treatment component of Alternative 7 would remove most of the DNAPL mass from the UCRS. It would remove DNAPL from the subsurface to be condensed by aboveground equipment. VOC-contaminated water condensed from the extracted vapor stream would be air stripped to remove VOCs. The VOCs in the air stripper emissions would be condensed and either recycled or destroyed off-site. Residual VOCs in air stripped water would be removed by adsorption on activated carbon. The spent carbon would be managed off-site, likely by thermal regeneration or incineration.

Alternative 8 also reduces toxicity by removal, treatment, and disposal of wastes the same as Alternative 7. There is even less likelihood that DNAPL will remain after active treatment than in the case of

Alternative 7 because the DNAPL-contaminated soil, if present, will be excavated and treated. There is a degree of uncertainty associated with identifying and excavating all the contaminated soil for DNAPL treatment.

7.5.2.3 Short-term effectiveness

The short-term effectiveness of Alternative 1 is low because RAOs would not be attained over any reasonable time frame.

The short-term effectiveness of Alternative 7 is moderate because of the increased potential for contact to workers and the community during excavation. The option to dispose of excavated waste in the WDF would improve the short-term effectiveness by eliminating risks associated with wastes leaving the site. The DNAPL source treatment component of Alternative 7 for DNAPL remediation has a high degree of short-term effectiveness, Active remedial action could be completed in a period of less than one year. Alternative 7 potentially could expose workers to chemical hazards during well drilling, installation of electrodes, and operation of the aboveground treatment system. Workers also could be exposed to thermal and electrical hazards due to installation and operation of electrodes. The ERH system is technically complex, but site workers will have gained valuable experience with the technology during the C-400 Remedial Action, so that the associated health and safety issues should be effectively managed. The potential risks to the community from Alternative 7 during the remedial action period for DNAPL are negligible.

The short-term effectiveness for Alternative 8 is potentially low. Greater depths of excavation, larger volumes of contaminated soil, potentially larger volumes of wastewater, increased requirements and size for treatment unit operations, and associated emissions all are factors that contribute negatively to the short-term effectiveness of Alternative 8.

7.5.2.4 Implementability

Alternative 1 would be the most readily implementable alternative because no construction or invasive action would be taken.

Alternative 7 is considered to be technically and administratively feasible and implementable. For the DNAPL remediation components of the alternative, the SPH Study at C-400 established system design parameters and the range of operating conditions. Subsurface objects that could interfere with construction of the underground components of the *in situ* DNAPL source treatment system would be removed prior to construction. Equipment, personnel, and services required to implement this alternative are readily available. Equipment replacement should be minimal during the remedial action period at any SWMU because RAOs should be achieved within less than one year of operation. The treatment system would generate several waste residuals that would require management, including condensed VOCs, treated water, and VOC-contaminated activated carbon.

Alternative 8 is technically feasible, but there are challenges. The main technical challenges are associated with the depth of excavation and shoring and groundwater control and treatment.

7.5.2.5 Cost

Capital and O&M costs for alternatives at SWMU 4 are presented in Table 7.3.

7.5.3 Summary of Comparative Analysis of Alternatives

Alternative 1 does not meet the threshold criterion of overall protection of human health and the environment. Alternative 1 would not treat, contain, or remove waste. Risk to future off-site groundwater users from the migration of COCs to RGA groundwater could reach unacceptable levels.

Alternative 7, excavation and disposal with *in situ* DNAPL source treatment, meets the threshold criteria by removing waste and contaminated soil from the site. This alternative would remove enough waste and contaminated soil so that the remaining soil at the sites likely would meet soil target concentrations and attain MCLs or risk-based values in RGA groundwater at the UCRS-RGA boundary beneath the SWMU. All ARARs defined for Alternative 7 would be met.

For DNAPL source areas, Alternative 7 provides a high degree of long- and short-term effectiveness. Alternative 7 also provides a high reduction in toxicity, mobility, and volume of contamination through treatment.

Alternative 8 is comparable in long-term effectiveness to Alternative 7, but its short-term effectiveness is less. Alternative 8 is also more challenging to implement than Alternative 7.

Alternative 7 provides high overall long-term effectiveness and permanence with fewer implementation challenges.

THIS PAGE INTENTIONALLY LEFT BLANK

8. SWMU 5

8.1 SWMU 5 HISTORY AND BACKGROUND

The C-746-F Burial Yard is located in the northwestern section of the PGDP secured area. SWMU 5 (which covers an area of approximately 197,400 ft^2) is located adjacent to a scrap yard to the north (C-746-P/P1) and SWMU 6 to the east. The ground surface is covered with short grasses and various flowering herbaceous plants (DOE 1998c).

Disposal pits were located on a grid system. Documentation of the size of these grids ranges from 10 by 10 ft cells to 20 by 20 ft cells excavated to a depth of 6 to 15 ft bgs. Figure 8.1 shows these cells as 20 by 20 ft. Worker interviews indicate this spacing is roughly accurate; however, historical aerial photographs indicate the earliest grid spacing may have been smaller. The fence around SWMU 5 has regularly spaced reflectors, which may have been used by workers as a reference in defining the waste cell grid in the field.

Waste placed in the yard disposal pits was covered with 2 to 3 ft of soil. SWMU 5 is fenced to limit access to authorized personnel only.

SWMU 5 was in operation from 1965 to 1987. The burial pits were used for the burial of components from the "Work for Others" activities, some radionuclide-contaminated scrap metal, and slag from the nickel and aluminum smelters. The total quantity of wastes buried at the yard could be up to 896,000 ft^3, assuming an average quantity of 2,800 ft^3 waste placed in each cell and 320 cells receiving waste.

Metals and radionuclides are the primary potential contaminants of interest at SWMU 5, since the majority of items believed to be buried there include some radionuclide-contaminated scrap metal and slag from PGDP nickel and aluminum smelters. The most prevalent metal detected in subsurface soils above background levels is beryllium (26 of 59 analyses), followed by iron and vanadium (4 of 59 analyses). The metals exceedances are well distributed across SWMU 5. High levels of vanadium tended to occur at moderate depths (15 to 30 ft), while beryllium exceedances mostly are at depths of 40 ft or greater. The screening process did not identify any radionuclides or organic compounds as potential contaminants for SWMU 5.

The RI identified many metals in these UCRS groundwater samples from SWMU 5 with concentrations that exceed RI screening criteria. Of these, iron, lead, manganese, and molybdenum analyses had the highest frequency of exceedances. Locations with metals that exceed screening criteria were well distributed across the SWMU. Historical samples of UCRS groundwater documented single detections of pyrene and TCE at concentrations that exceed screening levels. TCE was detected in UCRS groundwater at a concentration of 29 μg/L. No radionuclide analyses exceeded screening criteria in the UCRS groundwater samples.

Historical data were reviewed during the RI to determine that manganese and iron commonly were present at levels exceeding screening criteria in RGA groundwater at SWMU 5. Additionally, TCE concentrations exceeded screening criteria throughout the depth of the RGA. These occurrences likely are related to the Northwest Plume, which passes to the east of the SWMU 5 area.

The RI determined that there were no McNairy groundwater contaminants above screening criteria.

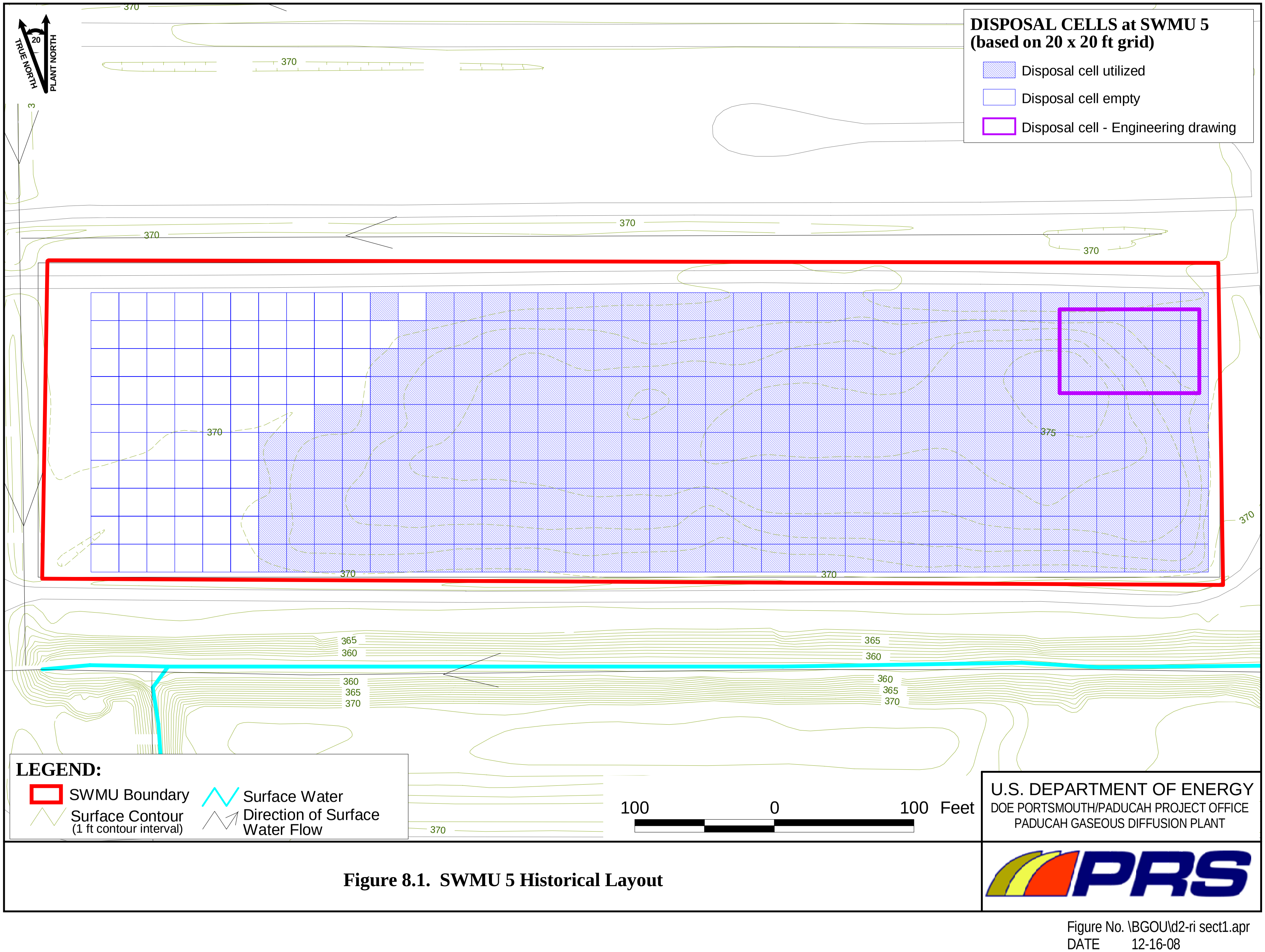


Figure 8.1. SWMU 5 Historical Layout

8.1.1 Hydrogeologic Interpretation

The study area geology and hydrogeology is summarized below as documented in the BGOU RI (DOE 2010). Because SWMUs 5 and 6 are adjacent to each other, their hydrogeologic interpretation is discussed as one.

Stratigraphy. The burial cells of SWMUs 5 and 6 are excavated into the HU1 loess member (silt with some clay) of the Upper Continental Deposits. Only the deeper SWMU 5 pits likely extend to near the base of the HU1 unit, at a depth of 18 to 20 ft. Soil borings of the WAG 3 RI document that the HU2 interval in this area is a silty clay with sand and gravel lenses, to a depth of 30 ft below SWMUs 6 and 40 ft below SWMU 5. The bottom of the HU3 interval, clay with variable amounts of silt and sand, occurs uniformly at depths of 58 to 60 ft. Soil borings infrequently identified a thin (5 to 7 ft thick) sand interval at the top of the RGA (HU4). In most soil borings, the RGA is a mix of sand and gravel deposits. In the area of SWMUs 5 and 6, the upper McNairy consists primarily of clay, beginning at depths of 100 to 105 ft.

UCRS Groundwater Flow and Hydraulic Potential. MW190, screened over the depth interval 17.5 to 22.5 ft bgs (elevation of 348.6 to 353.6 amsl) provides a direct measure of the hydraulic potential in HU2 on the north side of SWMU 5 and an approximation of the elevation of the water table in HU1. The average elevation of measured water levels in MW190 is 367.0 ft (4.1 ft bgs).

The base of the ditch on the south side of SWMUs 5 and 6, with a local elevation of 358 ft amsl, is a primary control on the elevation of the water table in the area. Because the ditch is a linear east-west discharge feature, the area's shallow groundwater flow is likely oriented north-south. The north-south distance between MW190 and the ditch is 350 ft. The difference in elevation of the average MW190 water level and the base of the ditch is 9 ft; thus, the gradient of the water table across SWMU 5 (and similar to that of SWMU 6) is oriented southward with an approximate value of 9/350 ft/ft (0.03 ft/ft). Because HU1 has low transmissivity, the gradient of the water table will tend to be less on the north side of SWMU 5 (although still southward) and much greater on the south side of SWMU 5 adjacent to the ditch.

The shallow depth to water in well MW190 (average of 4.1 ft) determines that the vertical hydraulic gradient within the HU1/HU2 hydrogeologic system must be negligible; thus, groundwater flow in HU1 in the area of SWMUs 5 and 6 has a south-oriented vector with a minimal vertical component. The limited shallow groundwater flow beneath SWMU 5 must discharge to the ditch.

Waste was buried to depths of 15 ft (approximate elevation of 355 ft) in SWMU 5; thus, at a minimum, the deepest buried waste cells are saturated over the bottom 3 ft of depth (358 ft amsl/base of ditch–355 ft amsl/base of waste). Assuming a minimal southward gradient of the water table across most of SWMUs 5 and 6, even the shallowest wastes (with top near 365 ft amsl) are likely buried below the water table (at an elevation of approximately 367 ft amsl on the north side of SWMU 5).

RGA Groundwater Flow and Hydraulic Potential. The high-concentration core of the Northwest Plume passes immediately to the east of SWMU 6 in the RGA. This plume vector defines the direction of RGA groundwater flow below SWMUs 5 and 6. It is anticipated that the hydraulic conductivity of the RGA beneath SWMUs 5 and 6 is similar to that of other on-site areas containing the main contaminant plumes, 1,200 to 1,300 ft/day. Average RGA groundwater flow velocity in the areas of the contaminant plumes is commonly 1 to 3 ft/day.

8.2 SWMU-SPECIFIC RAOS

RAOs that are specific to SWMU 5 were developed based on the findings and observations forthcoming from the BGOU RI Report. The SWMU-specific RAOs generally are directed toward conditions related to the waste materials, the surface soils, and the subsurface soils at the SWMU. A brief statement of the specific problem associated with the SWMU is followed by bulleted RAOs developed to address the problem.

Buried waste materials and associated subsurface soils contain radionuclides, metals, and SVOCs that present a potential risk to future outdoor worker, residents, and industrial workers and a potential future contribution to RGA groundwater and subsurface soils above acceptable levels.

- Prevent future contaminant migration to RGA groundwater such that MCLs, or in the absence of an MCL, risk-based levels are not exceeded.

- Prevent exposure to buried materials and subsurface soil within the SWMU boundary to 16 ft bgs that would cause an unacceptable cumulative risk to future outdoor worker.

- Prevent exposure from surface soil metals and radionuclides that would cause an unacceptable cumulative risk to future industrial receptors.

The FS process began with the full list of COCs identified in the RI Report. A detailed evaluation of the sample results for commonly occurring elements identified in the RI Report as COCs was performed by comparing field sample results against the PGDP site background concentrations. A number of COCs identified in the RI Report were eliminated from further consideration in the FS because they were below background levels. A discussion of the evaluation that was performed and its results are presented in detail in Section 1. The final list of COCs for the SWMU and their preliminary RGs for surface soil and subsurface soil are provided in Appendix C, Tables C.2 and C.3, respectively. Preliminary RGs for the SWMU meet the target cumulative ELCR and HI criteria for both surface and subsurface soil.

8.3 SCREENING OF ALTERNATIVES

Alternatives are screened in this section, using the process described in EPA (1988) and the NCP to reduce the number of alternatives carried forward to detailed analysis. Alternatives are screened with respect to effectiveness, implementability, and cost. The evaluation of effectiveness considers reductions in toxicity, mobility, and volume of COCs. The evaluation of implementability considers technical feasibility criteria, including the ability to construct, operate, and maintain the remedy, and administrative feasibility criteria, including the availability of treatment, storage, and disposal capacity. Evaluation of cost for the alternatives is based on the relative capital and O&M costs for the primary technologies utilized. Alternatives with the best combinations of effectiveness and implementability and the lowest costs are retained for detailed analysis and comparative analysis.

Surface area estimates and waste mass and volume estimates for cover and excavation alternatives, respectively, are developed and discussed in Appendix E. These area, mass, and volume estimates were used to support development of the cost estimates for the alternatives that also appear in Appendix E. The conceptual location of the radioactive/inorganic treatment area is presented on Figure 8.2.

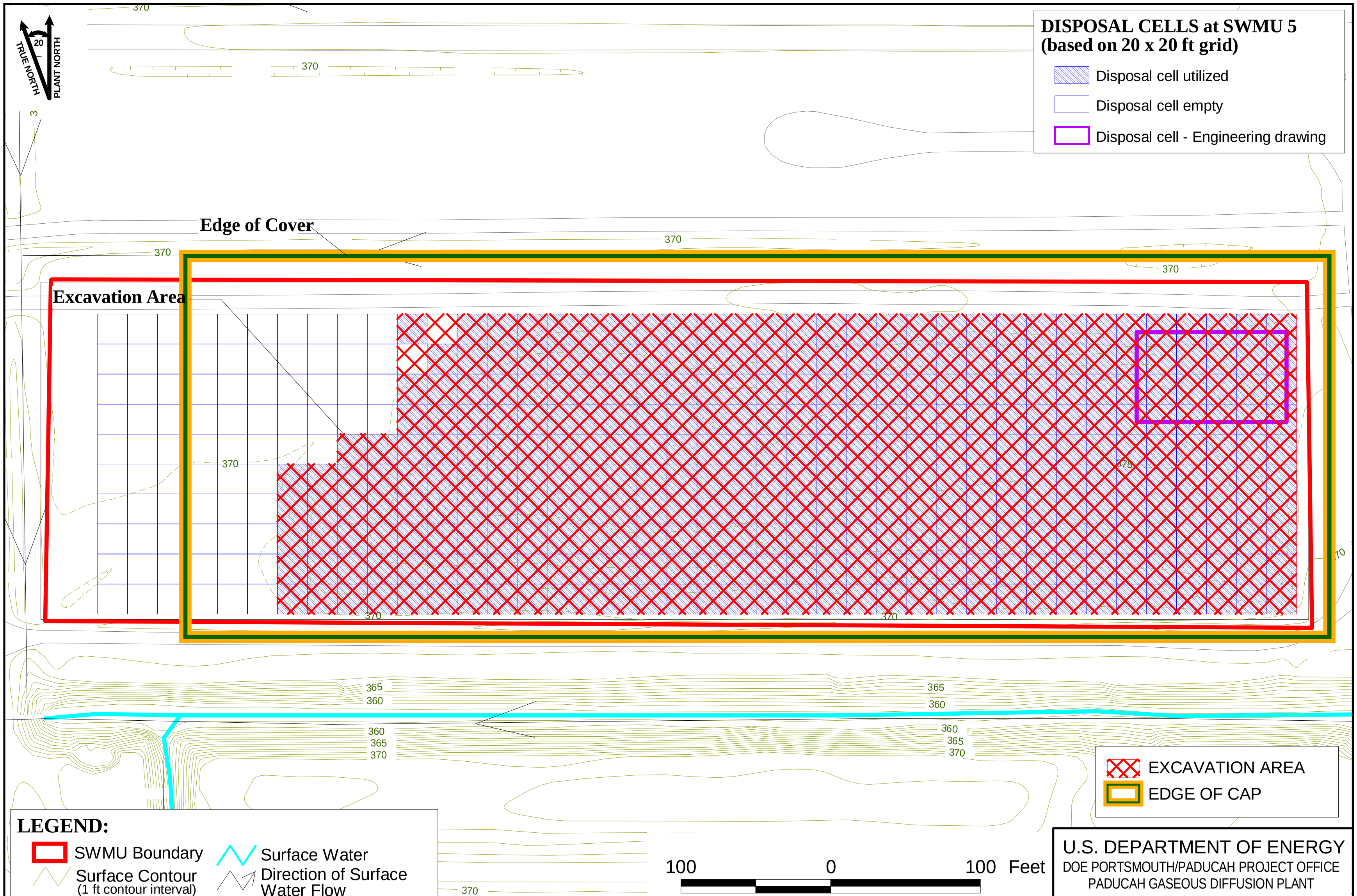


Figure 8.2. SWMU 5 Treatment Area

Figure No. \BGOU\FS_2-EXC.apr
DATE 07-08-09

Historical records indicate that scrap and metal parts, consisting primarily of nickel, were buried in SWMU 5. An alternative that incorporates metal melting to prepare the resulting metal ingots for recycle/reuse or disposal is evaluated for SWMU 5. Metal melting is an option for SWMU 5 only and will be evaluated for its cost effectiveness should excavation be implemented

8.3.1 Alternative Screening for SWMU 5 Source Areas

Table 8.1 summarizes the results of alternative screening for source areas for SWMU 5. Alternatives that were screened out at this step are shaded grey on the table. Alternative 1 (No Action) is not effective, but is retained for further consideration in the detailed analysis as a baseline alternative to which all other alternatives are compared, as required by CERCLA.

8.3.1.1 Alternative 2—Limited action

Alternative 2, which consists of long-term groundwater monitoring only, is screened from further consideration at SWMU 5. The RI Report documents the presence COCs above target concentrations in the surface layer. Alternative 2 provides no protection from these contaminants.

8.3.1.2 Alternative 4—Soil cover with *in situ* DNAPL source treatment and long-term monitoring

Alternative 4, which includes RPOs for DNAPL treatment, is screened from further consideration because there is no DNAPL present at SWMU 5.

8.3.1.3 Alternative 5—RCRA cover, hydraulic isolation, and long-term monitoring

Alternative 5 is screened from further consideration for SWMU 5 because the data from the RI Report indicate that contamination is limited to the surface, and this SWMU does not pose a sufficient threat to human health, the environment, or the groundwater to require the level of containment provided by this alternative.

8.3.1.4 Alternative 7—Excavation and disposal combined with *in situ* DNAPL source treatment and long-term monitoring

Alternative 7 is screened from further consideration at SWMU 5 because it incorporates contingency RPOs for remediation of DNAPL sources. There are no DNAPL sources at SWMU 5.

8.3.1.5 Alternative 8—Excavation and disposal combined with *ex situ* DNAPL source treatment and long-term monitoring

Alternative 8 is screened from further consideration at SWMU 5 because it incorporates contingency RPOs for remediation of DNAPL sources. There are no DNAPL sources at SWMU 5.

8.3.2 Summary of Alternatives Retained for Detailed Analysis

The following alternatives are carried forward for detailed analysis.

- Alternative 1: No action
- Alternative 3: Soil cover and long-term monitoring
- Alternative 6: Excavation and disposal

Comparative analyses are performed following the detailed analyses.

Table 8.1. Source Area Alternative Screening Summary for SWMU 5

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	Alternative 9
Screening Criteria	**No Action**	**Limited Action**	**Soil Cover and Long-Term Monitoring**	**Soil Cover with *In situ* DNAPL Source Treatment and Long-Term Monitoring**	**RCRA Cover with Hydraulic Isolation and Long-Term Monitoring**	**Excavation and Disposal**	**Excavation and Disposal combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring**	**Excavation and Disposal combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring**	***In situ* Containment and Long-Term Monitoring**
Overall Effectiveness	NA	NA[1]	Moderate to High[2]	NA[3]	NA[4]	High	NA[3]	NA[3]	NA
Short-term	NA	NA	High	NA	NA	Low to Moderate[5]	NA	NA	NA
Long-term	NA	NA	High	NA	NA	High	NA	NA	NA
Overall Implementability	NA	NA	High	NA	NA	Low to Moderate	NA	NA	NA
Technical	NA	NA	High	NA	NA	Moderate[5]	NA	NA	NA
Administrative	NA	NA	High	NA	NA	Low	NA	NA	NA
Overall Cost	NA	NA	Low	NA	NA	High	NA	NA	NA
Capital	NA	NA	Low	NA	NA	High	NA	NA	NA
Operation and maintenance	NA	NA	Low to Moderate	NA	NA	None	NA	NA	NA

NA—Not applicable based on-site conditions or nature of contamination present at the SWMU.
[1] Contamination levels at SWMU 5 are low and limited to surface soils; however, monitoring will not contain or remediate.
[2] Soil cover is effective because prevents direct contact with contaminants and reduces migration by reducing surface infiltration.
[3] DNAPL source treatment not applicable because no DNAPL present at SWMU 5.
[4] Contamination is limited to surface and near surface.
[5] Excavation alternative at SWMU 5 includes a process for metal melting to reduce volume of buried scrap metal.
NOTE: Alternatives shaded grey were screened out at this step.

8.4 DETAILED ANALYSIS OF ALTERNATIVES

8.4.1 Alternative 1—No Action

The No Action alternative is defined in accordance with CERCLA and provides a baseline to which other alternatives can be compared. Under this alternative, no action would be taken to implement remedial activities for SWMU 5 or to reduce the potential hazard to human or ecological receptors.

8.4.1.1 Overall protection of human health and the environment

No additional controls would be implemented to protect site workers or the public. The results of the risk-based evaluation of the No Action alternative indicate a low probability of the site's posing a threat to human health via the groundwater pathway. Existing site controls outside of the remedy would prevent a land use in which groundwater would be used as a water supply. Thus, these elements of the RAOs are achieved by the No Action alternative.

8.4.1.2 Compliance with ARARs

No ARARs have been identified for Alternative 1, the No Action alternative.

8.4.1.3 Long-term effectiveness and permanence

Alternative 1 provides no long-term effectiveness or permanence. Future potential leaching of contaminants to the RGA may result in concentrations above their MCL or risk-based value. Alternative 1 would leave the risk or hazard from radioactive or inorganic COCs at their current level at the SWMU. Over time, this alternative would not prevent future migration of contaminants. The alternative does not provide any long-term controls to manage residual risk at this SWMU.

8.4.1.4 Reduction of toxicity, mobility, or volume through treatment

Treatment would not be implemented with Alternative 1. Reduction of toxicity, mobility, or volume through treatment would not be applicable to the No Action alternative because it does not include treatment. The No Action alternative would not result in any reduction in the toxicity, mobility, or volume of contaminants other than those attributable to natural processes, such as degradation, dilution, or dispersion.

8.4.1.5 Short-term effectiveness

No actions would be implemented under Alternative 1; therefore, no additional risks to workers, the public, or the environment would be incurred. There would be no change to existing conditions. RAOs would not be met over any reasonable time period.

8.4.1.6 Implementability

The No Action alternative can be implemented readily. If future remedial action is necessary, this alternative would not impede implementation of such action.

The ongoing public awareness program would require regular coordination with DOE, KY, and possibly with other governmental agencies.

8.4.1.7 Cost

The preliminary cost estimates for Alternative 1 serve as a baseline for comparison of the other remedial alternatives. These cost estimates are based upon FS-level scoping and are intended to aid with selection of a preferred alternative. There are no capital or O&M costs associated with Alternative 1.

8.4.2 Alternative 3—Soil Cover and Long-Term Monitoring

Alternative 3 includes the following:

- Construction of a surface soil cover over the entire unit
- Additional groundwater monitoring

A surface soil cover will be constructed over the entire unit. This cover will be contoured to promote runoff and will reduce potential direct exposure to any surface soil hazardous and radioactive contamination.

A groundwater monitoring program would be implemented to monitor the upper RGA. The monitoring program will utilize existing PGDP MWs and additional groundwater MWs, as necessary, to monitor upgradient and downgradient groundwater contaminant levels.

8.4.2.1 Overall protection of human health and the environment

Construction of a surface soil cover over the unit will eliminate the potential exposure to workers from contaminated soil. Implementation of additional groundwater monitoring will provide an indirect protection, as monitoring contaminant migration allows for minimizing the potential for exposure to contaminated environmental media through early identification and avoidance. None of the elements of this alternative will provide a reduction in toxicity, mobility, or volume of contaminants.

8.4.2.2 Compliance with ARARs

Alternative 3 will meet this threshold criterion by complying with potential chemical-, location-, and action-specific ARARs. ARARs for this alternative are summarized in Appendix F.

8.4.2.3 Long-term effectiveness and permanence

Alternative 3 is designed to provide protection against exposure to waste in surface soils. Since the toxicity or volume of waste and contaminated environmental media will remain near current levels and concentrations (assuming limited degradation and negligible natural attenuation of residual waste and contaminants), some risk would remain. Migration of contaminants to groundwater would be reduced by soil cover limiting infiltration through surface soils. LUCs (see Section 2.4.1.1) would protect current and future site workers and the public.

8.4.2.4 Reduction of toxicity, mobility, or volume through treatment

Alternative 3 does not include any treatment technologies; therefore, a reduction in toxicity or volume through treatment would not be achieved. Installation of soil cover would reduce mobility of contaminants.

8.4.2.5 Short-term effectiveness

Implementation of Alternative 3 would not have any detrimental impact on the community.

Implementation of Alternative 3 has the potential for worker exposure to contaminated surficial soils and groundwater during environmental sampling. Potential exposure pathways include inhalation of dust containing surficial soils, dermal contact with surficial soils, and dermal contact with contaminated groundwater. PGDP worker protection programs will make worker exposure unlikely.

No ecological impacts at the BGOU are anticipated under this alternative. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archaeological or historical sites or T&E species would be impacted by this alternative. Risk assessment and mitigation for ecological receptors in nearby drainage ditches are within the scope of the Surface Water OU.

At the time that implementation of each component of Alternative 3 is completed, all RAOs will be achieved. Tentatively, implementation of Alternative 3 may take several months.

8.4.2.6 Implementability

Activities to be conducted under Alternative 3 include continuation/expansion of existing environmental media monitoring to track contaminant migration and construction of a soil cover.

Implementation of the remedial action components of Alternative 3 is technically feasible.

Implementation of Alternative 3 would use standard construction methods, materials, and equipment that are available from vendors and contractors.

8.4.2.7 Cost

Estimated capital and O&M costs for Alternative 3 address construction and maintenance of the soil cover as well as installation of a MW network and sampling analysis of the wells.

8.4.3 Alternative 6—Excavation and Disposal

Alternative 6 incorporates the following: installation of sheet piles around the perimeter of the waste unit; excavation of all buried materials and contaminated soils; emission control equipment; cover soil and waste disposal characterization sampling; excavation pit dewatering; and segregation, bulking, and consolidation of compatible waste groups. In addition, treatment of excavated materials may include *ex situ* thermal desorption to drive off VOCs and SVOCs that might be present; metal detection/magnetic separation of metallic materials (decayed drums and uranium for stabilization/solidification); and radiological separation. This alternative is described in detail in Section 3.

In addition to excavation and disposal of buried waste, Alternative 6 at SWMU 5 incorporates an option for metal melting. The metal melting process involves the following additional process elements in conjunction with excavation:

- Treatability study
- Sorting and size reduction
- Cleaning of metal surfaces
- Melting and casting of cleaned metal for reuse

Additional details on the metal melting process elements are presented in Section 3. For the treatment and segregation operations, short-term storage would be required for the excavated waste and for treated materials awaiting shipment to the disposal site.

8.4.3.1 Overall protection of human health and the environment

Alternative 6 would meet this threshold criterion. Potential short-term risks to remediation workers due to direct contact with the waste material and inhalation hazards are much larger than any of the other alternatives evaluated in this FS. In addition, potential risks to the public and the environment, as a result of potential shipping and handling concerns, should be considered for off-site shipments. These concerns are greatly reduced for disposal in the WDF.

Waste and contaminated soil will be physically removed from the SWMU and disposed of in one or more appropriate disposal facilities, including the WDF, thus meeting all RAOs for waste in the former burial pits.

8.4.3.2 Compliance with ARARs

Alternative 6 would meet this threshold criterion. ARARs for this alternative are summarized in Appendix F.

8.4.3.3 Long-term effectiveness and permanence

Complete excavation offers maximum control of contaminant migration, since no wastes or associated contaminated soils would remain in the SWMU; therefore, this alternative offers a high degree of risk reduction. Complete treatment processes manage or remove hazardous characteristics, or destroy the COCs.

Alternative 6 allows for potential risks associated with contaminants to be reduced or eliminated. Risks associated with direct contact with waste and surface soils will be eliminated since the primary source and associated contaminated soils will be removed. Alternative 6 allows for a maximum reduction of uncertainties associated with these soils in terms of continued contributions to the hydrogeologic system.

Previous attempts by others to prevent volumetric contamination of recovered nickel have not been successful.

8.4.3.4 Reduction of toxicity, mobility, or volume through treatment

This alternative reduces or eliminates the mobility and volume of contaminants from the unit. The toxicity of the treatment residuals also would be drastically reduced and/or eliminated. The removal and disposition of waste and contaminated soil from an unlined burial cell containing COCs to an appropriate disposal facility prevents those contaminants from migrating to the groundwater.

Excavated metal would be treated to remove surface contamination and allow the metal to be recycled. Waste materials and soil would be treated on-site as needed to allow excavated materials to be readied for transport or disposal. The recovered metal will have been treated by water washing and/or metal melting operations to reduce its toxicity before it can be released for general usage. It is likely that large volumes of contaminated liquid and solid waste will be generated for treatment and/or disposal as a result of the metal decontamination process.

8.4.3.5 Short-term effectiveness

Short-term risks to the community resulting from excavation activities at the SWMU would not be expected. Potential risks resulting from migration of contaminants to off-site locations would be controlled by the on-site vacuum hood and HEPA filtration system. Alternative 6, however, includes a potential risk to the public from transportation of the LLW or hazardous wastes/liquids to off-site disposal and/or treatment facilities. This risk would be greatly reduced by disposing of waste in the WDF.

Short-term exposures of workers to COCs during implementation of Alternative 6 could occur. Potential exposure pathways include direct contact with soil (ingestion, inhalation) and exposure to external penetrating radiation. Worker risks are not expected to exceed acceptable limits because exposure frequency and duration are less than those evaluated in the BHHRA. Typically, risks from handling waste/contaminated soils would be minimized through adherence to health and safety protocols. To protect workers, PPE, ambient conditions monitoring, and decontamination protocols would be used in accordance with an approved, site-specific HASP.

Time Until RAO is Achieved. The RAO would be achieved immediately following excavation. Excavation, treatment, and disposal of residuals could be accomplished in approximately three years. The time period required to implement and complete Alternative 6 with the inclusion of a metal melting process is difficult to estimate at this time because of the technical uncertainties associated with the surface cleaning required to reduce the radioactivity of recovered metal to make it safe for recycling. Additionally, the duration of remedial action would be extended by the time needed to design, construct, and start up a metal melting facility.

Excavation and disposal would be conducted by trained personnel in accordance with standard radiological, engineering, and operational procedures, DSAs, HASPs, and safe work practices to maintain a work environment that minimizes injury or exposure to risks to human health or the environment.

No ecological impacts at the BGOU are anticipated under this alternative. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archaeological or historical sites or T&E species would be impacted by this alternative. Risk assessment and mitigation for ecological receptors in nearby drainage ditches is within the scope of the Surface Water OU.

Metal cleaning and melting operations connected with the metal recovery will be carried out in closed, restricted facilities with controlled and filtered ventilation. Removed radioactivity would be combined with a suitable stream of radioactive waste already destined for proper disposal. There will be exposures to workers during the metal decontamination and recovery processes. Effective management and containment of decontamination waste residuals will be critical aspects of this alternative.

The RAOs for COCs identified at SWMU 5 would be achieved following completion of excavation and associated metal melting process.

8.4.3.6 Implementability

Alternative 6 is considered to be technically and administratively feasible and implementable. The equipment and technologies associated with implementation of this alternative have been proven to be technically feasible and are available from contractors or vendors. The implementability of construction-related activities during excavation and backfilling at SWMU 5 subject to Alternative 6 is very similar to that carried out routinely at other sites, so it is considered high. Likewise, sampling, analysis, transportation, and disposal at an approved location are routinely performed and, if properly implemented, are proven to be safe. Some excavated waste materials may be radioactive, RCRA hazardous, or mixed. Treatment of wastes with multiple regulatory classifications is more complex and may require more than one treatment process to make the waste suitable for transportation and/or land disposal. On-site treatment processes will comply with ARARs.

An option for disposal of waste and residuals at the WDF was considered under Alternative 6. The primary difference would be the elimination of waste leaving PGDP, related off-site transportation issues, and the cost for disposal. At this time, no capacity exists for disposal of these wastes at PGDP.

There are uncertainties associated with decontamination as part of the metal recycling process. Previous attempts to accomplish this task on a commercial scale have met with limited success (KRCEE 2007). Treatability studies on actual SWMU materials would be required to support this portion of the alternative. Requirements for management of decontamination residuals and potential air emissions from the metal melting process add complexity to the administrative implementability of this alternative.

There also are administrative uncertainties associated with metal recycling. On January 12, 2000, then Secretary of Energy, Bill Richardson, placed a moratorium on the unrestricted release of volumetrically contaminated nickel from DOE facilities. Concerns expressed by the scrap metals industry, consumer protection groups, and Congress were cited. Disposal abandons the significant economic and strategic value of the nickel.

8.4.3.7 Cost

Costs were estimated for transportation and disposal of waste at an off-site facility as well as for an option to dispose of waste at the WDF. Costs are provided for excavation and disposal of SWMU 5 in its entirety, including the recovery of the estimated quantity of buried nickel. An economic value was assigned to the estimated quantity of recoverable nickel and is reflected in the cost estimate. O&M costs are dependent upon the status of the SWMU upon completion of excavation. Cost will be low if SWMU closure can be achieved upon completion of excavation, and a long-term monitoring program is minimal or unnecessary.

8.5 COMPARATIVE ANALYSIS OF ALTERNATIVES

A comparative analysis summary for source area alternatives SWMU 5 is presented in Table 8.2 and the corresponding costs for the alternatives are presented in Table 8.3.

8.5.1 Threshold Criteria

Source area remedial alternatives are compared with respect to the threshold criteria in the following sections.

8.5.1.1 Overall protection of human health and the environment

Alternative 1 does not meet the threshold criterion of overall protection of human health and the environment. Alternative 1 would not treat, contain, or remove waste.

Alternative 3, soil cover, would meet the threshold criterion for contamination that is limited to the surface or near surface and the goal is to prevent direct contact. No waste would be removed or treated. A properly installed soil cover would reduce surface infiltration by reducing permeability relative to native soils and directing runoff away from the covered areas, thereby reducing contaminant migration to groundwater. LUCs (see Section 2.4.1.1) would protect current and future site workers and the public. While the short-term risks associated with excavation can be mitigated by proper engineering precautions in achieving long-term risk reduction, the trade-offs of removing risks that can be managed at the unit for elevated risks during excavation and removal are significant factors that favor Alternative 3.

Alternative 6, excavation and disposal, meets the threshold criterion by removing waste and contaminated soil contaminated from the SWMU. This alternative could remove enough waste and contaminated soil so that the remaining soil at the SWMU would meet soil target concentrations and attain MCLs or risk-based values in RGA groundwater at the UCRS-RGA boundary beneath the SWMU. All SWMU-specific RAOs would be met by implementing Alternatives 6.

8.5.1.2 Compliance with ARARs

No ARARs have been identified for Alternative 1, the No Action alternative.

Alternative 1 would meet some components of the threshold criterion, primarily when the contamination present at a site is not posing an immediate threat and has a low potential for posing a future threat to human health and the environment. Site controls coupled with monitoring environmental media would comply with ARARs under these circumstances.

Alternative 3 would meet the threshold criterion because contamination present at SWMU 5 is limited to the surface and near surface, and it does not pose a significant threat to human health and the environment.

Alternative 6 would meet this threshold criterion. This alternative could remove enough waste and contaminated soil to meet soil target concentrations and prevent contamination exceeding MCLs or risk-based values in RGA groundwater at the UCRS-RGA boundary beneath the SWMU. It should meet all location- and action-specific ARARs through design and planning during preparation of the RD/RAWP.

8.5.2 Balancing Criteria

Source area alternatives are compared with respect to the balancing criteria in the following sections.

8.5.2.1 Long-term effectiveness and permanence

Alternative 1 would not be effective. The risk posed by waste material and COCs in soil would remain unabated.

Alternative 3 provides a moderate degree of long-term effectiveness and permanence because it is effective in controlling direct contact with surface contamination. Residual risk would remain under this alternative.

Alternative 6 provides a high degree of long-term effectiveness and permanence. Residual risk should be the lowest under this alternative. Long-term controls may not be required under this alternative, provided that waste material and contaminated soil can be removed to attain soil target concentrations.

Table 8.2. Summary of Comparative Analysis of Source Area Alternatives SWMU 5

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 1: No Action	Does not physically prevent contact with contaminated surface soil. Threat to groundwater is low.	No actions implemented; no ARARs identified.	No long-term effectiveness or permanence. Site risk would remain at current levels.	Low. No treatment provided.	High. No actions implemented; therefore, no change to existing conditions.	High. No action would be implemented.
Alternative 3: Soil Cover and Long-Term Monitoring	High. Much more protective than Alternative 1 and less protective than Alternatives 6. Prevents direct contact with waste and reduces migration potential of contamination in surface soils. Land use controls protect current and future site workers and the public.	High. Complies with ARARs and potential TBCs.	High. Protects site workers from direct contact with waste and surface soil. Some reduction in mobility of contaminants by reducing infiltration.	Moderate. No reduction of toxicity or volume. Contaminant mobility is reduced through containment.	High. No negative impacts to community. Exposure to workers low during installation of cover. More short term risk to workers during implementation than Alternative 1, but much less than Alternative 6. Could be completed in months.	High. Services and materials are readily available.

Table 8.2. Summary of Comparative Analysis of Source Area Alternatives SWMU 5 (Continued)

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 6: Excavation and Disposal	High. Removal of contaminated waste offers the highest degree of overall protection with respect to RAOs.	High. Complies with ARARs and potential TBCs.	High. Contaminant sources removed; therefore, residual risks are negligible. Most adequate overall level of protection to humans and the environment.	Moderate to high. Excavation, waste treatment and disposal would reduce or eliminate mobility of radionuclides and inorganic COCs. Excavated metal will be treated to remove surface contamination so that the metal can be recycled. Overall reduction in waste volume for disposal is possible.	Low to moderate. Potential negative impacts to community from waste transportation to off-site disposal facility. Potential impacts reduced greatly if waste disposed at the WDF. Risk to workers higher than other alternatives but can be managed through site procedures during implementation. Additional potential for worker exposure during metal decontamination process and management of residuals. Implementation could take years. Time to complete action would be increased by treatability study needed to define cleaning process for nickel and the design, construction and start up of metal melting facility.	Low to Moderate. Excavation and associated technologies are readily implementable. Metal melting will increase technical complexity. Some excavated waste materials or soil may have multiple regulatory classifications, increasing the complexity of treatment required for transportation and/or disposal. WDF is being evaluated as part of the waste disposal option project, and a ROD has not been issued. Nature of waste and DOE moratorium on nickel recycling increases administrative complexity. Metal melting facility would involve compliance with more comprehensive and complicated regulatory requirements.

Table 8.3. SWMU 5 Remedial Alternatives Cost Estimate Summary

			PRESENT WORTH[1]		ESCALATED	
Alternative Description	**Annual Time Period, yrs**	**Capital $ (2010 Constant Dollars)**	**Total Annual $**	**Total $ (Capital and Annual)**	**Total Annual $**	**Total $ (Capital and Annual)**
Alternative 1—No Action	0	$0	$0	$0	$0	$0
Alternative 3—Soil Cover and Long-Term Monitoring	30	$4,288,000	$1,415,000	$5,703,000	$5,143,000	$9,692,000
Alternative 6a—Excavation and Disposal	0	$131,105,000	$0	$131,105,000	$0	$139,089,000
Alternative 6b—Excavation and Disposal (at the WDF)	0	$76,060,000	$0	$76,060,000	$0	$80,692,000
Contingency for Alternative 6—Metal Recovery/Recycle	0	$32,010,000	$0	$32,010,000	$0	$33,959,000
Metal Scrap Estimated Value	0	$30,000,000	$0	$30,000,000	0	$30,000,000

[1] Not used for budgeting or planning purposes because value is based on investing funds for outyear expenditures.

8.5.2.2 Reduction of toxicity, mobility, and volume through treatment

Alternative 1 would not reduce the toxicity, mobility, or volume of COCs in waste or soil at the SWMU.

Alternative 3 provides only limited reduction of mobility by preventing migration of surface contamination. It also reduces surface water infiltration and the ensuing subsurface migration of contaminants.

Alternative 6 reduces toxicity by removal, treatment, and disposal of wastes. Waste materials and soil would be treated on-site as needed to allow excavated materials to be readied for transport or disposal. Volume is similarly reduced. The relocation of waste and contaminated soil from an unlined burial cell that has COCs in direct contact with groundwater to an appropriate disposal facility will reduce the mobility of those contaminants in the environment. Removal of source material and surrounding contaminated soils will prevent future migration of contaminants at the SWMU. Alternative 6 will excavate metal, clean the surface of the metal objects, and melt the metal for potential recycling or reuse.

8.5.2.3 Short-term effectiveness

The short-term effectiveness of Alternative 1 is low because RAOs not would be attained.

Alternative 3 is moderately effective during implementation. There is very little risk to workers or the community during installation of the soil cover.

The short-term effectiveness of Alternative 6 is moderate to high. Disposal at the WDF would result in higher overall short-term effectiveness by eliminating risks associated with wastes leaving the site. The time frame for implementation of Alternative 6 would be extended with the addition of the metal melting process because a treatability study would be required to define the process to clean metal, and a metal melting facility would need to be designed and constructed before the metal could be recycled. Operation of the metal recovery process likely would extend the length of the excavation and disposal activity at SWMU 5.

8.5.2.4 Implementability

Alternative 1 would be the most readily implementable alternative because no construction or invasive action would be taken.

The implementability of Alternative 3 is high because the technology is readily available and the complexity is low.

Alternative 6 implementation is technically challenging because the technical obstacles to cleaning metal must be overcome before the metal can be recycled. The metal melting facility component of Alternative 6 would involve more complex process development and regulatory requirements than an excavation without metal melting. There also are administrative implementation obstacles in dealing with recycled nickel from a DOE facility because of the existing moratorium.

8.5.2.5 Cost

Capital and O&M costs for alternatives at SWMU 5 are presented in Table 8.3. Costs were estimated for transportation and disposal of wastes at an off-site facility as well as for an option to dispose of waste at the WDF. The costs for the metal melting process also are included in the SWMU 5 cost estimate.

8.5.3 Summary of Comparative Analysis of Alternatives

Alternative 1, No Action, may not provide an adequate level of overall protection to human health and the environment.

Alternative 3 provides containment of the waste by installing a soil cover over contaminated surface soils identified in the RI. The cover would reduce infiltration caused by precipitation and prevent direct contact with surface soils. Although this alternative does leave buried waste in place, it meets the threshold criteria with regard to radioactive and inorganic contaminants and achieves the RAOs for the SWMU.

Alternative 6, excavation and disposal, meets the threshold criteria by removing waste and contaminated soil from the SWMU. This alternative would remove enough waste and contaminated soil so that the remaining soil at the sites likely would meet soil target concentrations and attain MCLs or risk-based values in RGA groundwater at the UCRS-RGA boundary beneath the SWMU. All ARARs defined for Alternative 6 would be met.

Alternative 6 is the highest cost alternative, but it provides the greatest overall long-term effectiveness and permanence and would meet the RAOs for the SWMU.

THIS PAGE INTENTIONALLY LEFT BLANK

9. SWMU 6

9.1 SWMU 6 HISTORY AND BACKGROUND

The C-747-B Burial Ground is located in the northwestern section of the plant area east of SWMU 5. The entire burial area covers an area of approximately 13,500 ft^2, which is divided into five separate burial cells (Figure 9.1). The following are the dimensions of each of the cells.

- Area H—This disposal site covers an area of about 12 by 15 ft and is about 6-ft deep. A 3-ft cover of soil was placed on top of the buried drums.
- Area I—This discard pit is approximately 8 by 35 ft and is about 8-ft deep. The waste was covered with about 5 ft of soil. A smaller pit located near the northwest corner of Area I, designated I-2 on Figure 9.1, is approximately 6 ft by 6 ft.
- Area J—This burial site is about 4,000 ft^2 (37 by 110 ft) and was excavated to a depth of about 6 ft. The area was covered with about 3 ft of soil.
- Area K—This disposal site consists of an area of about 12 by 15 ft and is about 6-ft deep. A 3-ft cover of soil was placed on top of the buried drums.
- Area L—This burial area is about 20 by 30 ft and about 6-ft deep. The disposed waste was covered with about 3 ft of soil.

SWMU 6 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 ground surface is medium to tall grasses (up to 3 ft high), with occasional pockets of young trees and shrubs (DOE 1998c).

SWMU 6 was in operation from 1960 to 1976. Each of the burial cells was used for the disposal of a different waste. Each cell and its contents were identified in the WAG 3 RI Report (DOE 2000a) as follows:

- Area H—Magnesium Scrap Burial Area. The scrap buried at this location is magnesium, in various shapes, generated in the machine shop. A total of about ten drums of scrap was buried during midsummer 1971.
- Area I—Exhaust Fan Burial Area. Eight exhaust hood blowers removed from C-710 were discarded to this pit. These blowers, which were about 15 inches 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. In 1976, additional exhaust fans from C-710 were buried in pit I-2.
- Area J—Contaminated Aluminum Burial Area. 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., that were generated in the converter and compressor shop. This scrap was buried in the early 1960s.
- Area K—Magnesium Scrap Burial Area. 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.

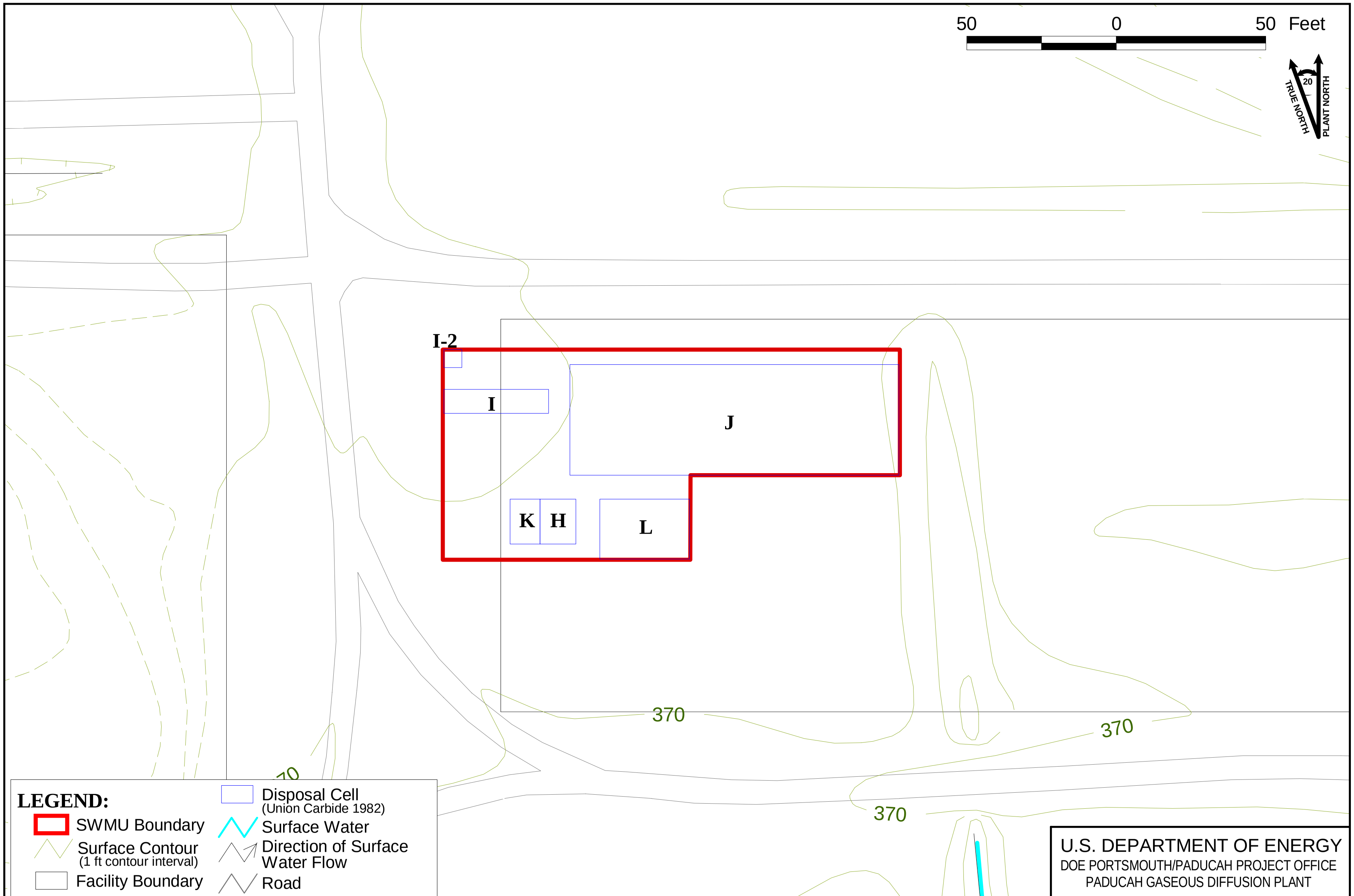


Figure 9.1. SWMU 6 Historical Layout

Figure No. \BGOU\d2-ri sect1.apr
DATE 09-29-09

- Area L—Modine Trap Burial Area. A single contaminated modine trap was buried in this area. The cold trap was about 4 ft in diameter, approximately 15 ft long, and weighed about 5,000 lb. This equipment was buried on March 5, 1969.

Metals analyses of subsurface soil samples from SWMU 6 rarely exceed RI screening criteria (both background and NALs, where applicable) for identifying contamination, through the RI identified beryllium and vanadium as the most frequent metal contaminants above background. Most of the NAL exceedances of beryllium occur in a horizon at 40 to 55 ft bgs. While there appears to be some zones of higher concentration (around 35-38 ft bgs), vanadium exceedances are found at all depths of the UCRS. Of the occurrences of aluminum detected above background levels, the majority represents samples collected beneath Area J (aluminum scrap). The RI did not identify any radionuclides or organic compounds as potential contaminants for SWMU 6.

Metals, notably iron, and the radionuclides neptunium-237, technetium-99, uranium-234, and uranium-238 exceeded screening criteria within UCRS groundwater at SWMU 6. Samples directly beneath and north of “Pit J,” (used for contaminated aluminum scrap disposal) contained the highest levels of beryllium, cadmium, iron, lead, manganese, and mercury. PCB detections in historical groundwater samples at SWMU 6 (0.05 to 0.26 mg/L of PCB-1016) were the only occurrences of organic contaminants at levels that exceed screening criteria in the UCRS. The radionuclides technetium-99, uranium-234, and uranium-238 exceeded screening criteria.

Iron and manganese were the most common metals to exceed RI screening levels in RGA groundwater samples at SWMU 6. TCE levels were greater than RI screening levels in nearly all RGA samples. The presence of TCE is due to the Northwest Plume; the west side of the plume passes beneath SWMU 6. The RI determined that no groundwater contaminants are present after screening the analyses of McNairy groundwater samples from SWMU 6.

9.1.1 Hydrogeologic Interpretation

The study area geology and hydrogeology is summarized below as documented in the BGOU RI (DOE 2010). Because SWMUs 5 and 6 are adjacent to each other, their hydrogeologic interpretation is discussed as one.

Stratigraphy. The burial cells of SWMUs 5 and 6 are excavated into the HU1 loess member (silt with some clay) of the UCD. Only the deeper SWMU 5 pits likely extend to near the base of the HU1 unit, at a depth of 18 to 20 ft. Soil borings of the WAG 3 RI document that the HU2 interval in this area is a silty clay with sand and gravel lenses, to a depth of 30 ft below SWMUs 6, and 40 ft below SWMU 5. The bottom of the HU3 interval, clay with variable amounts of silt and sand, occurs uniformly at depths of 58 to 60 ft. Soil borings infrequently identified a thin (5 to 7 ft thick) sand interval at the top of the RGA (HU4). In most soil borings, the RGA is a mix of sand and gravel deposits. In the area of SWMUs 5 and 6, the upper McNairy consists primarily of clay, beginning at depths of 100 to 105 ft.

UCRS Groundwater Flow and Hydraulic Potential. MW190, screened over the depth interval 17.5 to 22.5 ft bgs (elevation of 348.6 to 353.6 amsl), provides a direct measure of the hydraulic potential in HU2 on the north side of SWMU 5 and an approximation of the elevation of the water table in HU1. The average elevation of measured water levels in MW190 is 367.0 ft (4.1 ft bgs).

The base of the ditch on the south side of SWMUs 5 and 6, with a local elevation of 358 ft amsl, is a primary control on the elevation of the water table in the area. Because the ditch is a linear east-west discharge feature, the area’s shallow groundwater flow is likely oriented north-south. The north-south distance between MW190 and the ditch is 350 ft. The difference in elevation of the average MW190 water level and the base of the ditch is 9 ft; thus, the gradient of the water table across SWMU 5 (and similar to that of SWMU 6) is oriented southward with an approximate value of 9/350 ft/ft (0.03 ft/ft). Because HU1 has low transmissivity, the gradient of the water table will tend to be less on the north side of SWMU 5 (although still southward) and much greater on the south side of SWMU 5 adjacent to the ditch.

The shallow depth to water in well MW190 (average of 4.1 ft) determines that the vertical hydraulic gradient within the HU1/HU2 hydrogeologic system must be negligible; thus, groundwater flow in HU1 in the area of SWMUs 5 and 6 has a south-oriented vector with a minimal vertical component. The limited shallow groundwater flow beneath SWMU 5 must discharge to the ditch.

Waste was buried to depths of 15 ft (approximate elevation of 355 ft) in SWMU 5; thus, at a minimum, the deepest buried waste cells are saturated over the bottom 3 ft of depth (358 ft amsl/base of ditch–355 ft amsl/base of waste). Assuming a minimal southward gradient of the water table across most of SWMUs 5 and 6, even the shallowest wastes (with top near 365 ft amsl) likely are buried below the water table (at an elevation of approximately 367 ft amsl on the north side of SWMU 5).

RGA Groundwater Flow and Hydraulic Potential. The high-concentration core of the Northwest Plume passes immediately to the east of SWMU 6 in the RGA. This plume vector defines the direction of RGA groundwater flow below SWMUs 5 and 6. It is anticipated that the hydraulic conductivity of the RGA beneath SWMUs 5 and 6 is similar to that of other on-site areas containing the main contaminant plumes, 1,200 to 1,300 ft/day. Average RGA groundwater flow velocity in the areas of the contaminant plumes is commonly 1 to 3 ft/day.

9.2 SWMU-SPECIFIC RAOS

RAOs that are specific to SWMU 6 were developed based on the findings and observations forthcoming from the BGOU RI Report. The SWMU-specific RAOs generally are directed toward conditions related to the waste materials, the surface soils, and the subsurface soils at the SWMU. A brief statement of the specific problem associated with the SWMU is followed by bulleted RAOs developed to address the problem.

Buried waste materials present a risk to future outdoor worker. Waste metals are buried to a maximum of 8 ft and covered with 3 to 5 ft of soil.

- Prevent direct exposure by future outdoor worker to buried materials such that an unacceptable risk is not exceeded.

PAHs in surface soil present a cumulative ELCR to future industrial workers, exceeding a 1E-06 ELCR.

- Prevent exposure from surface soil PAHs that would cause an unacceptable cumulative risk to future industrial workers. (Note: The FS evaluation concluded that PAHs along the roadway outside the northern border of the SWMU are not within the scope of the BGOU and will be addressed by the Soils OU.)

Metals in subsurface soil present a potential risk to future outdoor worker exceeding a 1E-06 ELCR and HI=1.

- Prevent exposure to metals within the SWMU boundary to 16 ft bgs that would cause an unacceptable cumulative risk to future outdoor worker. (Note: The metals identified in the RI as potential risk drivers at this site were eliminated as a result of the evaluation described below and discussed in Section 2.)

The FS process began with the full list of COCs identified in the RI Report. A detailed evaluation of the sample results for commonly occurring elements identified in the RI Report as COCs was performed by comparing field sample results against the PGDP site background concentrations. A number of COCs identified in the RI Report were eliminated from further consideration in the FS because they were below background levels. A discussion of the evaluation that was performed and its results are presented in detail in Section 1. The final list of COCs for the SWMU and their preliminary RGs for surface soil and subsurface soil are provided in Appendix C, Tables C.2 and C.3, respectively. No COCs were identified for SWMU 6.

9.3 SCREENING OF ALTERNATIVES

Alternatives are screened in this section, using the process described in EPA (1988) and the NCP to reduce the number of alternatives carried forward to detailed analysis. Alternatives are screened with respect to effectiveness, implementability, and cost. The evaluation of effectiveness considers reductions in toxicity, mobility, and volume of COCs. The evaluation of implementability considers technical feasibility criteria, including the ability to construct, operate, and maintain the remedy, and administrative feasibility criteria, including the availability of treatment, storage, and disposal capacity. Evaluation of cost for the alternatives is based on the relative capital and O&M costs for the primary technologies utilized. Alternatives with the best combinations of effectiveness and implementability and the lowest costs are retained for detailed analysis and comparative analysis.

Surface area estimates and waste mass and volume estimates for cover and excavation alternatives, respectively, are developed and discussed in Appendix E. These area, mass, and volume estimates were used to support development of the cost estimates for the alternatives that also appear in Appendix E.

9.3.1 Alternative Screening for SWMU 6 Source Areas

Table 9.1 summarizes the results of alternative screening for SWMU 6. Alternatives that were screened out at this step are shaded grey on the tables. There were no site-related COCs identified at SWMU 6 within the confines of its administrative boundary that exceeded their RGs. This SWMU is a candidate for no action or limited action because there will be waste left in place. Alternative 1 (no action) may be effective at this SWMU and is retained for further consideration in the detailed analysis as well as to serve as a baseline alternative to which all other alternatives are compared, as required by CERCLA.

9.3.1.1 Alternative 3—Soil cover and long-term monitoring

Alternative 3 is screened from further consideration for SWMU 6 because the risk assessment indicates that there is not sufficient risk to human health or the environment to justify this action.

9.3.1.2 Alternative 4—Soil cover with *in situ* DNAPL source treatment and long-term monitoring

Alternative 4 is screened from further consideration for SWMU 6 because the risk assessment indicates that there is not sufficient risk to human health or the environment to justify this action. DNAPL is not present at SWMU 6.

Table 9.1. Source Area Alternative Screening Summary for SWMU 6

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	Alternative 9
Screening Criteria	**No Action**	**Limited Action**	**Soil Cover and Long-Term Monitoring**	**Soil Cover with *In situ* DNAPL Source Treatment and Long-Term Monitoring**	**RCRA Cover with Hydraulic Isolation and Long-Term Monitoring**	**Excavation and Disposal**	**Excavation and Disposal combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring**	**Excavation and Disposal combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring**	***In Situ* Containment and Long-Term Monitoring**
Overall Effectiveness	High[1]	High[2]	NA[3]	NA[4]	NA[3]	NA[1]	NA[4]	NA[4]	NA
Short-term	High	High	NA	NA	NA	NA	NA	NA	NA
Long-term	Moderate	High	NA	NA	NA	NA	NA	NA	NA
Overall Implementability	High	High	NA	NA	NA	NA	NA	NA	NA
Technical	High	High	NA	NA	NA	NA	NA	NA	NA
Administrative	High	High	NA	NA	NA	NA	NA	NA	NA
Overall Cost	Low	Low	NA	NA	NA	NA	NA	NA	NA
Capital	Low	Low	NA	NA	NA	NA	NA	NA	NA
Operation and maintenance	Low	Moderate	NA	NA	NA	NA	NA	NA	NA

NA—Not applicable based on-site conditions or nature of contamination present at the SWMU.
[1] No COCs are present at SWMU 6 above their RGs.
[2] No COCs are present at SWMU 6 above their RGs. Monitoring will verify that contaminants are not migrating from the site.
[3] A soil cover or RCRA cover is not applicable because there are no contaminants exceeding their RGs reported in the surface or subsurface soils at the site.
[4] DNAPL source treatment not applicable because no DNAPL present at SWMU 6.
NOTE: Alternatives shaded grey were screened out at this step.

9.3.1.3 Alternative 5—RCRA cover, hydraulic isolation, and long-term monitoring

Alternative 5 is screened from further consideration for SWMU 6 because the risk assessment indicates that there is not sufficient risk to human health or the environment to justify this action.

9.3.1.4 Alternative 6—Excavation and disposal

Alternative 6 is screened from further consideration for SWMU 6 because the risk assessment indicates that there is not sufficient risk to human health or the environment to justify this action.

9.3.1.5 Alternative 7—Excavation and disposal combined with *in situ* DNAPL source treatment and long-term monitoring

Alternative 7 is screened from further consideration for SWMU 6 because the risk assessment indicates that there is not sufficient risk to human health or the environment to justify this action. DNAPL is not present at SWMU 6.

9.3.1.6 Alternative 8—Excavation and disposal combined with *ex situ* DNAPL source treatment and long-term monitoring

Alternative 8 is screened from further consideration at SWMU 6 because it incorporates contingency RPOs for remediation of DNAPL sources. There are no DNAPL sources at SWMU 6.

9.3.2 Summary of Alternatives Retained for Detailed Analysis

The following alternatives are carried forward for detailed analysis.

- Alternative 1: No action
- Alternative 2: Limited action

Comparative analyses are performed following detailed analyses.

9.4 DETAILED ANALYSIS OF ALTERNATIVES

9.4.1 Alternative 1—No Action

The No Action alternative is defined in accordance with CERCLA and provides a baseline to which other alternatives can be compared. Under this alternative, no action would be taken to implement remedial activities for SWMU 6 or to reduce the potential hazard to human or ecological receptors. Existing site controls outside of the remedy, such as the E/PP Program, would remain in place to restrict access to buried waste materials. Some future groundwater monitoring may be performed at the site in support of groundwater OU evaluations or remedies (i.e., Northwest Plume), although no new wells would be installed at the site or monitoring performed specifically to assess groundwater quality at SWMU 6.

9.4.1.1 Overall protection of human health and the environment

Alternative 1 assumes the future use of the PGDP will remain industrial and that no additional controls would be implemented to protect site workers and the public. None of the chemicals detected in soil have been identified as a threat to groundwater, so the No Action alternative is protective of groundwater.

Alternative 1 also would protect an industrial worker from exposure, assuming that current site controls outside of the remedy, such as the E/PP Program, are maintained to prevent direct contact or intrusion into buried waste.

9.4.1.2 Compliance with ARARs

No ARARs have been identified for Alternative 1, the No Action alternative.

9.4.1.3 Long-term effectiveness and permanence

The No Action alternative does not include additional site controls beyond those DOE plant controls already in place and outside of the remedy. Alternative 1 should provide adequate long-term effectiveness as long as current site control procedures outside of the remedy, such as the existing E/PP Program, are maintained to prevent worker exposure to buried waste. SWMU-related COCs are below RGs.

9.4.1.4 Reduction of toxicity, mobility, or volume through treatment

Treatment would not be implemented with Alternative 1. The No Action alternative would not result in any reduction in the toxicity, mobility, or volume of contaminants other than those attributable to natural processes, such as degradation, dilution, or dispersion; however, SWMU-related COCs are below RGs.

9.4.1.5 Short-term effectiveness

No actions would be implemented under Alternative 1; therefore, no additional risks to workers, the public, or the environment would be incurred.

9.4.1.6 Implementability

The No Action alternative is considered implementable. This alternative would not impede implementation of other remedial activities in the future.

The ongoing public awareness program would require regular coordination with DOE, KY, and possibly with other governmental agencies.

9.4.1.7 Cost

The preliminary cost estimates for Alternative 1 serve as a baseline for comparison of the other remedial alternatives. These cost estimates are based upon FS-level scoping and are intended to aid with selection of a preferred alternative. There are no capital or O&M costs associated with Alternative 1.

9.4.2 Alternative 2—Limited Action

Alternative 2 consists of installation of additional MWs at the SWMU to monitor groundwater into the future. For cost estimating purposes only, it is assumed that four new MWs will be constructed in both the UCRS and RGA, one upgradient and three downgradient, for a total of eight wells. These wells will be sampled for full suite analysis quarterly for the first five years, semiannually for the next five years, and annually for years 11 through 30. Existing site control procedures would remain in place to restrict access to buried waste materials.

9.4.2.1 Overall protection of human health and the environment

None of the chemicals detected in soil have been identified as a threat to groundwater, but implementation of a SWMU-specific groundwater monitoring program under Alternative 2 provides additional protection against the migration of chemicals in soil that may not have been detected during the RI. This alternative proposes groundwater monitoring to track contaminant migration, which will provide an indirect protection against exposure to contaminated environmental media because it provides a mechanism for early identification and avoidance. None of the elements of this alternative will reduce volume, toxicity, or mobility of contaminants; however, site-related COCs are below RGs. Buried waste would remain in place; therefore, LUCs (see Section 2.4.1.1) would be implemented under this alternative that protect current and future site workers and the public.

9.4.2.2 Compliance with ARARs

This alternatives complies with the ARARs that are summarized in Appendix F.

9.4.2.3 Long-term effectiveness and permanence

Alternative 2 is designed to provide additional protection for groundwater by monitoring to track contaminant migration. LUCs (see Section 2.4.1.1) would be implemented to prevent exposure to buried waste. Residual risk at the SWMU would remain at current levels, but SWMU-related COCs are below RGs.

9.4.2.4 Reduction of toxicity, mobility, or volume through treatment

Treatment would not be implemented with Alternative 2. Some reduction in contaminant mass and concentration will occur through natural attenuation processes, such as degradation, dilution, or dispersion; however, SWMU-related COCs are below RGs.

9.4.2.5 Short-term effectiveness

Alternative 2 would not present any additional risks to the community. Risks to site workers during the construction, development, and sampling of MWs would be managed through the implementation of HASPs. No additional short-term risk to the environment would be incurred.

9.4.2.6 Implementability

Alternative 2 is readily implementable.

9.4.2.7 Cost

Estimated capital and O&M costs for Alternative 2 address installation of an MW network and sampling and analysis of the wells.

9.5 COMPARATIVE ANALYSIS OF ALTERNATIVES

A comparative analysis summary for source area alternatives for SWMU 6 is presented in Table 9.2, and the corresponding costs for the alternatives are presented in Table 9.3.

9.5.1 Threshold Criteria

SWMU 6 remedial alternatives are compared with respect to the threshold criteria in the following sections.

9.5.1.1 Overall protection of human health and the environment

Alternatives 1 and 2 meet the threshold criterion of overall protection of human health and the environment. None of the chemicals detected at SWMU 6 pose a threat to groundwater. Alternative 2 includes a groundwater monitoring component that would provide an additional protection for groundwater in case concentrations of chemicals in waste or soil not detected during the RI present a greater risk than estimated based on the available data. Alternative 2 also includes LUCs (see Section 2.4.1.1) because waste will remain in place.

9.5.1.2 Compliance with ARARs

No ARARs have been identified for Alternative 1, the No Action alternative. Alternative 2 would comply with ARARs.

9.5.2 Balancing Criteria

Remedial alternatives are compared with respect to the balancing criteria in the following sections.

9.5.2.1 Long-term effectiveness and permanence

Alternatives 1 and 2 both would be effective. None of the chemicals detected at SWMU 6 pose a threat to groundwater. Alternative 2 includes long-term groundwater monitoring as an additional risk mitigation component.

9.5.2.2 Reduction of toxicity, mobility, and volume through treatment

Alternatives 1 and 2 would not reduce the toxicity, mobility, or volume of COCs in waste or soil at the SWMU; however, SWMU-related COCs in soil are below RGs.

9.5.2.3 Short-term effectiveness

The short-term effectiveness of Alternatives 1 and 2 is high because there is no major threat to the community or the environment in the implementation of either alternative. The slight incremental risk to site workers during construction and sampling of MWs is easily managed.

9.5.2.4 Implementability

Alternatives 1 and 2 are both readily implementable.

9.5.2.5 Cost

Capital and O&M costs for alternatives at SWMU 6 are presented in Table 9.3.

Table 9.2. Summary of Comparative Analysis of Source Area Alternatives SWMU 6

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 1: No Action	High. Meets the threshold criterion. Maintenance of current site procedures would prevent exposure to waste materials. None of the chemicals detected at SWMU 6 present a threat to groundwater. Site-related COCs in soil are below RGs.	High. Meets the threshold criterion.	Moderate. None of the chemicals detected at SWMU 6 present a threat to groundwater. Site-related COCs in soil are below RGs. No other controls would be required to address residual contamination.	Low. No treatment provided, but none is required based on RI results.	High. No threat to community, site workers, or the environment.	High. No other action would be implemented.
Alternative 2: Limited Action	High. Meets the threshold criterion. None of the chemicals detected at SWMU 6 present a threat to groundwater. Site-related COCs in soil are below RGs. Long-term groundwater monitoring is an additional risk mitigation component used to protect groundwater. Land use controls protect current and future site workers and the public.	High. Meets the threshold criterion. Complies with ARARs.	High. None of the chemicals detected at SWMU 6 present a threat to groundwater. Site-related COCs in soil are below RGs. Long-term groundwater monitoring is an additional risk mitigation component used to protect groundwater.	Low. No treatment provided, but none is required based on RI results.	High. No threat to community or the environment. Potential risks to site workers during well construction and sampling are easily managed.	High. Monitoring well construction and sampling easily implemented.

Table 9.3. SWMU 6 Remedial Alternatives Cost Estimate Summary

			PRESENT WORTH[1]		ESCALATED	
Alternative Description	**Annual Time Period, yrs**	**Capital $ (2009 Constant Dollars)**	**Total Annual $**	**Total $ (Capital and Annual)**	**Total Annual $**	**Total $ (Capital and Annual)**
Alternative 1—No Action	0	$0	$0	$0	$0	$0
Alternative 2—Limited Action	30	$1,047,000	$727,000	$1,774,000	$2,262,000	$3,373,000

[1] Not used for budgeting or planning purposes because value is based on investing funds for outyear expenditures.

9.5.3 Summary of Comparative Analysis of Alternatives

Alternatives 1 and 2 both meet the threshold criteria, would be effective, and are readily implementable. Neither alternative would reduce the toxicity, mobility, or volume of contamination through treatment, but SWMU-related COCs in soil are already below RGs. None of the chemicals detected at SWMU 6 pose a threat to groundwater. Alternative 2 includes a groundwater monitoring component that would provide additional protection for the current and future off-site residential groundwater user by monitoring and providing continuing confirmation that concentrations of chemicals in soil detected during the RI do not present a risk to human health. In addition, Alternative 2 implements LUCs (see Section 2.4.1.1) to provide additional protection for current and future site workers and the public.

THIS PAGE INTENTIONALLY LEFT BLANK

10. SWMU 7

10.1 SWMU 7 HISTORY AND BACKGROUND

The C-747-A area is located in the northwest corner of PGDP secured area. SWMU 7 comprises the eastern two-thirds of C-747-A. The SWMU is bounded on the north and south sides by perimeter ditches, on the west side by the C-747-A Burn Area (SWMU 30), and on the east side by the C-746-E Contaminated Scrap Yard. SWMU 7 covers approximately 240,900 ft^2 and includes six discrete burial pit areas described below and illustrated in Figure 10.1 (DOE 1998d).

- Pit B—This pit is approximately 60 by 172 ft. According to the Phase II SI geophysical survey, the actual excavation extends beyond the designated boundaries and may connect with the adjacent burial pit (Pit C). A geophysical survey conducted for the BGOU RI interprets B and C as separate pits.

- Pit C—This pit is approximately the same size as Pit B. Based on the Phase II geophysical survey, Pit C and Pit B may be one continuous pit; however, a geophysical survey conducted for this RI interprets B and C as separate pits.

- Pit D—This pit is approximately 15 by 99 ft.

- Pit E (outside the eastern boundary of SWMU 7 and within the C-746-E Contaminated Scrap Yard)—This pit is approximately 15 by 143 ft.

- Pits F1–F5—These pits are all small (average size of each pit is approximately 20 by 80 ft). Engineering drawings indicate a sixth "F" pit that was not labeled.

- Pit G—This pit was documented as approximately 27 by 122 ft.

Records indicate the burial pits, in general, were excavated to a depth of 6 to 7 ft bgs, filled with wastes, and covered with approximately 3 ft of earth (Union Carbide 1978); however, geophysical surveys during the Phase II SI indicated waste in pits to a depth of 8-15 ft (CH2M HILL 1992).

A stockpile of radiologically contaminated scrap drums, locally known as Drum Mountain, formerly was located on the southeast corner covering Pit G. Interviews with a former operator who worked in the SWMU 7 area indicate Drum Mountain was created only after the area between the F Pits and Pit G had been filled with similar material. This interview was corroborated by geophysical evidence.

The land surface slopes within SWMU 7. Burial Pits B and C form a slight hill on the north side of SWMU 7, and Burial Pit F forms a lesser mound on the south side of the SWMU. Pit D underlies a level area north of where Drum Mountain once was located. Shallow drainage swales occur on the west side of Burial Pit B, between Burial Pits C and D. The surface water that drains from SWMU 7 into the surrounding ditches is carried west through Outfall 001 into Bayou Creek. In 2002, a sedimentation basin was constructed to contain runoff from PGDP scrap yards. Runoff now flows into the sedimentation basin and is released periodically into Outfall 001. The ground surface of the west half of the SWMU is covered by grassy vegetation, except where gravel roads extend through the site. A PGDP scrap metal project covered the west half of the SWMU with 1 to 2 ft of gravel as a working base for truck and tractor traffic. This gravel also prevents exposure to contaminated soils resulting from the earlier removal of scrap material in Drum Mountain.

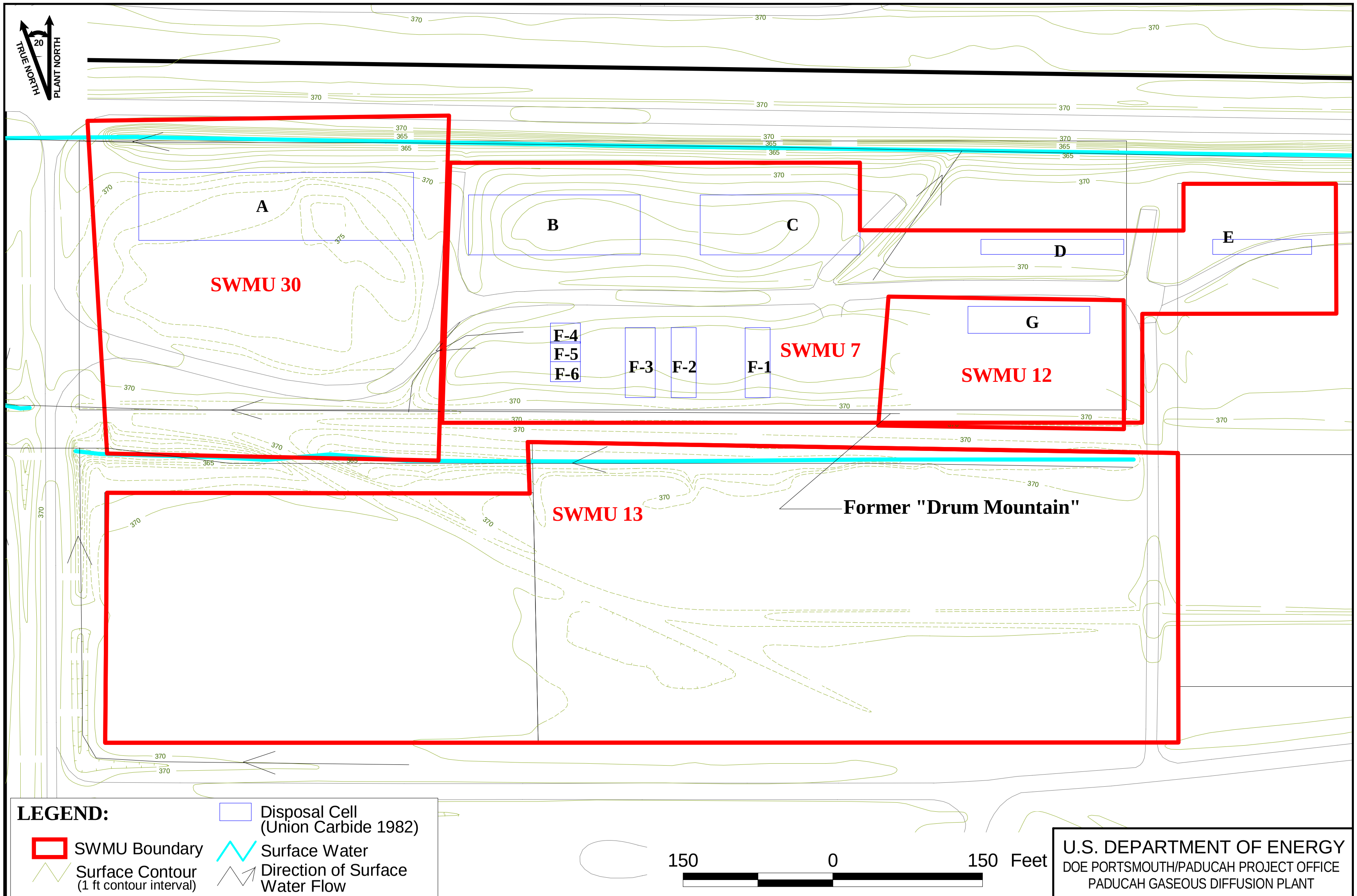


Figure 10.1. SWMUs 7 and 30 Historical Layout

Figure No. \BGOU\d2-ri sect1.apr
DATE 09-29-09

PGDP used the burial pits for disposal of wastes from 1957 to 1979. Burial Pits B, C, and G were used for disposal of noncombustible, contaminated and uncontaminated trash, material, and equipment. Contaminated concrete removed from the C-410 Feed Plant during May and June 1960 was placed in Burial Pits D and E. Burial Pit F was used for disposal of uranium-contaminated scrap metal and equipment. Empty uranium and magnesium powder drums also were reported to have been buried in Burial Pit F (Union Carbide 1978).

The following summarizes what is known about the disposed waste in the burial pits.

- Pit B—Buried material includes noncombustible trash and contaminated and noncombustible material and equipment (however, no specific disposal records exist).

- Pit C—Historic records indicate that both Pit B and C received the same material.

- Pit D—Documented buried material consists of uranium-contaminated concrete pieces of reactor tray bases from C-410 used during the fluorination process of uranium tetrafluoride to uranium hexafluoride.

- Pit E—Documented buried material consists of uranium-contaminated concrete pieces of reactor tray bases.

- Pits F1–F5—Documented buried material consists of uranium-contaminated scrap metal and equipment and empty uranium and magnesium powder drums (engineering drawings indicate there was a sixth "F" pit that was not numbered).

- Pit G—Documented buried material consists of noncombustible trash and contaminated and noncombustible material and equipment.

In addition to these burial pits, the Phase II SI geophysical investigation also identified another anomaly in the shape of a rough circular area (15-ft diameter) between SWMU 30 and SWMU 7, west of the F-4 and F-5 Pits. There is no information confirming the presence or the nature of any buried wastes associated with this anomaly.

Metals concentrations in subsurface soil samples of SWMU 7 rarely exceed background levels. Uranium metal has been detected above background levels only at three locations that characterize burial pits B and C, which contained uranium-contaminated noncombustible trash. The extent of contamination is limited to shallow soil depths (5 to 10 ft bgs).

Two VOCs (vinyl chloride and 1,1-DCE) were identified as contaminants, though both were detected infrequently. Uranium-238 is the most widely detected radionuclide contaminant above PGDP background levels in subsurface soils at SWMU 7; as expected, it is very similar to the uranium distribution, with most exceedances limited to depths less than 15 ft bgs. Subsurface soil samples for Pit E (located outside of the SWMU 7 boundary) at 10 ft depth contained arsenic concentrations in excess of screening levels. None of the other Pit E analyses documented metals or radionuclides above screening levels or the presence of any organic contaminants.

Several metals, the uranium isotopes, and vinyl chloride were the primary contaminants that exceeded screening levels in groundwater samples from within and immediately below waste pits. These same contaminants were common throughout the thickness of the UCRS.

The RI identified 14 metals in UCRS groundwater samples from SWMU 7 with above screening levels. Arsenic, iron, and manganese were the most frequently detected metals. Organic contaminants in UCRS groundwater at SWMU 7 consisted of five VOCs. TCE and its reductive dechlorination products, *cis*-12-DCE and vinyl chloride, were the most frequently detected organic contaminants. The radionuclide contaminants present in the SWMU 7 UCRS groundwater samples were radon-222 and the uranium isotopes uranium-234 and uranium-238.

The analyses of groundwater samples from MW66 (an upper RGA well located between burial pits A and B of SWMUs 30 and 7, respectively) reveal abrupt rises or spikes of dissolved TCE that correlate to periods of higher hydraulic head (TCE spikes often exceed 10,000 µg/L). This spiking behavior suggests a UCRS DNAPL source that releases contaminant mass in response to seasonal variations (more mass being released during times of higher hydraulic head). If this potential DNAPL source extended deeper into the RGA, the TCE trend should not fluctuate as much as observed. The SWMUs 7 and 30 RI report (DOE 1998a) also postulated a DNAPL source near burial pit B.

Historical and RI data reveal the occurrence of 12 metal contaminants in the RGA groundwater samples from SWMU 7. As in the UCRS samples, arsenic, iron, and manganese were the most frequently detected groundwater contaminants. All of the SWMU 7 RGA organic groundwater contaminants were VOCs. TCE was the dominant organic contaminant. The RGA groundwater radionuclide contaminants of SWMU 7 consist of technetium-99, uranium-234, and uranium-238. Although a potential TCE DNAPL source is believed to exist near Pit B, as discussed above, the primary occurrence of VOCs and technetium-99 in the RGA is largely due to the Northwest Plume, which passes beneath SWMU 7.

The review of the McNairy groundwater analyses identified TCE and chloroform as the only SWMU 7 McNairy groundwater contaminants.

10.1.1 Hydrogeologic interpretation

The study area geology and hydrogeology is summarized below as documented in the BGOU RI (DOE 2010). Because SWMUs 7 and 30 are adjacent to each other, their hydrogeologic interpretation is discussed as one.

Stratigraphy. Like all other on-site BGOU SWMUs, the HU1 silt interval contains the burial cells of SWMUs 7 and 30. The base of HU1 is at a depth of 20 ft, approximately 8 ft below the deepest of the burial cells (SWMU 30). A single sand and gravel horizon, in a clay matrix, defines the underlying HU2 interval. The sand and gravel deposits commonly range between 5 and 10 ft thick. Silt and clay members, with a cumulative thickness of 20 to 35 ft, comprise the HU3 interval below SWMUs 7 and 30.

In the area of SWMUs 7 and 30, the RGA consists of an intermittent HU4 sand overlying 20 to 40 ft of the HU5 sand with gravel layers. The top of the RGA commonly occurs at depths of 45 to 60 ft.

UCRS Groundwater Flow and Hydraulic Potential. The SWMUs 7 and 30 RI (DOE 1998a) determined that a shallow water table exists approximately 5 ft bgs and within the burial cells. UCRS piezometer and well measurements documented a strong downward gradient within the area UCRS. The vertical downward hydraulic gradient is more than 10 times the lateral hydraulic gradient at SWMUs 7 and 30. This, along with lack of connectivity with shallow sand and gravel strata, leads to predominantly downward groundwater flow through the UCRS. These trends determine that dissolved contaminants from the Burial Grounds have potential to migrate into the RGA.

The elevation of the water table is above the elevation of the ditches that bound SWMUs 7 and 30 on the north and south sides;[6] however, neither ditch gains significant flow along the reaches adjacent to SWMUs 7 and 30. These observations indicate that the UCRS groundwater flow vector must be oriented steeply downward and that the area contributing infiltration to the ditches typically is limited to a thin border along the ditches.

RGA Groundwater Flow and Hydraulic Potential. The high-contamination core of the Northwest Plume passes beneath the west end of SWMU 7 in the RGA. All RGA flow in SWMUs 7 and 30 is to the northwest, as defined by the plume orientation. The south well field of the Northwest Plume containment system is located approximately 650 ft to the northwest of SWMU 7. A pumping test of EW231, an extraction well of the south well field, determined the hydraulic conductivity of the area RGA to be approximately 1,300 ft/day.

The TCE trend in MW66, located near the boundary between SWMUs 7 and 30, exhibits spikes that can be correlated with similar TCE spikes at MW248 in the south well field. The distance between the wells (650 ft) divided by the time lag between TCE “events” in MW66 and MW248 (6 months) defines the local groundwater flow rate to be 3.5 ft/d. Typical groundwater flow rates in the Northwest Plume are thought to range from 1 to 3 ft/day. The RGA groundwater flow velocity beneath SWMUs 7 and 30 is accelerated by groundwater extraction in the south well field.

10.2 SWMU-SPECIFIC RAOs

RAOs that are specific to SWMU 7 were developed based on the findings and observations forthcoming from the BGOU RI Report. The SWMU-specific RAOs generally are directed toward conditions related to the waste materials, the surface soils, and the subsurface soils at the SWMU. A brief statement of the specific problem associated with the SWMU is followed by bulleted RAOs developed to address the problem.

Based on historic process knowledge, buried waste materials are assumed to pose a risk to future outdoor worker, industrial workers, and residents and a potential future contribution to RGA groundwater above acceptable levels. (Note: It was determined during the FS that the potential exists for leachate from buried waste to discharge from SWMU 7 into the adjoining ditches to the north and south.)

- Prevent future contaminant migration to RGA groundwater such that MCLs, or in the absence of an MCL, risk-based levels are not exceeded.

- Prevent direct exposure by future outdoor worker to buried materials and subsurface soils such that an unacceptable risk is not exceeded.

Radionuclides, organics, and metals in surface soil present a cumulative ELCR and an HI to current and future industrial workers, exceeding an ELCR=1E-06 and HI=1. Impacted area is within SWMU administrative boundary and adjacent northern and southern areas up to, but not including, the ditches that border the area, to a depth of one ft bgs.

- Prevent exposure from surface soil metals, radionuclides, PCBs, and SVOCs that would cause an unacceptable cumulative risk to current and future industrial workers.

[6] The bottom elevation of the ditches on the north and south sides of SWMUs 7 and 30, as well as piezometer measurements within SWMUs 7 and 30, provided definitive control of the water table in those areas. The trends of the water table on the east and west ends of SWMUs 7 and 30 were assumed to resemble the land topography.

Radionuclides, PCBs, PAHs, and metals in subsurface soil present a cumulative ELCR and an HI to future outdoor worker, exceeding an ELCR=1E-06 and HI=1.

- Prevent exposure to metals, radionuclides, PCBs, and PAHs within the SWMU boundary to 16 ft bgs that would cause an unacceptable cumulative risk to future outdoor worker.

Constituents in surface and subsurface soil exceed concentration criteria for threat to a potential future residential groundwater user.

- Prevent migration of radionuclides, organics, and metals in soil in the source areas to the RGA groundwater to the extent they do not contribute contamination exceeding MCLs, or in the absence of an MCL, a risk-based concentration.

VOCs in groundwater indicate a DNAPL source may exist between SWMUs 7 and 30, and VOC concentrations in soil exceed screening threshold values for protection of residential groundwater users.

- Remove or treat DNAPL such that contributions to RGA groundwater do not exceed MCLs or acceptable risk-based levels.

The FS process began with the full list of COCs identified in the RI Report. A detailed evaluation of the sample results for commonly occurring elements identified in the RI Report as COCs was performed by comparing field sample results against the PGDP site background concentrations. A number of COCs identified in the RI Report were eliminated from further consideration in the FS because they were below background levels. A discussion of the evaluation that was performed and its results are presented in detail in Section 1. The final list of COCs for the SWMU and their preliminary RGs for surface soil and subsurface soil are provided in Appendix C, Tables C.2 and C.3, respectively. Preliminary RGs for the SWMU meet the target cumulative ELCR and HI criteria for both surface and subsurface soil.

The presence of DNAPL at SWMU 7 is suspected, but not well defined. If an excavation alternative were to be implemented at SWMU 7, it is possible that any DNAPL source would be removed as part of the excavation. Therefore, alternatives that include RPOs for remediation of DNAPL at SWMU 7 are evaluated, with the DNAPL RPOs presented as contingency components of the alternatives. An alternative that incorporates DNAPL remediation RPOs would be fully implemented only if the engineering data collection to support technology sizing, design, and optimization confirmed the presence of a DNAPL source at SWMU 7.

10.3 SCREENING OF ALTERNATIVES

Alternatives are screened in this section, using the process described in EPA (1988) and the NCP to reduce the number of alternatives carried forward to detailed analysis. Alternatives are screened with respect to effectiveness, implementability, and cost. The evaluation of effectiveness considers reductions in toxicity, mobility, and volume of COCs. The evaluation of implementability considers technical feasibility criteria, including the ability to construct, operate, and maintain the remedy, and administrative feasibility criteria, including the availability of treatment, storage, and disposal capacity. Evaluation of cost for the alternatives is based on the relative capital and O&M costs for the primary technologies utilized. Alternatives with the best combinations of effectiveness and implementability and the lowest costs are retained for detailed analysis and comparative analysis.

Surface area estimates and waste mass and volume estimates for cover and excavation alternatives, respectively, are developed and discussed in Appendix E. These area, mass, and volume estimates were used to support development of the cost estimates for the alternatives that also appear in Appendix E. The conceptual location of the radioactive/inorganic treatment area is presented on Figure 10.2.

The estimated volume of potentially DNAPL-contaminated soils to be remediated at the SWMU was developed in Section 1. The conceptual location of the treatment area for the potential DNAPL at the SWMU is presented on Figure 10.3.

10.3.1 Alternative Screening for SWMU 7 Source Areas

Table 10.1 summarizes the results of alternative screening for source areas at SWMU 7. Alternatives that were screened out at this step are shaded grey on the table. Alternative 1 (no action) is not effective, but is retained for further consideration in the detailed analysis as a baseline alternative to which all other alternatives are compared, as required by CERCLA.

10.3.1.1 Alternative 2—Limited action

Alternative 2, which consists of long-term groundwater monitoring only, is screened from further consideration at SWMU 7. The RI Report cites the potential presence of DNAPL contamination at the site. Alternative 2 provides no protection from these contaminants.

10.3.1.2 Alternative 3—Soil cover and long-term monitoring

Alternative 3, soil cover and long-term monitoring, is screened from further consideration for SWMU 7 because the data in the RI Report indicate that buried wastes at the SWMU are in contact with the water table, and construction of a soil cover may not prevent the continued migration of contaminants, in particular a potential DNAPL source, to groundwater. The RI report indicates that the water table within the BGOU ranges from 5 to 10 ft bgs and intrudes into buried waste at the SWMU. This alternative would not treat or remove the DNAPL that is potentially present at the SWMU.

10.3.1.3 Alternative 6—Excavation and disposal

Alternative 6 is screened from further consideration at SWMU 7 because it does not incorporate contingency RPOs for remediation of a potential DNAPL source at SWMU 7.

10.3.2 Summary of Alternatives Retained for Detailed Analysis

The following alternatives are carried forward for detailed analysis at SWMU 7.

- Alternative 1: No Action
- Alternative 4: Soil cover with *in situ* DNAPL source treatment and long-term monitoring
- Alternative 7: Excavation and disposal combined with *in situ* DNAPL source treatment and long-term monitoring
- Alternative 8: Excavation and disposal combined with *ex situ* DNAPL source treatment and long-term monitoring

Comparative analyses of these alternatives are performed following the detailed analyses.

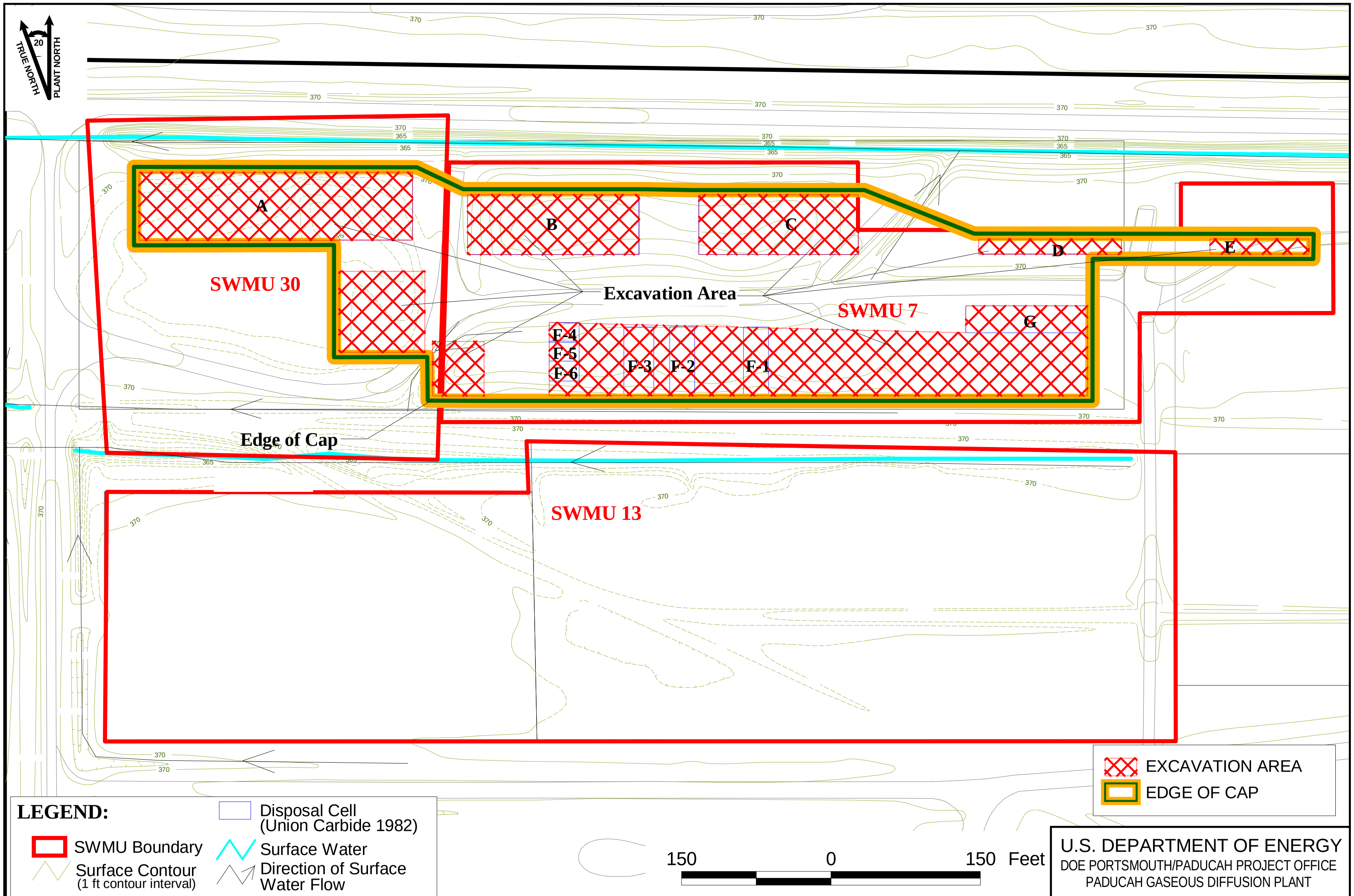
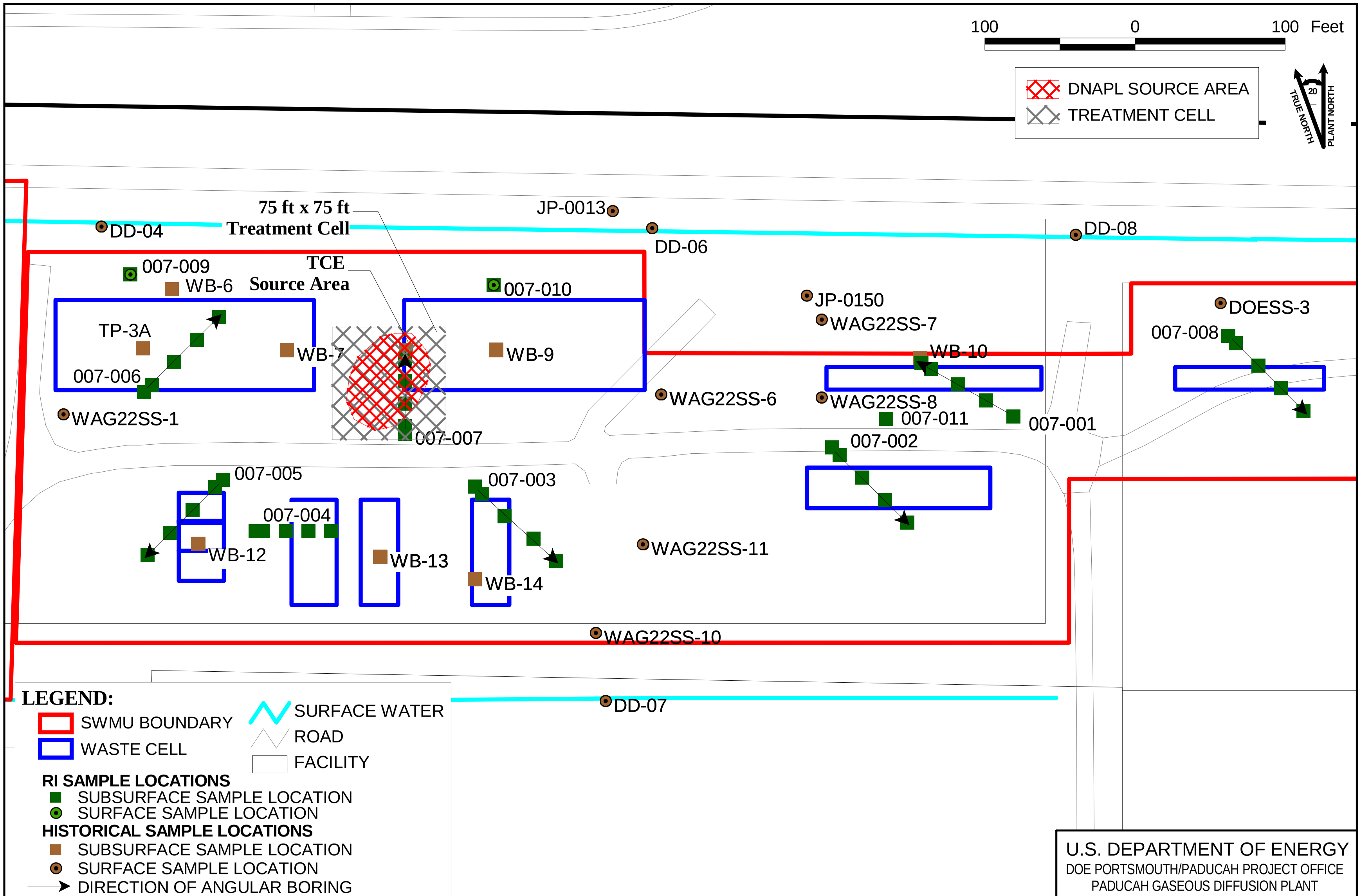


Figure 10.2. SWMUs 7 and 30 Treatment Area

Figure No. \BGOU\FS_2-EXCR2.apr
DATE 09-17-09



U.S. DEPARTMENT OF ENERGY
DOE PORTSMOUTH/PADUCAH PROJECT OFFICE
PADUCAH GASEOUS DIFFUSION PLANT

Figure 10.3. Location of SWMU 7 Potential DNAPL Source Area and Treatment Cell

Figure No. \BGOU\FS_2-VOCR1.apr
DATE 10-01-09

Table 10.1. Source Area Alternative Screening Summary for SWMU 7

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	Alternative 9
Screening Criteria	**No Action**	**Limited Action**	**Soil Cover and Long-Term Monitoring**	**Soil Cover with *In situ* DNAPL Source Treatment and Long-Term Monitoring**	**RCRA Cover with Hydraulic Isolation and Long-Term Monitoring**	**Excavation and Disposal**	**Excavation and Disposal combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring**	**Excavation and Disposal combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring**	***In situ* Containment and Long-Term Monitoring**
Overall Effectiveness	NA	NA[1]	NA[2]	High[3]	NA[4]	NA[4]	High	Moderate	NA
Short-term	NA	NA	NA	Moderate	NA	NA	Moderate to High	Low	NA
Long-term	NA	NA	NA	High	NA	NA	High	High	NA
Overall Implementability	NA	NA	NA	High	NA	NA	Moderate	Low to Moderate	NA
Technical	NA	NA	NA	Moderate to High	NA	NA	Moderate	Moderate	NA
Administrative	NA	NA	NA	Moderate	NA	NA	Moderate	Low	NA
Overall Cost	NA	NA	NA	Moderate	NA	NA	High	High	NA
Capital	NA	NA	NA	Moderate	NA	NA	High	High	NA
Operation and maintenance	NA	NA	NA	Low to Moderate	NA	NA	Low to Moderate	Low to Moderate	NA

NA—Not applicable based on-site conditions or nature of contamination present at the SWMU.
[1] Monitoring will not contain or remediate the contaminant levels at SWMU 7.
[2] Provides no contingency for remediation of potential DNAPL source.
[3] Effective in preventing contact with low-levels of radioactive and inorganic contamination present in surface soils. Provides contingency for potential DNAPL source.
[4] Radioactive and inorganic contamination is limited to surface and near surface. Provides no contingency for remediation of potential DNAPL source.
NOTE: Alternatives shaded grey were screened out at this step.

10.4 DETAILED ANALYSIS OF ALTERNATIVES

10.4.1 Alternative 1—No Action

The No Action alternative is defined in accordance with CERCLA and provides a baseline to which other alternatives can be compared. Under this alternative, no action would be taken to implement remedial activities for SWMU 7 or to reduce the potential hazard to human or ecological receptors.

10.4.1.1 Overall protection of human health and the environment

This alternative would not be protective of groundwater, and no additional controls would be implemented to protect site workers or the public. The results of the risk-based evaluation of the No Action alternative indicate a possible threat to human health via the groundwater pathways presented in Figure 2.1. Not all of the RAOs, particularly protection of groundwater, would be met because no action would be implemented.

Alternative 1 would not meet this threshold criterion for a DNAPL source. A potential DNAPL source would not be treated or removed, risks to potential receptors would not be reduced, and the RAOs would not be met because no action would be implemented.

10.4.1.2 Compliance with ARARs

No ARARs have been identified for Alternative 1, the No Action alternative.

10.4.1.3 Long-term effectiveness and permanence

Alternative 1 provides no long-term effectiveness or permanence. Future potential leaching of contaminants to the RGA may result in concentrations above their MCL or risk-based value. Alternative 1 leaves the risk or hazard from radioactive or inorganic COCs at an unacceptable level at the SWMU. Over time, this alternative would not prevent future migration of contaminants. Alternative 1 would leave the risk or hazard from a DNAPL source at an unacceptable level at SWMU 7. The alternative does not provide any long-term remedy to manage residual risk at this SWMU.

10.4.1.4 Reduction of toxicity, mobility, or volume through treatment

Treatment would not be implemented with Alternative 1. Reduction of toxicity, mobility, or volume through treatment would not be applicable to the No Action alternative because it does not include treatment. The No Action alternative would not result in any reduction in the toxicity, mobility, or volume of contaminants other than those attributable to natural processes, such as degradation, dilution, or dispersion.

10.4.1.5 Short-term effectiveness

No actions would be implemented under Alternative 1; therefore, no additional risks to workers, the public, or the environment would be incurred. There would be no change to existing conditions. RAOs would not be met over any reasonable time period.

10.4.1.6 Implementability

The No Action alternative can be implemented readily. If future remedial action is necessary, this alternative would not impede implementation of such action.

The ongoing public awareness program would require regular coordination with DOE, KY, and possibly with other governmental agencies.

10.4.1.7 Cost

The preliminary cost estimates for Alternative 1 serve as a baseline for comparison of the other remedial alternatives. These cost estimates are based upon FS-level scoping and are intended to aid with selection of a preferred alternative. There are no capital or O&M costs associated with Alternative 1.

10.4.2 Alternative 4—Soil Cover with *In situ* DNAPL Source Treatment and Long-Term Monitoring

Alternative 4 includes the following:

- Remedial design
- Partial excavation to remove obstructions to access DNAPL source for treatment
- DNAPL source treatment using *in situ* DNAPL source treatment
- Off-gas treatment
- Process monitoring
- Postremediation sampling
- Construction of a surface soil cover over the entire unit and the areas to the north and south extending to the bordering ditches
- Long-term groundwater monitoring
- LUCs (see Section 2.4.1.1)

Engineering data will be collected to confirm the presence of DNAPL and support the RD effort. A partial excavation above the DNAPL source area where waste was buried would be performed, if necessary, to remove disposed construction rubble, debris, or metallic waste that could interfere with the installation or operation of the *in situ* DNAPL source treatment system The excavation will be filled with clean fill material. If necessary, the *in situ* DNAPL source treatment system will be constructed and operated. Upon completion of DNAPL source treatment, a surface soil cover will be constructed over the entire unit. This cover will be contoured to promote runoff and will reduce potential direct exposure to the surface soil contamination present at SWMU 7.

A groundwater monitoring program would be implemented to monitor the upper RGA. The monitoring program will utilize existing PGDP MWs and additional groundwater MWs as necessary to monitor upgradient and downgradient groundwater contaminant levels.

10.4.2.1 Overall protection of human health and the environment

Construction of a surface soil cover over the unit will eliminate the potential exposure to workers from contaminated soil. Implementation of additional groundwater monitoring will provide an indirect protection, as monitoring contaminant migration allows for minimizing the potential for exposure to contaminated environmental media through early identification and avoidance. LUCs (see Section 2.4.1.1) protect current and future site workers and the public.

In situ DNAPL source treatment for potential DNAPL at SWMU 7 would meet the RAO for treating waste by removing the potential DNAPL source as vapor and destroying it *ex situ*. It also would meet the RAOs for groundwater protection and worker protection based on previous demonstrations. The C-400 SPH Study (DOE 2003) determined that over 98% of TCE was removed from soil in less than six months, and similar performance would be expected at SWMU 7.

10.4.2.2 Compliance with ARARs

Alternative 4 will meet this threshold criterion by complying with potential chemical-, location-, and action-specific ARARs. ARARs for this alternative are summarized in Appendix F.

10.4.2.3 Long-term effectiveness and permanence

Alternative 4 is designed to provide protection against exposure to waste in surface soils. Since the toxicity or volume of waste and contaminated environmental media will remain near current levels and concentrations (assuming limited degradation and negligible natural attenuation of residual waste and contaminants), some risk would remain. Migration of contaminants to groundwater would be reduced by soil cover limiting infiltration through surface soils.

An *in situ* DNAPL source treatment component is incorporated into Alternative 4 for removal of secondary sources of DNAPL in the event the engineering data collection determines that DNAPL is present at SWMU 7.

The long-term effectiveness and permanence of Alternative 4 for DNAPL remediation is high because much of the DNAPL in the source areas at SWMU 7 would be removed by *in situ* DNAPL source treatment. VOCs in the extracted vapor would be condensed. Overall removal efficiency is estimated at up to 98% over approximately six months, based on results of the C-400 SPH Study (DOE 2003). LUCs (see Section 2.4.1.1) protect current and future site workers and the public.

10.4.2.4 Reduction of toxicity, mobility, or volume through treatment

Installation of soil cover as part of Alternative 4 would reduce mobility of surface soil contaminants.

This alternative would remove and recondense most of the DNAPL potentially present at the site. Overall removal efficiency is estimated at up to 98% over approximately six months, based on results for the C-400 SPH Study (DOE 2003). The *in situ* DNAPL source treatment system design would include measures to reduce the potential for mobilization of DNAPL during treatment. Secondary wastes would include condensed VOC liquids, spent GAC, treated condensate, drill cuttings produced during electrode/vapor recovery well installation, PPE, and decontamination fluids. For cost-estimating purposes, drill cuttings, PPE, and decontamination fluids were assumed to be dewatered, sampled, and analyzed prior to bulk transport to off-site disposal. Actual disposal requirements would be determined during RD and by sampling of containerized soils. Condensed VOCs would be shipped off-site for recycling or destruction. Spent GAC would be shipped off-site for regeneration. It is assumed that treated condensate would be discharged to a permitted outfall.

10.4.2.5 Short-term effectiveness

Implementation of Alternative 4 would not have any detrimental impact on the community.

Implementation of Alternative 4 has the potential for worker exposure to contaminated surficial soils and groundwater during environmental sampling. Potential exposure pathways include inhalation of dust containing surficial soils, dermal contact with surficial soils, and dermal contact with contaminated groundwater. PGDP worker protection programs will make worker exposure unlikely.

At the time that implementation of each component of Alternative 4 is completed, all RAOs will be achieved. Tentatively, implementation of Alternative 4 may take approximately one year.

The short-term effectiveness of Alternative 4 is moderate to high for the *in situ* DNAPL source treatment process to remediate a DNAPL source. Installation of electrode/vapor recovery wells and monitoring equipment would encounter contaminated soils. Soil cuttings produced during installation of electrode/vapor recovery wells would be managed in accordance with the HASPs, WCP, and WMP prepared during the RD/RAWP. Installation and operation of the *in situ* DNAPL source treatment system would be conducted by trained personnel in accordance with procedures. Site preparation and *in situ* DNAPL source treatment system operation is expected to require less than one year.

No ecological impacts at the BGOU are anticipated under this alternative. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archaeological or historical sites or T&E species would be impacted by this alternative. Risk assessment and mitigation for ecological receptors in nearby drainage ditches are within the scope of the Surface Water OU.

The RAOs for radioactive and inorganic contaminants would be achieved by installation of the soil cover. The goal would be to remove as much DNAPL as practicable by the end of the treatment period, but any low-level contaminant residues remaining after a reasonable period of treatment will be remediated by natural attenuation processes.

10.4.2.6 Implementability

Activities to be conducted under Alternative 4 include continuation/expansion of existing environmental media monitoring to track contaminant migration and construction of a soil cover.

Implementation of the remedial action components of Alternative 4 is technically feasible. Implementation of Alternative 4 would use standard construction methods, materials, and equipment that are available from vendors and contractors.

Overall implementability of Alternative 4 for DNAPL is moderate. Waste material will be removed during partial excavation that could interfere with underground construction of the *in situ* DNAPL source treatment system.

Equipment, personnel, and services required to implement this alternative are readily commercially available. No additional development of these technologies would be required. Contractors possessing the required skills and experience are available.

Implementation of Alternative 4 for DNAPL remediation is administratively feasible. The electrode/vapor extraction wells would be constructed and abandoned according to the substantive requirements of KY regulations. Recovered vapor would be treated to meet allowable emission levels prior to discharge.

10.4.2.7 Cost

Estimated capital and O&M costs for Alternative 4 address construction and maintenance of the soil cover as well as installation of a monitoring well network and sampling and analysis of the wells. In addition there is a contingency cost for *in situ* DNAPL source treatment of a potential DNAPL source.

10.4.3 Alternative 7—Excavation and Disposal Combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring

This alternative is comprised of excavation to remove waste and contaminated soil, followed by a contingency RPO for *in situ* DNAPL source treatment to remove DNAPL that potentially may remain after excavation. The excavation component of this alternative includes the following: installation of sheet piles around the perimeter of the waste unit; excavation of all buried materials and contaminated soils; operation of emission control equipment; cover soil and waste disposal characterization sampling; excavation pit dewatering; and segregation, bulking, and consolidation of compatible waste groups. In addition, treatment of excavated materials may include the following: *ex situ* thermal desorption to drive off VOCs and SVOCs; metal detection/magnetic separation of metallic materials (decayed drums and uranium for stabilization/solidification); and radiological separation. For the treatment and segregation operations, short-term storage would be required for the excavated waste and for treated materials awaiting shipment to the disposal site. Disposal options include off-site disposal facilities, as well as the WDF. The contingency RPO for potential residual DNAPL is *in situ* DNAPL source treatment, assumed to be ERH for the purpose of cost estimation. A detailed description of this alternative is presented in Section 3.4.

10.4.3.1 Overall protection of human health and the environment

Alternative 7 would meet this threshold criterion. Potential short-term risks to remediation workers due to direct contact with the waste material are greater than some of the other alternatives evaluated for this SWMU. In addition, potential risks to the public and the environment as a result potential shipping and handling concerns should be considered for off-site shipments. These concerns are greatly reduced for disposal in the WDF. These risks may be mitigated by proper engineering and administrative precautions, while achieving the long-term risk reduction.

Waste and contaminated soil will be physically removed from the SWMU and disposed of in one or more appropriate disposal facilities, including the WDF, thus meeting all RAOs for waste in the former burial pits.

In situ DNAPL source treatment for potential DNAPL at SWMU 7 would meet the RAO for treating waste by removing the potential DNAPL source as vapor and destroying it *ex situ*. It also would meet the RAOs for groundwater protection and worker protection based on previous demonstrations. The C-400 SPH Study (DOE 2003) determined that over 98% of TCE was removed from soil in less than six months, and similar performance would be expected at SWMU 7.

10.4.3.2 Compliance with ARARs

Alternative 7 would meet this threshold criterion. ARARs for this alternative are summarized in Appendix F.

10.4.3.3 Long-term effectiveness and permanence

Complete excavation offers maximum control of contaminant migration, since no wastes or associated contaminated soils would remain in the SWMU; therefore, this alternative offers a high degree of risk reduction. Complete treatment processes manage or remove hazardous characteristics, or destroy the COCs.

Alternative 7 allows for potential risks associated with contaminants in the SWMU to be reduced or eliminated. Risks associated with direct contact with waste and surface soils will be eliminated since the primary source and associated contaminated soils will be removed. Alternative 7 allows for a maximum reduction of uncertainties associated with these soils in terms of continued contributions to the hydrogeologic system.

A contingency *in situ* DNAPL source treatment component is incorporated into Alternative 7 for DNAPL removal for this SWMU in the event postremediation samples indicate residual DNAPL after the excavation is completed.

The long-term effectiveness and permanence of Alternative 7 for DNAPL remediation is high because much of the DNAPL in the source areas at SWMU 7 would be removed by *in situ* DNAPL source treatment. VOCs in the extracted vapor would be condensed. Overall removal efficiency is estimated at up to 98% over approximately six months, based on results of the C-400 SPH Study (DOE 2003). The estimated degradation rate for TCE upon completion of active remediation is presented in Appendix B. *In situ* DNAPL source treatment should greatly reduce DNAPL levels in soil, protecting the future site worker and off-site groundwater user, thereby reducing SWMU risks to acceptable levels.

10.4.3.4 Reduction of toxicity, mobility, or volume through treatment

This alternative reduces or eliminates the mobility and volume of contaminants from the unit. The toxicity of the treatment residuals also would be drastically reduced and/or eliminated. The removal and disposition of waste and contaminated soil from an unlined burial cell containing COCs to an appropriate disposal facility prevents those contaminants from migrating to the groundwater.

This alternative would remove and recondense most of the DNAPL potentially present at the SWMU. Overall removal efficiency is estimated at up to 98% over approximately six months, based on results for the C-400 SPH Study (DOE 2003). The *in situ* DNAPL source treatment system design would include measures to reduce the potential for mobilization of DNAPL during treatment. Secondary wastes would include condensed VOC liquids, spent GAC, treated condensate, drill cuttings produced during electrode/vapor recovery well installation, PPE, and decontamination fluids. For cost-estimating purposes, drill cuttings, PPE, and decontamination fluids were assumed to be dewatered, sampled, and analyzed prior to bulk transport to off-site disposal. Actual disposal requirements would be determined during RD and by sampling of containerized soils. Condensed VOCs would be shipped off-site for recycling or destruction. Spent GAC would be shipped off-site for regeneration. It is assumed that treated condensate would be discharged to a permitted outfall.

10.4.3.5 Short-term effectiveness

Short-term risks to the community resulting from excavation activities at the SWMU would not be expected. Potential risks resulting from migration of contaminants to off-site locations would be controlled by the on-site vacuum hood and HEPA filtration system. Alternative 7, however, includes a potential risk to the public from transportation of the LLW or hazardous wastes/liquids to off-site disposal and/or treatment facilities. This risk would be greatly reduced by disposing of waste in the WDF.

Short-term exposures of workers to COCs could occur during implementation of Alternative 7. Potential exposure pathways include direct contact with soil (ingestion, inhalation) and exposure to external penetrating radiation. Worker risks are not expected to exceed acceptable limits because exposure frequency and duration are less than those evaluated in the BHHRA. Typically, risks from handling waste/contaminated soils would be minimized through adherence to health and safety protocols. To protect workers, PPE, ambient conditions monitoring, and decontamination protocols would be used in accordance with an approved, site-specific HASP.

The short-term effectiveness of Alternative 7 is moderate to high. The alternative includes *in situ* DNAPL source treatment process as a contingency remedial component to remediate a DNAPL source, if one is discovered. Installation of electrode/vapor recovery wells and monitoring equipment would encounter contaminated soils. Soil cuttings produced during installation of electrode/vapor recovery wells would be managed in accordance with the HASPs, WCP, and WMP prepared during the RD/RAWP. Installation and operation of the *in situ* DNAPL source treatment system would be conducted by trained personnel in accordance with procedures. Site preparation and *in situ* DNAPL source treatment system operation is expected to require less than one year.

Excavation and disposal would be conducted by trained personnel in accordance with standard radiological, engineering, and operational procedures, DSAs, HASPs, and safe work practices to maintain a work environment that minimizes injury or exposure to risks to human health or the environment.

No ecological impacts at the BGOU are anticipated under this alternative. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archaeological or historical sites or T&E species would be impacted by this alternative. Risk assessment and mitigation for ecological receptors in nearby drainage ditches are within the scope of the Surface Water OU.

The RAOs for radioactive and inorganic contaminants would be achieved following completion of excavation. The goal would be to remove as much DNAPL as practicable by the end of the treatment period, but any low-level contaminant residues remaining after a reasonable period of treatment will be remediated by natural attenuation processes.

10.4.3.6 Implementability

Alternative 7 is considered to be technically and administratively feasible and implementable. The equipment and technologies associated with implementation of this alternative have been proven to be technically feasible and are available from contractors or vendors. Treatability testing may be required for waste treatment processes including *ex situ* thermal desorption for excavated soils. The implementability of construction-related activities during excavation and backfilling at SWMU 7 subject to Alternative 7 is very similar to that carried out routinely at other sites. Likewise, sampling, analysis, transportation, and disposal at an approved location are routinely performed and, if properly implemented, are proven to be safe. Some excavated waste materials may be radioactive, RCRA hazardous, or mixed. Treatment of wastes with multiple regulatory classifications is more complex and may require more than one treatment process to make the waste suitable for transportation and/or land disposal. On-site treatment processes will comply with ARARs.

Overall implementability of Alternative 7 for DNAPL is moderate. Waste material will be removed during excavation that could interfere with underground construction of the *in situ* DNAPL source treatment system.

Equipment, personnel, and services required to implement this alternative are readily commercially available. No additional development of these technologies would be required. Contractors possessing the required skills and experience are available.

Implementation of Alternative 7 for DNAPL remediation is administratively feasible. The electrode/vapor extraction wells would be constructed and abandoned according to the substantive requirements of KY regulations. Recovered vapor would be treated to meet allowable emission levels prior to discharge.

An option for disposal of waste and residuals at the WDF was considered under Alternative 7. The primary difference would be the elimination of waste leaving the PGDP, related off-site transportation issues, and the cost for disposal. At this time, no capacity for disposal of these wastes exists at PGDP.

10.4.3.7 Cost

Costs were estimated for transportation and disposal of wastes at an off-site facility as well as for an option to dispose of waste at the WDF. O&M costs are dependent upon the status of the SWMU upon completion of excavation. Cost will be low if SWMU closure can be achieved upon completion of excavation, and a long-term monitoring program is minimal or unnecessary.

10.4.4 Alternative 8—Excavation and Disposal Combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring

This alternative is comprised of excavation to remove waste and contaminated soil, followed by *ex situ* DNAPL source treatment to remove DNAPL that potentially may remain after excavation of the buried wastes and long-term monitoring to confirm no further impacts to groundwater. The buried waste excavation component of this alternative includes the following: shoring around the perimeter of the waste unit; excavation of all buried materials and contaminated soils; operation of emission control equipment; cover soil and waste disposal characterization sampling; excavation pit dewatering; and segregation, bulking, and consolidation of compatible waste groups. In addition, treatment of excavated materials may include the following: *ex situ* thermal desorption to drive off VOCs and SVOCs; metal detection/magnetic separation of metallic materials (decayed drums and uranium for stabilization/solidification); and radiological separation. For the treatment and segregation operations, short-term storage would be required for the excavated waste and for treated materials awaiting shipment to the disposal site. Disposal options include off-site disposal facilities, as well as the WDF.

The RPO for potentially DNAPL-contaminated soils following excavation of buried waste is *ex situ* DNAPL source treatment. It consists of excavation of the DNAPL source and treatment, which is assumed to be oxidation for the purpose of cost estimation. A detailed description of this alternative is presented in Section 3.4.

10.4.4.1 Overall protection of human health and the environment

Alternative 8 would meet this threshold criterion. Potential short-term risks to remediation workers due to direct contact with the waste material and inhalation hazards are much larger than any of the other alternatives evaluated in this FS. In addition, potential risks to the public and the environment as a result shipping and handling should be considered for off-site shipments. These concerns are greatly reduced for disposal in the WDF.

Waste and contaminated soil will be physically removed from the SWMU and disposed of in one or more appropriate disposal facilities, including the WDF, thus meeting all RAOs for waste in the former burial pits.

Ex situ DNAPL source treatment for DNAPL at SWMU 7 would meet the RAO for treating waste by removing the DNAPL source and destroying it *ex situ*. It also would meet the RAOs for groundwater protection and worker protection. Long-term monitoring will verify that target concentrations are met after the action is complete.

10.4.4.2 Compliance with ARARs

Alternative 8 would meet this threshold criterion. ARARs for this alternative are summarized in Appendix F.

10.4.4.3 Long-term effectiveness and permanence

Complete excavation offers maximum control of contaminant migration, since no wastes or associated contaminated soils containing COCs above target concentrations would remain in the SWMU; therefore, this alternative offers a high degree of risk reduction. Complete treatment processes manage or remove hazardous characteristics or destroy the COCs.

Alternative 8 allows for potential risks associated with contaminants to be reduced or eliminated. Risks associated with direct contact with waste and surface soils will be eliminated since the primary source and associated contaminated soils will be removed; therefore, Alternative 8 allows for a maximum reduction of uncertainties associated with these soils in terms of continued contributions to the hydrogeologic system.

Secondary sources of TCE, in the form of contaminated soils, potentially may remain after excavation of buried waste; however, the residual concentrations are not anticipated to result in concentrations at the UCRS-RGA interface that would exceed the MCL or risk-based value. A contingency *ex situ* DNAPL source treatment component is incorporated into Alternative 8 for DNAPL removal for this SWMU in the event postremediation samples indicate residual DNAPL after the excavation is completed.

The long-term effectiveness and permanence of Alternative 8 for DNAPL remediation is high because the DNAPL in the source areas at SWMU 7 would be removed and treated. In the event that some TCE contaminated soils remain, the estimated degradation rate for TCE upon completion of active remediation is presented in Appendix B. Long-term groundwater monitoring will be conducted to confirm no further impacts to groundwater.

10.4.4.4 Reduction of toxicity, mobility, or volume through treatment

This alternative reduces or eliminates the mobility and volume of contaminants from the unit. The toxicity of the treatment residuals also would be drastically reduced and/or eliminated. The removal and disposition of waste and contaminated soil from an unlined burial cell containing COCs to an appropriate disposal facility prevents those contaminants from migrating to the groundwater.

This alternative would remove and capture or condense most of the DNAPL present at the SWMU. The *ex situ* DNAPL source treatment system design would include measures to reduce the potential for mobilization of DNAPL during treatment. Secondary wastes may include condensed VOC liquids, spent GAC, treated condensate, treated soil, and PPE. For cost-estimating purposes, treated soil, PPE, and decontamination fluids were assumed to be dewatered, sampled, and analyzed prior to bulk transport to off-site disposal. Actual disposal requirements would be determined during RD and by sampling of containerized soils. Condensed VOCs would be shipped off-site for recycling or destruction. Spent GAC would be shipped off-site for regeneration. It is assumed that treated condensate would be discharged. It is assumed that DNAPL-contaminated soils treated by oxidation will be sufficiently decontaminated to be returned to the excavation. If not, they should pass the WAC and be disposed of at the C-746-U Landfill; otherwise, they would be disposed of in the WDF or shipped to an off-site disposal facility.

10.4.4.5 Short-term effectiveness

Short-term risks to the community resulting from excavation of buried waste would not be expected. Potential risks resulting from migration of contaminants to off-site locations would be controlled by the on-site vacuum hood and HEPA filtration system. Alternative 8, however, includes a potential risk to the public from transportation of the LLW or hazardous wastes/liquids to off-site disposal and/or treatment facilities. This risk would be greatly reduced by disposing of waste in the WDF.

Short-term exposures of workers to COCs during implementation of Alternative 8 could occur. Potential exposure pathways include direct contact with soil (ingestion, inhalation) and exposure to external penetrating radiation. Worker risks are not expected to exceed acceptable limits because exposure frequency and duration are less than those evaluated in the baseline risk assessment. Typically, risks from handling waste/contaminated soils would be minimized through adherence to health and safety protocols. To protect workers, PPE, ambient conditions monitoring, decontamination protocols, and fire suppression measures would be used in accordance with an approved, site-specific HASP.

The short-term effectiveness of Alternative 8 is low. The alternative includes *ex situ* DNAPL source treatment as a contingency remedial component to remediate a DNAPL source if one is discovered. Risk to workers would be higher than other alternatives because of the depth of excavation, and volumes of waste and contaminated soils to be handled. There is a higher potential for fugitive dust and vapors because of the volumes being treated. Transportation issues are fewer for on-site disposal because waste will not leave PGDP property. Soil for treatment would be managed in accordance with the HASPs, WCP, and WMP prepared during the RD/RAWP. Installation and operation of the *ex situ* DNAPL source treatment system would be conducted by trained personnel in accordance with procedures.

Excavation and disposal would be conducted by trained personnel in accordance with standard radiological, engineering, and operational procedures, DSAs, HASPs, and safe work practices to maintain a work environment that minimizes injury or exposure to risks to human health or the environment.

No ecological impacts at the BGOU are anticipated under this alternative. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archaeological or historical sites or T&E species would be impacted by this alternative. Risk assessment and mitigation for ecological receptors in nearby drainage ditches is within the scope of the Surface Water OU.

The RAOs for radioactive and inorganic contaminants would be achieved following completion of excavation. The goal would be to remove as much DNAPL as practicable by the end of the treatment period, but any low-level contaminant residues remaining after a reasonable period of treatment will be remediated by natural attenuation processes.

10.4.4.6 Implementability

Alternative 8 is considered to be technically and administratively feasible, but its overall ease of implementation is low to moderate. The equipment and technologies associated with implementation of this alternative have been proven to be technically feasible and are available from contractors or vendors. Treatability testing may be required for waste treatment processes including *ex situ* thermal desorption for excavated soils. The implementability of construction-related activities during excavation and backfilling at SWMU 7 subject to Alternative 8 is very similar to that carried out routinely at other sites. Likewise, sampling, analysis, transportation, and disposal at an approved location are routinely performed and, if properly implemented, are proven to be safe. Some excavated waste materials may be radioactive, RCRA hazardous, or mixed. Treatment of wastes with multiple regulatory classifications is more complex and may require more than one treatment process to make the waste suitable for transportation and/or land disposal. On-site treatment processes will comply with ARARs.

Overall implementability of Alternative 8 for DNAPL is low to moderate. DNAPL-contaminated soils will be removed during excavation and treated *ex situ*.

Equipment, personnel, and services required to implement this alternative are readily commercially available. No additional development of these technologies would be required. Contractors possessing the required skills and experience are available, although the space constraints, depth of waste, and potential for groundwater intrusion into the excavation add complexity to the action.

Implementation of Alternative 8 for DNAPL remediation is administratively feasible; however, requirements for control and monitoring of air emissions may be greater than for other alternatives. Recovered vapor would be treated to meet allowable emission levels prior to discharge.

An option for disposal of waste and residuals at the WDF was considered under Alternative 8. The primary difference would be the elimination of waste leaving the PGDP, related off-site transportation issues, and the cost for disposal. At this time, no capacity for disposal of these wastes exists at PGDP. The following discussion assumes that future capacity to treat and dispose of the mixed and/or LLW at PGDP is available.

The PGDP disposal facility WAC would provide the basis for determining if waste sent to that facility is acceptable.

Wastes would be loaded into trucks and transported to the on-site disposal facility at PGDP. Wastes would be placed in the disposal facility so that the potential for releases, danger from the mixing of incompatible or unstable outdated materials, and environmental and personnel exposures are minimized.

10.4.4.7 Cost

Costs were estimated for transportation and disposal of wastes at an off-site facility as well as for an option to dispose of waste at the WDF. O&M costs are dependent upon the status of the SWMU upon completion of excavation. Cost will be low if target concentrations are achieved upon completion of excavation and a long-term monitoring program is minimal or unnecessary. Alternative 8 also includes cost for implementation of a contingency remediation of DNAPL employing *ex situ* DNAPL source treatment.

10.5 COMPARATIVE ANALYSIS OF ALTERNATIVES

A comparative analysis summary for source area alternatives at SWMU 7 is presented in Table 10.2, and the corresponding costs for the alternatives are presented in Table 10.3.

10.5.1 Threshold Criteria

Source area remedial alternatives are compared with respect to the threshold criteria in the following sections.

10.5.1.1 Overall protection of human health and the environment

Alternative 1 does not meet the threshold criterion of overall protection of human health and the environment. Alternative 1 would not treat or remove waste.

Alternative 4, soil cover with *in situ* DNAPL source treatment, would meet the threshold criterion for those sites where contamination is limited to the surface or near surface and the goal is to prevent direct contact. No waste would be removed or treated. A properly installed soil cover would reduce surface infiltration by reducing permeability relative to native soils and directing runoff away from the covered areas, thereby reducing contaminant migration to groundwater. Industrial workers would be protected from direct contact by the physical barrier of the cover. The public would be protected by site controls to monitor and ensure the integrity of the containment. Overall protection of human health and the environment for the DNAPL component of Alternative 4 would be comparable to that achieved for Alternative 7 described below. While the short-term risks associated with excavation can be mitigated by proper engineering precautions in achieving long-term risk reduction, the trade-offs of removing risks that can be managed at the unit for risks during excavation and removal are significant factors that favor Alternative 4.

Alternative 7, excavation and disposal combined with *in situ* DNAPL source treatment, meets the threshold criterion by removing waste and contaminated soil from the SWMU. This alternatives could remove enough waste and contaminated soil so that the remaining soil at the SWMU would meet soil target concentrations and attain MCLs or risk-based values in RGA groundwater at the UCRS-RGA boundary beneath the SWMU.

Should the presence of DNAPL be confirmed at SWMU 7, implementation of the *in situ* DNAPL source treatment component of Alternative 7 will remove DNAPL in soil. Based on the maximum observed concentration of TCE at SWMU 7 and modeling based on 98% removal of TCE DNAPL observed during the C-400 SPH Study (DOE 2003), the results for DNAPL removal after operating the system for less than one year were estimated. The time frames for reaching the maximum TCE concentration and the risk-based target concentrations necessary to meet the MCL beneath the SWMU were predicted by modeling. There is minimal benefit to operating the *in situ* DNAPL source treatment system for a longer than one year. The modeling approach and results are presented in Appendix B.

Alternative 8, which excavates buried waste and follows up with excavation and *ex situ* treatment of DNAPL, meets this threshold criterion by removing waste and contaminated soil. This alternative is at least as, if not more protective than, Alternative 7.

10.5.1.2 Compliance with ARARs

No ARARs have been identified for Alternative 1, the No Action alternative.

Alternative 4 would meet this threshold criterion for contamination limited to the surface and near surface. Compliance with ARARs for the DNAPL component of Alternative 4 would be comparable to that achieved for Alternative 7 described below.

Alternative 7 would meet this threshold criterion. This alternative could remove enough waste and contaminated soil so that the remaining soil at the sites would meet soil target concentrations and attain MCLs or risk-based values in RGA groundwater at the UCRS-RGA boundary beneath the SWMU.

Table 10.2. Summary of Comparative Analysis of Source Area Alternatives SWMU 7

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 1: No Action	Does not meet the threshold criterion because no action would be taken. Potential DNAPL source would remain untreated other than through natural processes. Not protective of RGA groundwater beneath the SWMU.	No actions implemented; no ARARs identified.	No long-term effectiveness or permanence.	Low. No direct treatment or containment provided.	High. No actions implemented; therefore, no change to existing conditions.	High. No action would be implemented. High technical and administrative implementability.
Alternative 4: Soil Cover with *In situ* DNAPL Source Treatment and Long-Term Monitoring	Moderate to high. Much more protective than Alternative 1 and less protective than Alternatives 7 and 8. Prevents direct contact with waste and reduces migration potential. Potential DNAPL source would be treated in UCRS. Significant reduction in DNAPL mass should be achieved by treatment. Land use controls protect current and future site workers and the public.	High. Threshold criterion met. Complies with ARARs and potential TBCs. Should provide groundwater protection based on results of C-400 SPH Study.	High. Protects site workers from direct contact with waste and surface soil. Significant reduction in DNAPL mass should be achieved by treatment. Remaining TCE DNAPL would be remediated over time by natural processes. Soil target concentrations should be attained based on results of C-400 SPH Study.	Moderate to high. No reduction of toxicity or volume of radioactive and inorganic COCs; however, mobility is reduced through containment. Potential DNAPL source would be treated in UCRS.	Moderate. No negative impacts to community. Exposure to workers low to moderate during installation of *in situ* DNAPL source treatment system and cover.	Moderate to high. Services and materials are readily available. Implementability could be impacted by presence of large pieces of buried debris or metallic waste in vicinity of potential DNAPL source.

Table 10.2. Summary of Comparative Analysis of Source Area Alternatives SWMU 7 (Continued)

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 7: Excavation and Disposal with *In situ* DNAPL Source Treatment and Long-Term Monitoring	High. Threshold criterion met. Removal of contaminated waste offers the highest degree of overall protection and achievement of RAOs. Potential DNAPL source would be treated in UCRS. Significant reduction in DNAPL mass should be achieved by treatment. Remaining TCE DNAPL would be remediated over time by natural processes. Soil target concentrations should be attained based on results of C-400 SPH Study.	High. Threshold criterion met. Complies with ARARs and potential TBCs. Should provide groundwater protection based on results of C-400 SPH Study.	High. Contaminant sources removed; therefore, residual risks are negligible. Most adequate overall level of protection to humans and the environment.	High. Excavation, treatment and disposal would reduce mobility of radionuclides, reduce or destroy toxicity of organics and DNAPL.	Moderate to High. Potential negative impacts to community from waste transportation for off-site disposal. Risk to workers higher than other alternatives but can be managed by applying appropriate health and safety procedures. Improves to high for on-site disposal. Transportation issues become negligible since waste will not leave PGDP property. Implementation could take years.	Moderate. Excavation and associated technologies are readily implementable. Some excavated waste materials or soil may have multiple regulatory classifications, increasing the complexity of treatment required for transportation and/or disposal. WDF is being evaluated as part of the waste disposal option project, and a ROD has not been issued.

Table 10.2. Summary of Comparative Analysis of Source Area Alternatives SWMU 7 (Continued)

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 8: Excavation and Disposal combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring	High. Threshold criterion met. Removal of contaminated waste offers the highest degree of overall protection and achievement of RAOs. Potential DNAPL source would be treated in UCRS. Removal of DNAPL mass should be achieved by excavation and treatment. Soil target concentrations should be attained. Long-term monitoring would verify that target concentrations are met after action is complete.	High. Threshold criterion met. Complies with ARARs and potential TBCs. Should provide groundwater protection.	High. Contaminant sources removed; therefore, no residual risks should remain. Long-term monitoring conducted to confirm no further impacts to groundwater.	High. Excavation, treatment and disposal would remove contamination sources.	Low. Potential negative impacts to community from waste transportation for off-site disposal. Risk to workers higher than other alternatives because depth of excavation, and volumes of waste and contaminated soils to be handled. Higher potential fugitive dust and vapors because of the volumes being treated. Transportation issues less for on-site disposal because waste will not leave PGDP property. Implementation could take years.	Low. Some excavated waste materials or soil may have multiple regulatory classifications, increasing the complexity of treatment, transportation and/or disposal. WDF is being evaluated as part of the waste disposal option project, and a ROD has not been issued.

Table 10.3. SWMU 7 Remedial Alternatives Cost Estimate Summary

			PRESENT WORTH[1]		ESCALATED	
Alternative Description	**Annual Time Period, yrs**	**Capital $ (2010 Constant Dollars)**	**Total Annual $**	**Total $ (Capital and Annual)**	**Total Annual $**	**Total $ (Capital and Annual)**
Alternative 1—No Action	0	$0	$0	$0	$0	$0
Alternative 4—Soil Cover and Long-Term Monitoring	30	$4,554,000	$2,043,000	$6,597,000	$7,659,000	$12,490,000
Contingency for Alternative 4—*In situ* DNAPL Source Treatment[2]	0	$17,786,000	$0	$17,786,000	$0	$18,869,000
Alternative 7a—Excavation and Disposal	0	$77,889,000	$0	$77,889,000	$0	$82,632,000
Alternative 7b—Excavation and Disposal (at the WDF)	0	$54,265,000	$0	$54,265,000	$0	$57,570,000
Contingency for Alternative 7—*In situ* DNAPL Source Treatment and Long-Term Monitoring	30	$8,556,000	$733,000	$9,288,000	$2,283,000	$11,360,000
Alternative 8a—Excavation and Disposal	0	$77,889,000	$0	$77,889,000	$0	$82,632,000
Alternative 8b—Excavation and Disposal (at the WDF)	0	$54,265,000	$0	$54,265,000	$0	$57,570,000
Contingency for Alternative 8—*Ex Situ* DNAPL Source Treatment and Long-Term Monitoring	30	$24,868,000	$739,000	$25,607,000	$2,296,000	$28,678,000

[1] Not used for budgeting or planning purposes because value is based on investing funds for outyear expenditures.

[2] Includes excavation of landfill contents above treatment area.

Should residual DNAPL remain upon completion of excavation, Alternative 7 would remove a large portion of the residual DNAPL mass in soil during the period of operation of the *in situ* DNAPL source treatment system, and natural processes would, in time, prevent further degradation of RGA groundwater from SWMU 7. This alternative is expected to meet all location- and action-specific ARARs through design and planning during preparation of the RD/RAWP.

Alternative 8 would meet this threshold criterion as well or better than Alternative 7.

10.5.2 Balancing Criteria

Source area alternatives are compared with respect to the balancing criteria in the following sections.

10.5.2.1 Long-term effectiveness and permanence

Alternative 1 would not be effective. The risk posed by waste material and COCs in soil would remain unabated. No additional controls would be implemented to protect current and future site workers or the public.

Alternative 4 provides a low to moderate degree of long-term effectiveness and permanence because it is effective in controlling direct contact with surface contamination. Residual risk would remain under this alternative. The long-term effectiveness and permanence for the DNAPL component of Alternative 4 would be comparable to that achieved for Alternative 7 described below. LUCs (see Section 2.4.1.1) protect current and future site workers and the public.

Alternative 7 provides a high degree of long-term effectiveness and permanence. Residual risk should be the lowest under this alternative. Long-term controls may not be required under this alternative provided that waste material and contaminated soil can be removed to attain soil target concentrations. Should residual DNAPL remain upon completion of excavation, *in situ* DNAPL source treatment should be effective at removing the majority of the mass of DNAPL from the UCRS, with the remainder being remediated by natural processes. Residual risk would be the lowest under this alternative.

The long-term effectiveness and permanence of Alternative 8 would be as good as or better than Alternative 7.

10.5.2.2 Reduction of toxicity, mobility, and volume through treatment

Alternative 1 would not reduce the toxicity, mobility, or volume of COCs in waste or soil at the SWMU.

Alternative 4 provides only limited control of mobility by preventing migration of surface contamination. It also reduces surface water infiltration and the ensuing subsurface migration of contaminants. Reduction of toxicity, mobility, and volume through treatment for the DNAPL component of Alternative 4 would be comparable to that achieved for Alternative 7 described below.

Alternative 7 reduces toxicity by removal, treatment, and disposal of wastes. Waste materials and soil would be treated on-site as needed to allow excavated materials to be readied for transport or disposal. Volume is similarly reduced. The relocation of waste and contaminated soil from an unlined burial cell that has COCs in direct contact with groundwater to an appropriate disposal facility will reduce the mobility of those contaminants in the environment. Removal of source material and surrounding contaminated soils will prevent future migration of contaminants at the SWMU.

If residual DNAPL is present at SWMU 7, the *in situ* DNAPL source treatment component of Alternative 7 would remove most of the DNAPL mass from the UCRS. It would remove DNAPL from the subsurface to be condensed by aboveground equipment. VOC-contaminated water condensed from the extracted vapor stream would be air stripped to remove VOCs. The VOCs in the air stripper emissions would be condensed and either recycled or destroyed off-site. Residual VOCs in air stripped water would be removed by adsorption on activated carbon. The spent carbon would be managed off-site, likely by thermal regeneration or incineration.

Alternative 8 also reduces toxicity by removal, treatment, and disposal of wastes the same as Alternative 7. There is even less likelihood that DNAPL will remain after active treatment than in the case of Alternative 7 because the DNAPL-contaminated soil, if present, will be excavated and treated. There is a degree of uncertainty associated with identifying and excavating all the contaminated soil for DNAPL treatment.

10.5.2.3 Short-term effectiveness

The short-term effectiveness of Alternative 1 is low because RAOs not would be attained over any reasonable time frame.

Alternative 4 is moderately effective during implementation. There is very little risk to workers or the community during installation of the soil cover. The short-term effectiveness for the DNAPL component of Alternative 4 would be comparable to that achieved for Alternative 7 described below.

The short-term effectiveness of Alternative 7 is moderate because of the increased potential for contact to workers and the community during excavation. The option to dispose of excavated waste in the WDF would improve the short-term effectiveness by eliminating risks associated with waste leaving the site. The *in situ* DNAPL source treatment component of Alternative 7 for DNAPL remediation has a high degree of short-term effectiveness, Active remedial action could be completed in a period of less than one year. Alternative 7 potentially could expose workers to chemical hazards during well drilling, installation of electrodes, and operation of the aboveground treatment system. Workers also could be exposed to thermal and electrical hazards due to installation and operation of electrodes. The ERH system is technically complex, but site workers will have gained valuable experience with the technology during the C-400 Remedial Action, so that the associated health and safety issues should be effectively managed. The potential risks to the community from Alternative 7 during the remedial action period for DNAPL are negligible.

The short-term effectiveness for Alternative 8 is potentially low. Greater depths of excavation, larger volumes of contaminated soil, potentially larger volumes of wastewater, increased requirements and size for treatment unit operations, and associated emissions are all factors that contribute negatively to the short-term effectiveness of Alternative 8.

10.5.2.4 Implementability

Alternative 1 would be the most readily implementable because no construction or invasive action would be taken.

The implementability of Alternative 4 is high because the technology is readily available and the complexity is low. The implementability for the DNAPL component of Alternative 4 would be comparable to that achieved for Alternative 7 described below.

Alternative 7 is considered to be technically and administratively feasible and implementable. For the DNAPL remediation components of the alternative, the SPH Study at C-400 established system design parameters and the range of operating conditions. Subsurface objects that could interfere with construction of the underground components of the *in situ* DNAPL source treatment system would be removed prior to construction. Equipment, personnel, and services required to implement this alternative are readily available. Equipment replacement should be minimal during the remedial action period at any SWMU because RAOs should be achieved within less than one year of operation. The treatment system would generate several waste residuals that would require management, including condensed VOCs, treated water, and VOC-contaminated activated carbon.

Alternative 8 is technically feasible, but there are challenges. The main technical challenges are associated with the depth of excavation and shoring and groundwater control and treatment.

10.5.2.5 Cost

Capital and O&M costs for alternatives at SWMU 7 are presented in Table 10.3. Costs were estimated for transportation and disposal of wastes at an off-site facility as well as for an option to dispose of waste at the WDF.

10.5.3 Summary of SWMU 7 Comparative Analysis of Alternatives

Alternative 1 does not meet the threshold criterion of overall protection of human health and the environment. Alternative 1 would not treat or remove waste. Risk to future off-site groundwater users from the migration of COCs to RGA groundwater could reach unacceptable levels. Although the RI data indicate that radioactive and inorganic contamination at SWMU 7 only is limited to the surface soils, this action may not provide an adequate level of overall protection to human health and the environment for these COCs.

Alternative 4 provides containment of the waste by installing a soil cover over contaminated surface soils identified in the RI. The cover would reduce infiltration caused by precipitation and prevent direct contact with surface soils. Although this alternative does leave buried waste in place, it meets the threshold criteria with regard to radioactive and inorganic contaminants and achieves the RAOs for the SWMU. For DNAPL source areas, Alternative 4 provides a high degree of long- and short-term effectiveness. Alternative also provides a high reduction in toxicity, mobility, and volume of DNAPL contamination through treatment.

Alternatives 1 and 4 would not prevent potential discharge of leachate into the ditches adjoining SWMU 7 to the north and south, but would provide limited control by reducing infiltration and managing runoff of precipitation.

Alternative 7, excavation and disposal with *in situ* DNAPL source treatment, meets the threshold criteria by removing waste and contaminated soil from the SWMU. This alternative may remove enough waste and contaminated soil so that the remaining soil at the sites could meet soil target concentrations and attain MCLs or risk-based values in RGA groundwater at the UCRS-RGA boundary beneath the SWMU. All ARARs defined for Alternative 7 would be met.

For DNAPL source areas, Alternative 7 provides a high degree of long- and short-term effectiveness. Alternative 7 also provides a high reduction in toxicity, mobility, and volume of DNAPL contamination through treatment.

Alternative 8 is comparable in long-term effectiveness to Alternative 7, but its short-term effectiveness is less. Alternative 8 is also more challenging to implement than Alternative 7.

Alternative 7 provides high overall long-term effectiveness and permanence with fewer implementation challenges.

11. SWMU 30

11.1 SWMU 30 HISTORY AND BACKGROUND

SWMU 30 includes the western one-third of C-747-A. It consists of an historical burn-and-burial pit (Burial Pit A) and the location of a former incinerator. The SWMU is bounded on the north and south sides by ditches, on the west side by a plant road, and on the east side by SWMU 7 (Figure 10.1). The unit encompasses approximately 128,000 ft^2. The pit is reported to have been excavated to a depth of 12 ft and covered with 4 ft of earth. The land surface slopes gently, and a slight mound rises over Burial Pit A. SWMU 30 is bordered by drainage ditches on the north and south side. Grassy vegetation covers the ground, except where gravel roads extend through the site.

SWMU 30 was used from 1951 to 1970 to burn combustible trash, which may have contained uranium contamination. An incinerator was constructed for use at SWMU 30, but the exact time frame is uncertain. The incinerator was a steel mesh, "tee pee" shaped structure primarily used to burn paper, wood, cardboard, and other combustibles. Ash and debris were buried below ground in Burial Pit A beginning in 1962, when use of an on-site incinerator was discontinued. It is assumed ash from incineration was buried at SWMU 30 rather than taken elsewhere at the site. Site maps and a surface electromagnetic geophysical survey of the Phase II SI identify the location of Burial Pit A. Prior to identification by Phase II SI surface geophysics testing, it was believed that remnants of the former incinerator were not present. Further research identified images of the incinerator at the location. This disposal site covers an area of about 250 ft by 50 ft. Geophysical data from the Phase II SI indicate that the actual area of excavation does not exactly match the rectangular outline and extends beyond the rectangular outline to the north and east. Material disposed in Pit A included contaminated and uncontaminated trash, ash, and debris.

In addition to Pit A, the Phase II SI geophysical investigation also identified another anomaly in the shape of a rough circle approximately 43 ft in diameter. The SWMUs 7 and 30 RI confirmed this anomaly likely was the metal reinforcement within the footer and retaining walls of the former incinerator and/or parts of the unit buried there upon decommissioning (DOE 1998a).

As in neighboring SWMU 7, metals concentrations in subsurface soil samples of SWMU 30 rarely exceed background levels. Iron, manganese, and vanadium are the most frequent metals to be detected above outdoor worker NALs. Concentrations above these levels extended throughout the depth of the UCRS. Few organic compounds are present in subsurface soils at SWMU 30. The RI identified benzo(a)pyrene and Total PAHs as organic contaminants. PCBs also were detected in historical samples at depths of 6 to 7 ft and distributed across the SWMU. The uranium isotopes uranium-234, uranium-235/236, and uranium-238 are the only radionuclide contaminants at depths of 10 ft or less.

RI screening of the sample analyses revealed nine metal contaminants in UCRS groundwater samples: arsenic, cadmium, iron, lead, manganese, molybdenum, nickel, uranium, and vanadium. All but cadmium were detected at levels exceeding screening criteria in 50% or more of the samples. The organics TCE, benzene, and vinyl chloride were detected above screening levels; and the uranium isotopes uranium-234 and uranium-238 frequently exceeded screening levels in the SWMU 30 UCRS groundwater samples.

The RGA groundwater samples from SWMU 30 contained five metal contaminants: arsenic, iron, lead, manganese, and uranium. Of the organic analytes, only TCE was detected frequently above screening levels, in all four RGA groundwater MWs. Tetrachloroethene was detected at only one location, MW66, at 0.32 mg/L, which is above the screening level. Radon-222 and technetium-99 were the most frequently detected radionuclide contaminants. All technetium-99 analyses above the MCL represented samples from MW66.

No McNairy groundwater data were available.

11.1.1 Hydrogeologic Interpretation

The study area geology and hydrogeology is summarized below as documented in the BGOU RI (DOE 2010). Because SWMUs 7 and 30 are adjacent to each other, their hydrogeologic interpretation is discussed as one.

Stratigraphy. Like all other on-site BGOU SWMUs, the HU1 silt interval contains the burial cells of SWMUs 7 and 30. The base of HU1 is at a depth of 20 ft, approximately 8 ft below the deepest of the burial cells (SWMU 30). A single sand and gravel horizon, in a clay matrix, defines the underlying HU2 interval. The sand and gravel deposits commonly range between 5 and 10 ft thick. Silt and clay members, with a cumulative thickness of 20 to 35 ft, comprise the HU3 interval below SWMUs 7 and 30.

In the area of SWMUs 7 and 30, the RGA consists of an intermittent HU4 sand overlying 20 to 40 ft of the HU5 sand with gravel layers. The top of the RGA commonly occurs at depths of 45 to 60 ft.

UCRS Groundwater Flow and Hydraulic Potential. The SWMUs 7 and 30 RI (DOE 1998a) determined that a shallow water table exists approximately 5 ft bgs and within the burial cells. UCRS piezometer and well measurements documented a strong downward gradient within the area UCRS. The vertical downward hydraulic gradient is more than 10 times the lateral hydraulic gradient at SWMUs 7 and 30. This, along with lack of connectivity with shallow sand and gravel strata, leads to predominantly downward groundwater flow through the UCRS. These trends determine that dissolved contaminants from the Burial Grounds have potential to migrate into the RGA.

The elevation of the water table is above the elevation of the ditches that bound SWMUs 7 and 30 on the north and south sides;[7] however, neither ditch gains significant flow along the reaches adjacent to SWMUs 7 and 30. These observations indicate that the UCRS groundwater flow vector must be oriented steeply downward and that the area contributing infiltration to the ditches typically is limited to a thin border along the ditches.

RGA Groundwater Flow and Hydraulic Potential. The high-contamination core of the Northwest Plume passes beneath the west end of SWMU 7 in the RGA. All RGA flow in SWMUs 7 and 30 is to the northwest, as defined by the plume orientation. The south well field of the Northwest Plume containment system is located approximately 650 ft to the northwest of SWMU 7. A pumping test of EW231, an extraction well of the south well field, determined the hydraulic conductivity of the area RGA to be approximately 1,300 ft/day.

The TCE trend in MW66, located near the boundary between SWMUs 7 and 30, exhibits spikes that can be correlated with similar TCE spikes at MW248 in the south well field. The distance between the wells (650 ft) divided by the time lag between TCE “events” in MW66 and MW248 (6 months) defines the local groundwater flow rate to be 3.5 ft/day. Typical groundwater flow rates in the Northwest Plume are thought to range from 1 to 3 ft/day. The RGA groundwater flow velocity beneath SWMUs 7 and 30 is accelerated by groundwater extraction in the south well field.

---

[7]The bottom elevation of the ditches on the north and south sides of SWMUs 7 and 30, as well as well and piezometer measurements within SWMUs 7 and 30 provided definitive control of the water table in those areas. The trends of the water table on the east and west ends of SWMUs 7 and 30 were assumed to resemble the land topography.

11.2 SWMU-SPECIFIC RAOS

RAOs that are specific to SWMU 30 were developed based on the findings and observations forthcoming from the BGOU RI Report. The SWMU-specific RAOs generally are directed toward conditions related to the waste materials, the surface soils, and the subsurface soils at the SWMU. A brief statement of the specific problem associated with the SWMU is followed by bulleted RAOs developed to address the problem.

Based on historic process knowledge, buried waste materials are assumed to pose a risk to future outdoor worker, industrial workers, and residents and a potential future contribution to RGA groundwater above acceptable levels. (Note: It was determined during the FS that the potential exists for leachate from buried waste to discharge from SWMU 30 into the adjoining ditches to the north and south.)

- Prevent future contaminant migration to RGA groundwater such that MCLs, or in the absence of an MCL, risk-based levels are not exceeded.

- Prevent direct exposure by future outdoor worker to buried materials and subsurface soils such that an unacceptable risk is not exceeded.

Constituents in surface soil present a cumulative ELCR and an HI to current and future industrial workers exceeding an ELCR=1E-06 and HI=1.

- Prevent exposure from surface soil metals, radionuclides, PCBs, and SVOCs that would cause an unacceptable cumulative risk to current and future industrial workers.

Radionuclides, organics, and metals in subsurface soil present a cumulative ELCR and an HI to future outdoor worker exceeding an ELCR=1E-06 and HI=1.

- Prevent exposure to metals, radionuclides, PCBs, and SVOCs within the SWMU boundary to 16 ft bgs that would cause an unacceptable cumulative risk to future outdoor worker.

Metals, radionuclides, and VOCs in subsurface soil present a risk to a potential future residential groundwater user exceeding ELCR=1E-06 and HI=1.

- Prevent migration of radionuclides, VOCs, and metals in soil in the source areas to the RGA groundwater to the extent they do not contribute contamination exceeding MCLs, or in the absence of an MCL, a risk-based concentration.

The FS process began with the full list of COCs identified in the RI Report. A detailed evaluation of the sample results for commonly occurring elements identified in the RI Report as COCs was performed by comparing field sample results against the PGDP site background concentrations. A number of COCs identified in the RI Report were eliminated from further consideration in the FS because they were below background levels. A discussion of the evaluation that was performed and its results are presented in detail in Section 1. The final list of COCs for the SWMU and their preliminary RGs for surface soil and subsurface soil are provided in Appendix C, Tables C.2 and C.3, respectively. If all COCs are measured in soil at their preliminary RG concentrations, soil at SWMU 30 would meet the target cumulative HI criteria, but exceed the target ELCR criteria for both surface and subsurface soil. The major contributors to the cumulative ELCR in excess of target criteria in both surface and subsurface soil are neptunium-237, plutonium-239 (in subsurface soil only), uranium-234, uranium-235/236, uranium-238, and total PAHs. Approximate lower-bound RG concentrations were developed for these COCs that meet the ELCR criteria at SWMU 30 and are shown in Appendix C.

Surface area estimates and waste mass and volume estimates for cover and excavation alternatives, respectively, are developed and discussed in Appendix E. These area, mass, and volume estimates were used to support development of the cost estimates for the alternatives that also appear in Appendix E. The conceptual location of the radioactive/inorganic treatment area is presented on Figure 10.2.

11.3 SCREENING OF ALTERNATIVES

Alternatives are screened in this section, using the process described in EPA (1988) and the NCP to reduce the number of alternatives carried forward to detailed analysis. Alternatives are screened with respect to effectiveness, implementability, and cost. The evaluation of effectiveness considers reductions in toxicity, mobility, and volume of COCs. The evaluation of implementability considers technical feasibility criteria, including the ability to construct, operate, and maintain the remedy, and administrative feasibility criteria, including the availability of treatment, storage, and disposal capacity. Evaluation of cost for the alternatives is based on the relative capital and O&M costs for the primary technologies utilized. Alternatives with the best combinations of effectiveness and implementability and the lowest costs are retained for detailed analysis and comparative analysis.

11.3.1 Alternative Screening for SWMU 30 Source Areas

Table 11.1 summarizes the results of alternative screening for source areas for SWMU 30. Alternatives that were screened out at this step are shaded grey on the table. Alternative 1 (no action) is not effective, but is retained for further consideration in the detailed analysis as a baseline alternative to which all other alternatives are compared, as required by CERCLA.

11.3.1.1 Alternative 2—Limited action

Alternative 2, which consists of long-term groundwater monitoring only, is screened from further consideration at SWMU 30. The RI Report documents the presence of COCs above RGs in the surface layer. Alternative 2 provides no protection from these contaminants.

11.3.1.2 Alternative 4—Soil cover with *In situ* DNAPL source treatment and long-term monitoring

Alternative 4, which includes RPOs for DNAPL treatment, is screened from further consideration because there is no DNAPL present at SWMU 30.

11.3.1.3 Alternative 5—RCRA cover, hydraulic isolation, and long-term monitoring

Alternative 5 is screened from further consideration for SWMU 30 because the data from the RI Report indicate that contamination is limited to the surface and this SWMU does not pose a sufficient threat to human health, the environment, or the groundwater to require the level of containment provided by this alternative.

11.3.1.4 Alternative 7—Excavation and disposal combined with *In situ* DNAPL source treatment and long-term monitoring

Alternative 7 is screened from further consideration at SWMU 30 because it incorporates contingency RPOs for remediation of DNAPL sources. There are no DNAPL sources at SWMU 30.

Table 11.1. Source Area Alternative Screening Summary for SWMU 30

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	Alternative 9
Screening Criteria	**No Action**	**Limited Action**	**Soil Cover and Long-Term Monitoring**	**Soil Cover with *In situ* DNAPL Source Treatment and Long-Term Monitoring**	**RCRA Cover with Hydraulic Isolation and Long-Term Monitoring**	**Excavation and Disposal**	**Excavation and Disposal combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring**	**Excavation and Disposal combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring**	***In situ* Containment and Long-Term Monitoring**
Overall Effectiveness	NA	NA[1]	High[2]	NA[3]	NA[4]	High	NA[3]	NA[3]	NA
Short-term	NA	NA	High	NA	NA	Moderate to High	NA	NA	NA
Long-term	NA	NA	High	NA	NA	High	NA	NA	NA
Overall Implementability	NA	NA	High	NA	NA	Moderate	NA	NA	NA
Technical	NA	NA	High	NA	NA	Moderate	NA	NA	NA
Administrative	NA	NA	High	NA	NA	Moderate	NA	NA	NA
Overall Cost	NA	NA	Low	NA	NA	High	NA	NA	NA
Capital	NA	NA	Low	NA	NA	High	NA	NA	NA
Operation and maintenance	NA	NA	Low to Moderate	NA	NA	None	NA	NA	NA

NA—Not applicable based on-site conditions or nature of contamination present at the SWMU.
[1] Monitoring will not contain or remediate the contaminant levels at SWMU 30.
[2] Soil cover is effective because prevents direct contact with contaminants and reduces migration by reducing surface infiltration.
[3] DNAPL source treatment not applicable because no DNAPL present at SWMU 30.
[4] Radioactive and inorganic contamination is limited to surface and near surface.
NOTE: Alternatives shaded grey were screened out at this step.

11.3.1.5 Alternative 8—Excavation and disposal combined with *ex situ* DNAPL source treatment and long-term monitoring

Alternative 8 is screened from further consideration at SWMU 30 because it incorporates contingency RPOs for remediation of DNAPL sources. There are no DNAPL sources at SWMU 30.

11.3.2 Summary of Alternatives Retained for Detailed Analysis

The following alternatives are carried forward for detailed analysis.

- Alternative 1: No action
- Alternative 3: Soil cover and long-term monitoring
- Alternative 6: Excavation and disposal

Comparative analyses are performed following the detailed analyses.

11.4 DETAILED ANALYSIS OF ALTERNATIVES

11.4.1 Alternative 1—No Action

The No Action alternative is defined in accordance with CERCLA and provides a baseline to which other alternatives can be compared. Under this alternative, no action would be taken to implement remedial activities for SWMU 30 or to reduce the potential hazard to human or ecological receptors.

11.4.1.1 Overall protection of human health and the environment

No additional controls would be implemented to protect site workers or the public. The results of the risk-based evaluation of the No Action alternative indicate a low probability of the SWMU posing a threat to human health via the groundwater pathway. Existing site controls outside of the remedy will prevent a land use in which groundwater would be used as a water supply. Thus, these elements of the RAOs are achieved by the No Action alternative.

11.4.1.2 Compliance with ARARs

No ARARs have been identified for Alternative 1, the No Action alternative.

11.4.1.3 Long-term effectiveness and permanence

Alternative 1 provides no long-term effectiveness or permanence. Future potential leaching of contaminants to the RGA may result in concentrations above their MCL or risk-based value. Alternative 1 would leave the risk or hazard from radioactive or inorganic COCs at their current level at the SWMU. Over time, this alternative would not prevent future migration of contaminants. The alternative does not provide any long-term controls to manage residual risk at this SWMU.

11.4.1.4 Reduction of toxicity, mobility, or volume through treatment

Treatment would not be implemented with Alternative 1. Reduction of toxicity, mobility, or volume through treatment would not be applicable to the No Action alternative because it does not include treatment. The No Action alternative would not result in any reduction in the toxicity, mobility, or volume of contaminants other than those attributable to natural processes, such as degradation, dilution, or dispersion.

11.4.1.5 Short-term effectiveness

No change to existing conditions. RAOs would not be met over any reasonable time period. No actions would be implemented under Alternative 1; therefore, no additional risks to workers, the public, or the environment would be incurred.

11.4.1.6 Implementability

The No Action alternative can be implemented readily. If future remedial action is necessary, this alternative would not impede implementation of other remedial activities in the future.

The ongoing public awareness program would require regular coordination with DOE, KY, and possibly with other governmental agencies.

11.4.1.7 Cost

The preliminary cost estimates for Alternative 1 serve as a baseline for comparison of the other remedial alternatives. These cost estimates are based upon FS-level scoping and are intended to aid with selection of a preferred alternative. There are no capital or O&M costs associated with Alternative 1.

11.4.2 Alternative 3—Soil Cover and Long-Term Monitoring

Alternative 3 includes the following:

- Construction of a surface soil cover over the entire unit and the areas to the north and south extending to the bordering ditches, and

- Additional groundwater monitoring.

A surface soil cover will be constructed over the entire unit. This cover will be contoured to promote runoff and will reduce potential direct exposure to the surface soil hazardous and radioactive contamination.

A groundwater monitoring program would be implemented to monitor the upper RGA. The monitoring program will utilize existing PGDP MWs and additional groundwater MWs as necessary, to monitor upgradient and downgradient groundwater contaminant levels.

11.4.2.1 Overall protection of human health and the environment

Construction of a surface soil cover over the unit will eliminate the potential exposure to workers from contaminated soil. Implementation of additional groundwater monitoring will provide an indirect protection, as monitoring contaminant migration allows for minimizing the potential for exposure to contaminated environmental media through early identification and avoidance. None of the elements of this alternative will provide a reduction in toxicity, mobility, or volume of contaminants. LUCs (see Section 2.4.1.1) protect current and future site workers and the public.

11.4.2.2 Compliance with ARARs

Alternative 3 will meet this threshold criterion by complying with potential chemical-, location-, and action-specific ARARs. ARARs for this alternative are summarized in Appendix F.

11.4.2.3 Long-term effectiveness and permanence

Alternative 3 is designed to provide protection against exposure to waste in surface soils. Since the toxicity or volume of waste and contaminated environmental media will remain near current levels and concentrations (assuming limited degradation and negligible natural attenuation of residual waste and contaminants), some risk would remain. Migration of contaminants to groundwater would be reduced by soil cover limiting infiltration through surface soils.

11.4.2.4 Reduction of toxicity, mobility, or volume through treatment

Alternative 3 does not include any treatment technologies; therefore, a reduction in toxicity, mobility, or volume through treatment would not be achieved. The mobility of contaminants in surface soil is reduced through containment.

11.4.2.5 Short-term effectiveness

Implementation of Alternative 3 would not have any detrimental impact on the community.

Implementation of Alternative 3 has the potential for worker exposure to contaminated surficial soils and groundwater during environmental sampling. Potential exposure pathways include inhalation of dust containing surficial soils, dermal contact with surficial soils and dermal contact with contaminated groundwater.

No ecological impacts at the BGOU are anticipated under this alternative. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archaeological or historical sites or T&E species would be impacted by this alternative. Risk assessment and mitigation for ecological receptors in nearby drainage ditches are within the scope of the Surface Water OU.

At the time that implementation of each component of Alternative 3 is completed, all RAOs will be achieved. Tentatively, implementation of Alternative 3 may take several months.

11.4.2.6 Implementability

Activities to be conducted under Alternative 3 include continuation/expansion of existing environmental media monitoring to track contaminant migration and construction of a soil cover.

Implementation of the remedial action components of Alternative 3 is technically feasible. Implementation of Alternative 3 would use standard construction methods, materials, and equipment that are available from vendors and contractors.

11.4.2.7 Cost

Estimated capital and O&M costs for Alternative 3 address construction and maintenance of the soil cover as well as installation of a monitoring well network, and sampling and analysis of the wells.

11.4.3 Alternative 6—Excavation and Disposal

Alternative 6 incorporates the following: installation of sheet piles around the perimeter of the waste unit; excavation of all buried materials and contaminated soils; emission control equipment; cover soil and waste disposal characterization sampling; excavation pit dewatering; and segregation, bulking, and consolidation of compatible waste groups. In addition, treatment of excavated materials may include the following: *ex situ* thermal desorption to drive off VOCs and SVOCs; metal detection/magnetic separation of metallic materials (decayed drums and uranium for stabilization/solidification); and radiological separation. This alternative is described in detail in Section 3. For the treatment and segregation operations, short-term storage would be required for the excavated waste and for treated materials awaiting shipment to the disposal site.

11.4.3.1 Overall protection of human health and the environment

Alternative 6 would meet this threshold criterion. Potential short-term risks to remediation workers due to direct contact with the waste material and inhalation hazards are much larger than any of the other alternatives evaluated in this FS. In addition, potential risks to the public and the environment as a result of potential shipping and handling concerns should be considered for off-site shipments. These concerns are greatly reduced for disposal in the WDF.

Waste and contaminated soil will be physically removed from the SWMU and disposed of in one or more appropriate disposal facilities, including the WDF, thus meeting all RAOs for waste in the former burial pits.

11.4.3.2 Compliance with ARARs

Alternative 6 would meet this threshold criterion. ARARs for this alternative are summarized in Appendix F.

11.4.3.3 Long-term effectiveness and permanence

Complete excavation offers maximum control of contaminant migration, since no wastes or associated contaminated soils would remain in the SWMU; therefore, this alternative offers a high degree of risk reduction. Complete treatment processes manage or remove hazardous characteristics, or destroy the COCs.

Alternative 6 allows for potential risks associated with contaminants in SWMU 30 to be reduced or eliminated. Risks associated with direct contact with waste and surface soils will be eliminated since the primary source and associated contaminated soils will be removed. Alternative 6 allows for a maximum reduction of uncertainties associated with these soils in terms of continued contributions to the hydrogeologic system.

11.4.3.4 Reduction of toxicity, mobility, or volume through treatment

This alternative reduces or eliminates the mobility and volume of contaminants from the unit. The toxicity of the treatment residuals also would be drastically reduced and/or eliminated. The removal and disposition of waste and contaminated soil from an unlined burial cell containing COCs to an appropriate disposal facility prevents those contaminants from migrating to the groundwater.

11.4.3.5 Short-term effectiveness

Short-term risks to the community resulting from excavation activities at the SWMU would not be expected. Potential risks resulting from migration of contaminants to off-site locations would be controlled by the on-site vacuum hood and HEPA filtration system. Alternative 6, however, includes a potential risk to the public from transportation of the LLW or hazardous wastes/liquids to off-site disposal and/or treatment facilities. This risk would be greatly reduced by disposing of waste in the WDF.

Short-term exposures of workers to COCs could occur during implementation of Alternative 6. Potential exposure pathways include direct contact with soil (ingestion, inhalation) and exposure to external penetrating radiation. Worker risks are not expected to exceed acceptable limits because exposure frequency and duration are less than those evaluated in the baseline risk assessment. Typically, risks from handling waste/contaminated soils would be minimized through adherence to health and safety protocols. To protect workers, PPE, ambient conditions monitoring, and decontamination protocols would be used in accordance with an approved, site-specific HASP.

Time until RAO is achieved. The RAO would be achieved immediately following excavation. Excavation, treatment, and disposal of residuals could be accomplished in approximately three years.

Excavation and disposal would be conducted by trained personnel in accordance with standard radiological, engineering, and operational procedures, DSAs, HASPs, and safe work practices to maintain a work environment that minimizes injury or exposure to risks to human health or the environment.

No ecological impacts at the BGOU are anticipated under this alternative. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archaeological or historical sites or T&E species would be impacted by this alternative. Risk assessment and mitigation for ecological receptors in nearby drainage ditches is within the scope of the Surface Water OU.

The RAOs for COCs identified at SWMU 30 would be achieved following completion of excavation.

11.4.3.6 Implementability

Alternative 6 is considered to be technically and administratively feasible and implementable. The equipment and technologies associated with implementation of this alternative have been proven to be technically feasible and are available from contractors or vendors. Treatability testing may be required for waste treatment processes including *ex situ* thermal desorption for excavated soils. The implementability of construction-related activities during excavation and backfilling at the SWMU subject to Alternative 6 is very similar to that carried out routinely at other sites, so it is considered high. Likewise, sampling, analysis, transportation, and disposal at an approved location are routinely performed and, if properly implemented, are proven to be safe. Some excavated waste materials may be radioactive, RCRA hazardous, or mixed. Treatment of wastes with multiple regulatory classifications is more complex and may require more than one treatment process to make the waste suitable for transportation and/or land disposal. On-site treatment processes will comply with ARARs. an option for disposal of waste and residuals at the WDF was considered under Alternative 6. The primary difference would be the elimination of waste leaving the PGDP, related off-site transportation issues, and the cost for disposal. At this time, no capacity for disposal of these wastes exists at PGDP.

11.4.3.7 Cost

Costs were estimated for transportation and disposal of wastes at an off-site facility as well as for an option to dispose of waste at the WDF.

11.5 COMPARATIVE ANALYSIS OF ALTERNATIVES

A comparative analysis summary for source area alternatives for SWMU 30 is presented in Table 11.2 and the corresponding costs for the alternatives are presented in Table 11.3.

11.5.1 Threshold Criteria

Source area remedial alternatives are compared with respect to the threshold criteria in the following sections.

11.5.1.1 Overall protection of human health and the environment

Alternative 1 does not meet the threshold criterion of overall protection of human health and the environment. Alternative 1 would not treat, contain, or remove waste.

Alternative 3, soil cover, would meet the threshold criterion for those sites where contamination is limited to the surface or near surface and the goal is to prevent direct contact. No waste would be removed or treated. A properly installed soil cover would reduce surface infiltration by reducing permeability relative to native soils and directing runoff away from the covered areas, thereby reducing contaminant migration to groundwater. LUCs (see Section 2.4.1.1) protect current and future site workers and the public. While the short-term risks associated with excavation can be mitigated by proper engineering precautions in achieving long-term risk reduction, the trade-offs of removing risks that can be managed at the unit for risks during excavation and removal are significant factors that favor Alternative 3.

Alternative 6, excavation and disposal, meets the threshold criterion by removing waste and contaminated soil from the SWMU. This alternative is assumed to remove enough waste and contaminated soil so that the remaining soil at the SWMU would meet soil target concentrations and attain MCLs or risk-based values in RGA groundwater at the UCRS-RGA boundary beneath the SWMU. All SWMU-specific RAOs would be met by implementing Alternatives 6.

11.5.1.2 Compliance with ARARs

No ARARs have been identified for Alternative 1, the No Action alternative.

Alternative 3 would meet the threshold criterion because contamination present at SWMU 30 is limited to the surface and near surface, and it does not pose a major threat to human health and the environment.

Alternative 6 would meet this threshold criterion. This alternative could remove enough waste and contaminated soil to meet soil target concentrations and prevent contamination exceeding MCLs or risk-based values in RGA groundwater at the UCRS-RGA boundary beneath the SWMU. It should meet all location- and action-specific ARARs through design and planning during preparation of the RD/RAWP.

11.5.2 Balancing Criteria

Source area alternatives are compared with respect to the balancing criteria in the following sections.

11.5.2.1 Long-term effectiveness and permanence

Alternative 1 would not be effective. The risk posed by waste material and COCs in soil would remain unabated.

Alternative 6 would meet this criterion. This alternative could remove enough waste and contaminated soil to meet soil target concentrations and prevent contamination exceeding MCLs or risk-based values in RGA groundwater at the UCRS-RGA boundary beneath the SWMU. It should meet all location- and action-specific ARARs through design and planning during preparation of the RD/RAWP. Alternative 6

Table 11.2. Summary of Comparative Analysis of Source Area Alternatives SWMU 30

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 1: No Action	May meet the threshold criterion. Site procedures protect future on-site industrial workers. Threat to groundwater is low.	No actions implemented; no ARARs identified.	No long-term effectiveness or permanence. Site risk would remain at current levels.	Low. No treatment provided.	High. No actions implemented; therefore, no change to existing conditions.	High. No action would be implemented.
Alternative 3: Soil Cover and Long-Term Monitoring	High. Much more protective than Alternative 1 and less protective than Alternatives 6. Prevents direct contact with waste and reduces migration potential of contamination in surface soils. Land use controls protect current and future site workers and the public.	High. Complies with ARARs and potential TBCs.	High. Protects site workers from direct contact with waste and surface soil. Some reduction in mobility of contaminants by reducing infiltration.	Moderate. No reduction of toxicity or volume. Contaminant mobility is reduced through containment.	High. No negative impacts to community. Exposure to workers low during installation of cover. More short term risk to workers during implementation than Alternative 1, but much less than Alternative 6. Could be completed in months.	High. Services and materials are readily available.
Alternative 6: Excavation and Disposal	High. Removal of contaminated waste offers the highest degree of overall protection with respect to RAOs.	High. Complies with ARARs and potential TBCs.	High. Contaminant sources removed; therefore, residual risks are negligible. Most adequate overall level of protection to humans and the environment.	High. Excavation, waste treatment and disposal would reduce or eliminate mobility of radionuclides and inorganic COCs, and reduce or eliminate toxicity of organics.	Moderate to High. Potential negative impacts to community from waste transportation to off-site disposal facility Potential impacts reduced greatly if waste disposed at the WDF. Risk to workers higher than other alternatives but can be managed through site procedures during implementation. Implementation could take years.	Moderate to high. Excavation and associated technologies are readily implementable. Some excavated waste materials or soil may have multiple regulatory classifications, increasing the complexity of treatment required for transportation and/or disposal. WDF is being evaluated as part of the waste disposal option project, and a ROD has not been issued.

Table 11.3. SWMU 30 Remedial Alternatives Cost Estimate Summary

			PRESENT WORTH[1]		ESCALATED	
Alternative Description	**Annual Time Period, yrs**	**Capital $ (2010 Constant Dollars)**	**Total Annual $**	**Total $ (Capital and Annual)**	**Total Annual $**	**Total $ (Capital and Annual)**
Alternative 1—No Action	0	$0	$0	$0	$0	$0
Alternative 3—Soil Cover and Long-Term Monitoring	30	$3,266,000	$1,423,000	$4,689,000	$5,059,000	$8,524,000
Alternative 6a—Excavation and Disposal	0	$25,235,000	$0	$25,235,000	$0	$26,772,000
Alternative 6b—Excavation and Disposal (at the WDF)	0	$17,906,000	$0	$17,906,000	$0	$18,996,000

[1] Not used for budgeting or planning purposes because value is based on investing funds for outyear expenditures.

provides a high degree of long-term effectiveness and permanence. Residual risk should be the lowest under this alternative. Long-term controls may not be required under this alternative provided that waste material and contaminated soil can be removed to attain soil target concentrations.

11.5.2.2 Reduction of toxicity, mobility, and volume through treatment

Alternative 1 would not reduce the toxicity, mobility, or volume of COCs in waste or soil at SWMU 30.

Alternative 3 provides only limited control of mobility by preventing migration of surface contamination. It also reduces surface water infiltration and the ensuing subsurface migration of contaminants.

Alternative 6 reduces toxicity by removal, treatment, and disposal of wastes. Waste materials and soil would be treated on-site as needed to allow excavated materials to be readied for transport or disposal. Volume is similarly reduced. The relocation of waste and contaminated soil from an unlined burial cell that has COCs in direct contact with groundwater to an appropriate disposal facility will reduce the mobility of those contaminants in the environment. Removal of source material and surrounding contaminated soils will prevent future migration of contaminants at the SWMU.

11.5.2.3 Short-term effectiveness

The short-term effectiveness of Alternative 1 is low because RAOs would not be attained.

Alternative 3 is moderately effective during implementation. There is very little risk to workers or the community during installation of the soil cover.

The short-term effectiveness of Alternative 6 is moderate to high. Disposal at the WDF would result in higher overall short-term effectiveness by eliminating risks associated with wastes leaving the site.

11.5.2.4 Implementability

Alternative 1 would be the most readily implementable alternative because no construction or invasive action would be taken. The implementability of Alternative 3 is high because the technology is readily available and the complexity is low. Alternative 6 is considered to be technically and administratively feasible and implementable.

11.5.2.5 Cost

Costs were estimated for transportation and disposal of wastes at an off-site facility as well as for an option to dispose of waste at the WDF.

11.5.3 Summary of Comparative Analysis of Alternatives

Alternative 1, No Action, may not provide an adequate level of overall protection to human health and the environment.

Alternative 3 provides containment of the waste by installing a soil cover over contaminated surface soils identified in the RI. The cover would reduce infiltration caused by precipitation and prevent direct contact with surface soils. Although this alternative does leave buried waste in place, it meets the threshold criteria with regard to radioactive and inorganic contaminants and achieves the RAOs for the SWMU.

Alternatives 1 and 3 would not prevent the future discharge of leachate into the ditches adjoining SWMU 30 to the north and south.

Alternative 6, excavation and disposal, meets the threshold criteria by removing waste and contaminated soil from the SWMU. This alternative would remove enough waste and contaminated soil so that the remaining soil at the sites likely would meet soil target concentrations and attain MCLs or risk-based values in RGA groundwater at the UCRS-RGA boundary beneath the SWMU. All ARARs defined for Alternative 6 would be met.

Alternative 6 is the highest cost alternative, but it provides the greatest overall long-term effectiveness and permanence and would meet the RAOs for the SWMU.

THIS PAGE INTENTIONALLY LEFT BLANK

12. SWMU 145

12.1 SWMU 145 HISTORY AND BACKGROUND

Area P (SWMU 145) is located north of the PGDP security area and is defined by encompassing the area underneath SWMUs 9 and 10 (the C-746-S&T Landfills, respectively). The SWMU is approximately 44 acres and began operation in the early 1950s. Currently, the C-746-S&T Landfills are located on top of SWMU 145, but are not included in SWMU 145 (DOE 1999c), as illustrated in the conceptual drawing, Figure 12.1. The boundaries of the area previously had not been well defined outside of the area utilized by the C-746-S&T Landfills.

SWMU 145 began operation in the early 1950s. A 1973 document *The Discard of Scrap Materials by Burial at the Paducah Plant* (Union Carbide 1973), states this area was used by the contractor during the construction of PGDP to discard all types of scrap and waste materials. Use of the area for discarding of scrap and waste by subcontractors was continued until the early 1980s. Construction debris, such as concrete, roofing materials, wire, wood, shingles with asbestos, and welding rods, are expected to have been disposed in the area. Approximately once a year, the accumulated scrap piles were moved by plant personnel into piles or earth depressions and, whenever practicable, covered with dirt. The area was later permitted for the construction and operation of the C-746-S&T Landfills (BJC 2001). The C-746-S Landfill began operation in 1981.

The metal detected predominantly above screening levels in subsurface soils at SWMU 145 is antimony. One third of the samples had an antimony level that exceeded background and the outdoor worker NAL criteria. Antimony concentrations, for the most part, exceeded the background value throughout the depth of the shallow soils to the top of the RGA. The only other metal that was frequently present at concentrations above the NAL (but rarely exceeds background) was arsenic. The arsenic background exceedances have a limited extent, as all occurred in samples collected at depths of 15 ft or less.

Of the organics in subsurface soils, PCBs were detected at levels above NAL criteria at three historical sampling locations within the former NSDD disposal trench at depths of 2 to 3 ft at a maximum value of 12.5 mg/kg. Radionuclides in subsurface soils at SWMU 145 include americium-241, cesium-137, technetium-99, thorium isotopes, and uranium isotopes. Most of these samples derive from investigation of the buried reach of the NSDD.

RI screening of the SWMU 145 analyses determined six metals that exceed contaminant criteria in UCRS groundwater. Iron and manganese were common groundwater contaminants. Arsenic and uranium accounted for most of the other metal exceedances. Chloroform, a VOC, was the only UCRS groundwater organic contaminant that exceeded RI screening criteria. Uranium and the uranium isotopes uranium-234 and uranium-238 accounted for radionuclide contamination in the UCRS groundwater.

Arsenic, chromium, iron, and manganese were detected above background levels in RGA groundwater at a frequency of over 10 %. The presence of TCE in the RGA was the subject of a summer 2004 SI of the SWMU 145 area (DOE 2006b). This SI postulated the presence of a small UCRS TCE source in SWMU 145. Seven RGA MWs of the C-746-S&T Landfills have produced samples with PCB contamination. The highest detected levels have been 0.001 mg/L PCB-1016 and 0.008 mg/L PCB-1242.

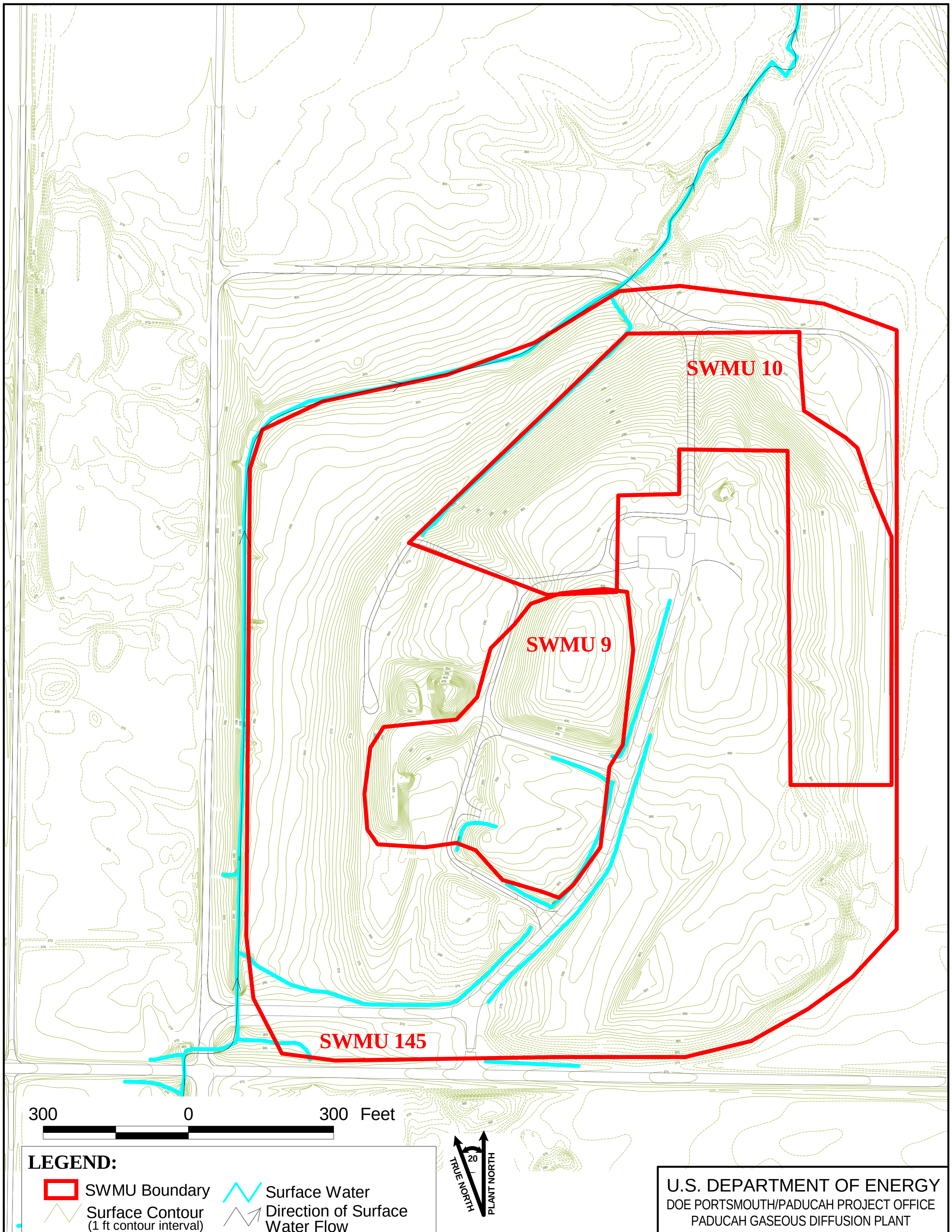


Figure 12.1. SWMU 145 Historical Layout

Figure No. \BGOU\RI.apr
DATE 12-18-07

12.1.1 Hydrogeologic interpretation

The study area geology and hydrogeology is summarized below as documented in the BGOU RI (DOE 2010).

Stratigraphy. The UCRS beneath SWMU 145 typically consists of a near continuous sequence of silt members down to the top of the RGA at depths of 40 to 60 ft. A thin (commonly less than 1 ft thick), intermittent, sand horizon at a depth of approximately 20 ft is the only vestige of the HU2 interval. The C-746-S&T Landfills SI (DOE 2006b) determined that the top of the RGA has approximately 20 ft of relief (elevations of 310 to 330 ft) beneath SWMU 145. Where the RGA is deepest, the UCRS grades downward into a series of fine sand layers with silt interbeds overlying the RGA.

An HU4 sand, averaging 5 ft thick, forms the top of the RGA. This, in turn, overlies 20 to 40 ft of gravely sand, made up of individual sand and gravel layers that range from 0.2 to 3.4 ft thick. The underlying McNairy Formation (top at an elevation of approximately 280 ft) consists of interbedded units of silt and fine sand.

UCRS Groundwater Flow and Hydraulic Potential. Water level elevations of shallow wells at SWMU 145 determine that a vertical hydraulic gradient of approximately 1 ft/ft is characteristic of the local UCRS. Lateral hydraulic gradients range from 0.03 to 0.12 ft/ft horizontally, as measured from the water table. The area SI analysis determined that lateral UCRS flow may be important where the horizontal hydraulic gradients are steepest, but that vertical flow predominates in the UCRS under most of SWMU 145.

RGA Groundwater Flow and Hydraulic Potential. The regional hydraulic gradient of the RGA in the SWMU 145 area is northward with a typical slope of 1E-03 ft/ft. Water level measurements of RGA wells for the area SI documented the presence of a hydraulic potential mound beneath SWMU 145. The implied groundwater flow directions, extending radically from SWMU 145 in the immediate vicinity of the Burial Grounds, were consistent with trends of the direction of dissolved TCE contamination associated with the Burial Grounds.

Groundwater modeling indicates that the hydraulic conductivity of the RGA in the area of SWMU 145 ranges between 200 to 500 ft/d. With the regional hydraulic gradient, average groundwater flow velocity in the RGA should range between 1 and 2 ft/d.

12.2 SWMU-SPECIFIC RAOS

RAOs that are specific to SWMU 145 were developed based on the findings and observations forthcoming from the BGOU RI Report, which did not identify any radionuclides above levels of concern in subsurface soils of the landfill area. Radionuclides were present in subsurface soils of the abandoned NSDD channel at SWMU 145. Elevated concentrations of uranium were present in shallow samples collected near the previous location of the NSDD.

The SWMU-specific RAOs generally are directed toward conditions related to the waste materials, the surface soils, and the subsurface soils at the SWMU. A brief statement of the specific problem associated with the SWMU is followed by bulleted RAOs developed to address the problem.

Construction debris, scrap, and waste materials are buried under subsurface soils and present a potential future contribution to RGA groundwater and subsurface soils.

- Prevent future contaminant migration to the environment such that it does not present unacceptable risks to future receptors or groundwater.

Metals, radionuclides, and organics in subsurface soil exceed concentration criteria for threat to a potential future residential groundwater user, exceeding an ELCR=1E-06 and an HI=1.

- Prevent migration of radionuclides, organics, and metals in soil in the source areas to the RGA groundwater to the extent they do not contribute contamination exceeding MCLs, or in the absence of an MCL, a risk-based concentration.

- Note 1: The Integrated Project Team determined that PCB detections at SWMU 145 likely derived from residual contamination in the well and monitoring equipment, which was rehabilitated from another PCB-contaminated site.

- Note 2: The Integrated Project Team determined that a potential TCE DNAPL source is indicated to exist in the southeast portion of SWMU 145 based on monitoring well data described in the BGOU RI, however the location and physical extent of this potential source cannot be defined given the current data.

The FS process began with the full list of COCs identified in the RI Report. A detailed evaluation of the sample results for commonly occurring elements identified in the RI Report as COCs was performed by comparing field sample results against the PGDP site background concentrations. A number of COCs identified in the RI Report were eliminated from further consideration in the FS because they were below background levels. A discussion of the evaluation that was performed and its results are presented in detail in Section 1. The final list of COCs for the SWMU and their preliminary RGs for surface soil and subsurface soil are provided in Appendix C, Tables C.2 and C.3, respectively. Preliminary RGs for the SWMU meet the target cumulative ELCR and HI criteria for both surface and subsurface soil.

Surface area estimates and waste mass and volume estimates for cover and excavation alternatives, respectively, are developed and discussed in Appendix E. These area, mass, and volume estimates were used to support development of the cost estimates for the alternatives that also appear in Appendix E. The conceptual location of the radioactive/inorganic treatment area is presented in Figure 12.2.

12.3 SCREENING OF ALTERNATIVES

Alternatives are screened in this section, using the process described in EPA (1988) and the NCP to reduce the number of alternatives carried forward to detailed analysis. Alternatives are screened with respect to effectiveness, implementability, and cost. The evaluation of effectiveness considers reductions in toxicity, mobility, and volume of COCs. The evaluation of implementability considers technical feasibility criteria, including the ability to construct, operate, and maintain the remedy, and administrative feasibility criteria, including the availability of treatment, storage, and disposal capacity. Evaluation of cost for the alternatives is based on the relative capital and O&M costs for the primary technologies utilized. Alternatives with the best combinations of effectiveness and implementability and the lowest costs are retained for detailed analysis in Section 4 and comparative analysis in Section 5.

12.3.1 Alternative Screening for SWMU 145

Table 12.1 summarizes the results of alternative screening for radioactive/inorganic source areas for SWMU 145. Alternatives that were screened out at this step are shaded grey on the table. Alternative 1

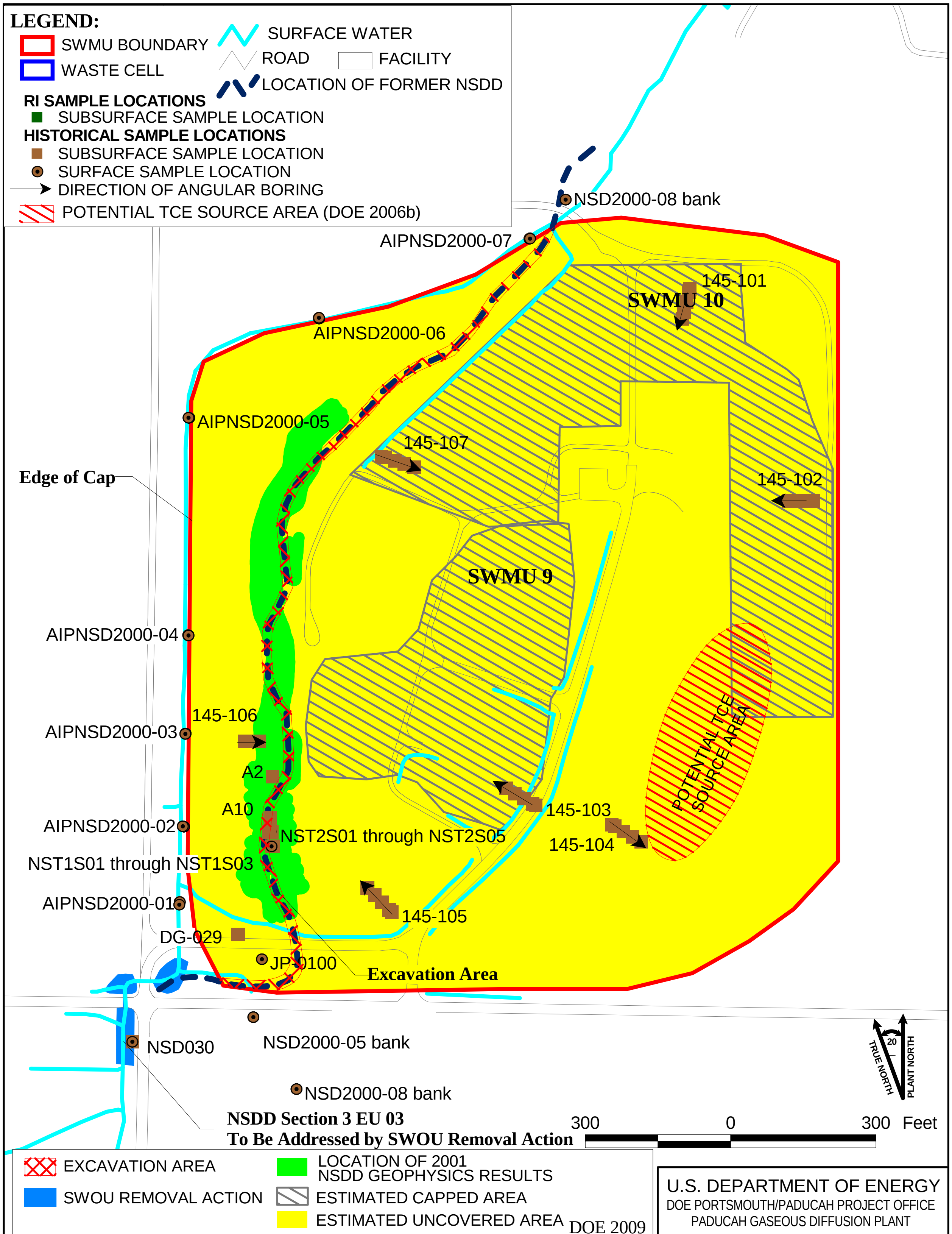


Figure 12.2. SWMU 145 Treatment Area

Figure No. \BGOU\FS_2-EXCR5.apr
DATE 03-08-10

Table 12.1. Source Area Alternative Screening Summary for SWMU 145

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7	Alternative 8	Alternative 9
Screening Criteria	**No Action**	**Limited Action**	**Soil Cover and Long-Term Monitoring**	**Soil Cover with *In situ* DNAPL Source Treatment and Long-Term Monitoring**	**RCRA Cover with Hydraulic Isolation and Long-Term Monitoring**	**Excavation and Disposal**	**Excavation and Disposal combined with *In situ* DNAPL Source Treatment and Long-Term Monitoring**	**Excavation and Disposal combined with *Ex situ* DNAPL Source Treatment and Long-Term Monitoring**	***In situ* Containment and Long-Term Monitoring**
Overall Effectiveness	NA	NA[1]	Moderate[2]	NA[3]	NA[4]	High[5]	NA[3]	NA[3]	NA
Short-term	NA	NA	High	NA	NA	Moderate to High	NA	NA	NA
Long-term	NA	NA	Moderate	NA	NA	High	NA	NA	NA
Overall Implementability	NA	NA	High	NA	NA	Moderate	NA	NA	NA
Technical	NA	NA	High	NA	NA	Moderate	NA	NA	NA
Administrative	NA	NA	High	NA	NA	Moderate	NA	NA	NA
Overall Cost	NA	NA	Low	NA	NA	High	NA	NA	NA
Capital	NA	NA	Low	NA	NA	High	NA	NA	NA
Operation and maintenance	NA	NA	Moderate	NA	NA	Low to Moderate	NA	NA	NA

NA—Not applicable based on-site conditions or nature of contamination present at the SWMU.
[1] Monitoring will not contain or remediate the contaminant levels at SWMU 145.
[2] Soil cover is effective because prevents direct contact with contaminants and reduces migration by reducing surface infiltration.
[3] DNAPL source treatment not applicable because no defined DNAPL source present at SWMU 145.
[4] RCRA cover is impractical for hot spot remediation along NSDD.
[5] Excavation limited to course of former NSDD. Remaining surface contamination, if any, will be covered. Long-term monitoring will be performed.
NOTE: Alternatives shaded grey were screened out at this step.

(no action) is not effective, but is retained for further consideration in the detailed analysis as a baseline alternative to which all other alternatives are compared, as required by CERCLA.

12.3.1.1 Alternative 2—Limited action

alternative 2 is screened from further consideration for SWMU 145. Maintenance existing of site controls outside of the remedy that restrict access to the site will not address the technetium-99 hot spots in soil along the NSDD that presents a potential threat to groundwater due to its mobility in soil.

12.3.1.2 Alternative 4—Soil cover with *In situ* DNAPL source treatment and long-term monitoring

alternative 4 is screened from further consideration for SWMU 145. *In situ* DNAPL source treatment is not needed at SWMU 145 because a DNAPL source has not been identified at the SWMU.

12.3.1.3 Alternative 5—RCRA cover, hydraulic isolation, and long-term monitoring

alternative 5 is screened from further consideration for SWMU 145. A RCRA cover is not a practical technology to address hot spots in soil in the NSDD.

12.3.1.4 Alternative 7—Excavation and disposal combined with *In situ* DNAPL source treatment and long-term monitoring

Alternative 7 is screened from further consideration for SWMU 145. *In situ* DNAPL source treatment is not needed at SWMU 145 because a DNAPL source has not been identified at the unit.

12.3.1.5 Alternative 8—Excavation and disposal combined with *ex situ* DNAPL source treatment and long-term monitoring

Alternative 8 is screened from further consideration at SWMU 145. *Ex situ* DNAPL source treatment is not needed at SWMU 145 because a DNAPL source has not been identified at the unit.

12.3.2 Summary of Alternatives Retained for Detailed Analysis

The following remedial alternatives are carried forward for detailed analysis.

- Alternative 1: No action
- Alternative 3: Soil cover and long-term monitoring
- Alternative 6: Excavation and disposal

Comparative analyses are performed following detailed analyses.

12.4 DETAILED ANALYSIS OF ALTERNATIVES

12.4.1 Alternative 1—No Action

The No Action alternative is defined in accordance with CERCLA and provides a baseline to which other alternatives can be compared. Under this alternative, no action would be taken to implement remedial activities for SWMU 145 or to reduce the potential hazard to human or ecological receptors. No additional groundwater monitoring would be performed at SWMU 145 specifically targeted to monitor groundwater quality at the site.

12.4.1.1 Overall protection of human health and the environment

Alternative 1 assumes the future use of the PGDP will remain industrial and that no additional controls would be implemented to protect site workers or the public. Current site controls outside of the remedy to restrict access will remain in place. This alternative may not be protective of groundwater, but it would be protective of the future industrial worker. The results of the risk-based evaluation of the No Action alternative indicate a possible threat to human health via the groundwater pathway at SWMU 145; however, this alternative would protect an industrial worker from exposure, assuming that current site controls outside of the remedy are maintained. Thus, these elements of the RAOs are achieved by the No Action alternative. Not all of the RAOs, particularly protection of groundwater, would be met because no action would be implemented. No additional groundwater monitoring would be conducted to assess changing conditions in groundwater quality.

12.4.1.2 Compliance with ARARs

No ARARs have been identified for Alternative 1, the No Action alternative.

12.4.1.3 Long-term effectiveness and permanence

The No Action alternative does not include additional site controls above and beyond those already in place, such as the E/PP Program, and outside of the remedy. Future potential leaching of contaminants to the RGA may result in concentrations above their MCL or risk-based RG. Alternative 1 leaves the risk or hazard from COCs at an unacceptable level at SWMU 145. Over time, this alternative would not prevent future migration of contaminants. No additional groundwater monitoring would be conducted to assess changing conditions in groundwater quality.

12.4.1.4 Reduction of toxicity, mobility, or volume through treatment

Treatment would not be implemented with Alternative 1. Reduction of toxicity, mobility, or volume through treatment would not be applicable to the No Action alternative because it does not include treatment. The No Action alternative would not result in any reduction in the toxicity, mobility, or volume of contaminants other than those attributable to natural processes such as degradation, dilution, or dispersion.

12.4.1.5 Short-term effectiveness

No actions would be implemented under Alternative 1; therefore, no additional risks to workers, the public, or the environment would be incurred.

12.4.1.6 Implementability

The No Action alternative is considered implementable. This alternative would not impede implementation of other remedial activities in the future.

The ongoing public awareness program would require regular coordination with DOE, KY, and possibly with other governmental agencies.

12.4.1.7 Cost

The preliminary cost estimates for Alternative 1 serve as a baseline for comparison of the other remedial alternatives. These cost estimates are based upon FS-level scoping and are intended to aid with selection of a preferred alternative. There are no capital or O&M costs associated with Alternative 1.

12.4.2 Alternative 3—Soil Cover and Long-Term Monitoring

Alternative 3 includes the following:

- Construction of a surface soil cover over the uncovered portion of SWMU 145 and
- Additional groundwater monitoring.

A surface soil cover will be constructed over the entire unit. This cover will be contoured to promote runoff and will reduce potential direct exposure to the surface soil hazardous and radioactive contamination. This cover will also reduce infiltration and contain any TCE contamination.

A groundwater monitoring program would be implemented to monitor the upper RGA. The monitoring program will utilize existing PGDP MWs and additional groundwater MWs, as necessary, to monitor upgradient and downgradient groundwater contaminant levels.

12.4.2.1 Overall protection of human health and the environment

Construction of a surface soil cover over the unit will eliminate the potential exposure to workers from contaminated soil. Covering the postulated area of TCE contamination would reduce infiltration, minimize migration of any TCE that may be present, and effectively contain the TCE to be protective of groundwater. Implementation of additional groundwater monitoring will provide an indirect protection, as monitoring contaminant migration allows for minimizing the potential for exposure to contaminated environmental media through early identification and avoidance. LUCs (see Section 2.4.1.1) protect current and future site workers and the public.

12.4.2.2 Compliance with ARARs

Alternative 3 will meet this threshold criterion by complying with potential chemical-, location-, and action-specific ARARs. ARARs for this alternative are summarized in Appendix F.

12.4.2.3 Long-term effectiveness and permanence

Alternative 3 is designed to provide protection against exposure to waste in surface soils. TCE would be effectively contained. Since the toxicity or volume of waste and contaminated environmental media will remain near current levels and concentrations (assuming limited degradation and negligible natural attenuation of residual waste and contaminants), some risk would remain. Migration of contaminants to groundwater would be reduced by soil cover limiting infiltration through surface soils.

12.4.2.4 Reduction of toxicity, mobility, or volume through treatment

Alternative 3 does not include any treatment technologies; therefore, a reduction in toxicity, mobility, or volume through treatment would not be achieved.

12.4.2.5 Short-term effectiveness

Implementation of Alternative 3 would not have any detrimental impact on the community.

Implementation of Alternative 3 has the potential for worker exposure to contaminated surficial soils and groundwater during environmental sampling. Potential exposure pathways include inhalation of dust containing surficial soils, dermal contact with surficial soils, and dermal contact with contaminated groundwater. PGDP worker protection programs will make worker exposure unlikely.

No ecological impacts at the BGOU are anticipated under this alternative. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archaeological or historical sites or T&E species would be impacted by this alternative. Risk assessment and mitigation for ecological receptors in nearby drainage ditches are within the scope of the Surface Water OU.

At the time that implementation of each component of Alternative 3 is completed, all RAOs will be achieved. Tentatively, implementation of Alternative 3 may take several months.

12.4.2.6 Implementability

Activities to be conducted under Alternative 3 include continuation/expansion of existing environmental media monitoring to track contaminant migration and construction of a soil cover.

Implementation of the remedial action components of Alternative 3 is technically feasible. Implementation of Alternative 3 would use standard construction methods, materials, and equipment that are available from vendors and contractors.

12.4.2.7 Cost

Estimated capital and O&M costs for Alternative 3 address construction and maintenance of the soil cover as well as installation of a monitoring well network and sampling and analysis of the wells.

12.4.3 Alternative 6—Excavation and Disposal

This alternative includes the excavation and disposal of contaminated soils above target concentrations. The contaminated soil requiring excavation lies along the course of the former NSDD, extending the full length of SWMU 145 from the southern boundary to the northern boundary. Only those portions of the NSDD determined to be contaminated during RD will actually be excavated; for the purpose of cost estimation, it is assumed the entire course of the ditch will be excavated. In addition, identified surface soil "hot spots" on the face of SWMU 145 and the postulated area of TCE contamination would be covered to reduce infiltration and provide protection from direct contact. For cost estimating purposes, it is assumed that four new MWs will be constructed in both the UCRS and RGA, one upgradient and three downgradient, for a total of eight wells. These wells will be sampled for full suite analysis quarterly for the first five years, semiannually for the next five years, and annually for years 11 through 30. Long-term groundwater monitoring would be implemented to track future groundwater quality.

12.4.3.1 Overall protection of human health and the environment

Alternative 6 would meet the threshold criterion of protection of human health and the environment by excavation of soil with concentrations of COCs above target concentrations and disposal of the soil at an appropriate disposal facility. Installation of a soil cover over identified surface soil "hot spots" would protect against direct contact with contamination. Covering the postulated area of TCE contamination would reduce infiltration, minimize migration of any TCE that may be present, and effectively contain the TCE to be protective of groundwater. Long-term groundwater monitoring would be performed to verify that wastes remaining in place at the SWMU are not contributing to further groundwater degradation. LUCs (see Section 2.4.1.1) protect current and future site workers and the public.

12.4.3.2 Compliance with ARARs

ARARs for this alternative are summarized in Appendix F. Alternative 6 would meet this threshold criterion by complying with all ARARs.

12.4.3.3 Long-term effectiveness and permanence

Excavation and disposal of contaminated soil above target concentrations will reduce residual risk at the SWMU to acceptable levels. Soil cover over identified surface soil “hot spots” would protect against direct contact with contamination. TCE would be effectively contained. Long-term groundwater monitoring would be performed to verify that wastes remaining in place at the SWMU are not contributing to further groundwater degradation.

12.4.3.4 Reduction of toxicity, mobility, or volume through treatment

This alternative reduces the mobility and volume of contaminants at the SWMU by excavation and relocation to an engineered disposal facility. Soil cover provides containment of surface contamination.

12.4.3.5 Short-term effectiveness

This alternative includes the excavation and disposal of contaminated soils above target concentrations. Most of the contaminated soil requiring excavation is along the NSDD. Long-term groundwater monitoring would be implemented to track future groundwater quality and to verify that wastes remaining in place at the SWMU are not contributing to groundwater degradation.

Short-term risks to the community resulting from excavation activities at the SWMU would not be expected. Potential risks resulting from migration of contaminants to off-site locations would be managed through engineering controls during excavation, staging, and transport.

Short-term exposures of remediation workers to COCs during implementation of Alternative 6 would be managed through adherence to health and safety protocols. To protect workers, PPE, ambient conditions monitoring, and decontamination protocols would be used in accordance with an approved, site-specific HASP.

No ecological impacts at the BGOU are anticipated under this alternative. The BGOU is located at an active operational facility already disturbed by construction and operational activities and does not support any unique or significant ecological resources. No known archaeological or historical sites or T&E species would be impacted by this alternative. Risk assessment and mitigation for ecological receptors in nearby drainage ditches are within the scope of the Surface Water OU.

RAOs would be achieved following excavation and disposal. It is estimated that RAOs would be attained in approximately three years.

12.4.3.6 Implementability

Alternative 6 is considered to be technically and administratively feasible and implementable. The equipment and technologies associated with implementation of this alternative are readily available from contractors or vendors.

12.4.3.7 Cost

Costs were estimated for transportation and disposal of wastes at an off-site facility as well as for an option to dispose of waste at the WDF.

12.5 COMPARATIVE ANALYSIS OF ALTERNATIVES

A comparative analysis summary of remedial alternatives for SWMU 145 is presented in Table 12.2, and the corresponding costs for the alternatives are presented in Table 12.3.

12.5.1 Threshold Criteria

Remedial alternatives are compared with respect to the threshold criteria in the following sections.

12.5.1.1 Overall protection of human health and the environment

Alternative 3, soil cover, would meet the threshold criterion for contamination that is limited to the surface or near surface, and the goal is to prevent direct contact. No waste would be removed or treated. A properly installed soil cover would reduce surface infiltration by reducing permeability relative to native soils and directing runoff away from the covered areas, thereby reducing contaminant migration to groundwater. LUCs (see Section 2.4.1.1) protect current and future site workers and the public. Long-term groundwater monitoring would be performed to verify that wastes remaining in place at the SWMU are not contributing to further groundwater degradation.

Alternative 6, excavation and disposal, meets the threshold criterion by reducing the concentrations of COCs in soil below target concentrations. Waste and contaminated soil will be physically removed from the SWMU and disposed of in one or more appropriate disposal facilities, including the WDF, thus meeting all RAOs for waste in the former burial pits. Soil cover will prevent direct contact with contaminated soil hot spots and contain any TCE contamination that may be present at SWMU 145. Long-term groundwater monitoring and LUCs will protect current and future site workers and the public.

12.5.1.2 Compliance with ARARs

No ARARs have been identified for Alternative 1, the No Action alternative.

Alternative 3 would meet the threshold criterion because contamination present at SWMU 145 is limited to the surface and near surface, and it does not pose a major threat to human health and the environment.

Alternative 6 would meet this threshold criterion. This alternative could remove enough waste and contaminated soil to meet soil target concentrations and prevent contamination exceeding MCLs or risk-based values in RGA groundwater at the UCRS-RGA boundary beneath the SWMU. It should meet all location- and action-specific ARARs through design and planning during preparation of the RD/RAWP.

Table 12.2. Summary of Comparative Analysis for SWMU 145 Remedial Alternatives

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 1: No Action	Does not meet the threshold criterion. Site procedures would be maintained to prevent direct contact with buried waste, but concentrations of Tc-99 in soil along NSDD will remain at levels that could pose a threat to groundwater. No controls implemented to mitigate or manage residual risk. Groundwater monitoring not performed to assess future groundwater quality.	ARARs are not applicable to the No Action alternative.	Not effective. Site risk would remain at or near current levels. Tc-99 in soil along NSDD could pose a future threat to groundwater. No controls implemented to mitigate or manage residual risk. Groundwater monitoring not performed to assess future groundwater quality.	Low. No treatment provided.	High. No actions implemented; therefore, no risks to community, site workers or the environment from implementation.	No additional action would be implemented. Current site procedures would be maintained.
Alternative 3: Soil Cover and Long-Term Monitoring	Moderate. Meets threshold criterion. More protective than Alternative 1 and less protective than Alternatives 6. Prevents direct contact with waste and reduces migration potential of contamination in surface soils and postulated TCE contaminations. Land use controls protect current and future site workers and the public.	High. Complies with ARARs and potential TBCs.	Moderate. Protects site workers from direct contact with waste and surface soil. Some reduction in mobility of contaminants by reducing infiltration.	Low to Moderate. No reduction of toxicity or volume. Contaminant mobility is reduced through containment.	High. No negative impacts to community. Exposure to workers low during installation of cover. More short term risk to workers during implementation than Alternative 1, but much less than Alternative 6. Could be completed in months.	High. Services and materials are readily available.

Table 12.2. Summary of Comparative Analysis of Remedial Alternatives SWMU 145 (Continued)

	Threshold Criteria		Primary Balancing Criteria			
Alternative	**Overall Protection of Human Health and the Environment**	**Compliance with ARARs and TBCs**	**Long-Term Effectiveness and Permanence**	**Reduction of Toxicity, Mobility, or Volume through Treatment**	**Short-Term Effectiveness**	**Implementability**
Alternative 6: Excavation and Disposal (Excavation of NSDD, soil cover of identified surface contamination "hot spots" and long-term monitoring in vicinity of postulated TCE contamination.) with Long-Term Groundwater Monitoring	High. Meets threshold criterion. Removal of contaminated soil reduces COCs in soil to RGs target concentrations, reducing direct contact threat and protecting groundwater. Long-term groundwater monitoring verifies that waste left in place does not contribute to further groundwater degradation.	High. Meets threshold criterion by complying with ARARs.	High. Reduces residual risk from COCs in soil to acceptable levels. Site procedures prevents exposure to buried waste. Long-term groundwater monitoring verifies that waste left in place does not contribute to further groundwater degradation.	Moderate to high. Removal and relocation of contaminated soil to engineered disposal facility reduces mobility of COCs and volume of contaminated soil at site.	Moderate to high. Risks to community, site workers and the environmental are minimal or readily managed. Approximately 3 years would be required to achieve implement and achieve RAOs.	High. Alternative is readily implementable at SWMU 145. Excavation would occur along the course of the former NSDD. Hot spots in surface soils would be covered. Groundwater monitoring is easily implemented.

Table 12.3. SWMU 145 Remedial Alternatives Cost Estimate Summary

			PRESENT WORTH[1]		ESCALATED	
Alternative Description	**Annual Time Period, yrs**	**Capital $ (2010 Constant Dollars)**	**Total Annual $**	**Total $ (Capital and Annual)**	**Total Annual $**	**Total $ (Capital and Annual)**
Alternative 1—No Action	0	$0	$0	$0	$0	$0
Alternative 3—Soil Cover and Long-Term Monitoring	30	$7,885,000	$5,006,000	$12,891,000	$20,207,000	$28,572,000
Alternative 6a—Excavation and Disposal[2]	0	$19,133,000	$0	$19,133,000	$0	$20,298,000
Alternative 6b—Excavation and Disposal (at the WDF)[2]	0	$18,109,000	$0	$18,109,000	$0	$19,212,000
Contingency for Alternative 6—Soil Cover and Long-Term Monitoring[3]	30	$3,378,000	$1,370,000	$4,748,000	$4,975,000	$8,559,000

[1] Not used for budgeting or planning purposes because value is based on investing funds for outyear expenditures.

[2] Excavation of only North-South Diversion Ditch.

[3] Assumed reductions in soil cover area based on results of proposed surface soil investigation.

12.5.2 Balancing Criteria

Remedial alternatives are compared with respect to the balancing criteria in the following sections.

12.5.2.1 Long-term effectiveness and permanence

Alternative 1 would not be effective because concentrations of technetium-99 would be left in place at concentrations that could pose a threat to groundwater and no remedial action would be taken to mitigate this risk.

Alternative 3 provides a moderate degree of long-term effectiveness and permanence because it is effective in controlling direct contact with surface contamination and reducing infiltration to contain possible TCE contamination. Residual risk would remain under this alternative.

Alternative 6 would be effective because the concentrations of COCs in soil would be reduced below target concentrations and reducing infiltration to contain possible TCE contamination. It provides a high degree of long-term effectiveness and permanence. Residual risk should be the lowest under this alternative. LUCs (see Section 2.4.1.1) protect current and future site workers and the public.

12.5.2.2 Reduction of toxicity, mobility, and volume through treatment

Alternative 1 would not reduce the toxicity, mobility, or volume of COCs in waste or soil.

Alternative 3 provides only limited reduction of mobility by preventing migration of surface contamination. It also reduces surface water infiltration and the ensuing subsurface migration of contaminants.

Alternative 6 would reduce the volume and mobility of COCs in soil at the SWMU by removal and relocation to an engineered disposal facility designed and constructed to prevent the uncontrolled migration of contaminants. Cover would reduce mobility and prevent migration of contaminants in surface soil and any TCE contamination that may be present.

12.5.2.3 Short-term effectiveness

The short-term effectiveness of Alternative 1 is low because RAOs would not be attained.

Alternative 3 is moderately effective during implementation. There is very little risk to workers or the community during installation of the soil cover.

The short-term effectiveness of Alternative 6 is moderate to high because threats to the community, site workers, and the environment are either minimal or easily managed, and RAOs could be attained in a short period of time (approximately 3 years). Disposal at the WDF would result in higher overall short-term effectiveness by eliminating risks associated with waste leaving the site.

12.5.2.4 Implementability

Alternative 1 is readily implementable because no additional action would be required. No additional controls would be implemented to protect site workers or the public.

The implementability of Alternative 3 is high because the technology is readily available and the complexity is low.

Alternative 6 is technically and administratively feasible and implementable. Excavation would occur along the former NSDD. Soil cover would be placed over surface soil hot spots and the area of postulated TCE contamination. Groundwater monitoring is easily implemented.

12.5.2.5 Cost

Capital and O&M costs for alternatives at SWMU 145 are presented in Table 12.3.

12.5.3 Summary of Comparative Analysis of Alternatives

Alternative 1, No Action, provides no action beyond existing DOE plant controls and monitoring. This does not provide an adequate level of overall protection to human health and the environment because concentrations of Tc-99 would be left in place that could pose a threat to groundwater, and no mechanism would be established to mitigate this potential threat. No additional groundwater monitoring would be performed to assess future groundwater quality.

Alternative 3, soil cover, would meet the threshold criteria for contamination limited to the surface or near surface and the goal is to prevent direct contact. No waste would be removed or treated. A properly installed soil cover would reduce surface infiltration by reducing permeability relative to native soils and directing runoff away from the covered areas, thereby reducing contaminant migration to groundwater. LUCs (see section 2.4.1.1) would protect current and future site workers and the public.

Alternative 6, excavation and disposal, meets the threshold criteria by removing waste and contaminated soil from the SWMU. This alternative could remove enough waste and contaminated soil along the course of the former NSDD so that the remaining soil at the SWMU would meet soil target concentrations and attain MCLs or risk-based values in RGA groundwater at the UCRS-RGA boundary beneath the SWMU. Soil cover would prevent direct contact with surface soil hot spots and reduce infiltration to contain any TCE that may be present. All SWMU-specific RAOs would be met by implementing Alternatives 6. Long-term groundwater monitoring would be performed to verify that wastes remaining in place at the SWMU are not contributing to further groundwater degradation.

THIS PAGE INTENTIONALLY LEFT BLANK

13. REFERENCES

AAEE 1998. *Innovative Site Remediation Technology, Design & Application, Volume 7, Vacuum Extraction and Air Sparging*, American Academy of Environmental Engineers, 130 Holiday Court, Suite 100, Annapolis, MD, EPA 542-B-97-010, May 1998.

Abriola, L. M. and S. A. Bradford 1998. “Experimental Investigations of the Entrapment and Persistence of Organic Liquid Contaminants in the Subsurface Environment,” *Environmental Health Perspectives*, Volume 106, Supplement 4, August.

AFCEE 2000. “Remediation of Chlorinated Solvent Contamination on Industrial and Airfield Sites,” Air Force Center for Environmental Excellence, 2000, U.S. Air Force Environmental Restoration Program.

ARS 2009. ARS Pneumatic Fracturing and Injection Field Services, Accessed at http://www.arstechnologies.com/pneumatic_fracturing.html.

Battelle 2001. *Final Air Sparging Guidance Document*, NFECS Technical Report TR-2193-ENV, Battelle, Columbus, Ohio, prepared for Naval Facilities Engineering Service Center, Port Hueneme, California, August 31, 2001.

BJC (Bechtel Jacobs Company LLC) 2001. *C-746-S&T Landfills Remedial Investigation Scoping Package*, LTR-PAD/EP-LL-01-0089, Bechtel Jacobs Company LLC, Paducah, KY, August.

BJC 2006. *Cultural Resources Survey for the Paducah Gaseous Diffusion Plant, Paducah, Kentuck*y, BJC/PAD–688/R1, Bechtel Jacobs Company LLC, March.

CDM 1994. *Investigation of Sensitive Ecological Resources Inside the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, Doc. No. 716-003-*FR*-BBRY, Paducah, KY, August 19.

CH2M HILL 1992. *Results of the Site Investigation, Phase II, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, KY/SUB/13B-97777CP-03/1991/1, April.

Clausen, J. L., N. C. Sturchio, L. J. Heraty, L. Huang, and T. Abrajano 1997. *Evaluation of Natural Attenuation Processes for Trichloroethylene and Technetium-99 in the Northeast and Northwest Plumes at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, KY/EM-113, November 25.

COE (U.S. Army Corps of Engineers) 1994. *Environmental Investigations at the Paducah Gaseous Diffusion Plant and Surrounding Area, McCracken County, Kentucky,* Volumes 1-5, United States Army Corps of Engineers, Nashville, TN, May.

COE 1995. U.S. Army Corps of Engineers, Louisville District, Louisville, KY, letter from Ronny J. Sadri, Project Manager, to Jimmie C. Hodges, Site Manager, U.S. Department of Energy, Paducah, KY, December 14.

COE 1999. *Multi-Phase Extraction Engineer Manual*, EM 1110-1-4010, Battelle Press, June 1.

COE 2008. *Engineering and Design, In Situ Air Sparging*, EM 1110-1-4005, January 31.

Deuren, J. V., T. Lloyd, S. Chherty, R. Liou, and J. Peck 2002. *Remediation Technologies Screening Matrix and Reference Guide*, 4th Edition, United States Army Environmental Center, SFIM-AEC-ET-CR-97053, January.

DOE (U.S. Department of Energy) 1987. *Closure Plan C-404 Low-Level Radioactive Waste Burial Grounds*, KY/B-257, Martin Marietta Energy Systems, Paducah, KY, April.

DOE 1989. *Post Closure Permit Application C-404 Low-Level Radioactive Waste Burial Grounds*, KY/H-35, Rev. 1, Martin Marietta Energy Systems, Paducah, KY, June.

DOE 1994a. *Secretarial Policy on the National Environmental Policy Act*, U.S. Department of Energy, June.

DOE 1994b. *Remedial Investigation Addendum for Waste Area Grouping 22, Burial Grounds Solid Waste Management Units 2 and 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1141&D2, U.S. Department of Energy, Paducah, KY, September.

DOE 1995a. *Background Concentrations and Human Health Risk-based Screening Criteria for Metals in Soil at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1417&D1, U.S. Department of Energy, Paducah, KY, September.

DOE 1995b. *Record of Decision for Interim Remedial Action at Solid Waste Management Units 2 and 3 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/06-1351&D1, U.S. Department of Energy, Paducah, KY, July.

DOE 1996. "*In Situ Enhanced Soil Mixing," Innovative Technology Summary Report, U.S. Department of Energy, Office of Environmental Management, Office of Science and Technology*, DOE/EM-0289, February.

DOE 1997. *Data Summary and Interpretation Report for Interim Remedial Design at Solid Waste Management Unit 2 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1549&D1, U.S. Department of Energy, Paducah, KY, February.

DOE 1998a. *Remedial Investigation Report for Solid Waste Management Units 7 and 30 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1604/V1&D2, U.S. Department of Energy, Paducah, KY, January.

DOE 1998b. *Work Plan for Waste Area Grouping 3 Remedial Investigation/Feasibility Study at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1649&D2, U.S. Department of Energy, Paducah, KY, July.

DOE 1998c. *Record of Decision for Remedial Action at Solid Waste Management Unit 91 of Waste Area Group 27 at the Paducah Gaseous Diffusion Plant*, U.S. Department of Energy, Paducah, KY, December.

DOE 1998d. *Feasibility Study for Solid Waste Management Units 7 and 30 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/06-1644&D2, U.S. Department of Energy, Paducah, KY, November.

DOE 1999a. *Proposed Remedial Action Plan for Solid Waste Management Unit 2 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/06-1690&D2, U.S. Department of Energy, Paducah, KY, November.

DOE 1999b. *Remedial Investigation Report for Waste Area Grouping 6 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR-07-1727&D2, U.S. Department of Energy, Paducah, KY, May.

DOE 1999c. *Bench Scale In-Situ Chemical Oxidation Studies of Trichloroethene in Waste Area Grouping 6 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-1788&D1, Secondary Document, Terra Vac and PNNL Team, February.

DOE 2000a. *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1895/V1-V4&D1, U.S. Department of Energy, Paducah, KY, September.

DOE 2000b. *Innovative Technology Summary Report*, *In Situ Redox Manipulation*, Subsurface Contaminants Focus Area, DOE/EM-99, January.

DOE 2001. *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Volume 1. Human Health and Volume II. Ecological*, DOE/OR/07-1506&D2/V1&V2/R0, U.S. Department of Energy, Paducah, KY, December.

DOE 2002a. *Final Technical Report Research and Development EarthSaw^{TM} In Situ Containment of Pits and Trenches*, U.S. Department of Energy Technology Laboratory, September.

DOE 2002b. *Final Remedial Action Report for Lasagna Phase Iib In Situ Remediation of Solid Waste Management Unit 91 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/OR/07-2037&D1, September.

DOE 2003. *Final Report, Six-Phase Heating Treatability Study at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2113&D1, Secondary Document, U.S. Department of Energy, Paducah, KY, December.

DOE 2004. *Final Environmental Impact Statement for Construction of a Depleted UF_6 Conversion Facility at Paducah Kentucky Site*, DOE-0359, U.S. Department of Energy, June.

DOE 2006a. *Work Plan for the Burial Grounds Operable Unit Remedial Investigation/Feasibility Study at Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2179&D2/R1, U.S. Department of Energy, Paducah, KY, August.

DOE 2006b. *Site Investigation Report for the C-746-S&T Landfills at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2212&D2, U.S. Department of Energy, Paducah, KY, February.

DOE 2007a. *Solid Waste Management Unit 4 Assessment Report for the Paducah Gaseous Diffusion Plant*. Paducah Remediation Services, LLC, Paducah, KY, July.

DOE 2007b. *Site Investigation Report for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2180&D2/R1, U.S. Department of Energy, Paducah, KY, June.

DOE 2008. *Class 2 Permit Modification Request for the Hazardous Waste Facility Permit KY8-890-008-982, Agency Interest No. 3059*, Letter from William Murphie to Anthony Hatton, KDWM, Paducah, KY, May.

DOE 2009a. *Site Management Plan, Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Annual Revision-FY 2009*, DOE/OR/07-0185&D2/R1, U.S. Department of Energy, Paducah, KY, March.

DOE 2009b. *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Volume 1, Human Health and Volume II, Ecological*, DOE/LX/07-0107&D1/V1, U.S. Department of Energy, Paducah, KY.

DOE 2010. *Remedial Investigation Report for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0030&D2, U.S. Department of Energy, Paducah, KY, April.

Dwyer, B. P. 2003. "Feasibility of Permeation Grouting for Constructing Subsurface Barriers," SAND94-0786, Sandia National Laboratories, April.

EPA (U.S. Environmental Protection Agency) 1987. *Design, Construction and Maintenance of Covers Systems for Hazardous Waste, An Engineering Guidance Document,* EPA/600/2-87/039, NTIS PB 87-191656, U.S. Environmental Protection Agency, May.

EPA 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, EPA/540/G-89/004, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC, October.

EPA 1991. *A Guide to Principal Threat and Low-Level Threat Wastes*, Office of Solid Waste and Emergency Response, Washington, DC, November.

EPA 1995. *How to Evaluate Alternative Cleanup Technologies for Underground Storage Tanks Sites*, Chapter XI, "Dual-Phase Extraction," Solid Waste and Emergency Response, May.

EPA 1996a. *How to Effectively Recover Free Products at Leaking Underground Storage Tank Sites,* U.S. Environmental Protection Agency, EPA/510-R-96-001, September. Accessed at http://www.epa.gov/oust/pubs/fprg.htm, September 15, 2009.

EPA 1996b. *Presumptive Response Strategy and Ex Situ Treatment Technologies for Contaminated Groundwater at CERCLA Sites, Final Guidance,* EPA/540/R-96/023, U.S. Environmental Protection Agency, October.

EPA 1997. *Rules of Thumb for Superfund Remedy Selection,* EPA 540-R-97-013, U.S. Environmental Protection Agency, August.

EPA 1998a. *Federal Facility Agreement for the Paducah Gaseous Diffusion Plant*, DOE/OR/07-1707, U.S. Environmental Protection Agency, Region 4, Atlanta, GA, February 13.

EPA 1998b. *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater*, EPA/600/R-98/128, U.S. Environmental Protection Agency, Washington DC, September.

EPA 1999a. *Cancer Risk Coefficients for Environmental Exposure to Radionuclides, Federal Guidance Report No. 13*, EPA 402-R-99-001, Air and Remediation, U. S. Environmental Protection Agency, September.

EPA 1999b. *Monitored Natural Attenuation of Chlorinated Solvents*, EPA/600/F-98/022, U.S. Environmental Protection Agency, May.

EPA 1999c. "Subsurface Containment and Monitoring Systems: Barriers and Beyond (Overview Report)," U.S. Environmental Protection Agency Office of Solid Waste and Emergency Response, Technology Innovation Office, Washington, DC, March. Accessed at http://www.clu-in.org.

EPA 2000a. *Soil Screening Guidance for Radionuclides: Technical Background Document*, EPA/540-R-00-006, Environmental Protection Agency, PB2000 963306, October.

EPA 2000b. "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study," U.S. Environmental Protection Agency, OSWER 9355.0-75, July. Accessed at http://www.epa.gov/superfund/policy/remedy/sfremedy/rifs/costest.htm.

EPA 2003. "Site Technology Capsule: MatCon Modified Asphalt for Waste Containment," EPA/540/R-03/505A, U.S. Environmental Protection Agency, June.

EPA 2004a. *Final Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)*, EPA/540/R/99/005 OSWER 9285.7-02EP PB99-963312, Office of Superfund Remediation and Technology Innovation, U.S. Environmental Protection Agency Washington, DC, July.

EPA 2004b. *How to Evaluate Alternative Cleanup Technologies for Underground Storage Tanks Sites*, EPA/510-R-04-002, Solid Waste and Emergency Response, May.

EPA 2005. *Steam Enhanced Remediation Research for DNAPL in Fractured Rock, Loring Air Force Base, Limestone, Maine*, EPA/540/R-05/010, August.

EPA 2006a. *Off-Gas Treatment Technologies for Soil Vapor Extraction Systems: State of the Practice*, EPA-542-R-05-028, Office of Superfund Remediation and Technology Innovation, Office of Solid Waste and Emergency Response, March.

EPA 2006b. *2006 Edition of the Drinking Water Standards and Health Advisories*, EPA 822-R-06-013, Office of Water, Washington, DC, August.

EPA 2007. *Presumptive Remedies: Policy and Procedures*, U.S. Environmental Protection Agency, last updated on Tuesday, July 17, 2007. Accessed 07/14/08, at http://www.epa.gov/superfund/policy/remedy/presump/pol.htm.

EPA 2008. "Contaminant Focus: DNAPLs," Accessed at http://www.clu-in.org/contaminantfocus/default.focus/sec/Dense_Nonaqueous_Phase_Liquids_(DNAPLs)/cat/Treatment_Technologies/p/5.

FRTR 2008. *Remediation Technologies Screening Matrix and Reference Guide*, Version 4.0, Federal Remediation Technologies Roundtable, accessed at http://www.frtr.gov/matrix2/top_page.html.

GSI 2004. "Final Report for Full-Scale Mulch Wall Treatment of Chlorinated Hydrocarbon-Impacted Groundwater," Offutt Air Force Base, Nebraska, Building 301, prepared for Air Force Center for Environmental Excellence, Brooks City-Base, TX, April 13. Accessed at http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA422621&Location=U2&doc=GetTRDoc.pdf.

Hightower, *et al.* 2001. *Innovative Treatment and Remediation Demonstration,* Paducah Groundwater Project Innovative Technology Review, March.

HPS 2000. Scrap Metal Recycle. Release and Recycling of Scrap Metal. Decommissioning Section of the Health Physics Society, accessed at http://www.hps1.org/sections/decom/scrap.html.

ISF 2008. *In Situ* Fixation, Inc., September. Accessed at http://www.insitufixation.com/services/index.shtml.

ITRC 2003. *Technical and Regulatory Guidance for Surfactant/Cosolvent Flushing of DNAPL Source Zones,* Interstate Technology & Regulatory Council, Dense Nonaqueous Phase Liquids Team, 444 North Capitol Street, Northwest, Suite 445, Washington, DC 20001, April 2003. Accessed at http://www.itrcweb.org/Documents/DNAPLs-3.pdf.

ITRC 2005. *Overview of In Situ Bioremediation of Chlorinated Ethene DNAPL Source Zones*, Interstate Technology & Regulatory Council, Bioremediation of DNAPLs Team, 444 North Capitol Street, Northwest, Suite 445, Washington, DC 20001, October. Accessed at http://www.itrcweb.org/Documents/BioDNAPL-1.pdf.

ITRC 2009. Evaluating LNAPL Remedial Technologies for Achieving Project Goals, Interstate Technology & Regulatory Council, LNAPLs Team, 444 North Capitol Street, Northwest, Suite 445, Washington, DC 20001, December 2009. Accessed at http://www.itrcweb.org/documents/LNAPL-2.pdf.

Jacobs, J. A. and Testa S. M. 2003. *Design Considerations for In Situ Chemical Oxidation Using High Pressure Jetting Technology*, http://www.ebsinfo.com/chemical_oxidation.pdf, preprint for an article to be featured in Association for Environmental Health and Science, April.

Jowitt, P. W. and Chengchao Xu 1990. "Optimal Value Control in Water-Distribution Networks," *Journal of Water Resources Planning and Management*, 116(4):455.

KDAQ (Kentucky Division of Air Quality) 2008. *Fiscal Year 2008 Annual Report*, Kentucky Division for Air Quality, Frankfort, KY.

Kirtland, B. C. and C. H. Aelion 2000. "Petroleum Mass Removal from Low Permeability Sediment Using Air Sparging/Soil Vapor Extraction: Impact of Continuous or Pulsed Operation," *Journal of Contaminant Hydrology*, 41(3-4):367.

KRCEE 2005. *Evaluation of Groundwater Management/Remediation Technologies for Application to the Paducah Gaseous Diffusion Plant*, UK/KRCEE Doc #: P7.1 2005, KRCEE, September.

KRCEE 2007. "Separation of Nickel from Technetium-Contaminated Scrap," accessed at http://www.uky.edu/krcee/Reports/KRCEE%20Reports/KRCEE%209.5%202007.pdf.

KRCEE 2008. *PGDP Trichloroethene Biodegradation Investigation Summary Report, Regional Gravel Aquifer and Northwest Plume*, prepared by TCE Fate and Transport Team through University of Kentucky Research Consortium for Energy and Environment, September.

KSNPC 1991. *Biological Inventory of the Jackson Purchase Region*, Kentucky State Nature Preserves Commission, Frankfort, KY.

Landis, Richard C. 2001. *The Innovative Use of High Pressure Jetting of Thin Diaphragm Walls to Construct Hydraulic Control Barriers*, E.I. Du Pont de Nemours and Company, Wilmington, DE, presented at the 2001 International Containment and Remediation Technology Conference and Exhibition, Orlando, FL. Accessed at http://www.containment.fsu.edu/cd/content/pdf/158.pdf.

LMES 1996. *Aquifer Test Analysis of the Northwest Plume, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, KY/EM-145, Lockheed Martin Energy Systems, Inc., Paducah, KY, June.

MMES (Martin Marietta Energy Systems) 1992. *Report of the Paducah Gaseous Diffusion Plant Groundwater Investigation Phase III*, KY/E-150, Martin Marietta Energy Systems, Inc., Paducah, KY, November.

NCRP Report 141. "Managing Potentially Radioactive Scrap Metal. National Council on Radiation Protection and Measurements" accessed at http://knovel.com/web/portal/browse/display.

NOAA (National Oceanic and Atmospheric Administration) 2004. *NOAA Atlas 14: Precipitation-Frequency Atlas of the United States, Volume 2*, Version 3.0. National Oceanic and Atmospheric Administration, Silver Spring, MD.

NRC (National Research Council) 2004. "Contaminants in the Subsurface, Source Zone Assessment and Remediation," National Research Council of the National Academies, National Academies Press, Washington, DC.

ORNL (Oak Ridge National Laboratory) 1995. *Risk Assessment for the Retrieval of Transuranic Waste: Pads 1, 2, and 4, Technical Area-54, Area G, Los Alamos National Loaboratory*, ORNL/TM-12994, Maritn Marietta Energy Systems, Inc., for the U.S. Department of Energy.

ORNL 1998. *Review of Uranium Geochemistry Relative to SWMU 2 at the Paducah Gaseous Diffusion Plant*, Oak Ridge National Laboratory, Grand Junction, CO, January.

Parsons (Parsons Inc.) 2004. *Principles and Practices fo Enhanced Anaerobic Bioremediation of Chlorinated Solvents*, prepared for Air Force Center for Environmental Excellence, Brooks City-Base, Texas, Naval Facilities Engineering Service Center, Port Hueneme, California, and Environmental Security Technology Certification Program, Arlington, VA, August.

Pettit, P. J., D. E. Ridenour, D. Harris, and J. Jalovec 1996. "Success in Horizontal Barrier Developments," FEMP-2491, CONF-960212-92, U.S. Department of Energy, Fernald Environmental Management Project, Presented at Waste Management 1996, Tucson, AZ, February 25-29.

PRS (Paducah Remediation Services, LLC) 2007. *Trichloroethene and Technetium-99 Groundwater Contamination in the Regional Gravel Aquifer for Calendar Year 2005 at the Paducah Gaseous Diffusion Plant Paducah*, Kentucky, PRS-PROJ-0019, Paducah Remediation Services, LLC, Paducah, KY, May.

PRS 2010. *Paducah Gaseous Diffusion Plant Fill and Cover Material Verification Guidance*, RS-ENR-0036, Paducah Remediation Services, LLC, February.

Royal Society 2002. "The Health Hazards of Depleted Uranium, Part II," March 12. Accessed at royalsociety.org.

Sale, T., M. Petersen, and D. Gilbert 2005. "Final Report Electrically Induced Redox Barriers for Treatment of Groundwater," prepared for Environmental Security Technology Certification Program, March 2005. Accessed at http://www.estcp.org/viewfile.cfm?Doc=cu%2D0112%2Dfr%2D01%2Epdf.

Suthersan, S. 1997. *Remediation Engineering: Design Concepts*, CRS Press, LLC, Boca Raton, FL.

TCT-St. Louis 1991. *Phase I Remedial Investigation at the Former Kentucky Ordance Works, McCracken County, Kentucky*¸1321K.920818.006, U.S. Army Corps of Engineers, Nashville District, Nashville, TN, November.

Terran 1990. *Groundwater Monitoring Phase II C-404 Aquifer Testing Program ESO 16749 Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, Report No. TX-8925, Terran Corp., Kettering, OH, February.

Terran 1992. *Aquifer Assessment Report–Groundwater Monitoring Phase III: Aquifer Test Program West of Building C-333, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, Report No. TK-9213, ESO 16905, Kettering, OH.

Terzaghi, K. T, R. B. Peck, and G. Mesri 1996. *Soil Mechanics in Engineering Practice*, Third Edition, John Wiley & Sons, Inc., New York, NY.

Thornthwaite, C. W. and J. R. Mather 1957. "Instructions and Tables for Computing Potential Evapotranspiration and the Water Balance," *Publications in Climatology* 10 (1957): 183-311.

Tri-Agency 2002. "Evaluation of Permeable Reactive Barrier Performance," prepared for the Federal Remediation Technologies Roundtable (FRTR) by the Tri-Agency Permeable Reactive Barrier Initiative-Members: U.S. Department of Defense, U.S. Department of Energy, U.S. Environmental Protection Agency, and Interstate Technology and Regulatory Council, December 9.

Union Carbide 1973. *The Discard of Scrap Materials by Burial at the Paducah Plant*, Union Carbide Corporation, Paducah, KY, October.

Union Carbide 1975. *Discard of Uranium-Bearing Scrap to the Burial Grounds through December 31, 1974*, internal correspondence from E. A. Kohler to G. T. Hull, Paducah, KY, January 31.

Union Carbide 1978. *The Disposal of Solid Waste at the Paducah Gaseous Diffusion Plant*, Union Carbide Corporation, Paducah, KY, December.

U.S. Census Bureau 2007. Population Finder, City of Paducah, Kentucky. Accessed at http://quickfacts.census.gov/ July 17, 2009.

USDA (U.S. Department of Agriculture) 1976. *Soil Survey of Ballard and McCracken Counties, Kentucky*, USDA Soil Conservation Service and Kentucky Agricultural Experiment Station.

USFWS (U.S. Fish and Wildlife Service) 2007. *Indiana Bat (Myotis sodalis) Draft Recovery Plan*: First Revision, U.S. Fish and Wildlife Service, Fort Snelling, MN.

VeruTEK 2009. http://www.verutek.com/technology.htm.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX A

COMPARISON OF SOIL CONCENTRATIONS TO REMEDIATION GOALS BY SADA LAYER

THIS PAGE INTENTIONALLY LEFT BLANK

TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

ACRONYMS

BHHRA	Baseline Human Health Risk Assessment
BGOU	Burial Grounds Operable Unit
COC	contaminant of concern
FS	Feasibility Study
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyl
PGDP	Paducah Gaseous Diffusion Plant
RG	remediation goal
RGA	Regional Gravel Aquifer
RI	remedial investigation
SADA	Statistical Analysis and Decision Acceptance
SWMU	solid waste management unit
TCE	trichloroethene
VOC	volatile organic compound

THIS PAGE INTENTIONALLY LEFT BLANK

A. COMPARISON OF SOIL CONCENTRATIONS TO REMEDIATION GOALS BY SADA LAYER

This appendix provides a layer-by-layer detailed comparison of the maximum concentration, mean of the detectable concentrations, and mean model concentration to the appropriate soil remediation goals (RGs) using the data available in the Burial Grounds Operable Unit (BGOU) Remedial Investigation (RI) Report (DOE 2010). These comparisons are presented as Tables A.1 to A.8 for each solid waste management unit (SWMU). Layer concentrations were developed by assigning data points for chemicals analyzed to the appropriate Statistical Analysis and Decision Acceptance (SADA) model layer as defined for the RI soil geostatistical modeling. The assignments of samples to specific layers was made based on the sample depths as reported in the BGOU RI Report (DOE 2010) and are used in this Feasibility Study (FS) to be fully consistent with the RI for the BGOU.

The observed maximum concentration, mean of the detectable concentrations, and model mean concentration for each contaminant of concern (COC) in each layer at each SWMU are compared to the preliminary RGs (Tables 2.1 and 2.2) for that respective COC. The value is shown in bold, red typeface where it exceeds the Preliminary RG. For COCs that are dispersed throughout the soil column and the mean of the detected concentrations exceeds the RG concentration, a Y in bold, red typeface in the last column indicates the entire layer is considered for remedial action. An H in bold, orange typeface indicates localized concentrations (i.e., “hotspots”) are considered for remedial action. Constituents that are COCs for surface soils indicate only the individual values that exceed RGs.

If the observed average concentration for a COC exceeded the RG and two or more concentrations exceeded the RG for that COC, the entire layer was evaluated for treatment, removal, or containment of the contaminated soils in the layer. If the maximum concentration exceeded the RG, but the average did not, a localized treatment option for the hotspot could be considered. Each table also provides for comparison, where available, the layer average concentration derived by the SADA geostatistical model and used in the Seasonal Soil Compartment Model leaching model conducted for the RI.

The average concentration for a COC in each subsurface soil conceptual layer was computed from the detected concentrations as reported in the data tables in the RI Report (DOE 2010) and are shown in Tables A.1 to A.8. The surface soil values shown in Tables A.1 to A.8 were extracted from the database contained in Appendix C of the RI Report (DOE 2010). The appropriate surface soil samples were utilized to derive the maximum and average concentrations for the 0 to 1 ft interval at each SWMU. RGs used for the comparison are shown in bold in the last column of the table for each SWMU in Tables A.1 to A.8 for COCs reported for surface soils only. The RG appears on the line for Layer 1. If there is no RG specifically for surface soil, the subsurface soil RG applies. COCs identified in the Baseline Human Health Risk Assessment (BHHRA) that were found to be immobile and did not impact the Regional Gravel Aquifer (RGA) within the 1,000 year period of model performance included the following: all polycyclic aromatic hydrocarbons (PAHs), all polychlorinated biphenyls (PCBs), uranium, neptunium, and plutonium.

Table A.1. Comparison of Average Layer Soil Concentrations of COCs to Remediation Goals for SWMU 2

COC SADA Layer[a]	Sample Depths (ft) Start	 End	Detectable Concentrations above the RG	Maximum Concentration[b] (mg/kg or pCi/g)	Layer Average[b] (mg/kg or pCi/g)	SADA Layer[c] (mg/kg or pCi/g)	RG for soil (mg/kg or pCi/g)
***cis*-1,2-DCE**							**2.2**
1	0		0	ND	ND	0	N
2	5 8		1	**2.7**	0.90	1.06	**H**
3	10 15	12 16	1	**130**	**130**	**115**	**H**
4	20		0	ND	ND	**70**	N
5	30		0	ND	ND	**81**	N
6	45		0	0.12	0.12	**45**	N
7	60		0	0.015	0.01	**37**	N
TCE							**0.13**
1	0		0	ND	ND	0	N
2	5 8		1	**0.28**	**0.15**	**0.13**	**H**
3	10 15	12 16	1	**140**	**47**	**43**	**H**
4	20	25	0	ND	ND	**24**	N
5	30	35	0	ND	ND	**15**	N
6	40	45	1	**0.43**	**0.22**	**8.9**	**H**
7	50	55	0	ND	ND	**0.20**	N
Uranium						**Subsurface soil** **Surface soil**	**113** **101**
1	0		4	**943**	**373**	**168**	**Y**
2	5 8		1	**1500**	**751**	**799**	**H**
3	10 15	12 16	0	33	20	15	N
4	20	25	0	24	18	18	N
5	30	35	0	22	22	14	N
6	40	45	0	ND	ND	12	N
7	50 60	55	0	24	24	5.79	N
Uranium-234						**Subsurface soil** **Surface soil**	**142** **99**
1	0		0	11.6	9.1	16	N
2	5 8		1	**155**	26.91	14	**H**
3	10 15	12 16	0	2.1	1	0.81	N
4	20	25	0	0.89	0.71	0.76	N
5	30	35	0	0.93	0.58	0.83	N
6	40	45	0	1.2	0.82	0.72	N
7	50 60	55	0	1.2	0.71	0.64	N

Table A.1. Comparison of Average Layer Soil Concentrations of COCs to Remediation Goals for SWMU 2 (Continued)

COC / SADA Layer [a]	Sample Depths (ft) Start	Sample Depths (ft) End	Detectable Concentrations above the RG	Maximum Concentration [b] (mg/kg or pCi/g)	Layer Average [b] (mg/kg or pCi/g)	SADA Layer [c] (mg/kg or pCi/g)	RG for soil (mg/kg or pCi/g)
Uranium-235/236[d]						**Subsurface soil**	**22.8**
						Surface soil	**2.0**
1	0		0	1.4	1.2	2.7	N
2	5	8	1	26	4.37	3.43	H
3	10 / 15	12 / 16	0	0.38	0.10	0.09	N
4	20	25	0	0.09	0.07	0.08	N
5	30	35	0	0.11	0.07	0.07	N
6	40	45	0	0.12	0.07	0.07	N
7	50	55	0	0.070	0.06	0.00	N
Uranium-238						**Subsurface soil**	**58.5**
						Surface soil	**8.6**
1	0		1	60	48	88	H
2	5	8	1	947	160	84	H
3	10 / 15	12 / 16	0	8.02	1.9	1.5	N
4	20	25	0	1.4	0.8	1.1	N
5	30	35	0	1.0	0.57	1.02	N
6	40	45	0	1	0.83	0.88	N
7	50 / 60	55	0	1.3	0.81	0.71	N
Technetium-99							**9.9**
1	0		1	15	3.4	1.8	H
2	5	8	0	2.24	0.62	0.58	N
3	10 / 15	12 / 16	0	0.79	0.21	0.32	N
4	20	25	0	0	0.03	0.10	N
5	30	35	0	0.3	0.16	0.16	N
6	40	45	0	0	0.02	0.07	N
7	50 / 60	55	0	0	0.02	0.07	N
COCs Identified for Surface Soils Only							
Naphthalene	0		3	0.4	0.2	0.3	**0.003**

COC—Identified according to criteria specified in the BHHRA and for inorganic constituents that exceed the range of Background for Paducah Gaseous Diffusion Plant (PGDP).
RG—Preliminary Remediation Goal.
N—The average layer concentration is less than the RG for subsurface soils. No action is warranted for soils in this layer, except where maximum concentrations exceed the RG.
ND—not detected.

Table A.1. Comparison of Average Layer Soil Concentrations of COCs to Remediation Goals for SWMU 2 (Continued)

Y—Bold, red typeface indicates the layer's mean concentration exceeds the RG for subsurface soils. An action is warranted to reduce concentration within the layer to below the RG.
H—Bold, orange typeface indicates the maximum concentration within the layer exceeds the RG for subsurface soils. An action to reduce concentration at a "hotspot" to below the RG may be needed.
[a] SADA Layer corresponds to the layer depth intervals used in the geostatistical model developed for the BGOU fate and transport modeling.
[b] Data for subsurface soil are detected concentrations as reported in Table 4.7 of the BGOU RI Report only. Nondetect results are not included in the computation of the layer mean. Surface soil data was obtained from the database in Appendix C of the BGOU RI Report.
[c] SADA layer concentrations are from reported values in Table E.3.3, Appendix E of the RI Report.
[d] RG is for uranium-235; decay energies are so close that these isotopes may not be distinguishable. Uranium-328 and 235 are COCs for surface soil only; however, the high concentrations in Layer 2 also are flagged.

Table A.2. Comparison of Average Layer Soil Concentrations of COCs to Remediation Goals for SWMU 3

COC SADA Layer[a]	Sample Depths (ft) Start	 End	Detectable Concentrations above the RG	Maximum Concentration[b] (mg/kg or pCi/g)	Layer Average[b] (mg/Kg or pCi/g)	SADA Layer[c] (mg/kg or pCi/g)	RG for soil (mg/kg or pCi/g)
Technetium-99							**4.5**
1	0	1	3	**22**	**12**	**13**	**Y**
2	5 10		2	**57**	**22**	**27**	**Y**
3	15		0	2.4	2.4	0.0	N
4	20	30	0	ND	ND	0.07	N
5	30		No Samples from this interval			0.07	
6	45		0	ND	ND	0.07	N
7	60		0	ND	ND	0.07	N
Uranium (mg/kg)[d]						**Subsurface Soil** **Surface Soil**	**101** **113**
1	0	1	0	43	18	16	N
2	5 10		0	84	26.3	21	N
3	15		0	5.18	5.18	40	N
4	20	30	0	ND	ND	39	N
5	30		No Samples from this interval			36	N
6	45		0	1.41	1.41	36	N
7	60		0	ND	ND	41	N
Uranium-238[d]						**Subsurface Soil** **Surface Soil**	**58.5** **8.6**
1	0	1	0	6.0	1.5	1.3	N
2	5 10		0	22	4.8	6.7	N
3	15		0	0.35	0.34	12.63	N
4	20	30	0	0.19	0.19	12.63	N
5	30		No Samples from this interval			12.26	
6	45		0	0.27	0.20	12.26	N
7	60		0	0.19	0.17	10.53	N
COCs Identified for Surface Soils Only							
Uranium-235[d]	0	1	0	1.7			**22.8**

COC—Identified according to criteria specified in the BHHRA and for inorganic constituents that exceed the range of Background for PGDP.
RG—Preliminary Remediation Goal.
N—The average layer concentration is less than the RG for subsurface soils. No action is warranted for soils in this layer, except where maximum concentrations exceed the RG.
ND—not detected.

Table A.2. Comparison of Average Layer Soil Concentrations of COCs to Remediation Goals for SWMU 3 (Continued)

Y—Bold, red typeface indicates the layer's mean concentration exceeds the RG for subsurface soils. An action is warranted to reduce concentration within the layer to below the RG.
H—Bold, orange typeface indicates the maximum concentration within the layer exceeds the RG for subsurface soils. An action to reduce concentration at a “hotspot” to below the RG may be needed.
[a] SADA Layer corresponds to the layer depth intervals used in the geostatistical model developed for the BGOU fate and transport modeling.
[b] Data for subsurface soil are detected concentrations as reported in Table 4.9 of the BGOU RI Report only. Nondetect results are not included in the computation of the layer mean. Surface soil data was obtained from the database in Appendix C of the BGOU RI Report.
[c] SADA layer concentrations are from reported values in Table E.3.7, Appendix E of the RI Report.
[d] Total uranium is reported in mg/kg, consistent with Table 4.7, BGOU RI. Uranium-238 is a COC for surface soil only; however, the maximum concentration in Layer 2 is flagged. Uranium-235 was identified as a COC in the WAG 22 RI Addendum (DOE/OR/07-1141&D2): however, no detectable concentrations were reported.

Table A.3. Comparison of Average Layer Soil Concentrations of COCs to Remediation Goals for SWMU 4

COC / SADA Layer[a]	Sample Depths (ft) Start	Sample Depths (ft) End	Detectable Concentrations above the RG	Maximum Concentration[b] (mg/kg or pCi/g)	Layer Average[b] (mg/kg or pCi/g)	SADA Layer[c] (mg/kg or pCi/g)	RG for soil (mg/kg or pCi/g)
TCE							**0.04**
1	0	1	0	ND	ND	0	N
2	3	6	0	0.035	0.01	**2.4**	N
	9	12					
3	15	16	2	**0.40**	**0.17**	**2.9**	**Y**
4	20	25	3	**0.82**	**0.26**	**3.0**	**Y**
	25	30					
5	30	40	6	**41**	**7.7**	**2.6**	**Y**
6	40	45	5	**9**	**2.3**	**2.5**	**Y**
7	50	55	9	**25**	**5.5**	**3.2**	**Y**
	60						
***cis*-1,2-DCE**							**0.77**
1	0	1	0	ND	ND	0	N
2	3	6	0	ND	ND	**3.40**	N
	9	12					
3	15	16	0	ND	ND	**1.64**	N
4	20	25	0	ND	ND	**1.54**	N
	25	30					
5	30	40	0	0.35	0.4	**1.11**	N
6	40	45	2	**9.8**	**4.1**	**0.88**	**Y**
7	50	55	2	**4**	**1.1**	**0.98**	**Y**
	60						
Vinyl Chloride							**0.04**
1	0	1	0	ND	ND	0	N
2	3	6	0	ND	ND	0.16	N
	9	12					
3	15	16	1	**0.05**	**0.05**	**0.08**	**H**
4	20	25	0	ND	ND	**0.09**	N
	25	30					
5	30	40	2	**0.29**	**0.26**	**0.19**	**Y**
6	40	45	0	0.018	0.018	**0.18**	N
7	50	55	1	**0.24**	**0.13**	**0.20**	**H**
	60						
PCBs Total							**10**
1	0	1	0	4.8	3.6	SADA Layer Means not calculated	N
2	3	6	2	**27**	4.9		**H**
	9	12					
3	15	16	0	ND	ND		N
4	20	25	0	ND	ND		N
	25	30					
5	30	40	0	ND	ND		N
6	40	45	0	ND	ND		N
7	50	55	0	ND	ND		N
	60						

Table A.3. Comparison of Average Layer Soil Concentrations of COCs to Remediation Goals for SWMU 4 (Continued)

COC SADA Layer[a]	Sample Depths (ft) Start	End	Detectable Concentrations above the RG	Maximum Concentration[b] (mg/kg or pCi/g)	Layer Average[b] (mg/kg or pCi/g)	SADA Layer[c] (mg/kg or pCi/g)	RG for soil (mg/kg or pCi/g)
Technetium-99							**6.3**
1	0	1	1	**39**	**39**	**39**	**H**
2	3	6	9	**269**	**56**	**50**	**Y**
	9	12					
3	15	16	0	ND	ND	0	N
4	20	25	0	ND	ND	0	N
	25	30					
5	30	40	0	ND	ND	0	N
6	40	45	0	ND	ND	0	N
7	50	55	0	ND	ND	0	N
	60						
Uranium (pCi/g)[d]						**Subsurface Soil**	**58.5**
						Surface Soil	**8.6**
1	0	1	7	**87**	**45**	**119**	**Y**
2	3	6	6	**6260**	**640**	**885**	**Y**
	9	12					
3	14	16	0	8.64	8.64	**828**	N
4	20	25	0	ND	ND	**808**	N
	25	30					
5	30	40	0	ND	ND	**790**	N
6	40	45	0	2	2	**768**	N
7	50	55	0	ND	ND	0	N
Uranium-238						**Subsurface Soil**	**58.5**
						Surface Soil	**8.6**
1	0	1	7	**57**	**30**	**31**	**Y**
2	3	6	4	**126**	48	52	**H**
	9	12					
3	15	16	0	ND	ND	52	N
4	20	25	0	ND	ND	52	N
	25	30					
5	30	40	0	ND	ND	53	N
6	40	45	0	ND	ND	54	N
7	50	55	0	ND	ND	0	N
	60						

COC—Identified according to criteria specified in the BHHRA and for inorganic constituents that exceed the range of Background for PGDP.
RG—Preliminary Remediation Goal.
N—The average layer concentration is less than the RG for subsurface soils. No action is warranted for soils in this layer, except where maximum concentrations exceed the RG.
ND—not detected.
Y—Bold, red typeface indicates the layer's mean concentration exceeds the RG for subsurface soils. An action is warranted to reduce concentration within the layer to below the RG.
H—Bold, orange typeface indicates the maximum concentration within the layer exceeds the RG for subsurface soils. An action to reduce concentration at a "hotspot" to below the RG may be needed.

Table A.3. Comparison of Average Layer Soil Concentrations of COCs to Remediation Goals for SWMU 4 (Continued)

[a] SADA Layer corresponds to the layer depth intervals used in the geostatistical model developed for the BGOU fate and transport modeling.
[b] Data for subsurface soil are detected concentrations as reported in Table 4.11 of the BGOU RI Report only. Nondetect results.
[c] SADA layer concentrations are from reported values in Table E.3.7, Appendix E of the BGOU RI Report.
[d] Total uranium is reported only in pCi/g in Table 4.19, BGOU RI. The RG for uranium metal given in the table assumes all activity is uranium-238.

Table A.4. Comparison of Average Layer Soil Concentrations of COCs to Remediation Goals for SWMU 5

<table>
<tr><th>COC</th><th colspan="2">Sample Depths (ft)</th><th rowspan="2">Detectable Concentrations greater than the RG</th><th rowspan="2">Maximum Concentration[b] (mg/kg or pCi/g)</th><th rowspan="2">Layer Average[b] (mg/kg or pCi/g)</th><th rowspan="2">SADA Layer[c] (mg/kg or pCi/g)</th><th rowspan="2">RG for soil (mg/kg or pCi/g)</th></tr>
<tr><th>SADA Layer[a]</th><th>Start</th><th>End</th></tr>
<tr><td>Technetium-99</td><td colspan="6"></td><td>5.4</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>2</td><td>17</td><td>7.9</td><td>7.2</td><td>Y</td></tr>
<tr><td>2</td><td>10</td><td>15</td><td>0</td><td>ND</td><td>ND</td><td>0</td><td>N</td></tr>
<tr><td>3</td><td>15</td><td>20</td><td>0</td><td>0.04</td><td>0.04</td><td>0</td><td>N</td></tr>
<tr><td rowspan="2">4</td><td>20</td><td>25</td><td rowspan="2">0</td><td rowspan="2">1.3</td><td rowspan="2">1.3</td><td rowspan="2">0</td><td rowspan="2">N</td></tr>
<tr><td>25</td><td>30</td></tr>
<tr><td rowspan="2">5</td><td>30</td><td>35</td><td rowspan="2">0</td><td rowspan="2">ND</td><td rowspan="2">ND</td><td rowspan="2">0</td><td rowspan="2">N</td></tr>
<tr><td>35</td><td>40</td></tr>
<tr><td>6</td><td>40</td><td>45</td><td>0</td><td>0.18</td><td>0.10</td><td>0</td><td>N</td></tr>
<tr><td rowspan="2">7</td><td>50</td><td>55</td><td rowspan="2">0</td><td rowspan="2">ND</td><td rowspan="2">ND</td><td rowspan="2">0</td><td rowspan="2">NA</td></tr>
<tr><td>60</td><td>65</td></tr>
<tr><td>PCBs</td><td colspan="6"></td><td>10</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>0</td><td>ND</td><td>ND</td><td>0.15</td><td>N</td></tr>
<tr><td>2</td><td>10</td><td>15</td><td>0</td><td>ND</td><td>ND</td><td>0.00</td><td>N</td></tr>
<tr><td>3</td><td>15</td><td>20</td><td>0</td><td>ND</td><td>ND</td><td>0.00</td><td>N</td></tr>
<tr><td rowspan="2">4</td><td>20</td><td>25</td><td rowspan="2">0</td><td rowspan="2">ND</td><td rowspan="2">ND</td><td rowspan="2">0.00</td><td rowspan="2">N</td></tr>
<tr><td>25</td><td>30</td></tr>
<tr><td rowspan="2">5</td><td>30</td><td>35</td><td rowspan="2">0</td><td rowspan="2">ND</td><td rowspan="2">ND</td><td rowspan="2">0.00</td><td rowspan="2">N</td></tr>
<tr><td>35</td><td>40</td></tr>
<tr><td>6</td><td>40</td><td>45</td><td>0</td><td>ND</td><td>ND</td><td>0.00</td><td>N</td></tr>
<tr><td rowspan="2">7</td><td>50</td><td>55</td><td rowspan="2">0</td><td rowspan="2">ND</td><td rowspan="2">ND</td><td rowspan="2">0.00</td><td rowspan="2">N</td></tr>
<tr><td>60</td><td>65</td></tr>
<tr><td colspan="8">COCs Identified for Surface Soil only</td></tr>
<tr><td>Naphthalene</td><td colspan="6"></td><td>0.0060</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>1</td><td>0.75</td><td>0.75</td><td>3.8</td><td>Y</td></tr>
<tr><td>PAHs[d]</td><td colspan="6"></td><td>1.2</td></tr>
<tr><td>1</td><td>0</td><td>1</td><td>4</td><td>34</td><td>7.6</td><td>6.1</td><td>Y</td></tr>
</table>

COC—Identified according to criteria specified in the BHHRA and for inorganic constituents that exceed the range of Background for PGDP.
RG—Preliminary Remediation Goal.
N—The average layer concentration is less than the RG for subsurface soils. No action is warranted for soils in this layer, except where maximum concentrations exceed the RG.
N—not detected.
Y—Bold, red typeface indicates the layer's mean concentration exceeds the RG for subsurface soils. An action is warranted to reduce concentration within the layer to below the RG.
H—Bold, orange typeface indicates the maximum concentration within the layer exceeds the RG for subsurface soils. An action to reduce concentration at a "hotspot" to below the RG may be needed.
[a] SADA Layer corresponds to the layer depth intervals used in the geostatistical model developed for the BGOU fate and transport modeling.
[b] Data for subsurface soil are detected concentrations as reported in Table 4.13 of the BGOU RI Report only. Nondetect results are not included in the computation of the layer mean. Surface soil data was obtained from the database in Appendix C of the BGOU RI Report.
[c] SADA layer concentrations are from reported values in Table E.3.15, Appendix E of the BGOU RI Report.
[d] Samples in which PAHs were detected were collected from surface sediments near SWMU 5. These samples are not within SWMU 5 and are associated with surface drainage control features and not associated with activities at SWMU 5 and, therefore, do not drive actions at SWMU 5.

Table A.5. Comparison of Average Layer Soil Concentrations of COCs to Remediation Goals for SWMU 6

COC	Sample Depths (ft)		Detectable Concentrations greater than the RG	Maximum Concentration[b] (mg/kg or pCi/g)	Layer Average[b] (mg/kg or pCi/g)	SADA Layer[c] (mg/kg or pCi/g)	RG for soil (mg/kg or pCi/g)
	Start	End					
COCs detected in Surface Soils only							
Total PAH[b]							**1.16**
1	0	1	0	0.50	0.42	NA	N

COC—Identified according to criteria specified in the BHHRA and for inorganic constituents that exceed the range of Background for PGDP.
RG—Preliminary Remediation Goal.
N—The average layer concentration is less than the RG for subsurface soils. No action is warranted for soils in this layer, except where maximum concentrations exceed the RG.
ND—not detected.
Y—Bold, red typeface indicates the layer's mean concentration exceeds the RG for subsurface soils. An action is warranted to reduce concentration within the layer to below the RG.
H—Bold, orange typeface indicates the maximum concentration within the layer exceeds the RG for subsurface soils. An action to reduce concentration at a “hotspot” to below the RG may be needed.
[a] SADA Layer corresponds to the layer depth intervals used in the geostatistical model developed for the BGOU fate and transport modeling.
[b] Surface soil data was obtained from the database in Appendix C of the BGOU RI Report. Samples were collected from surface sediments near SWMU 6 where PAHs were detected. These samples are not with in SWMU 6 and are associated with surface drainage control features and not associated with activities at SWMU 6 and, therefore, do not drive actions at SWMU 6.
[c] SADA layer concentrations are from reported values in Table E.3.19, Appendix E of the RI Report.

Table A.6. Comparison of Average Layer Soil Concentrations of COCs to Remediation Goals for SWMU 7

COC SADA Layer[a]	Sample Depths (ft) Start	 End	Detectable Concentrations greater than the RG	Maximum Concentration[b] (mg/kg or pCi/g)	Layer Average[b] (mg/kg or pCi/g)	SADA Layer[c] (mg/kg or pCi/g)	RG for soil (mg/kg or pCi/g)
1,1-DCE							**0.16**
1	0	1	0	ND	ND	0	N
2	5 10	10	1	**1.1**	**1.1**	**0.87**	**H**
3	15		10	**1.7**	**1.7**	**0.77**	**Y**
4	30		0	ND	ND	**0.80**	N
6	45		0	0.0065	0.0065	**0.68**	N
7	60		0	0.0055	0.0055	**0.53**	N
TCE							**0.10**
1	0	1	0	ND	ND	0	N
2	5 10	10	0	0.01	0.01	**0.56**	N
3	15		0	0.01	0.01	**0.57**	N
4	30		1	**0.26**	0.10	**0.82**	**H**
6	45		2	**0.16**	**0.12**	**1.00**	**Y**
7	60		0	0.09	0.09	**0.69**	N
***cis*-1,2-DCE**							**1.47**
1	0	1	0	ND	ND	0.0	N
2	5 10	10	0	0.03	0.02	1.0	N
3	15		0	0.01	0.01	0.97	N
4	30		0	0.68	0.19	1.1	N
6	45		0	0.10	0.06	1.1	N
7	60		0	0.01	0.01	**7.1**	N
Vinyl chloride							**0.08**
1	0	1	0	ND	ND	0	N
2	5 10	10	0	0.01	0.01	**0.13**	N
3	15		0	0.01	0.01	**0.15**	N
4	30		1	**0.59**	**0.31**	**0.15**	**H**
6	45		0	ND	ND	**0.59**	N
7	60		0	ND	ND	**0.59**	N
Uranium (mg/kg)						**Subsurface** **Surface**	**101** **113**
1	0	1	1	**1270**	**689**	**375**	**H**
2	5 10	10	0	45	10	16	N
3	15		0	ND	ND	21.4	N
4	30		0	1.5	1.3	16.2	N
6	45		0	1.3	1.3	12.3	N
7	60		0	1.2	1.1	14.8	N

Table A.6. Comparison of Average Layer Soil Concentrations of COCs to Remediation Goals for SWMU 7 (Continued)

COC / SADA Layer[a]	Sample Depths (ft) Start	End	Detectable Concentrations greater than the RG	Maximum Concentration[b] (mg/kg or pCi/g)	Layer Average[b] (mg/kg or pCi/g)	SADA Layer[c] (mg/kg or pCi/g)	RG for soil (mg/kg or pCi/g)
Neptunium-237						**Subsurface**	**1.4**
						Surface	**16**
1	0	1	0	0.8	0.8	SADA Layer Means not calculated	N
2	5 / 10	10	0	0.032	0.032		N
3	15		0	ND	ND		N
4	30		0	ND	ND		N
6	45		0	ND	ND		N
7	60		0	ND	ND		N
Plutonium-239/240[d]						**Subsurface**	**82**
						Surface	**58**
1	0	1	0	0.1	0.1	SADA Layer Means not calculated	N
2	3 / 10	5	0	0.136	0.136		N
3	15		0	ND	ND		N
4	30		0	ND	ND		N
6	45		0	ND	ND		N
7	60		0	ND	ND		N
Technetium-99							**7.2**
1	0	1	1	**11**	6.5	**54**	**H**
2	5 / 10	10	1	**8.2**	3.3	2.2	**H**
3	15		0	2.7	2.3	2.2	N
4	30		0	2.5	2.4	2.2	N
6	45		0	3.0	2.4	1.9	N
7	60		0	2.2	2.1	2.1	N
Uranium-234						**Subsurface**	**142**
						Surface	**99**
1	0	1	0	1.94	1.6	61	N
2	5 / 10	10	0	115	9.1	3	N
3	15		0	15	8.1	3.12	N
4	30		0	0.3	0.2	12.13	N
6	45		0	0.4	0.3	11.24	N
7	60		0	0.33	0.24	8.23	N

Table A.6. Comparison of Average Layer Soil Concentrations of COCs to Remediation Goals for SWMU 7 (Continued)

COC / SADA Layer[a]	Sample Depths (ft) Start	Sample Depths (ft) End	Detectable Concentrations greater than the RG	Maximum Concentration[b] (mg/kg or pCi/g)	Layer Average[b] (mg/kg or pCi/g)	SADA Layer[c] (mg/kg or pCi/g)	RG for soil (mg/kg or pCi/g)
Uranium-235/236[e]							**2.0**
2	5	10	0	1.0	0.5	NA	N
	10		Uranium 235/236 in L3 through L7 are not reported				
3	15						
4	30						
6	45						
7	60						
Uranium-238						**Subsurface**	**59**
						Surface	**8.6**
1	0	1	2	**2390**	**1282.0**	**388**	**Y**
2	5	10	0	6	1.5	8.7	N
	10						
3	15		0	0	0.2	24	N
4	30		0	0.5	0.3	26	N
6	45		0	1.3	0.6	25	N
7	60		0	0.20	0.20	22	N
These COCs were identified for Surface Soil only at SWMU 7							
PCBs							**10**
1	0	1	1	**15**	7.5	1.1	**H**
PAHs[d]							**1.1**
1	0	1	0	ND	ND	1.1	N

COC—Identified according to criteria specified in the BHHRA and for inorganic constituents that exceed the range of Background for PGDP.
RG—Preliminary Remediation Goal.
N—The average layer concentration is less than the RG for subsurface soils. No action is warranted for soils in this layer, except where maximum concentrations exceed the RG.
ND—not detected.
Y—Bold, red typeface indicates the layer's mean concentration exceeds the RG for subsurface soils. An action is warranted to reduce concentration within the layer to below the RG.
H—Bold, orange typeface indicates the maximum concentration within the layer exceeds the RG for subsurface soils. An action to reduce concentration at a "hotspot" to below the RG may be needed.
[a] SADA Layer corresponds to the layer depth intervals used in the geostatistical model developed for the BGOU fate and transport modeling.
[b] Data for subsurface soil are detected concentrations as reported in Table 4.17 of the BGOU RI Report only. Nondetect results are not included in the computation of the layer mean.
[c] SADA layer concentrations are from reported values in Table E.3.21, Appendix E of the RI Report.
[d] RG is for Plutonium-239; decay energies of these isotopes are so close that these isotopes may not be distinguishable.
[e] RG is for Uranium-235; decay energies of these isotopes are so close that these isotopes may not be distinguishable.
[f] Samples in which PAHs were detected were collected from surface sediments near SWMU 7. These samples are not with in SWMU 7 and are associated with surface drainage control features and not associated with activities at SWMU 7 and, therefore, do not drive actions at SWMU 7.

Table A.7. Comparison of Average Layer Soil Concentrations of COCs to Remediation Goals for SWMU 30

COC / SADA Layer[a]	Sample Depths (ft) Start	Sample Depths (ft) End	Detectable Concentrations greater than the RG	Maximum Concentration[b] (mg/kg or pCi/g)	Layer Average[b] (mg/kg or pCi/g)	SADA Layer[c] (mg/kg or pCi/g)	RG for soil (mg/kg or pCi/g)
Neptunium-237						**Subsurface**	**16.4**
						Surface	**1.4**
1	0		0	0.5	0.2	SADA Layer Means were not developed for Np-237	N
2	5 / 10	10	0	0.06	0.06		N
3	15		0	ND	ND		N
4	30		0	ND	ND		N
[d] 6	45		0	ND	ND		N
7	60		0	ND	ND		N
Plutonium-239[e]						**Subsurface**	**81.0**
						Surface	**57.8**
1	0		0	0.6	0.2	21	N
2	5 / 10	10	0	0.19	0.10	1.8	N
3	15		0	ND	ND	1.5	N
4	30		0	ND	ND	1.4	N
6	45		0	ND	ND	0.89	N
7	60		0	ND	ND	0.86	N
Technetium-99							**11.7**
1	0		0	2.5	1.0	**21**	N
2	5 / 10	10	0	6.8	1.9	1.8	N
3	15		0	ND	ND	1.5	N
4	30		0	ND	ND	1.4	N
6	45		0	ND	ND	0.89	N
7	60		0	ND	ND	0.86	N
Uranium (pCi/g)[f]						**Subsurface**	**58.5**
						Surface	**8.55**
1	0		5	**1400**	**405**	**797**	**Y**
2	5 / 10	10	1	**59**	24	4.4	**H**
3	15		0	3.0	2.1	4.2	N
4	30		0	ND	ND	4.2	N
6	45		0	0.82	0.82	4.1	N
7	60		0	0.65	0.65	3.9	N
Uranium-234						**Subsurface**	**142**
						Surface	**99**
1	0		2	**115**	56	43	**H**
2	5 / 10	10	0	21	5.2	4.4	N
3	15		0	2	1.5	4.6	N
4	30		0	ND	ND	4.5	N
6	45		0	0.43	0.25	4.0	N
7	60		0	0.52	0.28	3.5	N

Table A.7. Comparison of Average Layer Soil Concentrations of COCs to Remediation Goals for SWMU 30 (Continued)

COC / SADA Layer[a]	Sample Depths (ft) Start	Sample Depths (ft) End	Detectable Concentrations greater than the RG	Maximum Concentration[b] (mg/kg or pCi/g)	Layer Average[b] (mg/kg or pCi/g)	SADA Layer[c] (mg/kg or pCi/g)	RG for soil (mg/kg or pCi/g)
Uranium-235/236[g]						**Subsurface**	**22.8**
						Surface	**2.0**
1	0		3	17	6	4.4	Y
2	5	10	0	0.55	0.25	0.31	N
	10		Data is not reported below 7 ft in depth			0.33	NA
3	15					0.31	
4	30					0.34	
6	45					0.35	
7	60					0.36	
Uranium-238						**Subsurface**	**59**
						Surface	**8.5**
1	0		4	565	167	104	Y
2	5	10	0	37	10	7.6	N
	10						
3	15		0	1	0.6	9.4	N
4	30		0	ND	ND	10	N
6	45		0	0.36	0.25	9.0	N
7	60		0	ND	ND	8.6	N
1,1-DCE							**1.6**
1	0		0	ND	ND	0	N
2	5	10	0	0.06	0.02	0	N
	10						
3	15		0	ND	ND	0	N
4	30		0	ND	ND	0	N
6	45		0	ND	ND	5	N
7	60		0	ND	ND	5	N
TCE							**0.6**
1	0		0	ND	ND	0	N
2	5	10	0	ND	ND	0.037	N
	10						
3	15		0	ND	ND	0.037	N
4	30		0	0.04	0.037	0.037	N
6	45		0	ND	ND	0.037	N
7	60		0	ND	ND	0.037	N
PCBs, Total							**10**
1	0		1	15	2.87	1.74	H
2	5	10	0	0.18	0.07	0.08	N
	10						
3	15		0	ND	ND	0.07	N
4	30		0	ND	ND	0.07	N
6	45		0	ND	ND	0.05	N
7	60		0	ND	ND	0.05	N

Table A.7. Comparison of Average Layer Soil Concentrations of COCs to Remediation Goals for SWMU 30 (Continued)

COC SADA Layer[a]	Sample Depths (ft) Start	End	Detectable Concentrations greater than the RG	Maximum Concentration[b] (mg/kg or pCi/g)	Layer Average[b] (mg/kg or pCi/g)	SADA Layer[c] (mg/kg or pCi/g)	RG for soil (mg/kg or pCi/g) SADA Layer[a]
PAHs [h]						**Subsurface**	**1.16**
						Surface	**0.106**
1	0		3	**11**	**2**	**1**	**Y**
2	5	10	0	0.11	0.02	0.05	N
	10						
3	15		0	ND	ND	0.05	N
4	30		0	ND	ND	0.05	N
6	45		0	ND	ND	0.05	N
7	60		0	ND	ND	0.05	N

COC—Identified according to criteria specified in the BHHRA and for inorganic constituents that exceed the range of Background for PGDP.
RG—Preliminary Remediation Goal.
N—The average layer concentration is less than the RG for subsurface soils. No action is warranted for soils in this layer, except where maximum concentrations exceed the RG.
ND—not detected.
Y—Red bold typeface indicates the layer's mean concentration exceeds the RG for subsurface soils. An action is warranted to reduce concentration within the layer to below the RG.
H—Orange bold typeface indicates the maximum concentration within the layer exceeds the RG for subsurface soils. An action to reduce concentration at a "hotspot" to below the RG may be needed.
[a] SADA Layer corresponds to the layer depth intervals used in the geostatistical model developed for the BGOU fate and transport modeling.
[b] Data for subsurface soil are detected concentrations as reported in Table 4.19 of the BGOU RI Report only. Nondetect results are not included in the computation of the layer mean. Surface soil data was obtained from the database in Appendix C of the BGOU RI Report.
[c] SADA layer concentrations are from reported values in Table E.3.25, Appendix E of the RI Report
[d] No data is available for Layer 5, 30 to 40 ft depth.
[e] RG is for Plutonium-239; decay energies of these isotopes are so close that these isotopes may not be distinguishable.
[f] Total uranium is reported only in pCi/g in Table 4.40, BGOU RI. The RG for Uranium metal given in this table assumes all activity is uranium 238.
[g] RG is for uranium-235; decay energies of these isotopes are so close that these isotopes may not be distinguishable. Total uranium is reported in pCi/g, consistent with Table 4.40 BGOU RI.
[h] Samples in which PAHs were detected were collected from surface sediment locations near SWMU 30. These samples are not within SWMU 30 and are associated with surface drainage control features and not associated with activities at SWMU 30 and, therefore, do not drive actions at SWMU 30.

Table A.8. Comparison of Average Layer Soil Concentrations of COCs to Remediation Goals for SWMU 145

COC / SADA Layer[a]	Sample Depths (ft) Start	Sample Depths (ft) End	Detectable Concentrations greater than the RG	Maximum Concentration[b] (mg/kg or pCi/g)	Layer Average[b] (mg/kg or pCi/g)	SADA Layer[c] (mg/kg or pCi/g)	RG for soil (mg/kg or pCi/g)
Technetium-99							**8.1**
2	2	4	6	**153**	**67**	**27**	**Y**
	8	10					
3	11	15	3	**281**	**103**	**16**	**Y**
4	19	25	0	ND	ND	**16**	N
5	30	34	0	ND	ND	**16**	N
	35	37					
6	40	45	0	ND	ND	**12**	N
7	55	60	0	ND	ND	**12**	N

COC—Identified according to criteria specified in the BHHRA and for inorganic constituents that exceed the range of Background for PGDP.
RG—Preliminary Remediation Goal.
N—The average layer concentration is less than the RG for subsurface soils. No action is warranted for soils in this layer, except where maximum concentrations exceed the RG.
ND—not detected.
Y—Red bold typeface indicates the layer's mean concentration exceeds the RG for subsurface soils. An action is warranted to reduce concentration within the layer to below the RG.
H—Orange bold typeface indicates the maximum concentration within the layer exceeds the RG for subsurface soils. An action to reduce concentration at a “hotspot” to below the RG may be needed.
NA—Not Applicable, no exposure pathway exists.
[a] SADA Layer corresponds to the layer depth intervals used in the geostatistical model developed for the BGOU fate and transport modeling.
[b] Data for subsurface soil are detected concentrations as reported in Table 4.21 of the BGOU RI Report only. Nondetect results are not included in the computation of the layer mean. Surface soil data was obtained from the database in Appendix C of the BGOU RI Report.
[c] SADA layer concentrations are from reported values in Table E.3.29, Appendix E of the RI Report.

While aluminum and iron have been identified as COCs for the direct contact pathway at one or more of the BGOU SWMUs, these constituents form insoluble oxide minerals under the soil conditions at the BGOU (Garrels and Christ 1965; Prosbska and Mulder 2005) and, therefore, do not pose a threat to groundwater. Furthermore, all the detectable concentrations of the metals listed were, as discussed previously, found to be within the range of background; therefore, they are not considered to be risk drivers.

In addition, transport modeling shows that uranium (all isotopes) is not mobile in the soil environment found at the BGOU SWMUs. Uranium has about one half the mobility of neptunium (EPA 2000). The Preliminary RGs for COCs that are not mobile in soils will be the RG for the direct contact exposure pathway. Because the depth limit of wastes present in the BGOU SWMUs is less than 20 ft, direct exposure to soils below this depth will not occur. Thus, this exposure pathway is not applicable to Layers L3 to L7. This is indicated in Tables A.1 to A.8 by an "NA" in L3 to L7 where a soil concentration exceeds the RG for these COCs. Exceeding the RG in L3 through L7 for these COCs will not be a basis for remedial action.

The summary tables provide the following information for each COC for conceptual model Layers 1 through 7:

- The number of detectable concentrations above the RG in each layer;
- The maximum detectable concentration in each layer;
- The average concentration for the layer;
- The SADA model average concentration for each layer; and
- An indication if the layer exhibits an impact that may require an action.

Where the maximum and the average are different and only one detectable concentration exceeds the RG, one or more detectable concentrations below the RG bring down the average. Concentrations that exceed an RG are shown in a bold, red typeface. If the layer average concentration exceeds the RG, a bold, red "Y" is present in the last column. If a subsurface layer average concentration is below the RG, but the maximum concentration exceeds the RG, a bold, orange "H" is present in the last column indicating the presence of a "hotspot." The last column shown for the surface layer is the RG.

Summary of COC Distribution at Levels Warranting Action

The following summarizes by SWMU the layers that exhibit COCs and whether the entire layer within the SWMU appears contaminated or if the concentrations are localized and may be treated without addressing the entire layer. Surface soil data were obtained from Appendix C of the BGOU RI Report (DOE 2010). A tabular summary of the results generated by comparing COC concentrations to the RGs is provided as Table A.9.

The Remedial Alternatives in Chapters 5 through 12 of the FS were developed by using these comparisons to establish if contamination extended beyond the bottom of the buried waste (Layer 2) or if COCs were present in the subsurface. The summary of COCs that are present at concentrations potentially warranting action is based on the soils data in Tables A.1 to A.8, and the vertical distributions represented in Table A.9.

Table A.9. Summary of COCs Exceeding Remediation Goals

SADA Layer (Depth in feet below grade)	^{237}Pu	^{237}Np	^{99}Tc	Uranium	^{234}U	$^{235/236}U$	^{238}U	1,1 DCE	TCE	*Cis* 1,2 DCE	Vinyl Chloride	Naphthalene	PCBs
SWMU 2													
1 (0-1 ft bgs)	N	N	H	A			H	N			N	A	N
2 (1-10 ft bgs)	N	N		H	H	H	H	N	H	H	N		N
3 (10-20 ft bgs)	N	N						N	H	H	N		N
4 (20-30 ft bgs)	N	N						N			N		N
5 (30-40 ft bgs)	N	N						N			N		N
6 (40-50 ft bgs)	N	N						N	H		N		N
7 (50-65 ft bgs)	N	N						N			N		N
SWMU 3													
1 (0-1 ft bgs)	N	N	A		N			N	N	N	N	N	N
2 (1-10 ft bgs)	N	N	A		N			N	N	N	N	N	N
3 (10-20 ft bgs)	N	N			N			N	N	N	N	N	N
4 (20-30 ft bgs)	N	N			N			N	N	N	N	N	N
5 (30-40 ft bgs)	N	N			N			N	N	N	N	N	N
6 (40-50 ft bgs)	N	N			N			N	N	N	N	N	N
7 (50-65 ft bgs)	N	N			N			N	N	N	N	N	N
SWMU 4													
1 (0-1 ft bgs)	N	N	H	A	N	N	A	N				N	H
2 (1-10 ft bgs)	N	N	A	A	N	N	H	N				N	H
3 (10-20 ft bgs)	N	N			N	N		N	A		H	N	
4 (20-30 ft bgs)	N	N			N	N		N	A			N	
5 (30-40 ft bgs)	N	N			N	N		N	A		A	N	
6 (40-50 ft bgs)	N	N			N	N		N	A	A		N	
7 (50 - 65 ft bgs)	N	N			N	N		N	A	A	H	N	
SWMU 5													
1 (0-1 ft bgs)	N	N	A	N	N	N	N	N	N	N	N	A	
2 (1-10 ft bgs)	N	N		N	N	N	N	N	N	N	N	N	
3 (10-20 ft bgs)	N	N		N	N	N	N	N	N	N	N	N	
4 (20-30 ft bgs)	N	N		N	N	N	N	N	N	N	N	N	
5 (30-40 ft bgs)	N	N		N	N	N	N	N	N	N	N	N	
6 (40-50 ft bgs)	N	N		N	N	N	N	N	N	N	N	N	
7 (50-65 ft bgs)	N	N		N	N	N	N	N	N	N	N	N	

Table A.9. Summary of COCs Exceeding Remediation Goals (Continued)

SADA Layer (Depth in feet below grade)	^{237}Pu	^{237}Np	^{99}Tc	Uranium	^{234}U	$^{235/236}$U	^{238}U	1,1 DCE	TCE	*Cis* 1,2 DCE	Vinyl Chloride	Naphthalene	PCBs
SWMU 6													
1 (0-1 ft bgs)	N	N	N	N	N	N	N	N	N	N	N	N	N
2 (1-10 ft bgs)	N	N	N	N	N	N	N	N	N	N	N	N	N
3 (10-20 ft bgs)	N	N	N	N	N	N	N	N	N	N	N	N	N
4 (20-30 ft bgs)	N	N	N	N	N	N	N	N	N	N	N	N	N
5 (30-40 ft bgs)	N	N	N	N	N	N	N	N	N	N	N	N	N
6 (40-50 ft bgs)	N	N	N	N	N	N	N	N	N	N	N	N	N
7 (50-65 ft bgs)	N	N	N	N	N	N	N	N	N	N	N	N	N
SWMU 7													
1 (0-1 ft bgs)			H	H			A					N	H
2 (1-10 ft bgs)			H					H				N	
3 (10-20 ft bgs)								A				N	
4 (20-30 ft bgs)									H		H	N	
5 (30-40 ft bgs)	**Data not available for this layer**												
6 (40-50 ft bgs)									A			N	
7 (50-65 ft bgs)												N	
SWMU 30													
1 (0-1 ft bgs)				A	H	A	A			N	N	N	H
2 (1-10 ft bgs)				H						N	N	N	
3 (10-20 ft bgs)										N	N	N	
4 (20-30 ft bgs)										N	N	N	
5 (30-40 ft bgs)										N	N	N	
6 (40-50 ft bgs)										N	N	N	
7 (50-65 ft bgs)										N	N	N	
SWMU 145													
1 (0-1 ft bgs)	N	N	A	N	N	N	N	N	N	N	N	N	N
2 (1-10 ft bgs)	N	N	A	N	N	N	N	N	N	N	N	N	N
3 (10-20 ft bgs)	N	N		N	N	N	N	N	N	N	N	N	N
4 (20-30 ft bgs)	N	N		N	N	N	N	N	N	N	N	N	N
5 (30-40 ft bgs)	N	N		N	N	N	N	N	N	N	N	N	N
6 (40-50 ft bgs)	N	N		N	N	N	N	N	N	N	N	N	N
7 (50-65 ft bgs)	N	N		N	N	N	N	N	N	N	N	N	N

Transport modeling indicates neither neptunium nor uranium reaches the RGA from Layer 3.
PAHs were detected in isolated hotspots at SWMUs 6 and 30. These samples were sediments collected from ditches in or near the SWMUs and are not included in this Table.
Blanks cells indicate the COC is not present at that depth in concentrations that exceed its RG.

A	COC is detected above the RG at a frequency sufficiently high to warrant action for the entire waste unit.
H	COC is detected at concentrations above the RG in one or more samples.
N	Constituent was not identified as a COC for this SWMU.

The surface soil data sets include data collected near the SWMUs that may exhibit impact resulting from activities extraneous to the SWMU. Where surface soil data appears to drive an action at a SWMU, some additional assessment of those samples is warranted to establish if the contamination actually derives from the unit, as discussed below.

SWMU 2

Remedial action is recommended at SWMU 2 because of the presence of radioactive COCs in Layers 1 and 2, as well as the presence of volatile organic compounds (VOCs) in Layer 3 exceeding their respective RGs. The actions evaluated for SWMU 2 should address the radioactive COCs, as well as the VOCs present in Layers 1 to 3. Special consideration is required for the remediation of SWMU 2 because there is historical documentation stating that pyrophoric uranium was disposed of in this unit (DOE 2010).

SWMU 3

An existing Resource Conservation and Recovery Act cap at SWMU 3 appears to be effective in containing buried wastes and limiting infiltration from the surface, based on available leachate data and volumes.

SWMU 4

Remedial action is recommended at SWMU 4 because Layers 1 and 2 exhibit contamination by technetium-99 and uranium, and trichloroethene (TCE) and its degradation products (collectively TCE) are present in the subsurface (Layers 3 to 7) at levels that indicate continued impact to groundwater will occur. The TCE at SWMU 4 is suspected to extend down through the Upper Continental Recharge System and into the RGA. Radioactive COCs also are present at SWMU 4 in Layers 1 and 2 in concentrations exceeding their respective RGs. The nature and extent of contamination at SWMU 4 will require remedial action(s) that are effective for the radioactive COCs in Layers 1 to 3, as well as the VOCs present below Layer 3 and extending into the RGA.

SWMU 5

Remedial action at SWMU 5 should target the COCs in the surface soils that exceed their respective RGs; however, these COCs are associated with drainage features that will be addressed as part of the actions being taken for the sitewide Surface Water Operable Unit.

SWMU 6

The data points available for SWMU 6 indicate that COCs that might warrant action are associated with the roadway and a drainage feature and do not appear to be related to waste disposal activities at SWMU 6. Otherwise, the conditions at SWMU 6 do not appear to require any remedial action.

SWMU 7

Remedial action(s) implemented at SWMU 7 should address the TCE potentially present in the subsurface as well as the radioactive and inorganic COCs present in surface soils.

SWMU 30

The surface soil at SWMU 30 may require action, but there are only localized, infrequent, and dispersed concentrations of COCs present in the subsurface at SWMU 30 below 10 ft that exceed their RGs. There is no indication that there is contamination with any COC present in a subsurface layer at SWMU 30 that requires remedial action. A limited surface soil action may be appropriate for SWMU 30.

SWMU 145

There is an indication that technetium-99 contamination exceeds its RG at SWMU 145, but, based on the available data from the BGOU RI Report, the contamination is localized along the course of the former North-South Diversion Ditch. Groundwater data presented in the BGOU RI postulates a TCE source near or at SWMU 145 (DOE 2010), possibly inside the boundary of SWMU 145. A review of recent groundwater compliance monitoring data for the S&T landfills indicates that, if a TCE source is present, it is a diminishing source. Targeted remedial action for the technetium-99 contamination present at SWMU 145 and additional groundwater monitoring for SWMU 145 will address the technetium-99 and confirm the status of the potential TCE source. Remedial action at SWMU 145 must consider the proximity of SWMUs 9 and 10 and avoid negatively impacting those closed SWMUs.

REFERENCES

DOE (U.S. Department of Energy) 2010. *Remedial Investigation Report for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0030&D2, U.S. Department of Energy, Paducah, KY, April.

EPA (U.S. Environmental Protection Agency) 2000. *Soil Screening Guidance for Radionuclides: Technical Background Document*, Environmental Protection Agency, EPA/540-R-00-006, PB2000 963306, October.

Garrels, R.M. and C.I. Christ 1965. *Solutions, Minerals and Equilibria*; Freeman, Cooper, and Company, San Francisco, CA, Page 222.

Prosbska, G. and J. Mulder 2005. “The Chemistry of Aluminum in Strongly Acidified Sandy Soil in Poland;” *European Journal of Soil Science*, Volume 47, Issue 1, Pages 81-87, August.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX B

MODELING RESULTS

THIS PAGE INTENTIONALLY LEFT BLANK

B. MODELING RESULTS

Fate and transport modeling was conducted in support of the Burial Grounds Operable Unit (BGOU) Feasibility Study (FS). This modeling was necessary to evaluate the potential impact of contaminant concentrations in the waste zone [i.e., source layer 3 in Seasonal Soil Compartment Model (SESOIL) representing 10-20 ft depth interval]. The allowable contaminants of concern (COCs) soil concentrations for SESOIL layer 3 were then calculated based on the resulting groundwater concentrations from a unit source inventory in layer 3. The parameter values provided in Table B.1 were used in the modeling analyses and are the same values as those used in the BGOU Remedial Investigation (RI). The parameter values for the Upper Continental Recharge System (UCRS) and used in the SESOIL model are provided in Table B.2. The parameter values for the Regional Gravel Aquifer (RGA) and used in the AT123D model are provided in Table B.3. These model parameters are the same as those used in the BGOU RI modeling analyses.

B1.1 MODELING TO DEVELOP REMEDIATION GOALS

To establish the remediation goals (RGs) for the COCs, SESOIL contaminant layer 3 was set to a unit concentration (i.e., 1 mg/kg), while all other layers were set to zero concentration. The resulting groundwater concentration in the RGA directly below the solid waste management units (SWMUs) pathway of concern (POC) was obtained. The ratio of the soil concentration (e.g., 1 mg/kg) to the groundwater concentration in the RGA below the SWMU is the dilution attenuation factor:

$$\frac{[C]^{SOIL}\ mg/kg}{[C]^{GW}\ mg/L} = DAF\,(L/kg)$$

The dilution attenuation factor (DAF) is used to calculate the allowable concentrations in soil for the COCs that are protective of groundwater at the SWMU using the following equations (which are in footnotes to Tables 2.1 and 2.2 of the main text and in Table C.1):

For nonradiologic COCs

Groundwater-Protective Soil Concentration (mg/kg) = MCL (mg/L) x DAF (L/kg).

For radionuclides

Groundwater-Protective Soil Concentration (pCi/g) = MCL (pCi/L) x DAF (L/kg) x 1E-03 kg/g.

The results of the modeling analyses and DAF values are provided in Table B.4. The SESOIL and AT123D output data are provided in Attachments B.1 through B.7. The RGs are fully developed and presented in Appendix C.

Table B.5 illustrates the effect of applying a cover over the SWMU and reducing infiltration through the SWMU. By reducing surface infiltration and in turn reducing the migration potential of contaminants contained beneath the cover, the concentrations of contaminants that can be left in place are higher than the calculated RGs (Appendix C). The target groundwater concentrations from which these groundwater protective RGs for contained COCs are back-calculated are the maximum contaminant level (MCL) values.

Table B.1. Burial Grounds COCs for the Groundwater Pathway and Properties

Contaminant of Concern	Mol. Wt. (MW) (g/mol)	Solubility in water (mg/L)	Diffusion in air (cm^2/s)	Diffusion in water (m^2/hr)	Henry's Constant (atm.m3/mol)	Koc (L/kg)	Kd[a] (L/kg)	Half Life (years)
Antimony	121.75	1.00E+07	NA	3.60E-07	NA	NA	45	Infinite
PCB-1254	327	7.00E-02	1.56E-02	1.80E-06	3.40E-04	4.25E+04	34	Infinite
PCB-1260	375.7	2.70E-02	1.38E-02	1.56E-06	7.40E-05	2.07E+05	165.6	Infinite
cis-1,2-DCE	96.94	3.50E+03	0.07	4.07E-06	4.08E-03	35.5	0.028	Infinite
1,1-DCE	97	2.25E+03	0.09	3.74E-06	0.0261	65	0.013	Infinite
Naphthalene	128.16	31.0	0.059	3.28E-06	4.83E-04	1191.0	0.953	Infinite
^{137}Cs[b]	137	1.00E+07	NA	3.60E-07	NA	NA	280	30.17
^{90}Sr[b]	90	1.00E+07	NA	3.60E-07	NA	NA	1.0	28.6
^{237}Np	237	1.00E-07	NA	3.60E-07	NA	NA	70.0	2.14E+06
^{239}Pu	239	1.00E+07	NA	3.60E-07	NA	NA	550	2.41E+04
^{99}Tc	99	1.00E+07	NA	3.60E-07	NA	NA	0.2	2.13E+05
TCE	131	1,100	0.08	3.28E-06	0.0103	94	0.0752	26.6[c]
^{234}U	234	1.00E+07	NA	3.60E-07	NA	NA	66.8	2.44E+05
^{235}U	235	1.00E+07	NA	3.60E-07	NA	NA	66.8	7.04E+08
^{238}U	238	1.00E+07	NA	3.60E-07	NA	NA	66.8	4.47E+09
Uranium	238	1.00E+07	NA	3.60E-07	NA	NA	66.8	4.47E+09
Vinyl Chloride	63	2,760	0.11	4.43E-07	0.027	18.8	0.0152	Infinite

[a] Kd of an organic compound depends on the soil's organic content (foc) and compound's organic partition coefficient (Koc). Kd values presented for organic compounds are for UCRS soils (with foc value of 0.08%) only. Kd's used in AT123D are different due to the foc of 0.02% in the RGA.

[b] These radionuclides were not modeled in the RI because they were limited to surface soils. Their modeling parameters were taken from the U-Landfill Risk and Performance Evaluation Report. After completion of the modeling for the FS, ^{137}Cs and ^{90}Sr were not determined to be primary COCs for screening and analyzing alternatives.

[c] The 26.6 year half-life for TCE is applied to the URCS only (not used in the RGA).

Table B.2. Soil Parameters Used in SESOIL Modeling for the BGOU RI

Input Parameter	SWMU 2	Source
Soil type	Silty clay	PGDP site-specific
Bulk density (g/cm3)	1.46	Laboratory analysis
Percolation rate (cm/year)	11	PGDP calibrated model
Intrinsic permeability (cm2)	1.6E-10	Calibrated
Disconnectedness index	10	Calibrated
Porosity	0.45	Laboratory analysis
Depth to water table (m)		Site specific (to RGA) based on field observation
SWMU 2	19.5	
SWMU 3	19.8	
SWMU 4	19.2	
SWMU 5	18.3	
SWMU 6	19.2	
SWMU 7	18.3	
SWMU 30	18.6	
SWMU 145	17.7	
Fraction of organic carbon (%)	0.08	Laboratory analysis
Freundlich equation exponent	1	SESOIL default value

Table B.3. Hydrogeologic Parameters Used in AT123D Modeling for the BGOU RI

Input Parameter	SWMU 2	Source
Bulk density (kg/m3)	1,670	Laboratory analysis
Effective porosity	0.3	PGDP sitewide model calibrated value
Hydraulic conductivity (m/hour)		PGDP sitewide model calibrated value
SWMUs 2, 3, 4, 5, 6, 7, and 30	19.05	
SWMU 145	6.35	
Hydraulic gradient		PGDP sitewide model calibrated value
SWMUs 2 and 3	0.0002	
SWMU 4	0.0002	
SWMU 5	0.0002	
SWMUs 6 and 145	0.0008	
SWMU 7	0.0003	
SWMU 30	0.00036	
Aquifer thickness	9.14 m 30 ft	Site average
Longitudinal dispersivity (m)	15	Approximate values used in the past
Density of water (kg/m3)	1,000	Default
Fraction of organic carbon (%)	0.02	Laboratory analysis
Source Area	Variable	These dimensions were derived from the SADA analysis for each COPC in the BGOU RI.

Table B.4. Remediation Goal Based on Target Groundwater Concentrations at the SWMU

COC	Leachate Concentration (mg/L) *(pCi/L)*	Groundwater Concentration (mg/L) *(pCi/L)*	DAF	MCL (mg/L) *(pCi/L)*	Allowable Soil Concentration in Layer 3 (Initial RG) (mg/kg) *(pCi/g)*
SWMU 2					
cis-1,2-DCE	1.63E+00	5.23E-02	31	7.00E-02	2.18E+00
Naphthalene	4.97E-01	4.91E-02	10	2.00E-02	2.02E-01
TCE	3.97E-01	1.60E-02	25	5.00E-03	1.24E-01
Uranium	*No Load to Groundwater from SESOIL Layer 3*				
^{99}Tc	1.53E+00	1.37E-01	11	5.30E-05	5.91E-04
	2.59E+07	*2.32E+06*		*9.00E+02*	*1.00E+01*
SWMU 3					
cis-1,2-DCE	*No Load to Groundwater from SESOIL Layer 3*				
Uranium	*No Load to Groundwater from SESOIL Layer 3*				
^{238}U	*No Load to Groundwater from SESOIL Layer 3*				
^{99}Tc	1.52E+00	3.11E-01	5	5.30E-05	2.59E-04
	2.57E+07	*5.28E+06*		*9.00E+02*	*4.39E+00*
SWMU 4					
Uranium	*No Load to Groundwater from SESOIL Layer 3*				
^{234}U	*No Load to Groundwater from SESOIL Layer 3*				
^{137}Cs	*No Load to Groundwater from SESOIL Layer 3*				
cis-1,2-DCE	1.64E+00	1.44E-01	11	7.00E-02	7.95E-01
TCE	4.04E-01	5.01E-02	8	5.00E-03	4.03E-02
Vinyl Chloride	1.46E-01	8.29E-03	18	2.00E-03	3.53E-02
SWMU 5					
Aroclor-1260	*No Load to Groundwater from SESOIL Layer 3*				
Naphthalene	5.01E-01	2.15E-02	23	2.00E-02	1.00E+01
^{99}Tc	1.77E+00	2.55E-01	7	5.30E-05	3.68E-04
	3.00E+07	*4.33E+06*		*9.00E+02*	*6.25E+00*
SWMU 7					
^{99}Tc	1.55E+00	1.92E-01	8	5.30E-05	4.28E-04
	2.63E+07	*3.26E+06*		*9.00E+02*	*7.27E+00*
^{234}U	*No Load to Groundwater from SESOIL Layer 3*				
^{237}Np	*No Load to Groundwater from SESOIL Layer 3*				
cis-1,2-DCE	1.65E+00	7.83E-02	21	7.00E-02	1.47E+00
TCE	4.33E-01	2.14E-02	20	5.00E-03	1.01E-01
1,1-DCE	2.09E-01	9.06E-03	23	7.00E-03	1.61E-01
Vinyl Chloride	1.53E-01	3.75E-03	41	2.00E-03	8.18E-02
SWMU 30					
^{234}U	*No Load to Groundwater from SESOIL Layer 3*				

Table B.4. Remediation Goal Based on Target Groundwater Concentrations at the SWMU (Continued)

COC	Leachate Concentration (mg/L) *(pCi/L)*	Groundwater Concentration (mg/L) *(pCi/L)*	DAF	MCL (mg/L) *(pCi/L)*	Allowable Soil Concentration in Layer 3 (Initial RG) (mg/kg) *(pCi/g)*
^{235}U	*No Load to Groundwater from SESOIL Layer 3*				
^{238}U	*No Load to Groundwater from SESOIL Layer 3*				
^{237}Np	*No Load to Groundwater from SESOIL Layer 3*				
TCE	4.24E-01	3.34E-03	127	5.00E-03	6.34E-01
1,1-DCE	2.07E-01	9.29E-04	223	7.00E-03	1.56E+00
^{99}Tc	1.55E+00	1.22E-01	13	5.30E-05	6.74E-04
	2.63E+07	*2.07E+06*		*9.00E+02*	*1.14E+01*
SWMU 145					
Antimony	*No Load to Groundwater from SESOIL Layer 3*				
Aroclor-1254	*No Load to Groundwater from SESOIL Layer 3*				
Aroclor-1260	*No Load to Groundwater from SESOIL Layer 3*				
^{99}Tc	1.53E+00	1.61E-01	9	5.30E-05	5.03E-04
	2.59E+07	*2.73E+06*		*9.00E+02*	*8.53E+00*

COC = contaminant of concern
DAF = dilution attenuation factor
MCL = maximum contaminant level
DCE = dichloroethene
SWMU = solid waste management unit
TCE = trichloroethene

Table B.5. Remediation Goal Based on MCLs as Target Groundwater Concentrations at the SWMU

COC	Max Concentration (mg/Kg or *pCi/g*)	Calculated RGs at Reduced Infiltration										
		Infiltration Reduction Due to Capping										
		0%	*10%*	*20%*	*30%*	*40%*	*50%*	*60%*	*70%*	*80%*	*90%*	*99%*
SWMU 2												
cis-1,2-DCE	130	1.34E+00	1.53E+00	1.77E+00	2.06E+00	2.57E+00	3.27E+00	4.55E+00	7.06E+00	1.50E+01	9.89E+01	**6.48E+05**
Naphthalene	0.4	**4.07E-01**	**4.46E-01**	**4.90E-01**	**5.46E-01**	**6.31E-01**	**7.38E-01**	**9.17E-01**	**1.60E+00**	NV	NV	NV
TCE	140	3.13E-01	3.97E-01	5.13E-01	6.93E-01	1.05E+00	1.72E+00	3.42E+00	9.01E+00	5.03E+01	**4.59E+03**	NV
^{99}Tc	*2.24*	**6.57E+00**	**7.09E+00**	**7.69E+00**	**8.33E+00**	**9.34E+00**	**1.05E+01**	**1.22E+01**	**1.46E+01**	**1.91E+01**	**3.21E+01**	NV
SWMU 3												
^{99}Tc	2.4	**2.89E+00**	**3.10E+00**	**3.36E+00**	**3.66E+00**	**4.05E+00**	**4.62E+00**	**5.33E+00**	**6.47E+00**	**8.65E+00**	**1.49E+01**	NV
SWMU 4												
cis-1,2-DCE	4	4.86E-01	5.47E-01	6.42E-01	7.51E-01	9.00E-01	1.19E+00	1.63E+00	2.57E+00	**5.56E+00**	**3.78E+01**	**2.62E+05**
TCE	41	9.98E-02	1.23E-01	1.62E-01	2.19E-01	3.11E-01	5.44E-01	1.05E+00	2.84E+00	1.63E+01	**1.56E+03**	NV
Vinyl Chloride	0.29	**3.12E-01**	**4.64E-01**	**7.94E-01**	**1.43E+00**	**2.95E+00**	**9.71E+00**	**4.09E+01**	**4.18E+02**	**3.24E+04**	**4.19E+09**	NV
SWMU 5												
Naphthalene	0.75	**8.51E-01**	**9.30E-01**	**1.02E+00**	**1.14E+00**	**1.29E+00**	**1.52E+00**	**1.85E+00**	NV	NV	NV	NV
^{99}Tc	17	3.73E+00	4.02E+00	4.33E+00	4.71E+00	5.20E+00	5.84E+00	6.77E+00	8.11E+00	1.05E+01	**1.72E+01**	NV
SWMU 7												
Tc-99	11	4.69E+00	5.03E+00	5.42E+00	5.92E+00	6.52E+00	7.32E+00	8.49E+00	1.02E+01	**1.32E+01**	**2.15E+01**	NV
1,1-DCE	1.7	7.73E-01	1.11E+00	1.67E+00	**2.89E+00**	**5.60E+00**	**1.40E+01**	**5.11E+01**	**5.38E+02**	**1.65E+04**	**1.53E+10**	NV
cis-1,2-DCE	0.68	**8.94E-01**	**1.01E+00**	**1.16E+00**	**1.37E+00**	**1.67E+00**	**2.14E+00**	**2.97E+00**	**4.73E+00**	**1.02E+01**	**6.86E+01**	**5.98E+05**

Table B.5. Remediation Goal Based on MCLs as Target Groundwater Concentrations at the SWMU (Continued)

COC	Max Concentration (mg/Kg or *pCi/g*)	Calculated RGs at Reduced Infiltration										
		Infiltration Reduction Due to Capping										
		0%	*10%*	**20%**	*30%*	*40%*	*50%*	*60%*	*70%*	*80%*	*90%*	*99%*
TCE	0.3	2.34E-01	2.91E-01	**3.70E-01**	**5.07E-01**	**7.37E-01**	**1.21E+00**	**2.38E+00**	**6.60E+00**	**5.31E+01**	**3.68E+03**	NV
Vinyl Chloride	0.59	5.33E-01	**8.10E-01**	**1.31E+00**	**2.48E+00**	**5.39E+00**	**1.57E+01**	**7.19E+01**	**8.16E+02**	**6.99E+04**	**7.46E+09**	NV
SWMU 30												
1,1-DCE	0.06	**7.53E+00**	**1.11E+01**	**1.69E+01**	**2.79E+01**	**5.56E+01**	**1.40E+02**	**4.61E+02**	**3.55E+03**	**1.44E+05**	**1.41E+11**	NV
TCE	0.04	**1.50E+00**	**1.90E+00**	**2.45E+00**	**3.27E+00**	**4.85E+00**	**7.95E+00**	**1.49E+01**	**4.10E+01**	**2.37E+02**	**2.22E+04**	NV
^{99}Tc	6.8	**7.38E+00**	**7.96E+00**	**8.57E+00**	**9.31E+00**	**1.03E+01**	**1.16E+01**	**1.32E+01**	**1.60E+01**	**2.08E+01**	**3.42E+01**	NV
SWMU 145												
^{99}Tc	281	5.59E+00	6.04E+00	6.47E+00	7.03E+00	7.83E+00	8.74E+00	9.98E+00	1.20E+01	1.54E+01	2.45E+01	NV

Green shading indicates RGs that are below the Maximum Observed Concentration in surface or subsurface soils.
The RGs protective of groundwater are back calculated in the same manner as in B1.1 using the reduced infiltration rate to derive the DAF to serve as the basis for the calculation.
The RGs are back calculated in the same manner as in Table A.1.
NV—Not Valid; calculated RG results in soil concentrations greater than 1 kg/kg.
Table addresses only those COCs that are mobile in soils under site conditions.

Cells shaded green in Table B.5 are the containment RGs that are higher than the maximum observed soil concentration at the SWMU. These shaded values represent the concentration for the respective COCs that can be left in place, under a cover providing the necessary infiltration reduction, and not pose a threat to groundwater.

The predicted effects of using electrical resistance heating (ERH) as a representative technology at SWMUs 2, 4, and 7 to remediate dense nonaqueous-phase liquid (DNAPL) were modeled and the results presented in Table B.6 and Figure B.1. The assumptions that were made for this modeling were the same as the previous modeling performed for the Paducah Gaseous Diffusion Plant (PGDP) Southwest Plume:

- 98% of the mass of volatile organic compounds (VOCs) will be removed within the period of performance of the ERH system which is assumed to be less than one year.

- The half-life of trichloroethene (TCE) in the UCRS ranges from 5 to 50 years, with an average half-life of 26.6 years. Modeling was performed over the entire range of half lives, at 5, 26.6 and 50 years.

The modeling for an action using ERH was based on a starting concentration corresponding to the maximum observed soil sample result in each model layer for TCE at each of the SWMUs. No initial groundwater concentration was assumed so that the model results indicated impact from the SWMU only. The data indicate that the soils will remain above RGs protective of the MCLs in groundwater at SWMUs 2 and 4 for a period of time after treatment ends. The predicted time frame for TCE to reach the MCL in the RGA groundwater after the completion of treatment at SWMUs 2, 4, and 7 is presented as a range in Table B.6. Treatment of DNAPL at SWMU 7 results in residual soil concentrations that are protective of the groundwater, meeting the MCL, immediately following treatment.

B1.2 CALCULATIONS OF U-238 DAUGHTER INGROWTH

The uncertainty associated with the 1,000 year time horizon used in the groundwater modeling effort and the ingrowth of uranium-238 daughters after 1,000 years was discussed in the RI Report (Appendix E, DOE 2010). The ingrowth of uranium-238 daughters is slow, such that the contributions of uranium-238 daughters and their related radiation doses to an exposed worker will occur over the next 100,000 to 1 million years. Uranium at the PGDP had been chemically separated from its decay daughters prior to processing at PGDP. The daughters that were present at secular equilibrium with the uranium in the ore body remained with tailings at the uranium mill where it was extracted. The following calculations, therefore, refer to ingrowth of radium-226 and other daughters as secular equilibrium has begun to reestablish at PGDP.

The uranium-238 decay series is shown below in Table B.7.

Table B.6 ERH Summary of Results

	SWMU 2			SWMU 4			SWMU 7		
	$T_{1/2}$ = 5 yr	**$T_{1/2}$ = 26.6 yr**	**$T_{1/2}$ = 50 yr**	**$T_{1/2}$ = 5 yr**	**$T_{1/2}$ = 26.6 yr**	**$T_{1/2}$ = 50 yr**	**$T_{1/2}$ = 5 yr**	**$T_{1/2}$ = 26.6 yr**	**$T_{1/2}$ = 50 yr**
Max RGA Concentration (mg/L)	7.11E-03	5.19E-02	6.60E-02	5.00E-02	1.91E-01	2.01E-01	2.81E-04	4.81E-04	5.26E-04
Years to Peak Concentration	19	23	23	3	4	4	3	4	4
Years to MCL	25	73	91	28	79	100	0	0	0

Note: Max RGA concentration based on contributions from the SWMU and does not include contributions from upgradient sources.

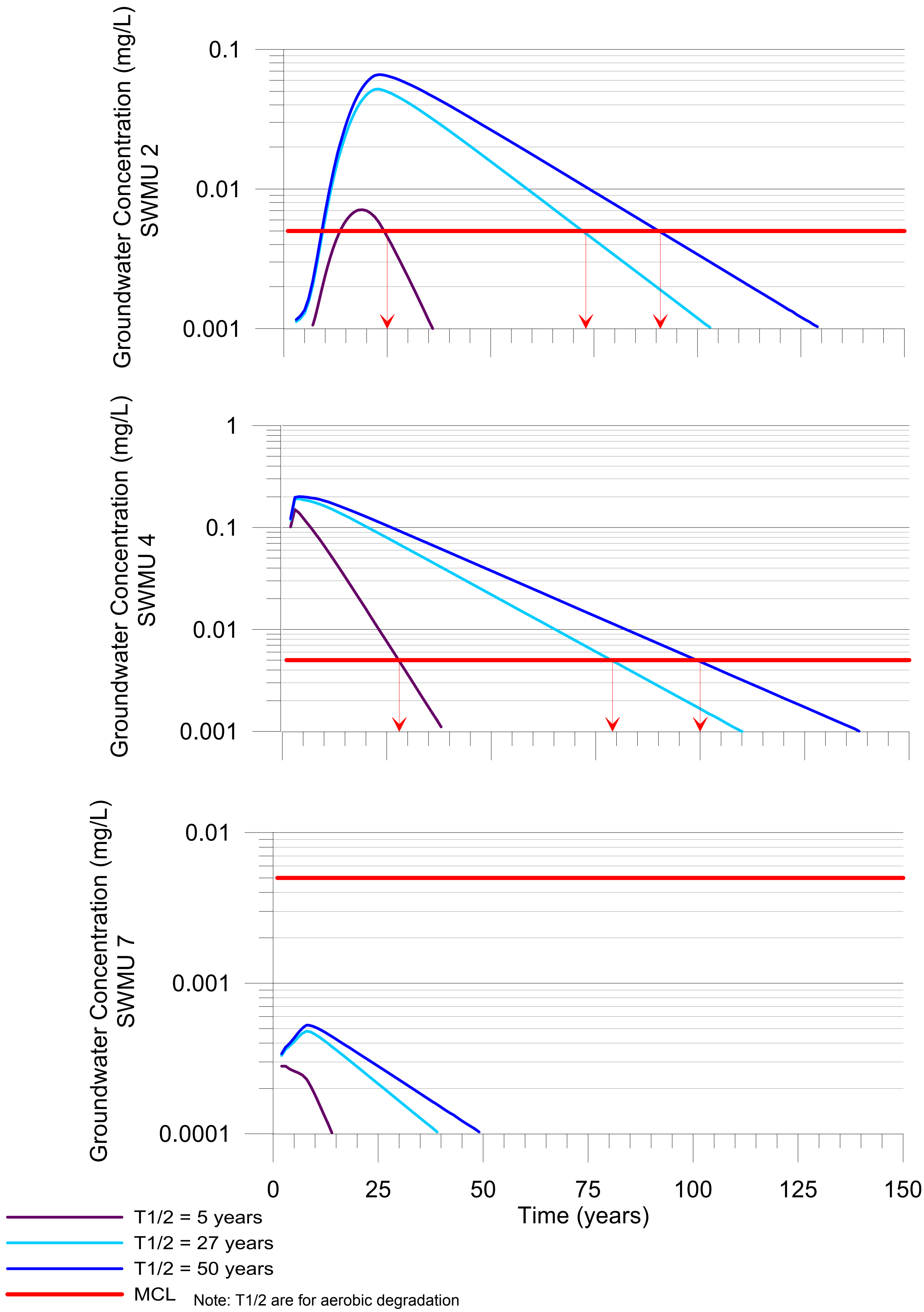


Figure B.1. TCE in Groundwater Following ERH Treatment at SWMUs 2, 4, and 7

Table B.7. Uranium-238 Decay Series

Parent	Half Life (T1/2)	Decay Mode	Branching Fraction	Daughter	Branching Fraction	Daughter
U-238	4.47E+09 yr	SF α	1.00E+00	Th-234		
Th-234	24.1 days	β-	1.00E+00	Pa-234m	2.00E-03	Pa-234
Pa-234m	1.17 min	β-IT	1.30E-03	Pa-234	1.00E+00	U-234
Pa-234	6.70 hr	β-	1.00E+00	U-234		
U-234	2.44E+05 yr	α	1.00E+00	Th-230		
Th-230	7.70E+04 yr	α	1.00E+00	Ra-226		
Ra-226	1.60E+03 yr	α	1.00E+00	Rn-222		
Rn-222	3.82 days	α	1.00E+00	Po-218		
Po-218	3.05 min	α β-	1.00E+00	Pb-214		
Pb-214	26.8 min	β-	1.00E+00	At-218		
At-218	2.00 sec	α	1.00E+00	Bi-214		
Bi-214	19.9 min	β-	1.00E+00	Po-214		
Po-214	1.64E+02 μsec	α	1.00E+00	Pb-210		
Pb-210	22.3 yr	β-	1.00E+00	Bi-210		
Bi-210	5.01 days	β-	1.00E+00	Po-210		
Po-210	1.38E+02 days	α				

SF = spontaneous fission, α = alpha decay, β-= beta decay, IT-internal transformation

The rate of ingrowth of uranium-238 series daughters is controlled by the half lives of uranium-238 and the slowest decaying daughters (uranium-238, thorium-230, radium-226, and lead-210).

The ingrowth of all of the daughters of a complex decay series of such as the uranium-238 series is described rigorously by the Bateman equations as applied in software based on radionuclide decay data (ORNL 2006). By making the assumption that the activities of all daughters is zero at time = 0, the software can be used to calculate the relative activity of each daughter at any subsequent time.

The ingrowth of uranium-238 daughters is shown in Table B.8 as follows:

Table B.8. Calculated Future Radionuclide Concentrations at the BGOU per 1 pCi/g URANIUM-238 With No Daughters Present at Time = 0

	1,000 years		10,000 years		100,000 years		3.5E+06 years	
Nuclide	Activity (pCi/g)	% Total Activity	Activity (pCi/g)	% Total Activity	Activity (pCi/g)	% Total Activity	Activity (pCi/g)	% Total Activity
U-238+D	3.00E+00	9.99E+01	3.00E+00	9.88E+01	3.00E+00	7.33E+01	3.00E+00	2.14E+01
U-234	2.84E-03	9.44E-02	2.80E-02	9.22E-01	2.47E-01	6.04E+00	1.00E+00	7.14E+00
Th-230	1.27E-05	4.24E-04	1.23E-03	4.05E-02	8.77E-02	2.14E+00	1.00E+00	7.14E+00
Ra-226+D	1.45E-05	4.82E-04	7.14E-03	2.35E-01	7.59E-01	1.85E+01	8.99E+00	6.43E+01
Total	3.00E+00	1.00E+02	3.04E+00	1.00E+02	4.10E+00	1.00E+02	1.40E+01	1.00E+02

The activity concentration of uranium-234 and its daughters will remain less than the activity of uranium-238 and daughters (uranium-238+D) through 100,000 years, when uranium-238 will represent over 73% of total activity. The concentrations of uranium-234 and its daughters will exceed uranium-238+D activity at some time after 1 million years. By approximating uranium-238 and uranium-234 as a series in transient equilibrium, it can be estimated that the maximum uranium-234 activity will occur at approximately 3.5 million years (Cember 1989). After that time, the activity of all uranium-238 daughters will decrease at the rate of uranium-238 decay.

The radiotoxicity of members of the uranium-238 series described by dose coefficients is provided by the EPA and the International Commission on Radiological Protection. These dose coefficients are implemented in the ORNL (2006) software.

The relative radiotoxicity of members of the uranium-238 series at 1,000 years is shown in Table B.9 as follows:

B.9. Calculated Radiological Dose at 1,000 Years per 1 pCi/g Uranium-238

	Activity		Radiation Dose (Sv)				
Nuclide	(pCi/g)	% Total	Ingestion	Inhalation	External (Sv/yr)	Total	% Total Dose
U-238+D	3.00E+00	9.99E+01	6.81E-08 Bone	8.63E-07 Bone	1.87E-10	9.31E-07	9.49E+01
U-234	2.84E-03	9.44E-02	2.02E-10	2.71E-09	2.71E-17	2.92E-09	2.97E-01
Th-230	1.27E-05	4.24E-04	6.23E-12	7.85E-10	3.25E-17	7.91E-10	8.06E-02
Ra-226+D	1.45E-05	4.82E-04	3.39E-12	7.21E-12	4.67E-08 Skin	4.67E-08	4.76E+00
Total	3.00E+00	1.00E+02	6.83E-08	8.66E-07	4.69E-08	9.82E-07	1.00E+02

The above radiological dose estimates are based on industrial worker exposure parameters for the ingestion and inhalation pathways as described in the ORNL (2006) software. These estimates indicate that at 1,000 years, the radiation dose is absorbed predominantly by bone surface tissue of radiation emitted by uranium-238 and its daughters (thorium-234 and protactinium-234). As daughter ingrowth increases, the predominant radiation dose is still estimated for bone tissue, but the dose delivered by thorium-230 exceeds the uranium-238+D dose after approximately 100,000 years. During this time, the radiation dose from radium-226+D nuclides also is delivered primarily to bone surface tissue, but remains less than that of the uranium and thorium isotopes even after 1 million years. The predominant role of dose absorbed by bone tissue results from the assumption that inhaled or ingested uranium-238 and daughters is rapidly transported from the lung or gastrointestinal tract and deposited in bone tissue where it is strongly incorporated into bone tissue.

It is important to note that the decay and ingrowth of uranium-238 daughters is independent of whether the uranium-238 atom is associated with soil or water. The rates of decay and daughter ingrowth are unchanged by the surrounding matrix.

The uncertainty associated with the ingrowth of uranium-238 daughters is characterized by slowly increasing radiation doses estimated for thorium-230, which is expected to become greater than the dose delivered by uranium-238, thorium-234, and protactinium-234 after approximately 100,000 years. Radiation doses associated with uranium-234 and radium-226+D nuclides remain secondary until the time of maximum daughter ingrowth net secular equilibrium is estimated at 3.5 million years. The predominant radiation dose is absorbed bone tissue, based on the assumption of fast absorption and translocation of inhaled or ingested nuclides. As with nonradioactive COCs, remediation alternatives are developed to prevent exposure to all of the radionuclide COCs (Section 3 of this FS).

APPENDIX C

DEVELOPMENT OF PRELIMINARY SOIL REMEDIATION GOALS AND APPROXIMATE LOWER-BOUND REMEDIATION GOALS FOR SOIL AT INDIVIDUAL SOLID WASTE MANAGEMENT UNITS

THIS PAGE INTENTIONALLY LEFT BLANK

CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

ACRONYMS

BGOU	Burial Ground Operable Unit
COC	contaminant of concern
DAF	dilution attenuation factor
DCE	dichloroethene
DOE	U.S. Department of Energy
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
FS	Feasibility Study
HI	hazard index
HQ	hazard quotient
KDEP	Kentucky Department for Environmental Protection
MCL	maximum contaminant level
NAL	no action level
NCP	National Contingency Plan
OU	operable unit
PAH	polyaromatic hydrocarbons
PCB	polychlorinated biphenyls
PGDP	Paducah Gaseous Diffusion Plant
RAO	remedial action objective
RG	remediation goals
RGA	Regional Gravel Aquifer
RI	remedial investigation
SWMU	solid waste management unit

THIS PAGE INTENTIONALLY LEFT BLANK

C.1. DEVELOPMENT OF PRELIMINARY AND APPROXIMATE LOWER-BOUND REMEDIATION GOALS FOR SOIL AT INDIVIDUAL SOLID WASTE MANAGEMENT UNITS

The development of preliminary remediation goals (RGs) for soil at each solid waste management unit (SWMU) is described in Section 2 of the main body of this document. Development of approximate lower-bound RGs for soil at selected SWMUs is described in this appendix.

C.2. GROUNDWATER CONCENTRATIONS USED TO CALCULATE GROUNDWATER-PROTECTIVE REMEDIATION GOALS FOR SOIL

Groundwater-protective RGs for soil were back calculated for each SWMU using concentrations of chemicals in groundwater beneath each SWMU that will not exceed the Maximum Contaminant Level (MCL) established in the Safe Drinking Water Act. One contaminant of concern (COC), naphthalene, does not have an MCL concentration. A risk-based groundwater concentration was developed for naphthalene as described below. These calculations are shown in Table C.1 and are based on the results of leaching and transport modeling conducted in the Burial Ground Operable Unit (BGOU) Remedial Investigation (RI) report (DOE 2010) and on risk-based concentrations developed in the 2001 Risk Methods Document (DOE 2001).

Groundwater-protective RG for soil is based on the MCL for the chemical as established in the Safe Drinking Water Act (EPA 2006). The MCL concentration for each COC was multiplied by the modeled dilution attenuation factor (DAF) to estimate the COC concentration in soil that would not exceed the MCL concentration beneath the SWMU if the COC were to leach from soil. The MCL concentrations are shown in column 3 of Table C.1.

The MCL concentration for gross alpha emitters is 15 pCi/L, excluding radon and uranium, and was applied to neptunium-237 and plutonium-239. At SWMU 7 and SWMU 30 where both neptunium-237 and plutonium-239 were identified as COCs, groundwater concentrations were adjusted according to relative cancer risk factors for tap water intake as given in U.S. Environmental Protection Agency (EPA) (1999) guidance according to the equation:

$$CGW_{i\ or\ j} = MCL\left(\frac{SF_{i\ or\ j}}{SF_i + SF_j}\right)$$

Where:

$CGW_{i\text{ or }j}$ = groundwater concentration of COC_i (neptunium-237+daughters) or $_j$ (plutonium-239).

$SF_{i\text{ or }j}$ = water ingestion cancer slope factor for COC_i (neptunium-237+daughters) or $_j$ (plutonium-239).

Table C.1. Groundwater-Protective Concentrations of Contaminant of Concern in Soil

SWMU No.	Contaminant of Concern[a]	Groundwater Concentration: MCL[b] (mg/L) (pCi/L)	Groundwater Concentration: NAL[c] (mg/L) (pCi/L)	Dilution Attenuation Factor (DAF)[d] (unitless)	Groundwater-Protective Soil Concentration at the SWMU[e] (mg/kg) (pCi/g)
2	Technetium-99[f]	9.00E+02	--	1.10E+01	9.90E+00
	Uranium (metal)	3.00E-02	--	no load	NA
	Uranium-234[g]	2.00E+01	--	no load	NA
	Uranium-235	2.00E+01	--	no load	NA
	Uranium-238[g]	2.00E+01	--	no load	NA
	cis-1,2-Dichloroethene	7.00E-02	--	3.10E+01	2.17E+00
	Trichloroethene	5.00E-03	--	2.50E+01	1.25E-01
	Naphthalene[h]	NE	2.85E-04	1.00E+01	2.85E-03
	Total PCBs[i]	i	i	i	10 ppm
3	Technetium-99[f]	9.00E+02	--	5.00E+00	4.50E+00
	Uranium (metal)	3.00E-02	--	no load	NA
	Uranium-235	2.00E+01	--	no load	NA
	Uranium-238[g]	2.00E+01	--	no load	NA
4	Technetium-99[f]	9.00E+02	--	7.00E+00	6.30E+00
	Uranium (metal)	3.00E-02	--	no load	NA
	Uranium-238[g]	2.00E+01	--	no load	NA
	cis-1,2-Dichloroethene	7.00E-02	--	1.10E+01	7.70E-01
	Trichloroethene	5.00E-03	--	8.00E+00	4.00E-02
	Vinyl chloride	2.00E-03	--	1.80E+01	3.60E-02
	Total Dioxins/Furans	3.00E-08	--	no load	NA
	Total PCBs[i]	i	i	i	10 ppm
5	Technetium-99[f]	9.00E+02	--	6.00E+00	5.40E+00
	Naphthalene[h]	NE	2.85E-04	2.10E+01	5.99E-03
	Total PAH[j]	2.00E-05	--	no load	NA
	Total PCBs[i]	i	i	i	10 ppm
6	Total PAH[j]	2.00E-05	--	no load	NA
7	Neptunium-237[k]	5.0E+00	--	no load	NA
	Plutonium-239[k]	1.0E+01	--	no load	NA
	Technetium-99[f]	9.00E+02	--	8.00E+00	7.20E+00
	Uranium (metal)	3.00E-02	--	no load	NA
	Uranium-234[g]	2.00E+01	--	no load	NA
	Uranium-235	2.00E+01	--	no load	NA
	Uranium-238[g]	2.00E+01	--	no load	NA
	1,1-Dichloroethene	7.00E-03	--	2.30E+01	1.61E-01
	cis-1,2-Dichloroethene	7.00E-02	--	2.10E+01	1.47E+00
	Trichloroethene	5.00E-03	--	2.00E+01	1.00E-01
	Vinyl chloride	2.00E-03	--	4.10E+01	8.20E-02
	Total PAH[j]	2.00E-05	--	no load	NA
	Total PCBs[i]	i	i	i	10 ppm
30	Neptunium-237[k]	5.0E+00	--	no load	NA
	Plutonium-239[k]	1.0E+01	--	no load	NA
	Technetium-99[f]	9.00E+02	--	1.30E+01	1.17E+01
	Uranium (metal)	3.00E-02	--	no load	NA
	Uranium-234[g]	2.00E+01	--	no load	NA
	Uranium-235	2.00E+01	--	no load	NA
	Uranium-238[g]	2.00E+01	--	no load	NA
	1,1-Dichloroethene	7.00E-03	--	2.23E+02	1.56E+00
	Trichloroethene	5.00E-03	--	1.27E+02	6.35E-01
	Total PAH[j]	2.00E-05	--	no load	NA
	Total PCBs[i]	i	i	i	10 ppm
145	Technetium-99[f]	9.00E+02	--	9.00E+00	8.10E+00

Table C.1. Groundwater-Protective Concentrations of Contaminant of Concern in Soil (Continued)

Notes:

[a] Contaminant of Concern (COC) identified according to criteria specified in the baseline human health risk assessment (BHHRA) as having ELCR > 1E-06 or hazard quotient (HQ) > 0.1 for the ingestion, inhalation and dermal exposure pathways or for residential groundwater use.

[b] The MCL concentration for the COC as established in the Safe Drinking Water Act. Chemical concentrations are given in mg/L units; radionuclide concentrations are given in pCi/L units. The "--" entry indicates no action level (NAL) value is used.

[c] NAL taken from the 2001 Risk Methods Document (*Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, Vol.1, Human Health, DOE/OR/07-1506&D2, December 2001). The value represents the concentration calculated for ELCR = 1E-06 for groundwater use by a rural resident. The lower of values calculated for the adult and child resident are taken from Table A.5 of Appendix A of the 2001 Risk Methods Document. Chemical concentrations are given in mg/L units; radionuclide concentrations are given in pCi/L units. The "--" entry indicates MCL value is used.

[d] Dilution Attenuation Factor for contaminant leaching from soil to groundwater beneath the SWMU (Column D of Table B.4).

[e] Contaminant concentration in soil at the SWMU that will not exceed the MCL, or the NAL for naphthalene, in groundwater beneath the SWMU. For chemical SOCs, Groundwater-Protective Soil Concentration (mg/kg) = MCL (mg/L) x DAF x 1L/kg. For radionuclides, Groundwater-Protective Soil Concentration (pCi/g) = MCL (pCi/L) x DAF x 1E-03L/g.

[f] The MCL concentration for beta and photon emitters corresponding to specified annual radiation dose limit of 4 mrem/yr equals 900 pCi/L for Tc-99. EPA Facts About Technetium-99, USEPA, July 2002.

[g] The MCL concentration used for U-234 U-235, and U-238 is 20 pCi/L (DOE 2001).

[h] Naphthalene does not have an MCL. Value equals the groundwater NAL calculated for the rural resident (see Note c).

[i] This RG was agreed upon as part of risk management discussions during a June 2009 BGOU scoping meeting among DOE, EPA, and KY. At that meeting, the group recognized that, when used as the upper-bound goal for individual detections, the average concentration of PCBs for the unit is expected to be significantly lower.

[j] Because individual polyaromatic hydrocarbons (PAH) compounds were detected only at isolated locations at some SWMUs, the PAH compounds that were detected are not mobile toward groundwater, and remediation alternatives developed for other COCs will remediate the isolated PAH concentrations also, no Total PAH RGs were developed for soil for the purpose of developing remediation alternatives. Individual PAH compounds were identified as COCs at SWMU 6 (DOE 2009). Later review of soil sampling data for SWMU 6 has shown that the location of this sample is not within SWMU 6 and is actually associated with another PGDP operable unit. Therefore, no COCS were identified for soil at SWMU 6.

[k] The MCL for gross alpha emitter concentrations is 15 pCi/L, excluding radon and uranium. Np-237 and Pu-239 are the alpha emitters at SWMU 7 and SWMU 30. Where both radionuclides were identified at the SWMU, values were adjusted according to relative cancer risk factors for tap water intake as given in Federal Guidance Report FGR-13, Table 2.2a. Values shown total 15 pCi/L.

NA Not applicable. There is no transport to groundwater (no load) and no groundwater-protective concentration is calculated.

NE MCL or NAL value not established.

no load Modeling indicates no transport to groundwater.

The MCL concentrations for beta and photon emitters correspond to an annual radiation dose limit of 4 mrem/yr, which corresponds to a concentration of 900 pCi/L for technetium-99 at BGOU SWMUs (*EPA Facts About Technetium-99*, EPA, July 2002). The MCL concentration of 20 pCi/L was applied to all uranium isotopes (DOE 2001). For naphthalene, which has no MCL, the groundwater concentration used equals the NAL concentration for residential groundwater use corresponding to 5 x the hazard quotient (HQ) = 0.1 value of 2.85E-04 mg/L given in Table A.5 and corresponds to a noncancer hazard quotient of 0.5.

C.3. SOIL RGs

Preliminary RGs for soil at all SWMUs were selected as the lower of the direct contact RG and the Groundwater-Protective RG for a chemical, as described in Section 2.2.3, and are shown in column 7 of Tables 2.1 and 2.2 of the main body of this document.

C.3.1. PRELIMINARY SOIL RGs USED TO DEVELOP REMEDIATION ALTERNATIVES

Preliminary RGs for contaminated surface and subsurface soils are used in Section 3 to develop remediation alternatives. RGs for COCs in surface soil (0 to 1 ft bgs) are protective of direct exposures of industrial workers and are protective of groundwater in the Regional Gravel Aquifer (RGA) beneath the SWMU from potential leaching of COCs from soil. RGs developed for COCs in subsurface soil are protective of direct exposures of outdoor worker and also are protective of groundwater in the RGA beneath the SWMU. The depth of subsurface soil varies according to SWMU, but is expected to extend from 0 to ~16 bgs, with a maximum expected depth of 20 ft bgs at BGOU SWMUs.

C.3.2. APPROXIMATE LOWER-BOUND SOIL RGs

In order to demonstrate that a remediation action has been effective at a SWMU, it will be necessary to attain the remedial action objectives (RAOs). These RAOs are described in Section 2.2.2:

(1) Contribute to the protection of current and future off-site residential receptors from exposure to contaminated groundwater by reducing/controlling sources of groundwater contamination;

(2) Protect industrial workers from exposure to waste and contaminated soils; and

(3) Treat or remove principal threat waste wherever practicable, consistent with 40 *CFR* § 300.430 (a)(1)(iii)(A).

For RAO number 1, this determination will be supported by comparison of residual soil concentrations to RGs developed to protect off-site groundwater users. For RAO number 2, this determination will be supported through the derivation of residual risks and hazards for the appropriate exposure scenarios (e.g., for direct contact with soil the exposure scenarios are the industrial worker and outdoor worker).

Specifically, to attain RAO number 2, following remediation, the cumulative excess lifetime cancer risk (ELCR) to the industrial worker from exposure to SWMU-specific residual COCs in surface soil must be shown to be below 1E-05 and the noncancer hazard index (HI) ≤ 1 and the cumulative ELCR and HI to the outdoor worker from exposure to residual COCs in subsurface soil must be below 1E-04 and 1, respectively (see Figure 2.3).

The eventual evaluation of soil concentrations achieved following a response action will be based on ELCR and HI calculations using concentrations measured in samples collected to verify that RAOs have been met at a SWMU; will follow the same approach described in the Risk Methods Document (DOE 2001); and will be consistent with EPA (1991) guidance.

It is possible that this postremediation sampling will show that only one or a few of the COCs identified at a specific SWMU will be detected or that all COCs will be detected. Under the conservative assumption that all COCs identified at each SWMU will be detected, approximate lower-bound RG concentrations have been calculated that meet the cumulative ELCR and HI criteria specified for the future industrial worker scenario (ELCR ≤ 1E-05 and HI ≤ 1) and for the future outdoor worker scenario (ELCR ≤ 1E-04 and HI ≤ 1). These approximate lower-bound RGs for surface and subsurface soil provide information on possible soil concentrations that might be encountered in postremediation sampling at each SWMU, but are not used in the development of remedial alternatives.

The approximate lower-bound RG concentrations are based on the preliminary RGs shown in Tables 2.1 and 2.2 and were estimated by adjusting the preliminary RGs downward to meet the cumulative ELCR and HI criteria.

The 10 ppm value for polychlorinated biphenyls (PCBs) in soil is the value jointly agreed upon by representatives of the EPA Region 4, the Kentucky Department for Environmental Protection (KDEP), and the U.S. Department of Energy (DOE) in June 2009 scoping meetings. This value was considered to be sufficiently protective of potential direct contact risk that could occur at the BGOU, and it also was recognized that actual postremediation PCB concentrations are likely to be lower than the 10 mg/kg value. As such, it was not included in the approximate lower-bound RG estimates.

Approximate lower-bound RGs for carcinogenic COCs are shown in Tables C.2 through C.15 to satisfy the following equation:

$$Cumulative\ Risk \leq \left(\frac{RG_{LB1}}{RG_1} + \frac{RG_{LB2}}{RG_2} + ... + \frac{RG_{LBi}}{RG_i} \right) \times 10^{-5}\ or \times 10^{-4}$$

Where:

Cumulative Risk	= target cumulative risk = 1E-05 for surface soil or 1E-04 for subsurface soil
$RG_{LB\,i}$	= approximate lower-bound RG for carcinogenic COC*i* (mg/kg or pCi/g)
RG_i	= RG calculated to represent a risk from exposure to COC*i* in soil at the SWMU that represents an individual ELCR ≤5E-06 for surface soil or an individual ELCR ≤5E-05 for subsurface soil
i	= the carcinogenic COCs in soil at the SWMU numbering from i=1, … , n
n	= number of carcinogenic COCs in soil at the SWMU

Approximate lower-bound RGs for noncarcinogenic COCs are shown in Tables C.2 through C.15 to satisfy the following equation:

$$1 \geq \left(\frac{RG_{LB1}}{RG_1} + \frac{RG_{LB2}}{RG_2} + ... + \frac{RG_{LBi}}{RG_i} \right)$$

Where: $RG_{LB\,i}$ = approximate lower-bound RG for noncarcinogenic COC*i* (mg/kg)

RG_i	=	RG calculated to represent a risk from exposure to COC*i* in soil at the SWMU that represents an individual HQ ≤0.5 for surface soil or an individual HQ of 1 for subsurface soil
i	=	number of noncarcinogenic COCs in soil at the SWMU
n	=	number of carcinogenic COCs in soil at the SWMU

Demonstration that approximate lower-bound RGs satisfy Equations 2 and 3 shows that the cumulative ELCR is ≤ 1E-05 for surface soil and that the cumulative ELCR is ≤ 1E-04 for subsurface soil. The cumulative HI is ≤ 1 for all COCs in surface and subsurface soil at the SWMU.

The preliminary RGs and approximate lower-bound RGs for surface and subsurface soil are described below in Tables C.2 through C.15.

Table C.2. Preliminary and Approximate Lower-Bound Remediation Goals for Surface Soil at SWMU 2

SWMU No.	Contaminant of Concern (COC)[1]	Toxic Effect	Preliminary Remediation Goal for Surface Soil[2] (mg/kg) (pCi/g)	ELCR for Preliminary Remediation Goal	HI for Preliminary Remediation Goal	Approximate Lower-Bound Remediation Goal for Surface Soil[3] (mg/kg) (pCi/g)	ELCR for Approximate Lower-Bound Remediation Goal	HI for Approximate Lower-Bound Remediation Goal
2	Technetium-99[4]	Carcinogen	**9.90E+00**	2.73E-08	--	--	--	--
	Uranium (metal)	Noncarcinogen	X	X	X	X	X	X
	Uranium-234	Carcinogen	X	X	X	X	X	X
	Uranium-235	Carcinogen	**1.98E+00**	5.00E-06	--	--	--	--
	Uranium-238	Carcinogen	**8.55E+00**	5.00E-06	--	--	--	--
	cis-1,2-Dichloroethene[5]	Noncarcinogen	**2.17E+00**	--	0.02	--	--	--
	Trichloroethene[6]	Carcinogen and Noncarcinogen	**1.25E-01**	4.98E-08	0.003	--	--	--
	Naphthalene[7]	Noncarcinogen	**2.85E-03**	--	0.00001	--	--	--
	Total PCBs[8]	Carcinogen	**1.0E+01**	--	--	--	--	--
			Cumulative ELCR or HI =	**1.E-05**	**0.02**	**Cumulative ELCR or HI[3] =**	**--**	**--**

[1] Contaminant of Concern identified according to the risk methods document: To determine COCs, risk characterization results for chemical hazard (HQi) and risk (ELCRi) over all pathways within a use scenario of concern will be compared to benchmarks of 0.1 and 1 × 10-6, respectively. Chemicals of potential concern within a use scenario of concern exceeding either of these benchmarks will be deemed COCs for the use scenario of concern. (DOE 2001 pg. 3-37).

[2] Preliminary Remediation Goal is the lower of the Direct Contact Remediation Goal for Surface Soil and the Groundwater-Protective Goal for Surface Soil that is protective of the MCL concentration (Table 2.1), or the risk-based concentration for naphthalene. The background concentration is shown if larger than this value. Radionuclide concentrations given in pCi/g units. This value is used to develop remediation alternatives for surface soil at the SWMU.

[3] Approximate Lower-Bound Remediation Goal is the Preliminary Remediation Goal adjusted for cumulative health effects, if necessary. If the cumulative ELCR calculated for the preliminary RG is < 1E-5 or the cumulative HI < 1, no Approximate Lower-Bound RG is calculated. This value is not used to develop remediation alternatives for the SWMU. The "--" entry indicates no approximate lower-bound RG is calculated for this COC.

[4] Chemical is not identified as a direct contact soil COC for this SWMU, but is identified as a groundwater COC (Table 1.6). The Preliminary Soil RG represents the groundwater-protective soil concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 362 pCi/g, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future industrial worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[5] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.6). The Preliminary Soil RG represents the groundwater protective soil RG back-calculated from the MCL concentration (Table C.1). The HQ associated with direct exposure to this concentration is calculated from the No Action Level of 13.4 mg/kg, which corresponds to HQ = 0.1 for direct-contact exposure of a future industrial worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[6] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.6). The Preliminary Soil RG represents the groundwater protective RG back-calculated from the MCL concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 2.51 mg/kg, which corresponds to ELCR = 1E-06 for direct-contact exposure of a industrial worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001). The HI associated with direct exposure is calculated from the No Action Level of 4.70 mg/kg, which corresponds to HQ = 0.1 for exposure of an industrial worker to soil (Table A.4 of DOE 2001).

Table C.2. Preliminary and Approximate Lower-Bound Remediation Goals for Surface Soil at SWMU 2 (Continued)

[7] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.6). The Preliminary Soil RG represents the groundwater protective RG back-calculated from the risk-based groundwater concentration (Table C.1). The HQ associated with direct exposure to this concentration is calculated from the No Action Level of 23.6 mg/kg, which corresponds to HQ = 0.1 for direct-contact exposure of a future industrial worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[8] PCBs are not mobile to groundwater from soil at COC for this SWMU (Section 2, this document). Value is the RG jointly agreed upon for PCBs by representatives of EPA Region 4, KDEP, and DOE in June 2009 scoping meetings.

X Chemical is not identified as a COC for direct contact exposure and, because of its immobility, it does not represent a threat to exceed its MCL concentration in groundwater beneath the SWMU. No RG is developed.

"--" Entry for ELCR or HI values indicates there is no cancer slope factor for ELCR assessment or noncancer reference dose for HI assessment, as applicable.

Bold Boldface type indicates Preliminary Remediation Goals used in the development of remediation alternatives and their associated cumulative ELCR and HI values.

Table C.3. Preliminary and Approximate Lower-Bound Remediation Goals for Subsurface Soil at SWMU 2

SWMU No.	Contaminant of Concern (COC)[1]	Toxic Effect	Preliminary Remediation for Subsurface Soil [2] (mg/kg) (pCi/g)	ELCR for Preliminary Remediation Goal	HI for Preliminary Remediation Goal	Approximate Lower-Bound Remediation Goal for Subsurface Soil[3] (mg/kg) (pCi/g)	ELCR for Approximate Lower-Bound Remediation Goal	HI for Approximate Lower-Bound Remediation Goal
2	Technetium-99[4]	Carcinogen	**9.90E+00**	1.71E-07	--	--	--	--
	Uranium (metal)	Noncarcinogen	X	X	X	X	X	X
	Uranium-234	Carcinogen	X	X	X	X	X	X
	Uranium-235	Carcinogen	Surface Soil Only See Table C.2	--	--	Surface Soil Only See Table C.2	--	--
	Uranium-238	Carcinogen	**5.85E+01**	5.00E-05	--	--	--	--
	cis-1,2-Dichloroethene[5]	Noncarcinogen	**2.17E+00**	--	0.01	--	--	--
	Trichloroethene[6]	Carcinogen and Noncarcinogen	**1.25E-01**	3.85E-08	0.0020	--	--	--
	Naphthalene[7]	Noncarcinogen	**2.85E-03**	--	0.000009	--	--	--
	Total PCBs[8]	Carcinogen	**1.0E+01**	--	--	--	--	--
			Cumulative ELCR or HI =	**5.E-05**	**0.01**	**Cumulative ELCR or HI[3] =**	**--**	**--**

[1] Contaminant of Concern identified according to the risk methods document: To determine COCs, risk characterization results for chemical hazard (HQi) and risk (ELCRi) over all pathways within a use scenario of concern will be compared to benchmarks of 0.1 and 1 × 10-6, respectively. Chemicals of potential concern within a use scenario of concern exceeding either of these benchmarks will be deemed COCs for the use scenario of concern. (DOE 2001, pg. 3-37).

[2] Preliminary Remediation Goal is the lower of the Direct Contact Remediation Goal for Subsurface Soil and the Groundwater-Protective Goal for Surface Soil that is protective of the MCL concentration (Table 2.2), or a risk-based concentration for naphthalene. The background concentration is shown if larger than this value. Radionuclide concentrations given in pCi/g units. This value is used to develop remediation alternatives for surface soil at the SWMU.

[3] Approximate Lower-Bound Remediation Goal is the Preliminary Remediation Goal adjusted for cumulative health effects, if necessary. If the cumulative ELCR calculated for the preliminary RG is < 1E-4 or the cumulative HI < 1, no Approximate Lower-Bound RG is calculated. This value is not used to develop remediation alternatives for the SWMU. The "--" entry indicates no approximate lower-bound RG is calculated for this COC.

[4] Chemical is not identified as a direct contact soil COC for this SWMU, but is identified as a groundwater COC (Table 1.6). The Preliminary Soil RG represents the groundwater-protective soil concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 57.9 pCi/g, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future outdoor worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[5] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.6). The Preliminary Soil RG represents the groundwater protective RG back-calculated from the MCL concentration (Table C.1). The HQ associated with direct exposure to this concentration is calculated from the No Action Level of 17.1 mg/kg, which corresponds to HQ = 0.1 for direct-contact exposure of a future outdoor worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

Table C.3. Preliminary and Approximate Lower-Bound Remediation Goals for Subsurface Soil at SWMU 2 (Continued)

[6] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.6).The Preliminary Soil RG represents the groundwater protective RG back-calculated from MCL concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 3.25 mg/kg, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future outdoor worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001). The HI associated with direct exposure is calculated from the No Action Level of 6.15 mg/kg, which corresponds to HQ = 0.1 for exposure of an outdoor worker to soil (Table A.4 of DOE 2001).

[7] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.6). The Preliminary Soil RG represents the groundwater protective RG back-calculated from the risk-based groundwater concentration (Table C.1). The HQ associated with direct exposure to this concentration is calculated from the No Action Level of 30.4 mg/kg, which corresponds to HQ = 0.5 for direct-contact exposure of a future outdoor worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[8] PCBs are not mobile to groundwater from soil at COC for this SWMU (Section 2, this document). Value is the RG jointly agreed upon for PCBs by representatives of EPA Region 4, KDEP, and DOE in June 2009 scoping meetings.

X Chemical is not identified as a COC for direct contact exposure and, because of its immobility, it does not represent a threat to exceed its MCL concentration in groundwater beneath the SWMU. No RG is developed.

"**--**" Entry for ELCR or HI values indicates there is no cancer slope factor for ELCR assessment or noncancer reference dose for HI assessment, as applicable.

Bold Boldface type indicates Preliminary Remediation Goals used in the development of remediation alternatives and their associated cumulative ELCR and HI values.

Table C.4. Preliminary and Approximate Lower-Bound Remediation Goals for Surface Soil at SWMU 3

SWMU No.	Contaminant of Concern (COC)[1]	Toxic Effect	Preliminary Remediation Goal for Surface Soil[2] (mg/kg) (pCi/g)	ELCR for Preliminary Remediation Goal	HI for Preliminary Remediation Goal	Approximate Lower-Bound Remediation Goal for Surface Soil[3] (mg/kg) (pCi/g)	ELCR for Approximate Lower-Bound Remediation Goal	HI for Approximate Lower-Bound Remediation Goal
3	Technetium-99[4]	Carcinogen	**4.50E+00**	1.24E-08	--	--	--	--
	Uranium (metal)	Noncarcinogen	X	X	X	X	X	X
	Uranium-235	Carcinogen	**1.98E+00**	5.00E-06	--	--	--	--
	Uranium-238	Carcinogen	**8.55E+00**	5.00E-06	--	--	--	--
			Cumulative ELCR or HI =	**1.E-05**	**--**	**Cumulative ELCR or HI[3] =**	**--**	**--**

[1] Contaminant of Concern identified according to the risk methods document: To determine COCs, risk characterization results for chemical hazard (HQi) and risk (ELCRi) over all pathways within a use scenario of concern will be compared to benchmarks of 0.1 and 1 × 10-6, respectively. Chemicals of potential concern within a use scenario of concern exceeding either of these benchmarks will be deemed COCs for the use scenario of concern. (DOE 2001, pg. 3-37).

[2] Preliminary Remediation Goal is the lower of the Direct Contact Remediation Goal for Surface Soil and the Groundwater-Protective Goal for Surface Soil that is protective of the MCL concentration (Table 2.1). The background concentration is shown if larger than this value. Radionuclide concentrations given in pCi/g units. This value is used to develop remediation alternatives for surface soil at the SWMU.

The "**--**" entry indicates no approximate lower-bound RG is calculated for this COC.

[3] Approximate Lower-Bound Remediation Goal is the Preliminary Remediation Goal adjusted for cumulative health effects, if necessary. If the cumulative ELCR calculated for the preliminary RG is < 1E-5 or the cumulative HI < 1, no Approximate Lower-Bound RG is calculated. This value is not used to develop remediation alternatives for the SWMU. The "--" entry indicates no approximate lower-bound RG is calculated for this COC.

[4] Chemical is not identified as a direct contact soil COC for this SWMU, but is identified as a groundwater COC (Table 1.6). The Preliminary Soil RG represents the groundwater-protective soil concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 362 pCi/g, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future industrial worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

X Chemical is not identified as a COC for direct contact exposure and, because of its immobility, it does not represent a risk to hypothetical residential groundwater users at the plant boundary. No RG is developed.

"--" Entry for ELCR or HI values indicates there is no cancer slope factor for ELCR assessment or noncancer reference dose for HI assessment, as applicable.

Bold Boldface type indicates Preliminary Remediation Goals used in the development of remediation alternatives and their associated cumulative ELCR and HI values.

Table C.5. Preliminary and Approximate Lower-Bound Remediation Goals for Subsurface Soil at SWMU 3

SWMU No.	Contaminant of Concern (COC)[1]	Toxic Effect	Preliminary Remediation Goal for Subsurface Soil[2] (mg/kg) (pCi/g)	ELCR for Preliminary Remediation Goal	HI for Preliminary Remediation Goal	Approximate Lower-Bound Remediation Goal for Subsurface Soil[3] (mg/kg) (pCi/g)	ELCR for Approximate Lower-Bound Remediation Goal	HI for Approximate Lower-Bound Remediation Goal
3	Technetium-99[4]	Carcinogen	**4.50E+00**	7.77E-08	--	--	--	--
	Uranium (metal)	Noncarcinogen	X	X	X	X	X	X
	Uranium-235	Carcinogen	Surface Soil Only See Table C.4	--	--	Surface Soil Only See Table C.4	--	--
	Uranium-238	Carcinogen	Surface Soil Only See Table C.4	--	--	Surface Soil Only See Table C.4	--	--
			Cumulative ELCR or HI =	**8.E-08**	**--**	**Cumulative ELCR or HI[3] =**	**--**	**--**

[1] Contaminant of Concern identified according to the risk methods document: To determine COCs, risk characterization results for chemical hazard (HQi) and risk (ELCRi) over all pathways within a use scenario of concern will be compared to benchmarks of 0.1 and 1 × 10-6, respectively. Chemicals of potential concern within a use scenario of concern exceeding either of these benchmarks will be deemed COCs for the use scenario of concern. (DOE 2001, pg. 3-37).

[2] Preliminary Remediation Goal is the lower of the Direct Contact Remediation Goal for Subsurface Soil and the Groundwater-Protective Goal for Surface Soil that is protective of the MCL concentration (Table 2.2). The background concentration is shown if larger than this value. Radionuclide concentrations given in pCi/g units. This value is used to develop remediation alternatives for surface soil at the SWMU.

[3] Approximate Lower-Bound Remediation Goal is the Preliminary Remediation Goal adjusted for cumulative health effects, if necessary. If the cumulative ELCR calculated for the preliminary RG is < 1E-4 or the cumulative HI < 1, no Approximate Lower-Bound RG is calculated. This value is not used to develop remediation alternatives for the SWMU. The "--" entry indicates no approximate lower-bound RG is calculated for this COC.

[4] Chemical is not identified as a direct contact soil COC for this SWMU, but is identified as a groundwater COC (Table 1.7). The Preliminary Soil RG represents the groundwater-protective soil concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 57.9 pCi/g, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future outdoor worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

X Chemical is not identified as a COC for direct contact exposure and, because of its immobility, it does not represent a risk to hypothetical residential groundwater users at the plant boundary. No RG is developed.

"--" Entry for ELCR or HI values indicates there is no cancer slope factor for ELCR assessment or noncancer reference dose for HI assessment, as applicable.

Bold Boldface type indicates Preliminary Remediation Goals used in the development of remediation alternatives and their associated cumulative ELCR and HI values.

Table C.6. Preliminary and Approximate Lower-Bound Remediation Goals for Surface Soil at SWMU 4

SWMU No.	Contaminant of Concern (COC)[1]	Toxic Effect	Preliminary Remediation Goal for Surface Soil[2] (mg/kg) (pCi/g)	ELCR for Preliminary Remediation Goal	HI for Preliminary Remediation Goal	Approximate Lower-Bound Remediation Goal for Surface Soil[3] (mg/kg) (pCi/g)	ELCR for Approximate Lower-Bound Remediation Goal	HI for Approximate Lower-Bound Remediation Goal
4	Technetium-99[4]	Carcinogen	**6.30E+00**	1.74E-08	--	--	--	--
	Uranium (metal)	Noncarcinogen	Subsurface Soil Only See Table C.7	--	--	Subsurface Soil Only See Table C.7	--	--
	Uranium-238	Carcinogen	**8.55E+00**	5.00E-06	--	--	--	--
	cis-1,2-Dichloroethene[5]	Noncarcinogen	**7.70E-01**	--	0.006	--	**--**	--
	Trichloroethene[6]	Carcinogen and Noncarcinogen	**4.00E-02**	1.59E-08	0.0009	--	--	--
	Vinyl chloride[7]	Carcinogen and Noncarcinogen	**3.60E-02**	2.69E-07	0.0004	--	--	--
	Total Dioxins/Furans[8]	Carcinogen	Subsurface Soil Only See Table C.7	--	--	Subsurface Soil Only See Table C.7	--	--
	Total PCBs[9]	Carcinogen	**1.0E+01**	--	--	--	--	--
			Cumulative ELCR or HI =	**5.E-06**	**0.007**	**Cumulative ELCR or HI[3] =**	**--**	**--**

[1] Contaminant of Concern identified according to the risk methods document: To determine COCs, risk characterization results for chemical hazard (HQi) and risk (ELCRi) over all pathways within a use scenario of concern will be compared to benchmarks of 0.1 and 1 × 10-6, respectively. Chemicals of potential concern within a use scenario of concern exceeding either of these benchmarks will be deemed COCs for the use scenario of concern. (DOE 2001, pg. 3-37).

[2] Preliminary Remediation Goal is the lower of the Direct Contact Remediation Goal for Surface Soil and the Groundwater-Protective Goal for Surface Soil that is protective of the MCL concentration (Table 2.1). The background concentration is shown if larger than this value. Radionuclide concentrations given in pCi/g units. This value is used to develop remediation alternatives for surface soil at the SWMU.

[3] Approximate Lower-Bound Remediation Goal is the Preliminary Remediation Goal adjusted for cumulative health effects, if necessary. If the cumulative ELCR calculated for the preliminary RG is < 1E-5 or the cumulative HI < 1, no Approximate Lower-Bound RG is calculated. This value is not used to develop remediation alternatives for the SWMU. The "--" entry indicates no approximate lower-bound RG is calculated for this COC.

[4] Chemical is not identified as a direct contact soil COC for this SWMU, but is identified as a groundwater COC (Table 1.8). The Preliminary Soil RG represents the groundwater-protective soil concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 362 pCi/g, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future industrial worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

Table C.6. Preliminary and Approximate Lower-Bound Remediation Goals for Surface Soil at SWMU 4 (Continued)

[5] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.8). The Preliminary Soil RG represents the groundwater protective soil RG back-calculated from the MCL concentration (Table C.1). The HQ associated with direct exposure to this concentration is calculated from the No Action Level of 13.4 mg/kg, which corresponds to HQ = 0.1 for direct-contact exposure of a future industrial worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[6] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.8). The Preliminary Soil RG represents the groundwater protective RG back-calculated from the MCL concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 2.51 mg/kg, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future industrial worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001). The HI associated with direct exposure is calculated from the No Action Level of 4.70 mg/kg, which corresponds to HQ = 0.1 for exposure of an industrial worker to soil (Table A.4 of DOE 2001).

[7] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.8). The Preliminary Soil RG represents the groundwater protective RG back-calculated from the MCL concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 0.134 mg/kg, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future industrial worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001). The HI associated with direct exposure is calculated from the No Action Level of 10.1 mg/kg, which corresponds to HQ = 0.1 for exposure of an industrial worker to soil (Table A.4 of DOE 2001).

[8] Total Dioxins and Furans are described as the 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) toxicity equivalent concentration (TEQ). Dioxins are not mobile to groundwater from soil at this SWMU (Section 2, this document). Value shown is the direct contact RG for outdoor worker exposure to subsurface soil (Table 2.1).

[9] PCBs are not mobile to groundwater from soil at COC for this SWMU (Section 2, this document). Value is the RG jointly agreed upon for PCBs by representatives of EPA Region 4, KDEP, and DOE in June 2009 scoping meetings.

"--" Entry for ELCR or HI values indicates there is no cancer slope factor for ELCR assessment or noncancer reference dose for HI assessment, as applicable.

Bold Boldface type indicates Preliminary Remediation Goals used in the development of remediation alternatives and their associated cumulative ELCR and HI values.

Table C.7. Preliminary and Approximate Lower-Bound Remediation Goals for Subsurface Soil at SWMU 4

SWMU No.	Contaminant of Concern (COC)[1]	Toxic Effect	Preliminary Remediation Goal for Subsurface Soil[2] (mg/kg) (pCi/g)	ELCR for Preliminary Remediation Goal	HI for Preliminary Remediation Goal	Approximate Lower-Bound Remediation Goal for Subsurface Soil[3] (mg/kg) (pCi/g)	ELCR for Approximate Lower-Bound Remediation Goal	HI for Approximate Lower-Bound Remediation Goal
4	Technetium-99[4]	Carcinogen	**6.30E+00**	1.09E-07	--	--	--	--
	Uranium (metal)	Noncarcinogen	**1.13E+02**	--	1.00	--	--	--
	Uranium-238	Carcinogen	**5.85E+01**	5.00E-05	--	--	--	--
	cis-1,2-Dichloroethene[5]	Noncarcinogen	**7.70E-01**	--	0.005	--	**--**	--
	Trichloroethene[6]	Carcinogen and Noncarcinogen	**4.00E-02**	1.23E-08	0.00065	--	--	--
	Vinyl chloride[7]	Carcinogen and Noncarcinogen	**3.60E-02**	2.55E-07	0.00030	--	--	--
	Total Dioxins/Furans[8]	Carcinogen	**1.75E-04**	5.00E-05	--	--	--	--
	Total PCBs[9]	Carcinogen	**1.0E+01**	--	--	--	--	--
			Cumulative ELCR or HI =	**1.E-04**	**1**	**Cumulative ELCR or HI [3] =**	**--**	**--**

[1] Contaminant of Concern identified according to the risk methods document: To determine COCs, risk characterization results for chemical hazard (HQi) and risk (ELCRi) over all pathways within a use scenario of concern will be compared to benchmarks of 0.1 and 1 × 10-6, respectively. Chemicals of potential concern within a use scenario of concern exceeding either of these benchmarks will be deemed COCs for the use scenario of concern. (DOE 2001, pg. 3-37).

[2] Preliminary Remediation Goal is the lower of the Direct Contact Remediation Goal for Subsurface Soil and the Groundwater-Protective Goal for Surface Soil that is protective of the MCL concentration (Table 2.2). The background concentration is shown if larger than this value. Radionuclide concentrations given in pCi/g units. This value is used to develop remediation alternatives for surface soil at the SWMU.

[3] Approximate Lower-Bound Remediation Goal is the Preliminary Remediation Goal adjusted for cumulative health effects, if necessary. If the cumulative ELCR calculated for the preliminary RG is < 1E-4 or the cumulative HI < 1, no Approximate Lower-Bound RG is calculated. This value is not used to develop remediation alternatives for the SWMU. The "--" entry indicates no approximate lower-bound RG is calculated for this COC.

[4] Chemical is not identified as a direct contact soil COC for this SWMU, but is identified as a groundwater COC (Table 1.8). The Preliminary Soil RG represents the groundwater-protective soil concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 57.9 pCi/g, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future outdoor worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[5] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.8). The Preliminary Soil RG represents the groundwater protective RG back-calculated from the MCL concentration (Table C.1). The HQ associated with direct exposure to this concentration is calculated from the No Action Level of 17.1 mg/kg, which corresponds to HQ = 0.1 for direct-contact exposure of a future outdoor worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

Table C.7. Preliminary and Approximate Lower-Bound Remediation Goals for Subsurface Soil at SWMU 4 (Continued)

[6] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.8). The Preliminary Soil RG represents the groundwater protective RG back-calculated from the MCL concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 3.25 mg/kg, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future outdoor worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001). The HI associated with direct exposure is calculated from the No Action Level of 6.15 mg/kg, which corresponds to HQ = 0.1 for exposure of an outdoor worker to soil (Table A.4 of DOE 2001).

[7] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.8). The Preliminary Soil RG represents the groundwater protective RG concentration back-calculated from the MCL concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 0.141 mg/kg, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future outdoor worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001). The HI associated with direct exposure is calculated from the No Action Level of 12.0 mg/kg, which corresponds to HQ = 0.1 for exposure of an outdoor worker to soil (Table A.4 of DOE 2001).

[8] Total Dioxins and Furans are described as the 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) toxicity equivalent concentration (TEQ). Dioxins are not mobile to groundwater from soil at this SWMU (Section 2, this document). Value shown is the direct contact RG for outdoor worker exposure to subsurface soil (Table 2.1).

[9] PCBs are not mobile to groundwater from soil at COC for this SWMU (Section 2, this document). Value is the RG jointly agreed upon for PCBs by representatives of EPA Region 4, KDEP, and DOE in June 2009 scoping meetings

"--" Entry for ELCR or HI values indicates there is no cancer slope factor for ELCR assessment or noncancer reference dose for HI assessment, as applicable.

Bold Boldface type indicates Preliminary Remediation Goals used in the development of remediation alternatives and their associated cumulative ELCR and HI values.

Table C.8. Preliminary and Approximate Lower-Bound Remediation Goals for Surface Soil at SWMU 5

SWMU No.	Contaminant of Concern (COC)[1]	Toxic Effect	Preliminary Remediation Goal for Surface Soil[2] (mg/kg) (pCi/g)	ELCR for Preliminary Remediation Goal	HI for Preliminary Remediation Goal	Approximate Lower-Bound Remediation Goal for Surface Soil[3] (mg/kg) (pCi/g)	ELCR for Approximate Lower-Bound Remediation Goal	HI for Approximate Lower-Bound Remediation Goal
5	Technetium-99[4]	Carcinogen	**5.40E+00**	1.49E-08	--	5.40E+00	--	--
	Naphthalene[5]	Noncarcinogen	**5.99E-03**	--	0.00003	5.99E-03	--	--
	Total PCBs[6]	Carcinogen	**1.0E+01**	--	--	1.0E+01	--	--
			Cumulative ELCR or HI =	**1.E-08**	**0.00003**	**Cumulative ELCR or HI[3] =**	**--**	**--**

[1] Contaminant of Concern identified according to the risk methods document: To determine COCs, risk characterization results for chemical hazard (HQi) and risk (ELCRi) over all pathways within a use scenario of concern will be compared to benchmarks of 0.1 and 1 × 10-6, respectively. Chemicals of potential concern within a use scenario of concern exceeding either of these benchmarks will be deemed COCs for the use scenario of concern. (DOE 2001, pg. 3-37).

[2] Preliminary Remediation Goal is the lower of the Direct Contact Remediation Goal for Surface Soil and the Groundwater-Protective Goal for Surface Soil that is protective of the MCL concentration (Table 2.1), or the risk-based concentration for naphthalene. The background concentration is shown if larger than this value. Radionuclide concentrations given in pCi/g units. This value is used to develop remediation alternatives for surface soil at the SWMU.

[3] Approximate Lower-Bound Remediation Goal is the Preliminary Remediation Goal adjusted for cumulative health effects, if necessary. If the cumulative ELCR calculated for the preliminary RG is < 1E-5 or the cumulative HI < 1, no Approximate Lower-Bound RG is calculated. This value is not used to develop remediation alternatives for the SWMU. The "--" entry indicates no approximate lower-bound RG is calculated for this COC.

[4] Chemical is not identified as a direct contact soil COC for this SWMU, but is identified as a groundwater COC (Table 1.9). The Preliminary Soil RG represents the groundwater-protective soil concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 362 pCi/g, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future industrial worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[5] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.9). The Preliminary Soil RG represents the groundwater protective RG back-calculated from the risk-based groundwater concentration (Table C.1). The HQ associated with direct exposure to this concentration is calculated from the No Action Level of 23.6 mg/kg, which corresponds to HQ = 0.1 for direct-contact exposure of a future industrial worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[6] PCBs are not mobile to groundwater from soil at COC for this SWMU (Section 2, this document). Value is the RG jointly agreed upon for PCBs by representatives of EPA Region 4, KDEP, and DOE in June 2009 scoping meetings.

"--" Entry for ELCR or HI values indicates there is no cancer slope factor for ELCR assessment or noncancer reference dose for HI assessment, as applicable.

Bold Boldface type indicates Preliminary Remediation Goals used in the development of remediation alternatives and their associated cumulative ELCR and HI values.

Table C.9. Preliminary and Approximate Lower-Bound Remediation Goals for Subsurface Soil at SWMU 5

SWMU No.	Contaminant of Concern (COC)[1]	Toxic Effect	Preliminary Remediation Goal for Subsurface Soil[2] (mg/kg) (pCi/g)	ELCR for Preliminary Remediation Goal	HI for Preliminary Remediation Goal	Approximate Lower-Bound Remediation Goal for Subsurface Soil[3] (mg/kg) (pCi/g)	ELCR for Approximate Lower-Bound Remediation Goal	HI for Approximate Lower-Bound Remediation Goal
5	Technetium-99[4]	Carcinogen	**5.40E+00**	9.33E-08	--	5.40E+00	--	--
	Naphthalene[5]	Noncarcinogen	**5.99E-03**	--	0.000020	5.99E-03	--	--
	Total PCBs[6]	Carcinogen	**1.0E+01**	--	--	1.0E+01	--	--
			Cumulative ELCR or HI =	**9.E-08**	**0.000020**	**Cumulative ELCR or HI[3] =**	**--**	**--**

[1] Contaminant of Concern identified according to the risk methods document: To determine COCs, risk characterization results for chemical hazard (HQi) and risk (ELCRi) over all pathways within a use scenario of concern will be compared to benchmarks of 0.1 and 1 × 10-6, respectively. Chemicals of potential concern within a use scenario of concern exceeding either of these benchmarks will be deemed COCs for the use scenario of concern. (DOE 2001, pg. 3-37).

[2] Preliminary Remediation Goal is the lower of the Direct Contact Remediation Goal for Subsurface Soil and the Groundwater-Protective Goal for Surface Soil that is protective of the MCL concentration (Table 2.2), or a risk-based concentration for naphthalene. The background concentration is shown if larger than this value. Radionuclide concentrations given in pCi/g units. This value is used to develop remediation alternatives for surface soil at the SWMU.

[3] Approximate Lower-Bound Remediation Goal is the Preliminary Remediation Goal adjusted for cumulative health effects, if necessary. If the cumulative ELCR calculated for the preliminary RG is < 1E-4 or the cumulative HI < 1, no Approximate Lower-Bound RG is calculated. This value is not used to develop remediation alternatives for the SWMU. The "--" entry indicates no approximate lower-bound RG is calculated for this COC.

[4] Chemical is not identified as a direct contact soil COC for this SWMU, but is identified as a groundwater COC (Table 1.9). The Preliminary Soil RG represents the groundwater-protective concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 57.9 pCi/g, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future outdoor worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[5] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.9). The Preliminary Soil RG represents the groundwater protective RG back-calculated from the risk-based groundwater concentration (Table C.1). The HQ associated with direct exposure to this concentration is calculated from the No Action Level of 30.4 mg/kg, which corresponds to HQ = 0.5 for direct-contact exposure of a future outdoor worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[6] PCBs are not mobile to groundwater from soil at COC for this SWMU (Section 2, this document). Value is the RG jointly agreed upon for PCBs by representatives of EPA Region 4, KDEP, and DOE in June 2009 scoping meetings.

"--" Entry for ELCR or HI values indicates there is no cancer slope factor for ELCR assessment or noncancer reference dose for HI assessment, as applicable.

Bold Boldface type indicates Preliminary Remediation Goals used in the development of remediation alternatives and their associated cumulative ELCR and HI values.

Table C.10. Preliminary and Approximate Lower-Bound Remediation Goals for Surface Soil at SWMU 7

SWMU No.	Contaminant of Concern (COC)[1]	Toxic Effect	Preliminary Remediation Goal for Surface Soil[2] (mg/kg) (pCi/g)	ELCR for Preliminary Remediation Goal	HI for Preliminary Remediation Goal	Approximate Lower-Bound Remediation Goal for Surface Soil[3] (mg/kg) (pCi/g)	ELCR for Approximate Lower-Bound Remediation Goal	HI for Approximate Lower-Bound Remediation Goal
7	Neptunium-237	Carcinogen	**1.36E+00**	5.00E-06	--	8.84E-01	3.25E-06	--
	Plutonium-239	Carcinogen	Subsurface Soil Only See Table C.15	--	--	Subsurface Soil Only See Table C.15	--	--
	Technetium-99[4]	Carcinogen	**7.20E+00**	1.99E-08	--	7.20E+00	1.99E-08	--
	Uranium (metal)	Noncarcinogen	**1.01E+02**	--	1.0	1.01E+02	--	--
	Uranium-234	Carcinogen	**9.90E+01**	5.00E-06	--	5.94E+01	3.00E-06	--
	Uranium-235, Uranium-235/236[5]	Carcinogen	**1.98E+00**	5.00E-06	--	1.19E+00	3.00E-06	--
	Uranium-238	Carcinogen	**8.55E+00**	5.00E-06	--	5.13E+00	3.00E-06	--
	1,1-Dichloroethene[6]	Carcinogen	**1.61E-01**	1.68E-06	--	1.61E-01	1.68E-06	--
	cis-1,2-Dichloroethene[7]	Noncarcinogen	**1.47E+00**	--	0.01	1.47E+00	--	--
	Trichloroethene[8]	Carcinogen and Noncarcinogen	**1.00E-01**	3.98E-08	0.002	1.00E-01	3.98E-08	--
	Vinyl chloride[9]	Carcinogen and Noncarcinogen	**8.20E-02**	6.12E-07	0.0008	8.20E-02	6.12E-07	--
	Total PCBs[10]	Carcinogen	**1.0E+01**	--	--	1.0E+01	--	--
			Cumulative ELCR or HI =	**2.E-05**	**1**	**Cumulative ELCR or HI[3] =**	**1.E-05**	**--**

[1] Contaminant of Concern identified according to the risk methods document: To determine COCs, risk characterization results for chemical hazard (HQi) and risk (ELCRi) over all pathways within a use scenario of concern will be compared to benchmarks of 0.1 and 1 × 10-6, respectively. Chemicals of potential concern within a use scenario of concern exceeding either of these benchmarks will be deemed COCs for the use scenario of concern. (DOE 2001, pg. 3-37).

[2] Preliminary Remediation Goal is the lower of the Direct Contact Remediation Goal for Surface Soil and the Groundwater-Protective Goal for Surface Soil that is protective of the MCL concentration (Table 2.1). The background concentration is shown if larger than this value. Radionuclide concentrations given in pCi/g units. This value is used to develop remediation alternatives for surface soil at the SWMU.

Table C.10. Preliminary and Approximate Lower-Bound Remediation Goals for Surface Soil at SWMU 7 (Continued)

[3] Approximate Lower-Bound Remediation Goal is the Preliminary Remediation Goal adjusted for cumulative health effects, if necessary. If the cumulative ELCR calculated for the preliminary RG is < 1E-5 or the cumulative HI < 1, no Approximate Lower-Bound RG is calculated. This value is not used to develop remediation alternatives for the SWMU. The "--" entry indicates no approximate lower-bound RG is calculated for this COC.

[4] Chemical is not identified as a direct contact soil COC for this SWMU, but is identified as a groundwater COC (Table 1.11). The Preliminary Soil RG represents the groundwater-protective soil concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 362 pCi/g, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future industrial worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[5] Uranium-235 and uranium-235/236 both were identified as COCs at this SWMU. This identification is assumed to result from use of data from analytical methods that are not able to differentiate the U-235 and U-236 isotopes. Cancer risk coefficients for morbidity from inhalation, ingestion, and external exposure to these isotopes are given in Table 2.1, Table 2.2a, and Table 2.3 of Cancer Risk Coefficients for Environmental Exposure to Radionuclides, Federal Guidance Report No. 13, EPA 402-R-99-001, Air and Remediation, U. S. Environmental Protection Agency, September, 1999. The inhalation risk coefficients for U-235 and U-236 are similar, 1.59E-08 Bq-1 and 1.61E-08 Bq-1, respectively. The risk coefficients for U-235 and U-236 ingestion for water are similar, 1.88E-09 Bq-1 and 1.81E-09 Bq-1, respectively. The external exposure risk coefficient for U-235 exceeds that for U-236, 4.44E-16 kg/Bq-sec and 1.07E-19 kg/Bq-sec, respectively. Because risks from direct exposure to U-235/U-236 is predominantly associated with ingestion exposure, the Remediation Goal developed for U-235 serves for both U-235 and U-235/236 at this SWMU.

[6] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.11). The Preliminary Surface Soil PRG represents the groundwater protective RG back-calculated from the MCL concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 0.0959 mg/kg, which corresponds to ELCR = 1 E-06, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[7] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.11). The Preliminary Soil RG represents the groundwater protective soil RG back-calculated from the MCL concentration (Table C.1). The HQ associated with direct exposure to this concentration is calculated from the No Action Level of 13.4 mg/kg, which corresponds to HQ = 0.1 for direct-contact exposure of a future industrial worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[8] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.11). The Preliminary Soil RG represents the groundwater protective RG back-calculated from the MCL concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 2.51 mg/kg, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future industrial worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001). The HI associated with direct exposure is calculated from the No Action Level of 4.70 mg/kg, which corresponds to HQ = 0.1 for exposure of an industrial worker to soil (Table A.4 of DOE 2001).

[9] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.11). The Preliminary Soil RG represents the groundwater protective RG back-calculated from the MCL concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 0.134 mg/kg, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future industrial worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001). The HI associated with direct exposure is calculated from the No Action Level of 10.1 mg/kg, which corresponds to HQ = 0.1 for exposure of an industrial worker to soil (Table A.4 of DOE 2001).

[10] PCBs are not mobile to groundwater from soil at COC for this SWMU (Section 2, this document). Value is the RG jointly agreed upon for PCBs by representatives of EPA Region 4, KDEP, and DOE in June 2009 scoping meetings.

"--" Entry for ELCR or HI values indicates there is no cancer slope factor for ELCR assessment or noncancer reference dose for HI assessment, as applicable.

Bold Boldface type indicates Preliminary Remediation Goals used in the development of remediation alternatives and their associated cumulative ELCR and HI values.

Table C.11. Preliminary and Approximate Lower-Bound Remediation Goals for Subsurface Soil at SWMU 7

SWMU No.	Contaminant of Concern (COC)[1]	Toxic Effect	Preliminary Remediation Goal for Subsurface Soil[2] (mg/kg) (pCi/g)	ELCR for Preliminary Remediation Goal	HI for Preliminary Remediation Goal	Approximate Lower-Bound Remediation Goal for Subsurface Soil[3] (mg/kg) (pCi/g)	ELCR for Approximate Lower-Bound Remediation Goal	HI for Approximate Lower-Bound Remediation Goal
7	Neptunium-237	Carcinogen	**1.64E+01**	5.00E-05	--	9.02E+00	2.75E-05	--
	Plutonium-239	Carcinogen	**8.15E+01**	5.00E-05	--	4.48E+01	2.75E-05	--
	Technetium-99[4]	Carcinogen	**7.20E+00**	1.24E-07	--	7.20E+00	1.24E-07	--
	Uranium (metal)	Noncarcinogen	**1.13E+02**	--	1.0	1.13E+02	--	--
	Uranium-234	Carcinogen	**1.42E+02**	5.00E-05	--	7.81E+01	2.75E-05	--
	Uranium-235, Uranium-235/236[5]	Carcinogen	**2.28E+01**	5.00E-05	--	1.25E+01	2.75E-05	--
	Uranium-238	Carcinogen	**5.85E+01**	5.00E-05	--	3.22E+01	2.75E-05	--
	1,1-Dichloroethene[6]	Carcinogen	**1.61E-01**	1.35E-06	--	1.61E-01	1.35E-06	--
	cis-1,2-Dichloroethene[7]	Noncarcinogen	**1.47E+00**	--	0.009	1.47E+00	--	--
	Trichloroethene[8]	Carcinogen and Noncarcinogen	**1.00E-01**	3.08E-08	0.002	1.00E-01	3.08E-08	--
	Vinyl chloride[9]	Carcinogen and Noncarcinogen	**8.20E-02**	5.82E-07	0.0007	8.20E-02	5.82E-07	--
	Total PCBs[10]	Carcinogen	**1.0E+01**	--	--	1.0E+01	--	--
			Cumulative ELCR or HI =	**3.E-04**	**1**	**Cumulative ELCR or HI[3] =**	**1.E-04**	**--**

[1] Contaminant of Concern identified according to the risk methods document: To determine COCs, risk characterization results for chemical hazard (HQi) and risk (ELCRi) over all pathways within a use scenario of concern will be compared to benchmarks of 0.1 and 1 × 10-6, respectively. Chemicals of potential concern within a use scenario of concern exceeding either of these benchmarks will be deemed COCs for the use scenario of concern. (DOE 2001, pg. 3-37).
[2] Preliminary Remediation Goal is the lower of the Direct Contact Remediation Goal for Subsurface Soil and the Groundwater-Protective Goal for Surface Soil that is protective of the MCL concentration (Table 2.2). The background concentration is shown if larger than this value. Radionuclide concentrations given in pCi/g units. This value is used to develop remediation alternatives for surface soil at the SWMU.
[3] Approximate Lower-Bound Remediation Goal is the Preliminary Remediation Goal adjusted for cumulative health effects, if necessary. If the cumulative ELCR calculated for the preliminary RG is < 1E-4 or the cumulative HI < 1, no Approximate Lower-Bound RG is calculated. This value is not used to develop remediation alternatives for the SWMU. The "--" entry indicates no approximate lower-bound RG is calculated for this COC.

Table C.11. Preliminary and Approximate Lower-Bound Remediation Goals for Subsurface Soil at SWMU 7 (Continued)

[4] Chemical is not identified as a direct contact soil COC for this SWMU, but is identified as a groundwater COC (Table 1.11. The Preliminary Soil RG represents the groundwater-protective soil concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 57.9 pCi/g, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future outdoor worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[5] Uranium-235 and uranium-235/236 both were identified as COCs at this SWMU. This identification is assumed to result from use of data from analytical methods that are not able to differentiate the U-235 and U-236 isotopes. Cancer risk coefficients for morbidity from inhalation, ingestion, and external exposure to these isotopes are given in Table 2.1, Table 2.2a, and Table 2.3 of Cancer Risk Coefficients for Environmental Exposure to Radionuclides, Federal Guidance Report No. 13, EPA 402-R-99-001, Air and Remediation, U. S. Environmental Protection Agency, September, 1999. The inhalation risk coefficients for U-235 and U-236 are similar, 1.59E-08 Bq-1 and 1.61E-08 Bq-1, respectively. The risk coefficients for U-235 and U-236 ingestion for water are similar, 1.88E-09 Bq-1 and 1.81E-09 Bq-1, respectively. The external exposure risk coefficient for U-235 exceeds that for U-236, 4.44E-16 kg/Bq-sec and 1.07E-19 kg/Bq-sec, respectively. Because risks from direct exposure to U-235/U-236 is predominantly associated with ingestion exposure, the Remediation Goal developed for U-235 serves for both U-235 and U-235/236 at this SWMU.

[6] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.11). The Preliminary Surface Soil PRG represents the groundwater protective RG back-calculated from the MCL concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 0.119 mg/kg, which corresponds to ELCR = 1 E-06, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[7] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.11). The Preliminary Soil RG represents the groundwater protective RG back-calculated from the MCL concentration (Table C.1). The HQ associated with direct exposure to this concentration is calculated from the No Action Level of 17.1 mg/kg, which corresponds to HQ = 0.1 for direct-contact exposure of a future outdoor worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[8] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.11). The Preliminary Soil RG represents the groundwater protective RG back-calculated from the MCL concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 3.25 mg/kg, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future outdoor worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001). The HI associated with direct exposure is calculated from the No Action Level of 6.15 mg/kg, which corresponds to HQ = 0.1 for exposure of an outdoor worker to soil (Table A.4 of DOE 2001).

[9] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.11). The Preliminary Soil RG represents the groundwater protective RG back-calculated from the MCL concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 0.141 mg/kg, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future outdoor worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001). The HI associated with direct exposure is calculated from the No Action Level of 12.0 mg/kg, which corresponds to HQ = 0.1 for exposure of an outdoor worker to soil (Table A.4 of DOE 2001).

[10] PCBs are not mobile to groundwater from soil at COC for this SWMU (Section 2, this document). Value is the RG jointly agreed upon for PCBs by representatives of EPA Region 4, KDEP, and DOE in June 2009 scoping meetings.

"--" Entry for ELCR or HI values indicates there is no cancer slope factor for ELCR assessment or noncancer reference dose for HI assessment, as applicable.

Bold Boldface type indicates Preliminary Remediation Goals used in the development of remediation alternatives and their associated cumulative ELCR and HI values.

Table C.12. Preliminary and Approximate Lower-Bound Remediation Goals for Surface Soil at SWMU 30

SWMU No.	Contaminant of Concern (COC)[1]	Toxic Effect	Preliminary Remediation Goal for Surface Soil[2] (mg/kg) (pCi/g)	ELCR for Preliminary Remediation Goal	HI for Preliminary Remediation Goal	Approximate Lower-Bound Remediation Goal for Surface Soil[3] (mg/kg) (pCi/g)	ELCR for Approximate Lower-Bound Remediation Goal	HI for Approximate Lower-Bound Remediation Goal
30	Neptunium-237	Carcinogen	**1.36E+00**	5.00E-06	--	6.53E-01	2.40E-06	--
	Plutonium-239	Carcinogen	Subsurface Soil Only See Table C.13	--	--	Subsurface Soil Only See Table C.13	--	--
	Technetium-99[4]	Carcinogen	**1.17E+01**	3.23E-08	--	1.17E+01	3.23E-08	--
	Uranium (metal)	Noncarcinogen	**1.01E+02**	--	1.0	1.01E+02	--	--
	Uranium-234	Carcinogen	**9.90E+01**	5.00E-06	--	4.75E+01	2.40E-06	--
	Uranium-235, Uranium-235/236[5]	Carcinogen	**1.98E+00**	5.00E-06	--	9.50E-01	2.40E-06	--
	Uranium-238	Carcinogen	**8.55E+00**	5.00E-06	--	4.10E+00	2.40E-06	--
	1,1-Dichloroethene[6]	Carcinogen	**4.80E-01**	5.01E-06	--	2.3E-01	2.40E-06	--
	Trichloroethene[7]	Carcinogen and Noncarcinogen	**6.35E-01**	2.53E-07	0.01	6.35E-01	2.53E-07	--
	Total PCBs[8]	Carcinogen	**1.0E+01**	--	--	1.0E+01	--	--
			Cumulative ELCR or HI =	**3.E-05**	**1**	**Cumulative ELCR or HI[3] =**	**1.E-05**	**--**

[1] Contaminant of Concern identified according to the risk methods document: To determine COCs, risk characterization results for chemical hazard (HQi) and risk (ELCRi) over all pathways within a use scenario of concern will be compared to benchmarks of 0.1 and 1 × 10-6, respectively. Chemicals of potential concern within a use scenario of concern exceeding either of these benchmarks will be deemed COCs for the use scenario of concern. (DOE 2001, pg. 3-37).

[2] Preliminary Remediation Goal is the lower of the Direct Contact Remediation Goal for Surface Soil and the Groundwater-Protective Goal for Surface Soil that is protective of the MCL concentration (Table 2.1). The background concentration is shown if larger than this value. Radionuclide concentrations given in pCi/g units. This value is used to develop remediation alternatives for surface soil at the SWMU.

[3] Approximate Lower-Bound Remediation Goal is the Preliminary Remediation Goal adjusted for cumulative health effects, if necessary. If the cumulative ELCR calculated for the preliminary RG is < 1E-5 or the cumulative HI < 1, no Approximate Lower-Bound RG is calculated. This value is not used to develop remediation alternatives for the SWMU. The "--"entry indicates no approximate lower-bound RG is calculated for this COC.

[4] Chemical is not identified as a direct contact soil COC for this SWMU, but is identified as a groundwater COC (Table 1.12). The Preliminary Soil RG represents the groundwater-protective soil concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 362 pCi/g, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future industrial worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[5] Uranium-235 and uranium-235/236 both were identified as COCs at this SWMU. This identification is assumed to result from use of data from analytical methods that are not able to differentiate the

Table C.12. Preliminary and Approximate Lower-Bound Remediation Goals for Surface Soil at SWMU 30 (Continued)

U-235 and U-236 isotopes. Cancer risk coefficients for morbidity from inhalation, ingestion, and external exposure to these isotopes are given in Table 2.1, Table 2.2a, and Table 2.3 of Cancer Risk Coefficients for Environmental Exposure to Radionuclides, Federal Guidance Report No. 13, EPA 402-R-99-001, Air and Remediation, U. S. Environmental Protection Agency, September, 1999. The inhalation risk coefficients for U-235 and U-236 are similar, 1.59E-08 Bq-1 and 1.61E-08 Bq-1, respectively. The risk coefficients for U-235 and U-236 ingestion for water are similar, 1.88E-09 Bq-1 and 1.81E-09 Bq-1, respectively. The external exposure risk coefficient for U-235 exceeds that for U-236, 4.44E-16 kg/Bq-sec and 1.07E-19 kg/Bq-sec, respectively. Because risks from direct exposure to U-235/U-236 is predominantly associated with ingestion exposure, the Remediation Goal developed for U-235 serves for both U-235 and U-235/236 at this SWMU.

[6] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.12). However, the preliminary RG shown represents the lower of the direct contact RG calculated from the No Action Level (Table 2.1) and the groundwater protective RG back-calculated from the MCL concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 0.0959 mg/kg, which corresponds to ELCR = 1 E-06, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[7] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.12). The Preliminary Soil RG represents the groundwater protective RG back-calculated from the MCL concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 2.51 mg/kg, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future industrial worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001). The HI associated with direct exposure is calculated from the No Action Level of 4.70 mg/kg, which corresponds to HQ = 0.1 for exposure of an industrial worker to soil (Table A.4 of DOE 2001).

[8] PCBs are not mobile to groundwater from soil at COC for this SWMU (Section 2, this document). Value is the RG jointly agreed upon for PCBs by representatives of EPA Region 4, KDEP, and DOE in June 2009 scoping meetings.

"--" Entry for ELCR or HI values indicates there is no cancer slope factor for ELCR assessment or noncancer reference dose for HI assessment, as applicable.

Bold Boldface type indicates Preliminary Remediation Goals used in the development of remediation alternatives and their associated cumulative ELCR and HI values.

Table C.13. Preliminary and Approximate Lower-Bound Remediation Goals for Subsurface Soil at SWMU 30

SWMU No.	Contaminant of Concern (COC)[1]	Toxic Effect	Preliminary Remediation Goal for Subsurface Soil[2] (mg/kg) (pCi/g)	ELCR for Preliminary Remediation Goal	HI for Preliminary Remediation Goal	Approximate Lower-Bound Remediation Goal for Subsurface Soil[3] (mg/kg) (pCi/g)	ELCR for Approximate Lower-Bound Remediation Goal	HI for Approximate Lower-Bound Remediation Goal
30	Neptunium-237	Carcinogen	**1.64E+01**	5.00E-05	--	7.71E+00	2.35E-05	--
	Plutonium-239	Carcinogen	**8.15E+01**	5.00E-05	--	3.83E+01	2.35E-05	--
	Technetium-99[4]	Carcinogen	**1.17E+01**	2.02E-07	--	1.17E+01	2.02E-07	--
	Uranium (metal)	Noncarcinogen	**1.13E+02**	--	1.00	1.13E+02	--	--
	Uranium-234	Carcinogen	**1.42E+02**	5.00E-05	--	6.67E+01	2.35E-05	--
	Uranium-235, Uranium-235/236[5]	Carcinogen	**2.28E+01**	5.00E-05	--	1.07E+01	2.35E-05	--
	Uranium-238	Carcinogen	**5.85E+01**	5.00E-05	--	2.75E+01	2.35E-05	--
	1,1-Dichloroethene[6]	Carcinogen	**1.56E+00**	1.31E-05	--	7.33E-01	6.16E-06	--
	Trichloroethene[7]	Carcinogen and Noncarcinogen	**6.35E-01**	1.95E-07	0.01	6.35E-01	1.95E-07	--
	Total PCBs[8]	Carcinogen	**1.0E+01**	--	--	1.0E+01	--	--
			Cumulative ELCR or HI =	**3.E-04**	**1**	**Cumulative ELCR or HI [3] =**	**1.E-04**	**--**

[1] Contaminant of Concern identified according to the risk methods document: To determine COCs, risk characterization results for chemical hazard (HQi) and risk (ELCRi) over all pathways within a use scenario of concern will be compared to benchmarks of 0.1 and 1 × 10-6, respectively. Chemicals of potential concern within a use scenario of concern exceeding either of these benchmarks will be deemed COCs for the use scenario of concern. (DOE 2001, pg. 3-37).

[2] Preliminary Remediation Goal is the lower of the Direct Contact Remediation Goal for Subsurface Soil and the Groundwater-Protective Goal for Surface Soil that is protective of the MCL concentration (Table 2.2). The background concentration is shown if larger than this value. Radionuclide concentrations given in pCi/g units. This value is used to develop remediation alternatives for surface soil at the SWMU.

[3] Approximate Lower-Bound Remediation Goal is the Preliminary Remediation Goal adjusted for cumulative health effects, if necessary. If the cumulative ELCR calculated for the preliminary RG is < 1E-4 or the cumulative HI < 1, no Approximate Lower-Bound RG is calculated. This value is not used to develop remediation alternatives for the SWMU. The "--" entry indicates no approximate lower-bound RG is calculated for this COC.

[4] Chemical is not identified as a direct contact soil COC for this SWMU, but is identified as a groundwater COC (Table 1.12). The Preliminary Soil RG represents the groundwater-protective soil concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 57.9 pCi/g, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future outdoor worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[5] Uranium-235 and uranium-235/236 both were identified as COCs at this SWMU. This identification is assumed to result from use of data from analytical methods that are not able to differentiate the U-235 and U-236 isotopes. Cancer risk coefficients for morbidity from inhalation, ingestion, and external exposure to these isotopes are given in Table 2.1, Table 2.2a, and Table 2.3 of Cancer Risk Coefficients for Environmental Exposure to Radionuclides, Federal Guidance Report No. 13, EPA 402-R-99-001, Air and Remediation, U. S. Environmental Protection Agency, September, 1999. The

Table C.13. Preliminary and Approximate Lower-Bound Remediation Goals for Subsurface Soil at SWMU 30 (Continued)

inhalation risk coefficients for U-235 and U-236 are similar, 1.59E-08 Bq-1 and 1.61E-08 Bq-1, respectively. The risk coefficients for U-235 and U-236 ingestion for water are similar, 1.88E-09 Bq-1 and 1.81E-09 Bq-1, respectively. The external exposure risk coefficient for U-235 exceeds that for U-236, 4.44E-16 kg/Bq-sec and 1.07E-19 kg/Bq-sec, respectively. Because risks from direct exposure to U-235/U-236 is predominantly associated with ingestion exposure, the Remediation Goal developed for U-235 serves for both U-235 and U-235/236 at this SWMU.

[6] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.12). The Preliminary Surface Soil PRG represents the groundwater protective RG back-calculated from the MCL concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 0.119 mg/kg, which corresponds to ELCR = 1 E-06, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

[7] Chemical is not identified as a direct contact soil COC for this SWMU (Table 1.12). The Preliminary Soil RG represents the groundwater protective RG back-calculated from the MCL concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 3.25 mg/kg, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future outdoor worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001). The HI associated with direct exposure is calculated from the No Action Level of 6.15 mg/kg, which corresponds to HQ = 0.1 for exposure of an outdoor worker to soil (Table A.4 of DOE 2001).

[8] PCBs are not mobile to groundwater from soil at COC for this SWMU (Section 2, this document). Value is the RG jointly agreed upon for PCBs by representatives of EPA Region 4, KDEP, and DOE in June 2009 scoping meetings.

"--" Entry for ELCR or HI values indicates there is no cancer slope factor for ELCR assessment or noncancer reference dose for HI assessment, as applicable.

Bold Boldface type indicates Preliminary Remediation Goals used in the development of remediation alternatives and their associated cumulative ELCR and HI values.

Table C.14. Preliminary and Approximate Lower-Bound Remediation Goals for Surface Soil SWMU 145

SWMU No.	Contaminant of Concern (COC)[1]	Toxic Effect	Preliminary Remediation Goal for Surface Soil[2] (mg/kg) (pCi/g)	ELCR for Preliminary Remediation Goal	HI for Preliminary Remediation Goal	Approximate Lower-Bound Remediation Goal for Surface Soil[3] (mg/kg) (pCi/g)	ELCR for Approximate Lower-Bound Remediation Goal	HI for Approximate Lower-Bound Remediation Goal
145	Technetium-99[4]	Carcinogen	**8.10E+00**	2.24E-08	--	8.1E+00	--	--
			Cumulative ELCR or HI =	**2.E-08**	**--**	**Cumulative ELCR or HI[3] =**	**--**	**--**

[1] Contaminant of Concern identified according to the risk methods document: To determine COCs, risk characterization results for chemical hazard (HQi) and risk (ELCRi) over all pathways within a use scenario of concern will be compared to benchmarks of 0.1 and 1 × 10-6, respectively. Chemicals of potential concern within a use scenario of concern exceeding either of these benchmarks will be deemed COCs for the use scenario of concern. (DOE 2001, pg. 3-37).

[2] Preliminary Remediation Goal is the lower of the Direct Contact Remediation Goal for Surface Soil and the Groundwater-Protective Goal for Surface Soil that is protective of the MCL concentration (Table 2.1). The background concentration is shown if larger than this value. Radionuclide concentrations given in pCi/g units. This value is used to develop remediation alternatives for surface soil at the SWMU.

[3] Approximate Lower-Bound Remediation Goal is the Preliminary Remediation Goal adjusted for cumulative health effects, if necessary. If the cumulative ELCR calculated for the preliminary RG is < 1E-5 or the cumulative HI < 1, no Approximate Lower-Bound RG is calculated. This value is not used to develop remediation alternatives for the SWMU. The "--" entry indicates no approximate lower-bound RG is calculated for this COC.

[4] Chemical is not identified as a direct contact soil COC for this SWMU, but is identified as a groundwater COC (Table 1.13). The Preliminary Soil RG represents the groundwater-protective soil concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 362 pCi/g, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future industrial worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

"--" Entry for ELCR or HI values indicates there is no cancer slope factor for ELCR assessment or noncancer reference dose for HI assessment, as applicable.

Bold Boldface type indicates Preliminary Remediation Goals used in the development of remediation alternatives and their associated cumulative ELCR and HI values.

Table C.15. Preliminary and Approximate Lower-Bound Remediation Goals for Subsurface Soil SWMU 145

SWMU No.	Contaminant of Concern (COC)[1]	Toxic Effect	Preliminary Remediation Goal for Subsurface Soil[2] (mg/kg) (pCi/g)	ELCR for Preliminary Remediation Goal	HI for Preliminary Remediation Goal	Approximate Lower-Bound Remediation Goal for Subsurface Soil[3] (mg/kg) (pCi/g)	ELCR for Approximate Lower-Bound Remediation Goal	HI for Approximate Lower-Bound Remediation Goal
145	Technetium-99[4]	Carcinogen	**8.10E+00**	1.40E-07	--	8.10E+00	--	--
			Cumulative ELCR or HI =	**1.E-07**	**--**	**Cumulative ELCR or HI[3] =**	**--**	**--**

[1] Contaminant of Concern identified according to the risk methods document: To determine COCs, risk characterization results for chemical hazard (HQi) and risk (ELCRi) over all pathways within a use scenario of concern will be compared to benchmarks of 0.1 and 1 × 10-6, respectively. Chemicals of potential concern within a use scenario of concern exceeding either of these benchmarks will be deemed COCs for the use scenario of concern. (DOE 2001, pg. 3-37).

[2] Preliminary Remediation Goal is the lower of the Direct Contact Remediation Goal for Subsurface Soil and the Groundwater-Protective Goal for Surface Soil that is protective of the MCL concentration (Table 2.2). The background concentration is shown if larger than this value. Radionuclide concentrations given in pCi/g units. This value is used to develop remediation alternatives for surface soil at the SWMU.

[3] Approximate Lower-Bound Remediation Goal is the Preliminary Remediation Goal adjusted for cumulative health effects, if necessary. If the cumulative ELCR calculated for the preliminary RG is < 1E-4 or the cumulative HI < 1, no Approximate Lower-Bound RG is calculated. This value is not used to develop remediation alternatives for the SWMU. The " --" entry indicates no approximate lower-bound RG is calculated for this COC.

[4] Chemical is not identified as a direct contact soil COC for this SWMU, but is identified as a groundwater COC (Table 1.13). The Preliminary Soil RG represents the groundwater-protective soil concentration (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the No Action Level of 57.9 pCi/g, which corresponds to ELCR = 1E-06 for direct-contact exposure of a future outdoor worker to soil, and is given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

"--" Entry for ELCR or HI values indicates there is no cancer slope factor for ELCR assessment or noncancer reference dose for HI assessment, as applicable.

Bold Boldface type indicates Preliminary Remediation Goals used in the development of remediation alternatives and their associated cumulative ELCR and HI values.

Certain chemicals were not selected as soil COCs but were identified as groundwater COCs [for example, technetium-99 (Tc-99) at SWMU 2 as shown in Table 2.1]. The preliminary RGs for such COCs were based on the back calculation using the MCL concentration as described in Section 2.

Other chemicals that were not selected as soil COCs, but were identified as groundwater COCs do not represent a threat to groundwater as indicated in Table 5.2 of the RI report (DOE 2010) (see Section 2.2.2). Uranium metal at SWMU 2 is an example of such a chemical. Because these chemicals do not represent a risk or hazard by direct contact with soil, and are not a threat to groundwater, no RGs for soil were developed for these chemicals.

The 10 ppm RG for PCBs in soil is the value jointly agreed upon by representatives of EPA Region 4, KDEP, and DOE in June 2009 scoping meetings. This value was considered to be sufficiently protective of potential direct contact risk that could occur at the BGOU, and it also was recognized that actual postremediation PCB concentrations are likely to be lower than the 10 mg/kg value. This value is applied at other Paducah Gaseous Diffusion Plant (PGDP) operable units (OUs) as the RG for soil.

C.3.3. SWMU 2

Preliminary RGs for remediation of soil at SWMU 2 are shown in column 4 of Tables C.2 and C.3. These RGs were taken from column 7 of Tables 2.1 and 2.2.

Preliminary RGs for Soil

The COCs identified in surface soil at this SWMU (Table C.2) include six carcinogens (Tc-99, U-234, U-235, U-238, TCE, and PCBs), and four noncarcinogens (uranium metal, *cis*-1,2-dichloroethene (DCE), TCE, and naphthalene). The COCs identified in subsurface soil at this SWMU (Table C.3) include six carcinogens (Tc-99, U-234, U-235, U-238, and TCE, and PCBs), and four noncarcinogens (uranium metal, *cis*-1,2-DCE, TCE, and naphthalene).

Preliminary RGs for COCs in Surface Soil and in Subsurface Soil are shown in column 4 of Tables C.2 and C.3, respectively. RGs for the COCs in soil are shown in columns 5 and 6 of these tables, respectively.

The preliminary soil RG for Tc-99 represents the groundwater-protective soil concentration for both surface and subsurface soil (Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the NAL for the industrial worker scenario (362 pCi/g, Table C.2) or for subsurface soil under the outdoor worker scenario (57.9 pCi/g, Table C.3), which corresponds to ELCR = 1E-06 for direct-contact exposure to soil at the BGOU. NALs are given in Table A.4 of the 2001 Risk Methods Document (DOE 2001).

Uranium metal and U-234 were not identified as COCs for direct contact exposure, but were identified in groundwater potentially used by a resident (Table 1.6); however, uranium does not represent a threat to groundwater beneath the SWMU because of its immobility. No RG is developed for uranium or U-234 in soil at this SWMU.

Cis-1,2-DCE was not identified as a direct contact soil COC for this SWMU (Table 1.6). The Preliminary Soil RG represents the groundwater-protective soil RG back-calculated from the MCL (column 3 of Table C.1). The HQ associated with direct exposure to this concentration is calculated from the NAL for the industrial worker scenario (13.4 mg/kg, Table C.2) or the outdoor worker scenario (17.1 mg/kg, Table C.3), which corresponds to HQ = 0.1 for direct-contact exposure of workers to soil (DOE 2001).

TCE was not identified as a direct contact soil COC for this SWMU (Table 1.6). The Preliminary Soil RG represents the groundwater-protective RG back-calculated from the MCL (column 3 of Table C.1). The ELCR associated with direct exposure to this concentration is calculated from the NAL for the industrial worker scenario (2.51 mg/kg, Table C.2) or the outdoor worker scenario (3.25 mg/kg, Table C.3), which corresponds to ELCR = 1E-06 for direct-contact exposure of workers to soil (DOE 2001). The HI associated with direct exposure is calculated from the NAL for the industrial worker scenario (4.70 mg/kg, Table C.2) or the outdoor worker scenario (6.15 mg/kg, Table C.3), which corresponds to HQ = 0.1 for exposure of workers to soil (DOE 2001).

Naphthalene was not identified as a direct contact soil COC for this SWMU (Table 1.6). The Preliminary Soil RG represents the groundwater-protective RG back-calculated from the risk-based groundwater concentration (column 4 of Table C.1). The HQ associated with direct exposure to this concentration is calculated from the NAL for the industrial worker scenario (23.6 mg/kg, Table C.2) or the outdoor worker scenario (30.4 mg/kg, Table C.3), which corresponds to HQ = 0.1 for direct-contact exposure of workers to soil (DOE 2001).

PCBs are not mobile to groundwater from soil at this SWMU (Section 2, main body of this document). The 10 ppm RG for PCBs in soil is the value jointly agreed upon by representatives of EPA Region 4, KDEP, and DOE in June 2009 scoping meetings. This value was considered to be sufficiently protective of potential direct contact risk that could occur at the BGOU.

Individual preliminary RGs for carcinogenic COCs in surface soil correspond to ELCR ≤ 5E-06 and the cumulative ELCR is ≤ 1E-05; the RGs for noncarcinogenic COCs in surface soil correspond to an HQ ≤0.5 and the cumulative HI ≤ 1 (Table C.2). For subsurface soil, individual RGs correspond to ELCR ≤ 5E-05 or less and the cumulative ELCR is ≤ 1E-04 and the RGs correspond to an HQ ≤ 1 and the cumulative HI is ≤ 1(Table C.3). Because the preliminary RGs for soil COCs at SWMU 2 meet target cumulative risk and hazard criteria described in Section 2 and the National Contingency Plan (NCP) requirements for use in the feasibility study (FS) (EPA 1994), they are used for development of remediation alternatives in Section 3 of this document.

Approximate lower-bound Soil RGs at SWMU 2

Because the preliminary RGs meet the target risk and hazard criteria, no approximate lower-bound RGs are calculated for soil at this SWMU.

C.3.4. SWMU 3

Preliminary RGs for remediation of soil at SWMU 3 are shown in Tables C.4 and C.5. These RGs were taken from column 7 of Tables 2.1 and 2.2.

Preliminary RGs for Soil

The COCs identified in surface soil (Table C.4) and subsurface soil (Table C.5) at this SWMU include three carcinogens (Tc-99, U-235, and U-238), and one noncarcinogen (uranium metal).

Preliminary RGs for COCs in Surface Soil and in Subsurface Soil are shown in column 4 of Tables C.4 and C.5, respectively. ELCR and HI values for the preliminary RGs for the COCs in soil are shown in columns 5 and 6 of these tables, respectively.

The Preliminary Soil RG for Tc-99 represents the groundwater-protective concentration (Table C.1). As described for SWMU 2, the ELCR associated with direct exposure to this concentration is calculated from the NAL for the industrial worker scenario (Table C.4) or for subsurface soil under the outdoor worker scenario (Table C.5), which corresponds to ELCR = 1E-06 for direct-contact exposure to soil.

Uranium metal was not identified as a COC for direct contact exposure, but was identified in groundwater potentially used by a resident (Table 1.7). Uranium does not represent a threat to groundwater beneath the SWMU because of its immobility; therefore, no RG is developed for uranium or U-234 in soil at this SWMU.

Individual preliminary RGs for carcinogenic COCs in surface soil correspond to ELCR ≤ 5E-06 and the cumulative ELCR is ≤ 1E-05; the RGs for noncarcinogenic COCs in surface soil correspond to an HQ ≤ 0.5 and the cumulative HI is ≤ 1 (Table C.4). For subsurface soil, individual RGs correspond to ELCR ≤ 5E-05 and the cumulative ELCR is ≤ 1E-04; the RGs correspond to an HQ ≤ 1 or less and the cumulative HI is ≤ 1(Table C.5). Because the preliminary RGs for soil COCs at SWMU 3 meet target risk and hazard criteria described in Section 2 and the NCP requirements for use in the FS (EPA 1994), they are used for development of remediation alternatives in Section 3 of this document.

Approximate lower-bound Soil RGs at SWMU 3

Because the preliminary RGs meet the target risk and hazard criteria, no approximate lower-bound RGs are calculated for soil at this SWMU.

C.3.5. SWMU 4

Preliminary RGs for remediation of soil at SWMU 4 are shown in Tables C.6 and C.7. These RGs were taken from column 7 of Tables 2.1 and 2.2.

Preliminary RGs for Soil

The COCs identified in surface soil at this SWMU (Tables C.6) include six carcinogens (Tc-99, U-238, TCE, vinyl chloride, dioxins, and PCBs) and three noncarcinogens (*cis*-1,2-DCE, TCE, and vinyl chloride).

The COCs identified in subsurface soil at this SWMU (Tables C.7) include six carcinogens (Tc-99, U-238, TCE, vinyl chloride, dioxins, and PCBs) and four noncarcinogens (uranium metal, *cis*-1,2-DCE, TCE, and vinyl chloride).

Preliminary RGs for COCs in Surface Soil and in Subsurface Soil are shown in column 4 of Tables C.6 and C.7, respectively. ELCR and HI values for the preliminary RGs for the COCs in soil are shown in columns 5 and 6 of these tables, respectively.

The Preliminary Soil RG for Tc-99 represents the groundwater-protective concentration (Table C.1). As described for SWMU 2, the ELCR associated with direct exposure to this concentration is calculated from the NAL for the industrial worker scenario (Table C.6) or for subsurface soil under the outdoor worker scenario (Table C.7), which corresponds to ELCR = 1E-06 for direct-contact exposure to soil.

Cis-1,2-DCE, TCE, and vinyl chloride were not identified as direct contact soil COCs for this SWMU (Table 1.8). The Preliminary Soil RGs represent the groundwater-protective soil RGs back-calculated from the MCL groundwater concentration (Table C.1). As described above for SWMU 2, the ELCR and HI values associated with direct exposure to this concentration are calculated from the NAL for the industrial worker and outdoor worker scenarios.

Total dioxins and furans were identified as COCs in subsurface soil only (Table C.7). Because dioxins are not mobile from soil to groundwater at this SWMU (Section 2, this document), the RG shown is the direct contact RG for outdoor worker exposure to subsurface soil (Table 2.2).

PCBs are not mobile to groundwater from soil at this SWMU (Section 2, this document). The 10 ppm RG for PCBs in soil is the value jointly agreed upon by representatives of EPA Region 4, KDEP, and DOE in June 2009 scoping meetings. This value was considered to be sufficiently protective of potential direct contact risk that could occur at the BGOU.

Individual preliminary RGs for carcinogenic COCs in surface soil correspond to ELCR ≤ 5E-06 and the cumulative ELCR is ≤ 1E-05; the RGs for noncarcinogenic COCs in surface soil correspond to an HQ ≤ 0.5 and the cumulative HI is ≤ 1 (Table C.10). For subsurface soil, individual RGs correspond to ELCR ≤ 5E-05 and the cumulative ELCR is ≤ 1E-04; the RGs correspond to an HQ ≤ 1 and the cumulative HI is ≤ 1 (Table C.11). Because the preliminary RGs for soil COCs at SWMU 4 meet Target risk and hazard criteria described in Section 2 and the NCP requirements (EPA 1994) for use in the FS, they are used for development of remediation alternatives in Section 3 of this document.

Approximate lower-bound Soil RGs at SWMU 4

Because the preliminary RGs meet the target risk and hazard criteria, no approximate lower-bound RGs are calculated for soil at this SWMU.

C.3.6. SWMU 5

Preliminary RGs for remediation of soil at SWMU 5 are shown in Tables C.8 and C.9. These RGs were taken from column 7 of Tables 2.1 and 2.2.

Preliminary RGs for Soil

The COCs identified in surface soil (Table C.8) and subsurface soil (Table C.9) at this SWMU include three carcinogens [Tc-99, total polyaromatic hydrocarbons (PAHs), and total PCBs], and one noncarcinogen (naphthalene).

Preliminary RGs for COCs in surface soil and in subsurface soil are shown in column 4 of Tables C.8 and C.9, respectively. ELCR and HI values for the preliminary RGs for the COCs in soil are shown in columns 5 and 6 of these tables, respectively.

The Preliminary Soil RG for Tc-99 represents the groundwater-protective concentration (Table 2.1). As described for SWMU 2, the ELCR associated with direct exposure to this concentration is calculated from the NAL for the industrial worker scenario (Table C.8) or for subsurface soil under the outdoor worker scenario (Table C.9), which corresponds to ELCR = 1E-06 for direct-contact exposure to soil.

Naphthalene was not identified as a direct contact soil COC for this SWMU (Table 1.9). The Preliminary Soil RG represents the groundwater-protective RG back-calculated from the MCL concentration (Table C.1). As described for SWMU 2, the HQ associated with direct exposure to this concentration is calculated from the NAL for the industrial worker scenario (Table C.8) and the outdoor worker scenario (Table C.9), which corresponds to HQ = 0.1 for direct-contact exposure of a workers to soil.

PCBs are not mobile to groundwater from soil at this SWMU (Section 2, this document). The 10 ppm RG for PCBs in soil is the value jointly agreed upon by representatives of EPA Region 4, KDEP, and DOE in

June 2009 scoping meetings. This value was considered to be sufficiently protective of potential direct contact risk that could occur at the BGOU.

Individual preliminary RGs for carcinogenic COCs in surface soil correspond to ELCR ≤ 5E-06 or less and the cumulative ELCR is ≤ 1E-05; the RGs for noncarcinogenic COCs in surface soil correspond to an HQ ≤ 0.5 and the cumulative HI is ≤ 1 (Table C.8). For subsurface soil, individual RGs correspond to ELCR ≤ 5E-05 and the cumulative ELCR is 1≤ E-04; the RGs correspond to an HQ ≤ 1 and the cumulative HI is ≤ 1(Table C.9). Because the preliminary RGs for soil COCs at SWMU 5 meet target risk and hazard criteria described in Section 2 and the NCP requirements for use in the FS (EPA 1994), they are used for development of remediation alternatives in Section 3 of this document.

Approximate lower-bound Soil RGs at SWMU 5

Because the preliminary RGs meet the target risk and hazard criteria, no approximate lower-bound RGs are calculated for soil at this SWMU.

C.3.7. SWMU 6

Total PAH compounds were identified as COCs at this SWMU (DOE 2010). Later review of soil sampling data for this SWMU has shown that the location of this sample is not within SWMU 6 and is actually associated with another PGDP OU; therefore, no RGs were developed for SWMU 6.

C.3.8. SWMU 7

Preliminary RGs for remediation of soil at SWMU 7 are shown in Tables C.10 and C.11. The preliminary RGs for Soil shown in column 4 of Tables C.10 and C.11 were taken from column 7 of Tables 2.1 and 2.2.

Preliminary RGs for Soil

The COCs identified in surface soil at this SWMU (Table C.10) include 9 carcinogens [Np-237, Tc-99, U-234, U-235 (including U-236), U-238, 1,1-DCE, TCE, vinyl chloride, and PCBs], and four noncarcinogens (uranium metal, and *cis*-1,2-DCE, TCE, and vinyl chloride). The COCs identified in subsurface soil (Table C.11) include 10 carcinogens (Np-237, Pu-239, Tc-99, U-234, U-235 (including U-235/236), U-238, 1,1-DCE, TCE, vinyl chloride, and PCBs), and four noncarcinogens (uranium metal, *cis*-1,2-DCE, TCE, and vinyl chloride).

Preliminary RGs for COCs in Surface Soil and in Subsurface Soil shown in column 4 of Tables C.10 and C.11, respectively. ELCR and HI values for the preliminary RGs for the COCs in soil are shown in columns 5 and 6 of these tables, respectively.

The preliminary soil RG for Tc-99 represents the groundwater-protective soil concentration for both surface and subsurface soil (Table C.1). As described for SWMU 2, the ELCR values associated with direct exposure to surface soil under the industrial worker scenario (Table C.10) and for subsurface soil under the outdoor worker scenario (Table C.11), are calculated from their respective NAL concentrations for direct-contact exposure to soil.

The identification of uranium-235/236 as a COC is assumed to result from use of data from radioanalytical methods that are not able to differentiate the U-235 and U-236 isotopes. It can be shown that carcinogenicity of these two isotopes is such that an RG developed for U-235 is also be protective of exposure to U-236 by comparing cancer risk coefficients for these isotopes. These cancer morbidity risk coefficients are given in Table 2.1, Table 2.2a, and Table 2.3 of EPA (1999) guidance.

The cancer risk coefficients for inhalation exposure to U-235 and U-236 are similar, 1.59E-08 Bq^{-1} and 1.61E-08 Bq^{-1}, respectively. The risk coefficients for ingestion exposure to U-235 and U-236 in water are similar, 1.88E-09 Bq^{-1} and 1.81E-09 Bq^{-1}, respectively. The risk coefficient for external exposure to U-235 radiation exceeds that for U-236, 4.44E-16 kg/Bq-sec and 1.07E-19 kg/Bq-sec, respectively. Because risks from potential inhalation and ingestion exposure to U-235/U-236 are predominantly associated with ingestion exposure, and external exposure to U-235 is greater than for U-236, the RG developed for U-235 serves for both isotopes.

1,1-DCE, *cis*-1,2-DCE, TCE, and vinyl chloride were not identified as direct contact soil COCs for this SWMU (Table 1.11). The Preliminary Surface Soil PRGs represent their groundwater-protective RG back-calculated from the MCL groundwater concentrations (Table C.1). As described for the above SWMUs, ELCR and HI values associated with direct exposure to this concentration are calculated from the NAL for the industrial worker and outdoor worker scenarios.

PCBs are not mobile to groundwater from soil at this SWMU (Section 2, this document). The 10 ppm RG for PCBs in soil is the value jointly agreed upon by representatives of EPA Region 4, KDEP, and DOE in June 2009 scoping meetings. This value was considered to be sufficiently protective of potential direct contact risk that could occur at the BGOU.

The Cumulative HI values for both surface and subsurface soil meet the HI ≤ 1 criterion (Tables C.10 and C.11). The Cumulative ELCR estimates slightly exceed their respective ELCR criteria for both surface and subsurface soil COCs; therefore, approximate lower-bound RG concentrations are developed below that meet the ELCR criteria.

Approximate lower-bound Soil RGs at SWMU 7

The major contributors to the cumulative ELCR in excess of target criteria in both surface and subsurface soil are Np-237, Pu-239, U-234, U-235/U-236, and U-238 (Tables C.10 and C.11); therefore, approximate lower-bound RG concentrations are developed for these COCs that meet the ELCR criteria at this SWMU.

Future remediation alternative selection (Sections 3 and 4) are based on the preliminary RGs for surface soil (column 4 of Table C.10) and for subsurface soil (column 4 of Table C.11). Following the remediation activity, it will be necessary to demonstrate successful remediation by meeting the RAOs developed for this SWMU (Section 5.2). This demonstration will be based in part on COC concentrations measured in soil samples and the associated cumulative ELCR and HI values for direct contact exposures of future industrial workers and outdoor workers. The cumulative ELCR and HI values will be calculated following the same approach described in the Risk Methods Document (DOE 2001), which also will be consistent with EPA (1991) guidance.

Although future postremediation in sampling results cannot be predicted, approximate lower-bound estimates of the COC concentrations in surface and subsurface soil that will meet target cumulative ELCR and HI criteria can be made using a conservative assumption. It is possible that this postremediation sampling will show that only one or a few of the COCs identified at a specific SWMU will be detected or that all COCs will be detected. Under the assumption that all COCs identified at a SWMU will be detected, approximate lower-bound RG concentrations have been calculated for the major COCs that meet the cumulative ELCR and HI criteria for surface soil (column 7 of Table C.10) and for subsurface soil (column 7 of Table C.11). The ELCR and HI values based on approximate lower-bound RG concentrations and their cumulative ELCR and HI values are shown in columns 8 and 9 of Tables C.10 and C.11 to demonstrate that the approximate lower-bound RGs meet the ELCR and HI criteria.

These approximate lower-bound RGs for surface and subsurface soil concentrations provide information on possible soil concentrations that might be encountered in post-remediation samples from the SWMU, but are not used otherwise in the development of remediation alternatives, as described in Section 2.2.3.3.

C.3.9. SWMU 30

Preliminary RGs for remediation of soil at SWMU 30 are shown in Tables C.12 and C.13. These RGs were taken from column 7 of Tables 2.1 and 2.2.

Preliminary RGs for Soil

The COCs identified in surface soil at this SWMU (Table C.12) include eight carcinogens (Np-237, Tc-99, U-234, U-235 (including U-236), U-238, 1,1-DCE, TCE, and total PCBs), and two noncarcinogens (uranium metal and TCE).The COCs identified in subsurface soil (Table C.13) include 9 carcinogens [Np-237, Pu-239, Tc-99, U-234, U-235 (including U-236), U-238, 1,1-DCE, TCE, and total PCBs] and two noncarcinogens (uranium metal and TCE).

Preliminary RGs for COCs in Surface Soil and in Subsurface Soil are shown in column 4 of Tables C.12 and C.13, respectively. ELCR and HI values for the preliminary RGs for the COCs in soil are shown in columns 5 and 6 of these tables, respectively.

The preliminary soil RG for Tc-99 represents the groundwater-protective soil concentration for both surface and subsurface soil (Table C.1). As described for SWMU 2, the ELCR values associated with direct exposure to surface soil under the industrial worker scenario (Table C.12) and for subsurface soil under the outdoor worker scenario (Table C.13), are calculated from their respective NAL concentrations for direct-contact exposure to soil.

The identification of U-235/236 as a COC is assumed to result from use of data from analytical methods that are not able to differentiate the U-235 and U-236 isotopes. The RG developed for U-235 serves for both isotopes at this SWMU, as described for SWMU 7.

1,1-DCE and TCE were not identified as a direct contact soil COCs for this SWMU (Tables 2.1 and 2.2). The Preliminary Surface Soil PRGs represent their groundwater-protective RGs back-calculated from their MCL groundwater concentrations (Table C.1). As described for the above SWMUs, ELCR and HI values associated with direct exposure to this concentration are calculated from the NAL for the industrial worker and outdoor worker scenarios.

PCBs are not mobile to groundwater from soil at this SWMU (Section 2, this document). The 10 ppm RG for PCBs in soil is the value jointly agreed upon by representatives of EPA Region 4, KDEP, and DOE in June 2009 scoping meetings. This value was considered to be sufficiently protective of potential direct contact risk that could occur at the BGOU.

The Cumulative HI values for both surface and subsurface soil meet the HI ≤ 1 criterion (Tables C.12 and C.13). The Cumulative ELCR estimates slightly exceed their respective ELCR criteria for both surface and subsurface soil COCs; therefore, approximate lower-bound RG concentrations are developed below that meet the ELCR criteria.

Approximate lower-bound Soil RGs at SWMU 30

The major contributors to the cumulative ELCR are Np-237, Pu-239, U-234, U-235/U-236, and U-238 (Tables C.12 and C.13); therefore, approximate lower-bound RG concentrations are developed for these COCs that meet the ELCR criteria at this SWMU.

Future remediation alternative selections (Sections 3 and 4) are based on the preliminary RGs for surface soil (column 4 of Table C.12) and for subsurface soil (column 4 of Table C.13). Following the remediation activity, it will be necessary to demonstrate successful remediation by meeting the RAOs developed for this SWMU (Section 5.2). This demonstration will be based in part on COC concentrations measured in soil samples and the associated cumulative ELCR and HI values for direct contact exposures of future industrial workers and outdoor workers. The cumulative ELCR and HI values will be calculated following the same approach described in the Risk Methods Document (DOE 2001), which also will be consistent with EPA (1991) guidance.

Although future postremediation sampling results cannot be predicted, approximate lower-bound estimates of the COC concentrations in surface and subsurface soil that will meet target cumulative ELCR and HI criteria can be made using a conservative assumption. It is possible that this postremediation sampling will show that only one or a few of the COCs identified at a specific SWMU will be detected or that all COCs will be detected. Under the assumption that all COCs identified at a SWMU will be detected, approximate lower-bound RG concentrations were calculated for the major COCs that meet the cumulative ELCR and HI criteria for surface soil (column 7 of Table C.12) and for subsurface soil (column 7 of Table C.13). The ELCR and HI values based on approximate lower-bound RG concentrations, and their cumulative ELCR and HI values, are shown in columns 8 and 9 of these tables to demonstrate that the approximate lower-bound RGs meet the ELCR and HI criteria.

These approximate lower-bound RGs for surface and subsurface soil concentrations provide information on possible soil concentrations that might be encountered in postremediation samples from the SWMU, but are not used otherwise in the development of remediation alternatives, as described in Section 2.2.3.3.

C.3.10. SWMU 145

Because SWMU 145 is located beneath two landfill caps (SWMU 9 and SWMU 10), excavation remediation at SWMU 145 is limited to the North-South Diversion Ditch.

Preliminary RGs for remediation of soil and groundwater at SWMU 145 are shown in Tables C.14 and C.15. These RGs were taken from column 7 of Tables 2.1 and 2.2.

Preliminary RGs for Soil

The COCs identified in surface soil at this SWMU (Table C.14) and subsurface soil (Table C.15) include one carcinogen (Tc-99).

The preliminary soil RG for Tc-99 represents the groundwater-protective soil concentration for both surface and subsurface soil (Table C.1). As described for SWMU 2, the ELCR values associated with direct exposure to surface soil under the industrial worker scenario (Table C.14) and for subsurface soil under the outdoor worker scenario (Table C.15), are calculated from their respective NAL concentrations for direct-contact exposure to soil.

Approximate lower-bound Soil RGs at SWMU 145

Because the preliminary RGs meet the target risk and hazard criteria, no approximate lower-bound RGs are calculated for soil at this SWMU.

C.4. EVALUATION OF RADIATION DOSE ASSOCIATED WITH REMEDIATION

Following execution of remediation activities at each SWMU, postremediation sampling will demonstrate that the remediation has achieved soil concentrations that do not represent a cumulative cancer risk or noncancer hazard above acceptable limits (see Section 2). In addition, to considering ELCR and HI (as applicable) for radionuclide COCs, the confirmation sampling results will be used in part to demonstrate that the residual soil concentrations of radionuclide COCs do not represent a potential annual radiation dose to the public above 100 mrem/year (consistent with DOE Order 5400.5).

C.5. REFERENCES

DOE (U. S. Department of Energy) 2001. *Methods for Conducting Human Health Risk Assessment and Risk Evaluations at the Paducah Gaseous Diffusion Plant*, DOE/OR/07-1506&D1, U. S. Department of Energy, Paducah, KY, December.

DOE 2010. *Remedial Investigation Report for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0030&D2/R1, U.S. Department of Energy, Paducah, KY, January.

EPA (U.S. Environmental Protection Agency) 1991. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part C, Risk Evaluation of Remedial Alternatives*, OSWER Directive 9285.7-01c, Office of Emergency and Remedial Response, Washington, DC, October.

EPA 1994. *National Oil and Hazardous Substances Pollution Contingency Plan*, 40 *CFR* Part 300, 59 *Federal Register* 47384, October 10.

EPA 1999. *Cancer Risk Coefficients for Environmental Exposure to Radionuclides, Federal Guidance Report FGR-13*, Office of Radiation and Indoor Air, Washington, D. C., September and as given in *Radionuclide Carcinogenicity Slope Factors: HEAST*, accessed online at http://www.epa.gov/rpdweb00/heast/.

EPA 2006. *2006 Edition of the Drinking Water Standards and Health Advisories*, EPA 822-R-06-013, Office of Water, Washington, DC, August.

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX D

EVALUATION OF TECHNOLOGIES AND PROCESS OPTIONS

THIS PAGE INTENTIONALLY LEFT BLANK

Table D.1. BGOU Source Areas Technology Screening

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
Land use controls	Institutional controls	E/PP program	Requires review and approval of any proposed intrusive activities to protect workers and remedy integrity.	Available	Technically implementable. Retained for possible alternative development.
Monitoring	Monitoring Wells	Install/sample groundwater monitoring wells	Monitors potential contaminant migration in groundwater.	Available	Technically implementable. Retained for possible alternative development.
Removal	Excavators	Backhoes, trackhoes	Tracked excavators with 45 ft arms limited to approximately 30 ft bgs.	Commercially available	Technically implementable. Retained for possible alternative development.
		Vacuum excavation, remote excavator	Commercial vacuum excavators used for potholing, radioactive waste cleanup.	Commercially available	Technically implementable. Retained for possible alternative development.
		Crane and clamshell	Excavation at depths greater than 100 ft bgs possible.	Commercially available	Technically implementable. Retained for possible alternative development.
		Bucket auger	Capable of drilling to depths of 100 ft bgs.	Commercially available	Technically implementable. Retained for possible alternative development.
Containment	Hydraulic containment	Recharge controls	Recharge controls can reduce facility discharges to the UCRS, promote surface water run-off, and reduce recharge of the UCRS in the BGOU TCE source areas, thereby limiting leaching of TCE from NAPL source areas and migration to the RGA.	Implements best management practices and equipment/materials	Technically implementable. Retained for possible alternative development.

Table D.1. BGOU Source Areas Technology Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
		Groundwater extraction	Groundwater pumping wells create a cone of depression in the piezometric surface, causing flow to the well resulting in a capture zone.	Commercially available	Yields of wells in the UCRS may be too low to be technically implementable. Groundwater extraction is implementable in the RGA, although hydraulic control may require pumping large volumes of water. Retained for possible alternative development as a secondary technology for other treatments.
	Surface barriers	RCRA Subtitle C cover	Multi-layer cover incorporating compacted clay and geosynthetics used for RCRA hazardous waste landfill closures.	Commercially available	Technically implementable. Retained for possible alternative development.
		RCRA Subtitle D cover	Multi-layer cover used for RCRA non-hazardous waste landfill closures.	Commercially available	Technically implementable. Retained for possible alternative development.
		Soil cover	Mono-layer cover used for RCRA non-hazardous waste landfill closures.	Commercially available	Technically implementable. Retained for possible alternative development.
		Concrete-based cover	Concrete cover systems may consist of a single layer of concrete pavement over a prepared subgrade to isolate contaminated soils, reduce infiltration, and provide a trafficable surface.	Commercially available	Technically implementable. Retained for possible alternative development.
		Conventional asphalt cover	Asphalt cover systems may consist of a single layer of bituminous pavement over a prepared subgrade to isolate contaminated soils, reduce infiltration, and provide a trafficable surface. Must be sealed and/or combined with a low-permeability membrane to effectively reduce permeability.	Commercially available	Technically implementable. Retained for possible alternative development.
		MatCon™ asphalt	MatCon™ asphalt has been used for RCRA Subtitle C-equivalent closures of landfills and soil contamination sites. MatCon™ is produced using a mixture of a proprietary binder and a specified aggregate in a conventional hot-mix asphalt plant.	Commercially available	Technically implementable. Retained for possible alternative development.

Table D.1. BGOU Source Areas Technology Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
		Flexible membrane	Single layers of relatively impermeable polymeric plastic [high-density polyethylene (HDPE) and others] laid out in rolls or panels and welded together. The resulting membrane cover essentially is impermeable to transmission of water unless breached. Flexible membranes can be sealed around surface infrastructure using waterproof sealants.	Commercially available	Technically implementable. Retained for possible alternative development.
	Subsurface horizontal barriers	Freeze walls	Constructed by artificially freezing the soil pore water, resulting in decreased permeability and formation of a low-permeability barrier. The frozen soil remains relatively impermeable and migration of contaminants is thereby reduced. A horizontal barrier would be constructed by installing freeze pipes through wells drilled at a 45 degree angle along the sides of an area to be contained.	Commercially available	Technically implementable, but less practical as a permanent barrier. Eliminated from alternative development.
		Jet grouting	Grouts are injected through drill rods to reduce infiltration of water. The jetted grout mixes with the soil to form a column or panel.	Commercially available	Uncertain technical implementability. Retained for possible alternative development.
		Permeation grouting	Low-viscosity grout is injected vertically or directionally at multiple locations into soil. Establishing and verifying a continuous, effective subsurface barrier is difficult or impossible in heterogeneous and/or low-permeability soils or in the presence of subsurface infrastructure.	Commercially available	Uncertain technical implementability. Retained for possible alternative development.
	Subsurface vertical barriers	Freeze walls	Constructed by artificially freezing the soil pore water, resulting in decreased permeability and formation of a low-permeability barrier. The frozen soil remains relatively impermeable and migration of contaminants is thereby reduced.	Commercially available	Technically implementable, but typically used to construct a temporary vertical hydraulic barrier during construction projects. Technology less practical as a permanent barrier. Retained for possible alternative development.

Table D.1. BGOU Source Areas Technology Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
		Slurry walls	Vertically excavated trenches that are kept open backfilled with a slurry, generally bentonite and water. Soil (often excavated material) is then mixed with bentonite and water to create a low-permeability soil-bentonite backfill.	Commercially available	Technically implementable. Retained for possible alternative development.
		Sheet pilings	Long (e.g., 60 ft) structural steel sections with a vertical interlocking system that are driven into the ground to create a continuous subsurface wall. After the sheet piles have been driven to the required depth, they are cut off at the surface. The subsurface soils must be relatively homogenous (i.e., no boulders) to allow for a uniform installation.	Commercially available	Technically implementable. Retained for possible alternative development.
		Jet grouting	This system breaks up the soil structure completely and performs deep soil mixing to create a homogeneous soil, which, in turn, solidifies. The jet grouting technique can be used regardless of soil, permeability, or grain size distribution. It is possible to apply jet grouting to most soils, from soft clays and silts to sands and gravels. Although it is possible to inject any binder, water-cement-bentonite mixtures are typically used when an impermeable vertical barrier is to be created.	Commercially available	Technically implementable. Retained for possible alternative development.
		Permeable reactive barrier (PRB)	PRBs are designed and constructed to permit the passage of water while immobilizing or destroying contaminants through the use of various reactive agents. PRBs may be constructed to depths of 60 ft bgs, but complexity and cost increase with depth.	Commercially available	Not technically implementable because hydraulic gradients in the UCRS are primarily downward and the construction depths required in the RGA exceed the current practical limit of the technology. Eliminated from alternative development.

Table D.1. BGOU Source Areas Technology Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
Treatment	Biological	Anaerobic reductive dechlorination (ARD)	ARD occurs when microbes utilize chloroethenes as terminal electron acceptors in metabolic processes. Saturated conditions are required.	Commercially available	Technical implementability is uncertain. The low hydraulic conductivity of the UCRS limits the ability to effectively distribute substrate using injection technologies. High groundwater flow rates in the RGA may make it difficult to sustain anaerobic conditions. Establishing anaerobic conditions may inhibit ongoing natural aerobic degradation processes. Retained for possible alternative development.
		Aerobic cometabolism	Aerobic cometabolism of TCE occurs when a microbe using a different organic compound as a carbon and energy source produces enzymes that fortuitously degrade a second compound without deriving energy or carbon for growth from that compound. Saturated conditions are required.	Commercially available	Technically implementable as this process has been demonstrated to occur naturally in RGA groundwater. Evidence of aerobic cometabolism has not yet been developed in the UCRS. Retained for possible alternative development.
		Phytoremediation	Phytoremediation exploits plant processes, including transpiration and rhizosphere enzymatic activity, to uptake water and dissolved-phase contaminants or to transform contaminants.	Commercially available	Not technically implementable due to depth of NAPL. Eliminated from alternative development.
	Physical/chemical	Soil vapor extraction	Removal of unsaturated zone air and vapor by applying vacuum.	Commercially available	Technical implementability is uncertain in the UCRS due to low intrinsic permeability, stratified soil conditions and high water table. Not technically implementable in RGA due to saturated soil conditions. Retained for possible alternative development.

Table D.1. BGOU Source Areas Technology Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
		Dual-phase extraction *in situ*	Enhancement of SVE that includes extraction of groundwater and soil vapor.	Commercially available	Technical implementability is uncertain in the UCRS due to low intrinsic permeability and stratified soil conditions. Extraction of a significant volume of water may be required in RGA to depress the water table. Retained for possible alternative development.
		Air sparging *in situ*	Promotes volatilization of VOCs in saturated zone by injecting air. Can be combined with SVE.	Commercially available	Technical implementability is uncertain. UCRS has low intrinsic permeability and stratified soil conditions, although pulsed air sparging has been used effectively under these site conditions. Effectiveness in RGA may be limited by depth of implementation in saturated zone and difficulty capturing volatilized constituents. DNAPLs are difficult to treat with air sparging. Retained for possible alternative development.
		Soil flushing *in situ*	Promotes dissolution or desorption of VOCs in soil, may mobilize NAPLs by reducing interfacial tension. Can be applied *in situ* or *ex situ.*	Commercially available	Technical implementability uncertain. Surfactant/cosolvent flushing is typically ineffective in low-permeability settings such as the UCRS, but could be effective in the more permeable RGA. Retained for possible alternative development.
		Electrokinetics *in situ*	Applied *in situ* as LASAGNA™ process.	Commercially available	Technically implementable. Retained for possible alternative development.

Table D.1. BGOU Source Areas Technology Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
		Air stripping *ex situ*	Applied *ex situ* for secondary waste treatment.	Commercially available	Technically implementable. Retained for possible alternative development.
		Ion exchange *ex situ*	Applied *ex situ* for removal of cations or anions from aqueous secondary wastes.	Commercially available	Technically implementable. Retained for possible alternative development.
		Granular activated carbon *ex situ*	Applied *ex situ* for secondary aqueous waste or off-gas treatment.	Commercially available	Technically implementable. Retained for possible alternative development.
		Vapor condensation	Applied *ex situ* for secondary waste off-gas treatment.	Commercially available	Technically implementable. Retained for possible alternative development.
		Soil fracturing *in situ*	Highly pressurized gas (nitrogen or air) is injected into soil via borings to extend existing fractures and create a secondary network of subsurface channels. Hydraulic fracturing (hydrofracturing) uses water or slurry instead of gas. Soil fracturing can extend the range of treatment when combined with other technologies such as bioremediation, chemical oxidation/reduction, or soil vapor extraction. Potential adjunct technology for some *in situ* treatment, containment, or removal technologies.	Commercially available	Technical implementable. Potentially applicable in UCRS. Would not be required in more permeable RGA. Retained for possible alternative development.

Table D.1. BGOU Source Areas Technology Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
		Soil mixing *in situ*	Potential adjunct technology for some *in situ* treatment, containment, or removal technologies.	Commercially available	Technical implementability uncertain due to the potential presence of undocumented waste material, underground objects, or other hazards that could be encountered during operation of the augers. Retained for possible alternative development.
	Thermal	Catalytic oxidation *ex situ*	Applied *ex situ* for secondary vapor treatment.	Commercially available	Technically implementable. Retained for possible alternative development.
		Electrical resistance heating *in situ*	Saturated or unsaturated soils are heated by applying current in subsurface, resulting in *in situ* steam stripping. VOCs and steam are recovered by dual phase extraction wells and treated. Can be implemented as three-phase or six-phase heating.	Commercially available	Technically implementable. Retained for possible alternative development.
		Thermal conduction heating *in situ*	Saturated or unsaturated soils are heated via thermal conduction by placing heating elements in wells. VOCs and steam are recovered by dual phase extraction wells and treated.	Commercially available	Technically implementable. Retained for possible alternative development.
		Thermal desorption *ex situ*	Soils are heated to volatilize VOCs, which are then treated. Applied *ex situ* for excavated waste treatment.	Commercially available	Technically implementable. Retained for possible alternative development.
		Steam stripping *in situ*	Saturated or unsaturated soils are heated by injecting steam resulting in *in situ* VOC stripping. VOCs and steam are recovered by SVE wells and treated. Can be implemented with three-phase or six-phase heating.	Commercially available	Technically implementable. Retained for possible alternative development.

Table D.1. BGOU Source Areas Technology Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
		Ex situ vitrification	Electrical melting of contaminated solids at high temperature. Waste and glass-forming additives are heated to produce a molten mass. Contaminants not destroyed by the heat are encapsulated within the glass so they cannot leach into the surrounding soil or groundwater. The fused mass of insoluble products is removed as blocks or granules for disposal.	Commercially available	Technically implementable. Retained for possible alternative development.
		Metal melting (Smelting)	Recoverable scrap metals are segregated, preferably surface cleaned, size-reduced, and introduced into a smelting furnace from which metal ingots are produced. Destroys classifieds shapes and reduces volume for recovery or disposal.	Commercially available	Technically implementable. Retained for possible alternative development.
	Chemical	Permanganate *in situ*	Injection of permanganate species in subsurface to oxidize VOCs. Does not act directly on isolated pockets of NAPLs.	Commercially available	Technical implementability uncertain in the UCRS due to low soil permeability, soil heterogeneity and stratification, and variable extent of saturation. Bench-scale test of permanganate on TCE-spiked RGA sediments determined it would not be effective on TCE DNAPL in RGA. Retained for possible alternative development.
		Fenton's reagent *in situ*	Injection of hydrogen peroxide and ferrous iron in subsurface to oxidize VOCs. Does not act directly on isolated pockets of NAPLs.	Commercially available	Technical implementability uncertain in the UCRS due to low soil permeability, soil heterogeneity and stratification, and variable extent of saturation. Bench-scale test of Fenton's reagent on TCE-spiked RGA sediments determined it may be effective on TCE DNAPL in RGA. Retained for possible alternative development.

Table D.1. BGOU Source Areas Technology Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
		ZVI *in situ*	Dechlorination of chloroethenes by elemental iron. Applied *in situ* as permeable reactive treatment zone or barrier.	Commercially available	Not technically implementable as a permeable reactive barrier. The hydraulic gradient of the UCRS is primarily downward. The placement depth in the RGA makes its use impractical. Injection of micro- or nano-scale ZVI in the UCRS may have limited effectiveness due to low soil permeability, soil heterogeneity and stratification, and variable extent of saturation. Potentially more implementable in RGA. Retained for possible alternative development.
		Ozonation *in situ*	Injection of ozone gas in saturated zone to oxidize VOCs. Does not act directly on isolated pockets of NAPLs.	Commercially available	Technical implementability uncertain in the UCRS due to low soil permeability, soil heterogeneity, stratification, and variable extent of saturation. Potentially more implementable in RGA. Retained for possible alternative development.
		Persulfate *in situ*	Injection of sodium persulfate in soils to oxidize VOCs. Most effective when ferrous iron or other reagents are added as catalysts, or when heated.	Commercially available	Technical implementability uncertain in the UCRS due to low soil permeability, soil heterogeneity and stratification, and variable extent of saturation. Potentially more implementable in RGA. Retained for possible alternative development.

Table D.1. BGOU Source Areas Technology Screening (Continued)

General Response Action	Technology Type	Process Options	Description	Technology Status	Screening Comments
		Surfactant enhanced *in situ* chemical oxidation (S-ISCO)	Co-injection of surfactant with one of the oxidants previously listed. The surfactant disperses DNAPL so that it can be readily destroyed by the oxidant.	Commercially available	Technical implementability uncertain in the UCRS due to low soil permeability, soil heterogeneity and stratification, and variable extent of saturation. Potentially more implementable in the RGA. S-ISCO is an emerging technology with few full-scale field applications. Retained for possible alternative development.
	Monitored natural attenuation	Monitoring and natural processes	Natural processes including dilution, diffusion, dispersion, sorption, and biodegradation, combined with monitoring.	Commercially available	Technically implementable. Retained for possible alternative development.
Disposal	Land disposal	Off-site permitted commercial disposal facility	Shallow land burial site for LLW, MLLW, and HW disposal option.	Commercially available	Technically implementable. Retained for possible alternative development.
		On-site waste disposal facility (WDF)	Planned radioactive and mixed waste on-site WDF.	Under consideration	Technically implementable. Retained for possible alternative development.
		PGDP C-746-U Landfill	Existing on-site nonhazardous nonradioactive waste landfill.	Available	Technically implementable. Retained for possible alternative development.
	Discharge of wastewater	In accordance with substantive requirements of Kentucky surface water standards	Allowed under CERCLA after treatment.	Available	Technically implementable. Retained for possible alternative development.

Gray shading indicates the technology was screened out as not applicable or not technically implementable.
Potholing = filling in potholes.

ARD = anaerobic reductive dechlorination
BGOU = Burial Grounds Operable Unit
bgs = below ground surface
E/PP = excavation/penetration permit
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
DNAPL = dense nonaqueous phase liquid
HDPE = high density polyethylene
LLW = low-level waste
MLLW = mixed low-level waste
NAPL = nonaqueous-phase liquid
PGDP = Paducah Gaseous Diffusion Plant
PRB = permeable reactive barriers
RCRA = Resource Conservation and Recovery Act
RGA = Regional Gravel Aquifer
S-ISCO = surfactant *in situ* chemical oxidation
SVE = soil vapor extraction
TCE = trichloroethene
UCRS = Upper Continental Recharge System
VOC = volatile organic compound
WDF= waste disposal facility
ZVI = zero valent iron

Table D.2. Evaluation of BGOU Source Area Process Options

General Response Action	Technology Type	Process Option	Effectiveness			Implementability		Relative Cost		Selected as RPO?
			Long-term effectiveness	Short-term effectiveness	Demonstrated effectiveness and reliability	Technical	Administrative	Capital	O&M	
Land use controls	Institutional controls	E/PP program	High—effective for duration of plant operations	High—effective at preventing worker exposure	High—already implemented	High—already implemented	High—already implemented	Low	Low	Yes
Monitoring	Monitoring wells	Install and sample	High—sampling can continue many years	High—can be installed quickly	High	High	High	Moderate	Low	Yes
Removal	Excavators	Backhoes, trackhoes	High—remove source to 30-40 ft bgs	Moderate—risks to workers in excavation	High	High	High	Low	Low	Yes
		Vacuum excavation, remote excavator, clamshells	High—remove source to 9.14 to 12.2 m (30-40 ft) bgs	High—lower worker risks	High	High	High	Moderate	Moderate	No
		Crane and clamshell	High—remove source to > 30 m (100 ft) bgs	Moderate—more technically complex; hoisting and rigging concerns	High	Moderate	Moderate	High	High	Yes

Table D.2. Evaluation of BGOU Source Area Process Option (Continued)

General Response Action	Technology Type	Process Option	Effectiveness			Implementability		Relative Cost		Selected as RPO?
			Long-term effectiveness	Short-term effectiveness	Demonstrated effectiveness and reliability	Technical	Administrative	Capital	O&M	
		Bucket auger	High—remove source to > 30 m (100 ft) bgs	Low—generates significant quantities of cuttings and fluid in saturated zones	High	Low	High	High	High	No
	Groundwater extraction	Pumping wells	Low for DNAPL	High for groundwater control during implementa-tion	Low for DNAPL	Low in UCRS	Moderate—discharge or reinjection required	High—well installation costs	High—continuous operating costs	No
Containment	Hydraulic containment	Recharge controls	Potentially high	High	Potentially high	High	High	Low	Low	No
		Groundwater extraction	Low in UCRS	Moderate	Low in UCRS.	Low in UCRS	Moderate—discharge or reinjection required	High—well installation costs	High—continuous operating costs	No
	Surface barriers	RCRA Subtitle C cover	Potentially high.	High	Moderate	Low	High	High—complex construction	Moderate—ongoing maintenance and monitoring required	Yes
		RCRA Subtitle D cover	Potentially high.	High	Moderate	Low	High	High	Moderate	No
		Soil cover	Moderate	High	Moderate	Low	High	Moderate	Moderate	Yes
		Concrete-based cover	Low—prone to cracking	High	Low—prone to cracking	Moderate	High	High	High	No
		Conventional asphalt cover	Low—relatively permeable	High	Low—relatively permeable	High	High	Low	Moderate	No
		Low-permeability asphalt	High	High	High	Moderate	High	Moderate	Moderate	No

Table D.2. Evaluation of BGOU Source Area Process Option (Continued)

General Response Action	Technology Type	Process Option	Effectiveness			Implementability		Relative Cost		Selected as RPO?
			Long-term effectiveness	Short-term effectiveness	Demonstrated effectiveness and reliability	Technical	Administrative	Capital	O&M	
		Flexible membrane	Potentially high	High	Moderate—must be protected from damage	High	High	Moderate	Low	No
	Subsurface vertical barriers	Freeze walls	Low for permanent installation. Effectiveness can't be readily monitored	High	Low—few long-term applications, but effectively used as a temporary measure in construction industry to stabilize excavation sidewalls	Low	High	High	High—energy and refrigerant costs	Yes
		Jet grouting	Potentially high	Moderate—installation may contact waste and generate some residuals for management	Moderate	Moderate	Low	High	Low	Yes
		Slurry walls	Potentially high	Low—intrusive and requires adequate space to implement	Moderate	Low	High	High	Moderate	No

Table D.2. Evaluation of BGOU Source Area Process Option (Continued)

General Response Action	Technology Type	Process Option	Effectiveness			Implementability		Relative Cost		Selected as RPO?
			Long-term effectiveness	Short-term effectiveness	Demonstrated effectiveness and reliability	Technical	Administrative	Capital	O&M	
		Sheet pilings	High	Moderate to high—installation may contact waste depending upon placement	High	High	High	High	None	Yes
Treatment	Biological	Anaerobic reductive dechlorination	Uncertain in UCRS due to low permeability, heterogeneity, and variable saturation of soils.	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Moderate—effectiveness on DNAPL is not as well established as dissolved-phase contamination	Moderate—soil fracturing may be required to implement in UCRS. May be difficult to maintain anaerobic conditions in RGA	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Moderate	Moderate—multiple injections may be required to treat DNAPL	No
		Aerobic cometabolism	Uncertain for DNAPL—potentially high for dissolved-phase VOCs	Moderate	Moderate	Low	Moderate—discharge or reinjection required	Moderate	Moderate	No
	Physical/chemical	Soil vapor extraction	Uncertain in UCRS due to low permeability, heterogeneity, and variable saturation of soils	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Moderate to high—presumptive remedy for VOCs in soil	Moderate—shallow water table at sites	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Moderate	Moderate	Yes

Table D.2. Evaluation of BGOU Source Area Process Option (Continued)

General Response Action	Technology Type	Process Option	Effectiveness			Implementability		Relative Cost		Selected as RPO?
			Long-term effectiveness	Short-term effectiveness	Demonstrated effectiveness and reliability	Technical	Administrative	Capital	O&M	
		Dual phase extraction	Uncertain in UCRS due to low permeability, heterogeneity, and variable saturation of soils	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Moderate to high—effectiveness increases when combined with an *in situ* thermal process option	High	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Moderate	Moderate	Yes
		Air sparging	Uncertain in UCRS due to low permeability, heterogeneity, and variable saturation of soils. Uncertain in RGA due to depth of injection in saturated zone	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Low to moderate—may not be effective on DNAPL	Moderate—may be difficult to capture contaminants volatilized from RGA	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Moderate	Low	No
		Soil flushing	Unlikely to be effective in UCRS due to low permeability, heterogeneity, and variable saturation of soils. May be effective in RGA	Moderate—may require drilling into contaminated areas resulting in contact with buried waste. Uncontrolled mobilization of DNAPL may occur if not carefully implemented	Low	Moderate—complex technology that requires significant lab and modeling work to select surfactant/cosol-vent and design a surfactant flood. Location of DNAPL must be defined. Requires good knowledge of site hydrogeology and geochemistry	Moderate—regulatory requirements may prevent chemical injection at some sites. May require drilling into contaminated areas resulting in contact with buried waste	High	High—injected surfactant/cosol-vent and mobilized DNAPL must be recovered and treated *ex situ*	No

Table D.2. Evaluation of BGOU Source Area Process Option (Continued)

General Response Action	Technology Type	Process Option	Effectiveness			Implementability		Relative Cost		Selected as RPO?
			Long-term effectiveness	Short-term effectiveness	Demonstrated effectiveness and reliability	Technical	Administrative	Capital	O&M	
		Electrokinetics *in situ*	High—demonstrated at PGDP	Low	High	Moderate	High	High	High—short duration	No
		Soil mixing *in situ*	Potentially high—can treat all VOC phases	Moderate	Low	Moderate—buried materials must be cleared from treatment area	Moderate	High	Varies depending on application	No
		Air stripping *ex situ*	High	High	High	High	Moderate—air emissions	Moderate	Moderate—ongoing energy costs	Yes
		Ion exchange *ex situ*	High	High	High	High	High	Low	Moderate—ongoing secondary waste treatment and disposal	Yes
		Granular activated carbon *ex situ*	High	High	High	High	High	Low	High—ongoing carbon replacement costs	Yes
		Vapor condensation	High	Moderate—a limited number of vendors available	High	Moderate	High	High	High	Yes
		Soil fracturing	Uncertain—potentially high	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Low	Low	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Moderate	None	No

Table D.2. Evaluation of BGOU Source Area Process Option (Continued)

General Response Action	Technology Type	Process Option	Effectiveness			Implementability		Relative Cost		Selected as RPO?
			Long-term effectiveness	Short-term effectiveness	Demonstrated effectiveness and reliability	Technical	Administrative	Capital	O&M	
		Soil mixing	Potentially high	Low to moderate—potential to encounter undocumen-ted waste material, underground objects, or other hazards during operation of the augers	Low	Uncertain. More source characterization data needed to evaluate. More easily implemented at depths to 40 ft although treatment depths of 100 ft are achievable	Moderate—would require drilling into contaminated areas potentially resulting in contact with buried waste	High	Varies depending on application	No
	Thermal	Catalytic oxidation *ex situ*	High	High	High	Moderate	High	High	Moderate—ongoing energy costs	Yes
		Electrical resistance heating *in situ*	High—demonstrated at Paducah Gaseous Diffusion Plant	High— *in situ* process	High	High	Moderate—air emissions	Moderate	High energy costs during implementation; none after completion	Yes
		Thermal conduction heating *in situ*	High	High— *in situ* process	High	High	Moderate—air emissions	Moderate	High energy costs during implementation; none after completion	No
		Thermal desorption *ex situ*	High	Moderate—soil must be excavated	High	High	Moderate—air emissions	High	High energy costs during implementation; none after completion	Yes

Table D.2. Evaluation of BGOU Source Area Process Option (Continued)

General Response Action	Technology Type	Process Option	Effectiveness			Implementability		Relative Cost		Selected as RPO?
			Long-term effectiveness	Short-term effectiveness	Demonstrated effectiveness and reliability	Technical	Administrative	Capital	O&M	
		Steam stripping *in situ*	High	Moderate—soil must be removed	Moderate	Moderate	Moderate—air emissions	High	High energy costs during implementation; none after completion	No
		Ex situ Vitrification	High—immobilizes contaminants.	Moderate with adequate process design	High—requires extensive waste characterize-ation to be effective	Moderate	Moderate—rigorous engineering and administrative controls required	High	High	No
		Metal melting (smelting)	High—Contaminants segregated from metal	Low— has not been proven economical at field scale	Low—has not been implemented at field scale	High	Moderate	Moderate—most equipment is commercially available	High	Yes
	Chemical	Permanganate	Uncertain in UCRS due to low permeability, heterogeneity, and variable saturation of soils. Bench-scale treatability study determined that permangan-ate would be ineffective on DNAPL in RGA	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Uncertain for DNAPLs	Low in UCRS. Uncertain in RGA	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Moderate	Low to moderate—primarily monitoring, but multiple injections may be required to treat DNAPL	No

Table D.2. Evaluation of BGOU Source Area Process Option (Continued)

General Response Action	Technology Type	Process Option	Effectiveness			Implementability		Relative Cost		Selected as RPO?
			Long-term effectiveness	**Short-term effectiveness**	**Demonstrated effectiveness and reliability**	**Technical**	**Administrative**	**Capital**	**O&M**	
		Fenton's reagent	Uncertain in UCRS due to low permeability, heterogeneity, and variable saturation of soils. Bench-scale treatability study determined that Fenton's might be effective on DNAPL in RGA	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Uncertain for DNAPLs	Low in UCRS. Uncertain in RGA because significant technical issues remain unresolved from bench-scale treatability study concerning full-scale implementation	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	High—large amounts of oxidant would be required to generate the heat necessary to volatilize DNAPL mass	Low—primarily monitoring	No
		ZVI	Uncertain in UCRS due to low permeability, heterogeneity, and variable saturation of soils. Untested on DNAPLs in RGA	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Uncertain for DNAPLs	Low in UCRS. Uncertain in RGA	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Moderate to high depending on the grade of ZVI used	Low to moderate—primarily monitoring, but multiple injections may be required to treat DNAPL	No

Table D.2. Evaluation of BGOU Source Area Process Option (Continued)

General Response Action	Technology Type	Process Option	Effectiveness			Implementability		Relative Cost		Selected as RPO?
			Long-term effectiveness	Short-term effectiveness	Demonstrated effectiveness and reliability	Technical	Administrative	Capital	O&M	
		Ozonation	Uncertain in UCRS due to low permeability, heterogeneity, and variable saturation of soils. Untested on DNAPLs in RGA	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Uncertain for DNAPLs	Low in UCRS. Uncertain in RGA	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Moderate	Moderate—continuing operation of ozone generator and sparging system	No
		Persulfate	Uncertain in UCRS due to low permeability, heterogeneity, and variable saturation of soils. Untested on DNAPLs in RGA	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Uncertain for DNAPLs	Low in UCRS. Uncertain in RGA	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Moderate	Low to moderate—primarily monitoring, but multiple injections may be required to treat DNAPL	No

Table D.2. Evaluation of BGOU Source Area Process Option (Continued)

General Response Action	Technology Type	Process Option	Effectiveness			Implementability		Relative Cost		Selected as RPO?
			Long-term effectiveness	Short-term effectiveness	Demonstrated effectiveness and reliability	Technical	Administrative	Capital	O&M	
		Surfactant enhanced *in situ* chemical oxidation	Uncertain in UCRS due to low permeability, heterogeneity, and variable saturation of soils. Untested on DNAPLs in RGA	Moderate—may require drilling into contaminated areas resulting in contact with buried waste. Uncontrolled mobilization of DNAPL could occur if adequate oxidant is not available to completely treat all mobilized DNAPL	Low—emerging technology	Moderate—complex technology that requires significant lab and modeling work to select surfactant/cosol-vent and design a surfactant flood. Location of DNAPL must be defined. Requires good knowledge of site hydrogeology and geochemistry	Moderate—may require drilling into contaminated areas resulting in contact with buried waste	Moderate to high	Low to moderate—primarily monitoring, but multiple injections may be required to treat DNAPL	No
	Monitored natural attenuation	Monitoring and natural processes	Low for NAPL	High	Low for NAPL	High	Low—inadequate for DNAPL	Low	Moderate	No
Disposal	Land disposal	Off-site permitted commercial disposal facility	High	Moderate—long-distance transportation required	High	High	High	High	None	Yes
		On-site WDF	High	High	High	Moderate	Moderate	Low	None	Yes
		On-site C-746-U Landfill	High	High	High	High	High	Low	None— long-term monitoring and maintenance not paid by program	Yes
		To excavation as backfill after treatment	High	Uncertain	High	High	High	Low	None	No

Table D.2. Evaluation of BGOU Source Area Process Option (Continued)

General Response Action	Technology Type	Process Option	Effectiveness			Implementability		Relative Cost		Selected as RPO?
			Long-term effectiveness	Short-term effectiveness	Demonstrated effectiveness and reliability	Technical	Administrative	Capital	O&M	
	Discharge of wastewater	Kentucky surface water standards	High	Moderate	High	High	Moderate	Moderate	Moderate—monitoring required	Yes

DNAPL = dense nonaqueous phase liquid
E/PP = excavation/penetration permit
O&M = operation and maintenance
NAPL = nonaqueous-phase liquid
PGDP = Paducah Gaseous Diffusion Plant
RCRA = Resource Conservation and Recovery Act
RGA = Regional Gravel Aquifer
RPO = representative process option
UCRS = Upper Continental Recharge System
VOC = volatile organic compound
WDF = waste disposal facility
ZVI = zero valent iron

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX E

COST ESTIMATES

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX E

COST ESTIMATES (on CD)

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX F

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND TO BE CONSIDERED GUIDANCE

THIS PAGE INTENTIONALLY LEFT BLANK

CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

F.1. INTRODUCTION

Section 121(d) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and 40 *CFR* § 300.430(f)(1)(ii)(B) of the National Contingency Plan require that remedial actions at CERCLA sites attain legally applicable or relevant and appropriate requirements (ARARs) or provide grounds for invoking a CERCLA waiver. ARARs include the substantive requirements of federal or more stringent state environmental or facility siting laws/regulations. Additionally, per 40 *CFR* § 300.400(g)(3), other advisories, criteria, or guidance may be considered in determining remedies [to be considered (TBC) category]. CERCLA § 121(d)(4) provides several ARAR waiver options that may be invoked, provided that human health and the environment are protected. ARARs do not include occupational safety or worker protection requirements. On-site activities must comply with the substantive, but not administrative requirements. Administrative requirements include applying for permits, recordkeeping, consultation, and reporting. Activities conducted off-site must comply with both the substantive and administrative requirements of applicable laws.

ARARs typically are divided into three categories: (1) chemical-specific, (2) location-specific, and (3) action-specific. "Chemical-specific ARARs usually are health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numerical values" [53 *FR* 51394, 51437 (December 21, 1988)]. (In the absence of chemical-specific ARARs, cleanup criteria are based upon risk calculations.) Location-specific ARARs generally are restrictions placed upon the concentration of hazardous substances or the conduct of activities solely because they are in special locations [53 *FR* 51394, 51437 (December 21, 1988)]. Action-specific ARARs usually are technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes or requirements to conduct certain actions to address particular circumstances at a site [53 *FR* 51394, 51437 (December 21, 1988)]. ARARs and TBC guidance for the Burial Grounds Operable Unit Feasibility Study are identified in Tables F.1 and F.2.

In addition to ARARs, policies such as *Management of Contaminated Media*, EPA Region 4, September 7, 1999, allow use of an area of contamination (AOC). Use of an AOC does not constitute "placement" and, therefore, does not trigger land disposal restriction and other Resource Conservation and Recovery Act (RCRA) requirements.

F.2. CHEMICAL-SPECIFIC ARARS/TBC

Chemical-specific ARARs provide health or risk-based concentration limits or values in environmental media for hazardous substances, pollutants, or contaminants. There are no chemical-specific ARARs for remediation of the contaminated soils at the source areas with identified chemicals of concern. The Kentucky drinking water standard maximum contaminant levels, however, were used for calculation of soil remedial goals (see 401 *KAR* 8:250 for inorganic compounds, 8:420 for volatile organic compounds, and 8:550 for radionuclides).

F.3. LOCATION-SPECIFIC ARARS/TBC

Location-specific requirements establish restrictions on activities conducted within protected or environmentally sensitive areas. In addition, these requirements establish restrictions on permissible concentrations of hazardous substances within these areas.

F.3.1 WETLANDS

A wetlands assessment would be performed prior to remedy implementation. Although it is not anticipated, if an action should involve discharge of dredge or fill material into waters of the United States, including jurisdictional wetlands, the substantive requirements of Nationwide Permit 38, General Conditions, would be complied with, as appropriate.

F.4. ACTION-SPECIFIC ARARS/TBCS

Action-specific ARARs include operation, performance, and design requirements or limitations based on waste type, media, and remedial activities. Component actions include groundwater extraction, treatment and monitoring, institutional controls, waste management, and transportation.

F.4.1 GENERAL CONSTRUCTION ACTIVITIES

General site preparation activities would trigger general requirements for storm water runoff and air emission control measures. ARARs for these common activities are discussed here.

F.4.2 STORM-WATER RUNOFF

Storm-water discharges from activities involving construction operations that result in the disturbance of land equal to or greater than one acre and less than five acres require implementation of good site planning and best management practices.

F.4.3 FUGITIVE EMISSIONS

Emission of airborne particulate concentrations may result from construction activities. Fugitive emissions are regulated by Kentucky through administrative rules at 401 *KAR* 63:010. An operator must take reasonable precautions to prevent particulate matter from becoming airborne.

40 *CFR* § 61, Subpart H, addresses atmospheric radionuclide emissions, excluding radon 220 and 222, from the U.S. Department of Energy (DOE) facilities and applies to airborne emissions during construction and operation activities. National Emissions Standards for Hazardous Air Pollutants limits ambient air radionuclide emissions from DOE facilities to levels that would prevent any individual from receiving an effective dose equivalent (EDE) of 10 millirem per year (mrem/year) or more (40 *CFR* § 61.92). Nonpoint-source fugitive radionuclide emissions are estimated by plant monitoring stations.

F.4.4 COLLECTION/TREATMENT OF VOLATILE ORGANIC CONSTITUENTS

Alternatives 4 and 7 involve *in situ* heating of soils by use of an electrical resistance heating process. This will result in the collection and recovery of contaminants from the aquifer and vadose zone. Prior to emission of collection vapor/gases, contaminants must be removed to comply with 401 *KAR* 63:020. An off-gas treatment system shall be employed to ensure contaminant emissions do not exceed allowable levels. This system may include such equipment as condensers and/or filters to accomplish the required contaminant removal.

F.4.5 WASTE-WATER TREATMENT

Contaminated water, including decontamination fluid, collected storm water, groundwater, and condensate from the off-gas treatment system, shall be treated before discharge. A waste water treatment facility will be constructed and designed to meet the substantive requirements of the Kentucky Pollutant Discharge Elimination System program for discharge of this water.

F.4.6 WASTE MANAGEMENT

All primary wastes (i.e., groundwater and contaminated soils) and secondary wastes (i.e., contaminated personal protective equipment, treatment residuals, and decontamination wastewaters) generated during remedial activities will be characterized as either RCRA wastes (solid or hazardous), Toxic Substances Control Act (TSCA) waste, low-level radioactive waste(s), and/or mixed waste(s), as appropriate, and each must be managed in accordance with appropriate RCRA, TSCA, or DOE Order/Manual requirements. Wastes managed on-site must comply with the substantive requirements of the aforementioned ARARs.

F.4.7 TRANSPORTATION

Any remediation wastes transferred off-site or transported in commerce along public rights-of-way must be conducted in compliance with all applicable laws and regulations. These transportation requirements include provisions for proper packaging, labeling, marking, manifesting, record keeping, licensing, and placarding that must be fully complied with for shipment. Before shipment of CERCLA wastes to any off-site facility, DOE must ensure the acceptance of the receiving site under the CERCLA Off-site Rule (40 *CFR* § 300.440 *et seq.*).

THIS PAGE INTENTIONALLY LEFT BLANK

Table F.1. Location-Specific ARARs and TBC Guidance for BGOU FS

Location-specific ARARs											
Location	**Requirement**	**Prerequisite**	**Citation**	**SWMU 2**	**SWMU 3**	**SWMU 4**	**SWMU 5**	**SWMU 6**	**SWMU 7**	**SWMU 30**	**SWMU 145**
Wetlands											
Presence of wetlands as defined in 10 *CFR* § 1022.4	Avoid, to the extent possible, the long- and short-term adverse effects associated with destruction, occupancy, and modification of wetlands.	DOE actions that involve potential impacts to, or take place within, wetlands—**applicable**.	10 *CFR* § 1022.3(a)	✓	✓	✓	✓	✓	✓	✓	✓
	Take action, to extent practicable, to minimize destruction, loss, or degradation of wetlands and to preserve and enhance the natural and beneficial values of wetlands.		10 *CFR* § 1022.3(a)(7) and (8)	✓	✓	✓	✓	✓	✓	✓	✓
	Undertake a careful evaluation of the potential effects of any new construction in wetlands. Identify, evaluate, and, as appropriate, implement alternative actions that may avoid or mitigate adverse impacts on wetlands.		10 *CFR* § 1022.3(b) and (d)	✓	✓	✓	✓	✓	✓	✓	✓
	Measures that mitigate the adverse effects of actions in a wetland including, but not limited to, minimum grading requirements, runoff controls, design and construction constraints, and protection of ecologically-sensitive areas.		10 *CFR* § 1022.13(a)(3)	✓	✓	✓	✓	✓	✓	✓	✓
	If no practicable alternative to locating or conducting the action in the wetland is available, then before taking action design or modify the action in order to minimize potential harm to or within the wetland, consistent with the policies set forth in E.O. 11990.		10 *CFR* § 1022.14(a)	✓	✓	✓	✓	✓	✓	✓	✓

Table F.1. Location-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Location-specific ARARs											
Location	**Requirement**	**Prerequisite**	**Citation**	**SWMU 2**	**SWMU 3**	**SWMU 4**	**SWMU 5**	**SWMU 6**	**SWMU 7**	**SWMU 30**	**SWMU 145**
Location encompassing aquatic ecosystem as defined in 40 *CFR* § 230.3(c)	Except as provided under section 404(b)(2), no discharge of dredged or fill material is permitted if there is a practicable alternative that would have less adverse impact on the aquatic ecosystem or if it will cause or contribute to significant degradation of the waters of the United States.	Action that involves the discharge of dredged or fill material into waters of the United States, including jurisdictional wetlands—**relevant and appropriate**.	40 *CFR* § 230.10(a) and (c)	✓	✓	✓	✓	✓	✓	✓	✓
	Except as provided under section 404(b)(2), no discharge of dredged or fill material shall be permitted unless appropriate and practicable steps have been taken that will minimize potential adverse impacts of the discharge on the aquatic ecosystem. 40 *CFR* § 230.70 *et seq*. identifies such possible steps.		40 *CFR* § 230.10(d)	✓	✓	✓	✓	✓	✓	✓	✓
Nationwide Permit Program	Must comply with the substantive requirements of the NWP 38, General Conditions, as appropriate.	Discharge of dredged or fill material into *waters of the United States*, including jurisdictional wetlands—**relevant and appropriate**.	Nation Wide Permit (38) Cleanup of Hazardous and Toxic Waste 33 *CFR* § 323.3(b)	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
General Standards of Performance											
Activities causing fugitive dust emissions	No person shall cause, suffer, or allow any material to be handled, processed, transported, or stored; a building or its appurtenances to be constructed, altered, repaired, or demolished, or a road to be used without taking reasonable precaution to prevent particulate matter from becoming airborne. Such reasonable precautions shall include, when applicable, but not be limited to the following: • Use, where possible, of water or chemicals for control of dust in the demolition of existing buildings or structures, construction operations, the grading of roads or the clearing of land; • Application and maintenance of asphalt, oil, water, or suitable chemicals on roads, materials stockpiles, and other surfaces which can create airborne dusts; • Covering, at all times when in motion, open bodied trucks transporting materials likely to become airborne; • The maintenance of paved roadways in a clean condition; and • The prompt removal of earth or other material from a paved street which earth or other material has been transported thereto by trucking or earth moving equipment or erosion by water.	Fugitive emissions from land-disturbing activities (e.g., handling, processing, transporting or storing of any material, demolition of structures, construction operations, grading of roads, or the clearing of land, etc.)—**applicable**.	401 *KAR* 63:010 § 3(1) and (1)(a), (b), (d), (e) and (f)	✓	✓	✓	✓	✓	✓	✓	✓
	No person shall cause or permit the discharge of visible fugitive dust emissions beyond the lot line of the property on which the emissions originate.		401 *KAR* 63:010 § 3(2)	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
Radiation protection of the public and the environment	Except as provided in 5400.1(II)(1)(a)(4), the exposure of members of the public to radiation sources as a consequence of all routine DOE activities shall not cause, in a year, an EDE greater than 100 mrem per year. The ALARA process shall be implemented for all DOE activities and facilities that cause public doses.	Dose received from all exposure modes from all DOE activities (including remedial actions) at a DOE facility—**TBC**.	DOE O 5400.5(II)(1) (a) and (2)	✓	✓	✓	✓	✓	✓	✓	✓
Air Emissions											
Activities causing radionuclide emissions	Emissions of radionuclides to the ambient air from DOE facilities shall not exceed those amounts that would cause any member of the public to receive in any year an EDE of 10 mrem/yr.	Radionuclide emissions at a DOE facility—**applicable**.	40 *CFR* § 61.92 401 *KAR* 57:002	✓	✓	✓	✓	✓	✓	✓	✓
Activities causing toxic substances or potentially hazardous matter emissions	Persons responsible for a source from which hazardous matter or toxic substances may be emitted shall provide the utmost care and consideration in the handling of these materials to the potentially harmful effects of the emissions resulting from such activities. Shall not allow any affected facility to emit potentially hazardous matter or toxic substances in such quantities or duration as to be harmful to the health and welfare of humans, animals and plants.	Emissions of potentially hazardous matter or toxic substances as defined in 401 *KAR* 63:020 § 2 (2) —**applicable**.	401 *KAR* 63:020 § 3		✓	✓	✓	✓	✓	✓	✓
Emission standards for stationary emergency engines, (e.g. power for generators)	Must comply with the emission standards in table 1 Subpart IIII of Part 60.	Operation of pre-2007 model year emergency stationary compression ignition internal combustion engines as defined in 40 *CFR* § 60.4219 with a displacement of less than 10 liters per cylinder that are not fire pump engines—**applicable**.	40 *CFR* § 60.4205(a)			✓		✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	Must comply with the emission standards for new nonroad compression ignition engines in 40 *CFR* § 60.4202, for all pollutants, for the same model year and maximum engine power for their 2007 model year and later emergency stationary compression ignition internal combustion engines.	Operation of 2007 model year and later emergency stationary compression ignition internal combustion engines with a displacement of less than 30 liters per cylinder that are not fire pump engines—**applicable**.	40 *CFR* § 60.4205(b)			✓		✓	✓	✓	
	Must meet the following • Reduce NO_X emissions by 90 percent or more, or limit the emissions of NO_X in the stationary CI internal combustion engine exhaust to 1.6 grams per KW-hour (1.2 grams per HP-hour). • Reduce PM emissions by 60 percent or more, or limit the emissions of PM in the stationary CI internal combustion engine exhaust to 0.15 g/KW-hr (0.11 g/HP-hr).	Operation of emergency stationary compression ignition internal combustion engines with a displacement of greater than or equal to 30 liters per cylinder—**applicable**.	40 *CFR* § 60.4205(d)			✓		✓	✓	✓	
Emission standards for a stationary spark ignition internal combustion engine (e.g., power for generators)	Operators of stationary spark ignition internal combustion must comply with the emission standards in §60.4231(a) for their stationary spark ignition internal combustion engines.	Operation of a stationary spark ignition internal combustion engine with a maximum engine power less than or equal to 19 KW (25 HP) manufactured on or after July 1, 2008, as defined in 40 *CFR* § 60.4248 as specified in 40 *CFR* § 60.4230 (a)(4) and (5). For the purposes of Subpart, JJJJ of part 60 the date that construction commences is the date the engine is ordered by the operator—**applicable**.	40 *CFR* § 60.4233(a)			✓		✓	✓	✓	
	Must comply with the emission standards in 40 *CFR* § 60.4231(b) for their stationary	Operation of stationary spark ignition internal combustion	40 *CFR* § 60.4233(b)			✓		✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	spark ignition internal combustion engines.	engines with a maximum engine power greater than 19 KW (25 HP) manufactured on or after the applicable date in 40 *CFR* § 60.4230(a)(4) that use gasoline—**applicable**.									
	Must comply with the emission standards in 40 *CFR* § 60.4231(c) for their stationary spark ignition internal combustion engines.	Operation of stationary spark ignition internal combustion engines with a maximum engine power greater than 19 KW (25 HP) manufactured on or after the applicable date in §60.4230(a)(4) that are rich burn engines that use LPG—**applicable**.	40 *CFR* § 60.4233(c)			✓		✓	✓	✓	
	Must comply with the emission standards in Table 1 to Subpart JJJJ of Part 60 for their emergency stationary spark ignition internal combustion engines.	Operation of emergency stationary spark ignition internal combustion engines with a maximum engine power greater than 19 KW (25 HP) and less than 75 KW (100 HP) (except gasoline and rich burn engines that use LPG)—**applicable**.	40 *CFR* § 60.4233(d)			✓		✓	✓	✓	
	May optionally choose to meet the standards in Table 1 to Subpart JJJJ of Part 60 applicable to engines with a maximum engine power greater than or equal to 100 HP and less than 500 HP.	Operation of stationary spark ignition internal combustion engines with a maximum engine power greater than 19 KW (25 HP) and less than 75 KW (100 HP) manufactured prior to January 1, 2011, that were certified to the standards in Table 1 to Subpart JJJJ of Part 60 applicable to engines with a maximum engine power greater than or equal to 100	40 *CFR* § 60.4233(d)			✓		✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
		HP and less than 500 HP—**applicable**.									
	Must comply with the emission standards in Table 1 to Subpart JJJJ of Part 60 for their stationary spark ignition internal combustion engines.	Operation of stationary spark ignition internal combustion engines with a maximum engine power greater than or equal to 75 KW (100 HP) (except gasoline and rich burn engines that use LPG)—**applicable**.	40 *CFR* § 60.4233(e)			✓		✓	✓	✓	
Emission standards for new hazardous waste combustors (i.e., hazardous waste incinerators)	Must not discharge or cause combustion gases to be emitted into the atmosphere that contain: • Dioxins and furans in excess of 0.11 ng TEQ/dscm corrected to 7 percent oxygen for incinerators equipped with either a waste heat boiler or dry air pollution control system; or • Dioxins and furans in excess of 0.20 ng TEQ/dscm corrected to 7 percent oxygen for sources not equipped with either a waste heat boiler or dry air pollution control system;	Thermal desorber that meets the definition of a hazardous waste incinerator in 40 *CFR* § 260.10 that burn hazardous waste at any time, including all associated firing systems and air pollution control devices, as well as the combustion chamber equipment, except as otherwise exempt in Table 1 of 40 *CFR* § 63.1200—**applicable**.	40 *CFR* § 63.1219(b)(1)					✓	✓	✓	
	Mercury in excess of 8.1 μgm/dscm, corrected to 7 percent oxygen;		40 *CFR* § 63.1219(b)(2)					✓	✓	✓	
	Cadmium and lead in excess of 10 μgm/dscm, combined emissions, corrected to 7 percent oxygen;		40 *CFR* § 63.1219(b)(3)					✓	✓	✓	
	Arsenic, beryllium, and chromium in excess of 23 μgm/dscm, combined emissions, corrected to 7 percent oxygen;		40 *CFR* § 63.1219(b)(4)					✓	✓	✓	
	For carbon monoxide and hydrocarbons, either:		40 *CFR* § 63.1219 (b)(5)					✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	• Carbon monoxide in excess of 100 parts per million by volume, over an hourly rolling average (monitored continuously with a continuous emissions monitoring system), dry basis and corrected to 7 percent oxygen. If you elect to comply with this carbon monoxide standard rather than the hydrocarbon standard under 40 *CFR* § 63.1219(b)(5)(ii), must also document that, during the destruction and removal efficiency (DRE) test runs or their equivalent as provided by §63.1206(b)(7), hydrocarbons do not exceed 10 parts per million by volume during those runs, over an hourly rolling average (monitored continuously with a continuous emissions monitoring system), dry basis, corrected to 7 percent oxygen, and reported as propane; or • Hydrocarbons in excess of 10 parts per million by volume, over an hourly rolling average (monitored continuously with a continuous emissions monitoring system), dry basis, corrected to 7 percent oxygen, and reported as propane;										
	Hydrogen chloride and chlorine gas in excess of 21 parts per million by volume, combined emissions, expressed as a chloride (Cl(−)) equivalent, dry basis and corrected to 7 percent oxygen; and		40 *CFR* § 63.1219(b)(6)					✓	✓	✓	
	Except as provided by 40 *CFR* § 63.1219(e), particulate matter emissions in excess of 0.0016 gr/dscf corrected to 7 percent oxygen.		40 *CFR* § 63.1219(b)(7)					✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	Except as provided in 40 *CFR* § 63.1219(c)(2), must achieve a destruction and removal efficiency (DRE) of 99.99% for each principle organic hazardous constituent (POHC) designated under 40 *CFR* § 63.1219(c)(3). Must calculate DRE for each POHC from the following equation: $DRE = [1 - (W_{out}/ W_{in})] \times 100\%$ Where: W_{in}= mass feedrate of one POHC in a waste feedstream; and W_{out}= mass emission rate of the same POHC present in exhaust emissions prior to release to the atmosphere.		40 *CFR* § 63.1219(c) (1)					✓	✓	✓	
	Must treat each POHC in the waste feed that you specify under 40 *CFR* § 63.1219(c)(3)(ii) to the extent required by 40 *CFR* § 63.1219(c)(1). Must specify one or more POHCs that are representative of the most difficult to destroy organic compounds in your hazardous waste feedstream. Must base this specification on the degree of difficulty of incineration of the organic constituents in the hazardous waste and on their concentration or mass in the hazardous waste feed, considering the results of hazardous waste analyses or other data and information.		40 *CFR* § 63.1219(c) (3)					✓	✓	✓	
	The emission limits provided by 40 *CFR* § 63.1219 (b) are presented with two significant figures. Although intermediate calculations must be performed using at least three significant figures, may round the resultant emission levels to two significant figures to document compliance.		40 *CFR* § 63.1219(d)					✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
Alternative metal emission control requirements to the particulate matter standard	In lieu of complying with the particulate matter standards of this section, you may elect to comply with the following alternative metal emission control requirement:		40 *CFR* § 63.1219(e) (1)					✓	✓	✓	
	• Must not discharge or cause combustion gases to be emitted into the atmosphere that contain cadmium, lead, and selenium in excess of 10 µgm/dscm, combined emissions, corrected to 7 percent oxygen; and, • Must not discharge or cause combustion gases to be emitted into the atmosphere that contain antimony, arsenic, beryllium, chromium, cobalt, manganese, and nickel in excess of 23 µgm/dscm, combined emissions, corrected to 7 percent oxygen.		40 *CFR* § 63.1219(e) (3)					✓	✓	✓	
	Semivolatile and low volatile metal operating parameter limits must be established to ensure compliance with the alternative emission limitations described in 40 *CFR* § 63.1219 (e)(3) pursuant to § 63.1209(n), except that semivolatile metal feedrate limits apply to lead, cadmium, and selenium, combined, and low volatile metal feed rate limits apply to arsenic, beryllium, chromium, antimony, cobalt, manganese, and nickel, combined.		40 *CFR* § 63.1219(e) (4)					✓	✓	✓	
General standards for process vents used in treatment of VOCs	Select and meet the requirements under one of the options specified below: • Control HAP emissions from the affected process vents according to the applicable standards specified in §§ 63.7890 through 63.7893. • Determine for the remediation material	Process vents as defined in 40 *CFR* § 63.7957 used in site remediation of media (e.g., soil and groundwater) that could emit hazardous air pollutants (HAP) listed in Table 1 of Subpart GGGGG	40 *CFR* § 63:7885(b) 401 *KAR* 63:002, §§ 1 and 2, except for 40 *CFR* §			✓		✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	treated or managed by the process vented through the affected process vents that the average total volatile organic hazardous air pollutant (VOHAP) concentration, as defined in § 63.7957, of this material is less than 10 (ppmw). Determination of VOHAP concentration will be made using procedures specified in § 63.7943. • Control HAP emissions from affected process vents subject to another subpart under 40 *CFR* part 61 or 40 *CFR* part 63 in compliance with the standards specified in the applicable subpart.	of Part 63 and vent stream flow exceeds the rate in 40 *CFR* § 63.7885(c)(1)—**relevant and appropriate**.	63.72 as incorporated in § 2(3)								
Emission limitations for process vents used in treatment of VOCs	Meet the requirements under one of the options specified below: • Reduce from all affected process vents the total emissions of the HAP to a level less than 1.4 kilograms per hour (kg/hr) and 2.8 Mg/yr (3.0 pounds per hour (lb/hr) and 3.1 tpy); or • Reduce from all affected process vents the emissions of total organic compounds (TOC) (minus methane and ethane) to a level below 1.4 kg/hr and 2.8 Mg/yr (3.0 lb/hr and 3.1 tpy); or • Reduce from all affected process vents the total emissions of the HAP by 95 percent by weight or more; or • Reduce from all affected process vents the emissions of TOC (minus methane and ethane) by 95 percent by weight or more.	Process vents as defined in 40 *CFR* § 63.7957 used in site remediation of media (e.g., soil and groundwater) that could emit hazardous air pollutants (HAP) listed in Table 1 of Subpart GGGGG of Part 63 and vent stream flow exceeds the rate in 40 *CFR* § 63.7885(c)(1)—**relevant and appropriate**.	40 *CFR* § 63.7890(b)(1) -(4) 401 *KAR* 63:002, §§ 1 and 2, except for 40 *CFR* § 63.72 as incorporated in § 2(3)			✓		✓	✓	✓	
Standards for closed vent systems and control devices used in treatment of VOCs	For each closed vent system and control device you use to comply with the requirements above, you must meet the operating limit requirements and work practice standards in Sec. 63.7925(d) through (j) that apply to the closed vent	Closed vent system and control devices as defined in 40 *CFR* § 63.7957 that are used to comply with § 63.7890(b)—**relevant and appropriate**.	40 *CFR* § 63.7890(c)			✓		✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	system and control device. *NOTE:* EPA approval to use alternate work practices under paragraph (j) in 40 *CFR* § 63.7925 will be obtained in FFA CERCLA document (e.g., Remedial Design).										
Monitoring of closed vent systems and control devices used in treatment of VOCs	Must monitor and inspect the closed vent system and control device according to the requirements in 40 *CFR* § 63.7927 that apply to the affected source. *NOTE:* Monitoring program will be developed as part of the CERCLA process and included in a Remedial Design or other appropriate FFA CERCLA document.	Closed vent system and control devices as defined in 40 *CFR* § 63.7957 that are used to comply with § 63.7890(b)—**relevant and appropriate**.	40 *CFR* § 63.7892			✓		✓	✓	✓	
Hazardous waste incinerators meeting MACT standards	Except as provided by 40 *CFR* § 264.340 (b)(2) through (b)(3), the standards of 40 *CFR* Part 264 do not apply to a new hazardous waste incineration unit that demonstrates compliance with the maximum achievable control technology (MACT) requirements of part 63, Subpart EEE, of this chapter by conducting a comprehensive performance test and documenting compliance with the requirements of part 63, Subpart EEE, of chapter 1.	Thermal desorption in units meeting definition of hazardous waste incinerator in 40 *CFR* § 260.10—**applicable**.	40 *CFR* § 264.340(b)(1) 401 *KAR* 34:240 § 1					✓	✓	✓	
	The MACT standards do not replace the closure requirements of 40 *CFR* § 264.351 or the applicable requirements of Subparts A through G, BB and CC that are identified as ARARS in Table F.2.		40 *CFR* § 264.340(b)(2) 401 *KAR* 34:240 § 1					✓	✓	✓	
	The particulate matter standard of 40 *CFR* § 264.343(c) remains in effect for incinerators that elect to comply with the alternative to the particulate matter standard under 40 *CFR* § 63.1206(b)(14) and 63.1219(e).		40 *CFR* § 264.340(b)(3) 401 *KAR* 34:240 § 1					✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
Activities causing storm water runoff (e.g., clearing, grading, excavation)	Implement good construction techniques to control pollutants in storm water discharges during and after construction in accordance with substantive requirements provided by permits issued pursuant to 40 *CFR* § 122.26(c).	Storm water discharges associated with small construction activities as defined in 40 *CFR* § 122.26(b)(15) and 401 *KAR* 5:002 § 1 (157)—**applicable**.	40 *CFR* § 122.26(c)(1) (ii)(C) and (D) 401 *KAR* 5:060 § 8	✓	✓	✓	✓	✓	✓	✓	✓
	Storm water runoff associated with construction activities taking place at a facility with an existing Best Management Practices (BMP) Plan shall be addressed under the facility BMP and not under a storm water general permit.	Storm water discharges associated with small construction activities as defined in 40 *CFR* § 122.26(b)(15) and 401 *KAR* 5:002 § 1 (157)**—TBC**.	Fact Sheet for the KPDES General Permit For Storm water Discharges Associated with Construction Activities, June 2009	✓	✓	✓	✓	✓	✓	✓	✓
	Best management storm water controls will be implemented and may include, as appropriate, erosion and sedimentation control measures, structural practices (e.g., silt fences, straw bale barriers) and vegetative practices (e.g., seeding); storm water management (e.g. diversion); and maintenance of control measures in order to ensure compliance with the standards in Section C.5. Storm Water Discharge Quality.	Storm water runoff associated with construction activities taking place at a facility [PGDP] with an existing BMP Plan**—TBC**.	Appendix C of the PGDP Best Management Practices Plan (2007) — Examples of Storm water Controls	✓	✓	✓	✓	✓	✓	✓	✓
Monitoring, Extraction, and Injection Well Installation and Abandonment											
Monitoring well	Permanent monitoring wells shall be constructed, modified, and abandoned in	Construction of monitoring well as defined in 401 *KAR*	401 *KAR*	✓	✓	✓	✓		✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
installation	such a manner as to prevent the introduction or migration of contamination to a water-bearing zone or aquifer through the casing, drill hole, or annular materials.	6:001 § 1(18) for remedial action—**applicable**.	6:350 § 1(2)								
	All permanent monitoring wells (including boreholes) shall be constructed to comply with the substantive requirements provided in the following Sections of 401 *KAR* 6:350: • Section 2. Design Factors; • Section 3. Monitoring Well Construction; • Section 7. Materials for Monitoring Wells; and • Section 8. Surface Completion.		401 *KAR* 6:350 § 2, 3, 7, and 8	✓	✓	✓	✓		✓	✓	✓
	If conditions exist or are believed to exist that preclude compliance with the requirements of 401 *KAR* 6:350, may request a variance prior to well construction or well abandonment. *NOTE: Variance shall be made as part of the FFA CERCLA document review and approval process and shall include:* • A justification for the variance; and • Proposed construction, modification, or abandonment procedures to be used in lieu of compliance with 401 *KAR* 6:350 and an explanation as to how the alternate well construction procedures ensure the protection of the quality of the groundwater and the protection of public health and safety.		401 *KAR* 6:350 § 6 (a)(6) and (7)	✓	✓	✓	✓		✓	✓	✓
Development of monitoring well	Newly installed wells shall be developed until the column of water in the well is free of visible sediment. This well-development protocol shall not be used as a method for purging prior to water	Construction of monitoring well as defined in 401 *KAR* 6:001 § 1(18) for remedial action—**applicable**.	401 *KAR* 6:350 § 9	✓	✓	✓	✓		✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	quality sampling.										
Direct Push monitoring well installation	Wells installed using direct push technology shall be constructed, modified, and abandoned in such a manner as to prevent the introduction or migration of contamination to a water-bearing zone or aquifer through the casing, drill hole, or annular materials.	Construction of direct push monitoring well as defined in 401 *KAR* 6:001 § 1(18) for remedial action—**applicable**.	401 *KAR* 6:350 § 5 (1)	✓	✓	✓	✓		✓	✓	✓
	Shall also comply with the following additional standards: (a) The outside diameter of the borehole shall be a minimum of 1 inch greater than the outside diameter of the well casing; (b) Premixed bentonite slurry or bentonite chips with a mini,um of one-eighth (1/8) diameter shall be used in the sealed interval below the static water level; an (c) 1. Direct push wells shall not be constructed through more than one water-bearing formation unless the upper water bearing zone is isolated by temporary or permanent casing. 2. The direct push tool string may serve as the temporary casing.		401 *KAR* 6:350 § 5 (3)	✓	✓	✓	✓		✓	✓	✓
Monitoring well abandonment	A monitoring well that has been damaged or is otherwise unsuitable for use as a monitoring well, shall be abandoned within 30 days from the last sampling date or 30 days from the date it is determined that the well is no longer suitable for its intended use.	Construction of monitoring well as defined in 401 *KAR* 6:001 § 1(18) for remedial action—**applicable**.	401 *KAR* 6:350 § 11 (1)	✓	✓	✓	✓		✓	✓	✓
	Wells shall be abandoned in such a manner as to prevent the migration of surface water or contaminants to the subsurface and to prevent migration of contaminants among water bearing zones.		401 *KAR* 6:350 § 11 (1)(a)	✓	✓	✓	✓		✓	✓	✓
	Abandonment methods and sealing		401 *KAR*	✓	✓	✓	✓		✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	materials for all types of monitoring wells provided in subparagraphs (a)-(b) and (d)-(e) shall be followed.		6:350 § 11 (2)								
Extraction well installation	Wells shall be constructed, modified, and abandoned in such a manner as to prevent the introduction or migration of contamination to a water-bearing zone or aquifer through the casing, drill hole, or annular materials.	Construction of extraction well for remedial action—**relevant and appropriate**.	401 *KAR* 6:350 § 1 (2)			✓			✓		
Reinjection of treated contaminated groundwater	No owner or operator shall construct, operate, maintain, convert, plug, abandon, or conduct any other injection activity in a manner that allows the movement of fluid containing any contaminant into underground sources of drinking water, if the presence of that contaminant may cause a violation of any primary drinking water regulation under 40 *CFR* Part 142 or may otherwise adversely affect the health of persons.	Underground injection into an underground source of drinking water—**relevant and appropriate**.	40 *CFR* § 144.12(a)			✓			✓		
	Wells are not prohibited if injection is approved by EPA or a State pursuant to provisions for cleanup of releases under CERCLA or RCRA *as provided in the FFA CERCLA document.*	Class IV wells [as defined in 40 *CFR* § 144.6(d)] used to reinject treated contaminated groundwater into the same formation from which it was drawn—**relevant and appropriate**.	40 *CFR* § 144.13(c) RCRA § 3020(b)			✓			✓		
	Prior to abandonment any Class IV well, the owner or operator shall plug or otherwise close the well in a manner *as provided in the FFA CERCLA document*.	Class IV wells [as defined in 40 *CFR* § 144.6(d)] used to reinject of treated contaminated groundwater into the same formation from which it was drawn—**relevant and appropriate**.	40 *CFR* § 144.23(b)(1)			✓			✓		
Plugging and abandonment of Class IV injection	Prior to abandoning the well, the owner or operator shall close the well in accordance with 40 *CFR* § 144.23(b).	Operation of a Class IV injection well [as defined in 40 *CFR* § 144.6(d)] —	40 *CFR* § 146.10(b)			✓			✓		

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
wells		**relevant and appropriate**.									
Groundwater monitoring requirements											
Groundwater monitoring requirements for RCRA hazardous waste landfills	All or part of the requirements for releases from solid waste management units of 40 *CFR* §§ 264.91 through 264.100 may be replaced with alternative requirements for groundwater monitoring and corrective action for releases to groundwater set out in the enforceable CERCLA document where it has been determined that: (1) The regulated unit is situated among solid waste management units (or areas of concern), a release has occurred, and both the regulated unit and one or more solid waste management unit(s) (or areas of concern) are likely to have contributed to the release; and (2) It is not necessary to apply the groundwater monitoring and corrective action requirements of 40 *CFR* §§ 264.91 through 264.100 because alternative requirements will protect human health and the environment.	Conducting monitoring for responding to releases from landfills under 40 *CFR* § 264.90—**applicable**.	40 *CFR* § 264.90(f)(1) and (2) 401 *KAR* 34:060 § 1	✓							
General post-closure care	Owner or operator must:	Post-closure of a RCRA landfill—**applicable**.	40 *CFR* § 264.310(b) 401 *KAR* 34:230 § 7	✓							
	• maintain the effectiveness and integrity of the final cover including making repairs to the cap as necessary to correct effects of settling, erosion, etc.;		40 *CFR* § 264.310(b)(1) 401 *KAR* 34:230 § 7	✓							
	• continue to operate the leachate collection and removal system until leachate is no longer detected;		40 *CFR* § 264.310(b)(2) 401 *KAR*	✓							

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
			34:230 § 7								
	• maintain and monitor the leachate detection		40 *CFR* § 264.310(b)(3) 401 *KAR* 34:230 § 7	✓							
	• maintain and monitor a ground water monitoring system and comply with all other applicable provisions 40 *CFR* 264, Subpart F;		40 *CFR* § 264.310(b)(4) 401 *KAR* 34:230 § 7	✓							
	• prevent run-on and run-off from eroding or otherwise damaging final cover; and		40 *CFR* § 264.310(b)(5) 401 *KAR* 34:230 § 7	✓							
	• protect and maintain surveyed benchmarks used to locate waste cells.		40 *CFR* § 264.310(b)(6) 401 *KAR* 34:230 § 7	✓							
Cover design and construction											
Installation of low-permeability cover	Must install cover designed and constructed to: • provide long-term minimization of migration of liquids through the closed landfill; • function with minimum maintenance; • promote drainage and minimize erosion or abrasion of the cover; • accommodate settling and subsidence so that the cover's integrity is maintained; and • have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.	Design and construction of cover—**relevant and appropriate**.	40 *CFR* § 265.310(a) 401 *KAR* 34:230 § 7				✓				
Maintenance of low-permeability cover	Must maintain the integrity and effectiveness of the cover, including making repairs to the cap as necessary to correct the	Installation of cover—**relevant and appropriate**.	40 *CFR* § 265.310(b)				✓				

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	effects of settling, subsidence, erosion, or other events; and Must prevent run-on and run-off from eroding or otherwise damaging the cover.		401 *KAR* 34:230 § 7								
	Must continue maintenance for 30 years.		40 *CFR* § 265.117(a)(1) 401 *KAR* 34:070 § 8				✓				
Disturbance of integrity of low-permeability cover	Must never allow disturbance of the integrity of the cover, or any other components of the containment system, or the function of the facility's monitoring systems, unless the disturbance: • Is necessary to the proposed use of the property, and will not increase the potential hazard to human health or the environment; or • Is necessary to reduce a threat to human health or the environment.		40 *CFR* § 265.117(c) 401 *KAR* 34:070 § 8				✓				
Installation of a cover system	The cover system must be designed and constructed to • Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present, or a permeability no greater than 1×10^{-5}cm/sec, whichever is less, and • Minimize infiltration by the use of an infiltration layer that contains a minimum 18-inches of earthen material, and • Minimize erosion of the final cover by the use of an erosion layer that contains a minimum 6-inches of earthen material that is capable of sustaining native plant growth.	Design and construction of a cover system to minimize infiltration and erosion—**relevant and appropriate**.	40 *CFR* § 258.60 (a)		✓	✓					
Maintenance of cover	Must continue maintenance for 30 years, except as provided under 40 *CFR* § 258.61(b), and consist of at least the	Installation of cover—**relevant and appropriate**.	40 *CFR* § 258.61 (a)(1)		✓	✓					

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	following: • Maintaining the integrity and effectiveness of any cover, including making repairs to the cover as necessary to correct the effects of settlement, subsidence, erosion, or other events, and preventing run-on and run-off from eroding or otherwise damaging the cover.										
		Waste management									
Management of PCB waste	Any person storing or disposing of PCB waste must do so in accordance with 40 *CFR* § 761, Subpart D.	Storage or disposal of waste containing PCBs at concentrations ≥ 50 ppm—**applicable**.	40 *CFR* § 761.50(a)	✓	✓	✓	✓	✓	✓	✓	✓
Management of PCB remediation waste	Any person cleaning up and disposing of PCBs shall do so based on the concentration at which the PCBs are found.	Cleanup and disposal of PCB remediation waste as defined in 40 *CFR* § 761.3—**applicable**.	40 *CFR* § 761.61	✓	✓	✓	✓	✓	✓	✓	✓
Management of PCB/Radioactive waste	Any person storing such waste must do so taking into account both its PCB concentration and radioactive properties, except as provided in 40 *CFR* § 761.65(a)(1), (b)(1)(ii) and (c)(6)(i).	Generation of PCB/radioactive waste with ≥50 ppm PCBs for storage—**applicable**.	40 *CFR* § 761.50(b)(7) (i)	✓	✓	✓	✓	✓	✓	✓	✓
	Any person disposing of such waste must do so taking into account both its PCB concentration and its radioactive properties. If, taking into account only the PCB properties in the waste (and not the radioactive properties of the waste), the waste meets the requirements for disposal in a facility permitted, licensed, or registered by a state as a municipal or nonmunicipal nonhazardous waste landfill [e.g., PCB bulk-product waste under 40 *CFR* § 761.62(b)(1)], then the person may dispose of PCB/radioactive waste, without regard to the PCBs, based on its radioactive properties in accordance with applicable		40 *CFR* § 761.50(b)(7) (ii)	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	requirements for the radioactive component of the waste.										
Waste Characterization											
Characterization of solid waste	Must determine if solid waste is excluded from regulation under 40 *CFR* § 261.4.	Generation of solid waste as defined in 40 *CFR* § 261.2—**applicable**.	40 *CFR* § 262.11(a) 401 *KAR* 32:010 § 2	✓	✓	✓	✓	✓	✓	✓	✓
	Must determine if waste is listed as a hazardous waste in Subpart D of 40 *CFR* Part 261.	Generation of solid waste which is not excluded under 40 *CFR* § 261.4—**applicable**.	40 *CFR* § 262.11(b) 401 *KAR* 32:010 § 2	✓	✓	✓	✓	✓	✓	✓	✓
	Must determine whether the waste is characteristic waste (identified in Subpart C of 40 *CFR* Part 261) by using prescribed testing methods or applying generator knowledge based on information regarding material or processes used.	Generation of solid waste that is not listed in Subpart D of 40 *CFR* Part 261 and not excluded under 40 *CFR* § 261.4—**applicable**.	40 *CFR* § 262.11(c) 401 *KAR* 32:010 § 2	✓	✓	✓	✓	✓	✓	✓	✓
	Must refer to Parts 261, 262, 264, 265, 266, 268, and 273 of Chapter 40 for possible exclusions or restrictions pertaining to management of the specific waste.	Generation of solid waste which is determined to be hazardous waste—**applicable**.	40 *CFR* § 262.11(d) 401 *KAR* 32:010 § 2	✓	✓	✓	✓	✓	✓	✓	✓
Characterization of hazardous waste	Must obtain a detailed chemical and physical analysis on a representative sample of the waste(s), which at a minimum contains all the information that must be known to treat, store, or dispose of the waste in accordance with pertinent sections of 40 *CFR* §§ 264 and 268.	Generation of RCRA-hazardous waste for storage, treatment or disposal—**applicable**.	40 *CFR* § 264.13(a)(1) 401 *KAR* 34:020 § 4	✓	✓	✓	✓	✓	✓	✓	✓
Characterization of industrial wastewater	Industrial wastewater discharges that are point source discharges subject to regulation under § 402 of the Clean Water Act, as amended, are not solid wastes for the purpose of hazardous waste	Generation of industrial wastewater and discharge into surface water—**applicable**.	40 *CFR* § 261.4(a)(2) 401 *KAR* 31:010 § 4	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	management. [Comment: This exclusion applies only to the actual point source discharge. It does not exclude industrial wastewaters while they are being collected, stored or treated before discharge, nor does it exclude sludges that are generated by industrial wastewater treatment.] *NOTE: For purpose of this exclusion, the CERCLA on-site treatment system for groundwater will be considered equivalent to a wastewater treatment unit and the point source discharges subject to regulation under CWA § 402, provided the effluent meets all identified CWA ARARs.*										
Determinations for management of hazardous waste	Must determine each EPA Hazardous Waste Number (Waste Code) to determine the applicable treatment standards under 40 *CFR* § 268.40 *et. seq.* *Note:* This determination may be made concurrently with the hazardous waste determination required in 40 *CFR* § 262.11.	Generation of hazardous waste—**applicable**.	40 *CFR* § 268.9(a) 401 *KAR* 37:010 § 8	✓	✓	✓	✓	✓	✓	✓	✓
	Must determine the underlying hazardous constituents [as defined in 40 *CFR* § 268.2(i)] in the characteristic waste.	Generation of RCRA characteristic hazardous waste (and is not D001 non-wastewaters treated by CMBST, RORGS, or POLYM of Section 268.42 Table 1) for storage, treatment or disposal—**applicable**.	40 *CFR* § 268.9(a) 401 *KAR* 37:010 § 8	✓	✓	✓	✓	✓	✓	✓	✓
	Must determine if the hazardous waste meets the treatment standards in 40 *CFR* §§ 268.40, 268.45, or 268.49 by testing in accordance with prescribed methods or use of generator knowledge of waste. *Note:* This determination can be made	Generation of hazardous waste—**applicable**.	40 *CFR* § 268.7(a) 401 *KAR* 37:020 § 7	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	concurrently with the hazardous waste determination required in 40 *CFR* § 262.11.										
Characterization of LLW	Shall be characterized using direct or indirect methods and the characterization documented in sufficient detail to ensure safe management and compliance with the WAC of the receiving facility.	Generation of LLW for storage and disposal at a DOE facility—**TBC**.	DOE M 435.1-1(IV)(I)	✓	✓	✓	✓	✓	✓	✓	✓
	Characterization data shall, at a minimum, include the following information relevant to the management of the waste: • physical and chemical characteristics; • volume, including the waste and any stabilization or absorbent media; • weight of the container and contents; • identities, activities, and concentration of major radionuclides; • characterization date; • generating source; and • any other information that may be needed to prepare and maintain the disposal facility performance assessment, or demonstrate compliance with performance objectives.		DOE M 435.1-1(IV)(I)(2)	✓	✓	✓	✓	✓	✓	✓	✓
Waste Storage and Staging											
Temporary on-site storage of hazardous waste in containers	A generator may accumulate hazardous waste at the facility provided that	Accumulation of RCRA hazardous waste on-site as defined in 40 *CFR* § 260.10—**applicable**.	40 *CFR* § 262.34(a) 401 *KAR* 32:030 § 5	✓	✓	✓	✓	✓	✓	✓	✓
	• waste is placed in containers that comply with 40 *CFR* § 265.171-173;		40 *CFR* § 262.34(a)(1)(i) 401 *KAR* 32:030 § 5	✓	✓	✓	✓	✓	✓	✓	✓
	• the date upon which accumulation begins		40 *CFR* §	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	is clearly marked and visible for inspection on each container;		262.34(a)(2) 401 *KAR* 32:030 § 5								
	• container is marked with the words "hazardous waste."		40 *CFR* § 262.34(a)(3) 401 *KAR* 32:030 § 5	✓	✓	✓	✓	✓	✓	✓	✓
	Container may be marked with other words that identify the contents.	Accumulation of 55 gal or less of RCRA hazardous waste or one quart of acutely hazardous waste listed in 261.33(e) at or near any point of generation—**applicable**.	40 *CFR* § 262.34(c)(1) 401 *KAR* 32:030 § 5	✓	✓	✓	✓	✓	✓	✓	✓
Use and management of containers holding hazardous waste	If container is not in good condition or if it begins to leak, must transfer waste into container in good condition.	Storage of RCRA hazardous waste in containers—**applicable**.	40 *CFR* § 265.171 401 *KAR* 35:180 § 2	✓	✓	✓	✓	✓	✓	✓	✓
	Use container made or lined with materials compatible with waste to be stored so that the ability of the container is not impaired.		40 *CFR* § 265.172 401 *KAR* 35:180 § 3	✓	✓	✓	✓	✓	✓	✓	✓
	Keep containers closed during storage, except to add/remove waste.		40 *CFR* § 265.173(a) 401 *KAR* 35:180 § 4	✓	✓	✓	✓	✓	✓	✓	✓
	Open, handle and store containers in a manner that will not cause containers to rupture or leak.		40 *CFR* § 265.173(b) 401 *KAR* 35:180 § 4	✓	✓	✓	✓	✓	✓	✓	✓
Storage of hazardous waste in container area	Area must have a containment system designed and operated in accordance with 40 *CFR* § 264.175(b).	Storage of RCRA hazardous waste in containers with free liquids—**applicable**.	40 *CFR* § 264.175(a) 401 *KAR* 34:180 § 6	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	Area must be sloped or otherwise designed and operated to drain liquid from precipitation, or Containers must be elevated or otherwise protected from contact with accumulated liquid.	Storage of RCRA-hazardous waste in containers that do not contain free liquids (other than F020, F021, F022, F023,F026 and F027)—**applicable**.	40 *CFR* § 264.175(c) 401 *KAR* 34:180 § 6	✓	✓	✓	✓	✓	✓	✓	✓
Temporary tanks and container storage areas used to treat or store hazardous remediation wastes	EPA may replace the design, operating, or closure standards with alternate requirements that protect human health and the environment. *NOTE:* EPA approval of alternate design, operating, or closure requirements for a temporary unit will be obtained by approval of a FFA CERCLA document	Generation of RCRA remediation waste during remedial activities that require treatment or storage where they are located within the facility boundary; and used only for treatment or storage of remediation wastes—**applicable**.	40 *CFR* § 264.553(a) and (b) 401 *KAR* 34:287							✓	
	In establishing standards to be applied to a temporary unit, the following factors shall be considered: • Length of time such unit will be in operation; • Type of unit; • Volumes of wastes to be managed; • Physical and chemical characteristics of the wastes to be managed in the unit; • Potential for releases from the unit; • Hydrogeological and other relevant environmental conditions at the facility which may influence the migration of any potential releases; and • Potential for exposure of humans and environmental receptors if releases were to occur from the unit.		40 *CFR* § 264.553(c) 401 *KAR* 34:287							✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
Temporary on-site storage of remediation waste in staging piles (e.g., excavated soils/sediments, sludge)	May be temporarily stored, (including mixing, sizing, blending, or other similar physical operations intended to prepare the wastes for subsequent management or treatment) at a facility if used only during remedial operations provided that the staging pile will be designed to	Accumulation of non-flowing hazardous remediation waste in staging pile (or remediation waste otherwise subject to land disposal restrictions)—**applicable**.	40 *CFR* § 264.554(a)(1) 401 *KAR* 34:287 § 5					✓	✓	✓	
	• facilitate a reliable, effective, and protective remedy;		40 *CFR* § 264.554(d)(1)(i) 401 *KAR* 34:287 § 5					✓	✓	✓	
	• prevent or minimize releases of hazardous wastes and constituents into the environment, and minimize or adequately control cross-media transfer as necessary to protect human health and the environment (e.g., use of liners, covers, run-off/run-on controls, as appropriate).		40 *CFR* § 264.554(d)(1)(ii) 401 *KAR* 34:287 § 5					✓	✓	✓	
	Must not place ignitable or reactive remediation waste in a staging pile unless the remediation waste has been treated, rendered, or mixed before placed in the staging pile so that	Storage of ignitable or reactive remediation waste in staging piles in—**applicable**.	40 *CFR* § 264.554(e) 401 *KAR* 34:287 § 5					✓	✓	✓	
	• The remediation waste no longer meets the definition of ignitable or reactive under 401 *KAR* 31:030 § 2 and § 4; and		40 *CFR* § 264.554(e)(1)(i) 401 *KAR* 34:287 § 5					✓	✓	✓	
	• You have complied with 401 *KAR* 34:020 § 8, General Requirements for Ignitable, Reactive, or Incompatible Wastes.		40 *CFR* § 264.554(e)(1)(ii) 401 *KAR* 34:287 § 5					✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	Must not place in the same staging pile unless you have complied with 40 *CFR* § 264.17(b).	Storage of incompatible remediation waste in staging piles in—**applicable**.	40 *CFR* § 264.554(f)(1) 401 *KAR* 34:287 § 5					✓	✓	✓	
	Must separate the incompatible materials or protect them from one another by using a dike, berm, wall, or other device.		40 *CFR* § 264.554(f)(2) 401 *KAR* 34:287 § 5					✓	✓	✓	
Storage of PCB waste and/or PCB/radioactive waste in a RCRA-regulated container storage area	Does not have to meet storage unit requirements in 40 *CFR* § 761.65(b)(1) provided the unit	Storage of PCBs and PCB Items at concentrations ≥ 50ppm designated for disposal— **applicable**.	40 *CFR* § 761.65(b)(2)	✓	✓	✓	✓	✓	✓	✓	✓
	• is permitted by EPA under RCRA § 3004 to manage hazardous waste in containers and spills of PCBs cleaned up in accordance with Subpart G of 40 *CFR* § 761; or		40 *CFR* § 761.65(b)(2)(i)	✓	✓	✓	✓	✓	✓	✓	✓
	• qualifies for interim status under RCRA § 3005 to manage hazardous waste in containers and spills of PCBs cleaned up in accordance with Subpart G of 40 *CFR* § 761; or		40 *CFR* § 761.65(b)(2)(ii)	✓	✓	✓	✓	✓	✓	✓	✓
	• is permitted by an authorized state under RCRA § 3006 to manage hazardous waste in containers and spills of PCBs cleaned up in accordance with Subpart G of 40 *CFR* § 761.		40 *CFR* § 761.65(b)(2)(iii)	✓	✓	✓	✓	✓	✓	✓	✓
	NOTE: For purpose of this exclusion, CERCLA remediation waste, which is also considered PCB waste, can be stored on-site provided the area meets all of the identified RCRA container storage ARARs and spills of PCBs cleaned up in accordance with Subpart G of 40 *CFR* §			✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	761.										
Storage of PCB waste and/or PCB/radioactive waste in non-RCRA regulated unit	Except as provided in 40 *CFR* §§ 761.65 (b)(2), (c)(1), (c)(7), (c)(9), and (c)(10), after July 1, 1978, owners or operators of any facilities used for the storage of PCBs and PCB Items designated for disposal shall comply with the storage unit requirements in 40 *CFR* § 761.65(b)(1).	Storage of PCBs and PCB Items at concentrations ≥ 50ppm designated for disposal —**applicable**.	40 *CFR* § 761.65(b)	✓	✓	✓	✓	✓	✓	✓	✓
	• Adequate floor that has continuous curbing with a minimum 6-inch high curb. Floor and curb must provide a containment volume equal to at least two times the internal volume of the largest PCB article or container or 25% of the internal volume of all articles or containers stored there, whichever is greater. *Note*: 6 inch minimum curbing not required for area storing PCB/radioactive waste;		40 *CFR* § 761.65(b)(1) (ii)	✓	✓	✓	✓	✓	✓	✓	✓
	• No drain valves, floor drains, expansion joints, sewer lines, or other openings that would permit liquids to flow from curbed area;		40 *CFR* § 761.65(b)(1) (iii)	✓	✓	✓	✓	✓	✓	✓	✓
	• Floors and curbing constructed of Portland cement, concrete, or a continuous, smooth, non-porous surface that prevents or minimizes penetration of PCBs; and		40 *CFR* § 761.65(b)(1) (iv)	✓	✓	✓	✓	✓	✓	✓	✓
	• Not located at a site that is below the 100-year flood water elevation.		40 *CFR* § 761.65(b)(1) (v)	✓	✓	✓	✓	✓	✓	✓	✓
	Storage area must be properly marked as required by 40 *CFR* § 761.40(a)(10).		40 *CFR* § 761.65(c)(3)	✓	✓	✓	✓	✓	✓	✓	✓
Risk-based storage of PCB remediation waste	May store PCB remediation waste in a manner other than prescribed in 40 *CFR* § 761.65(b) if approved in writing from EPA provided the method will not pose an	Storage of waste containing PCBs in a manner other than prescribed in 40 *CFR* § 761.65(b) (see above)	40 *CFR* § 761.61(c)	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	unreasonable risk of injury to human health or the environment. *NOTE:* EPA approval of alternative storage method will be obtained by approval of the FFA CERCLA document.	—**applicable**.									
Temporary storage of PCB waste (e.g., PPE, rags) in a container(s)	Container(s) shall be marked as illustrated in 40 *CFR* § 761.45(a).	Storage of PCBs and PCB items at concentrations ≥ 50ppm in containers for disposal—**applicable**.	40 *CFR* § 761.40(a)(1)	✓	✓	✓	✓	✓	✓	✓	✓
	Storage area must be properly marked as required by 40 *CFR* § 761.40(a)(10).		40 *CFR* § 761.65(c)(3)	✓	✓	✓	✓	✓	✓	✓	✓
	Any leaking PCB Items and their contents shall be transferred immediately to a properly marked nonleaking container(s).		40 *CFR* § 761.65(c)(5)			✓		✓	✓	✓	✓
	Container(s) shall be in accordance with requirements set forth in DOT HMR at 49 *CFR* §§ 171-180.		40 *CFR* § 761.65(c)(6)	✓	✓	✓	✓	✓	✓	✓	✓
Storage of PCB/radioactive waste in containers	For liquid wastes, containers must be nonleaking.	Storage of PCB/radioactive waste in containers other than those meeting DOT HMR performance standards —**applicable**.	40 *CFR* § 761.65(c)(6) (i)(A)	✓	✓	✓	✓	✓	✓	✓	✓
	For nonliquid wastes, containers must be designed to prevent buildup of liquids if such containers are stored in an area meeting the containment requirements of 40 *CFR* § 761.65(b)(1)(ii)~~.~~		40 *CFR* § 761.65(c)(6) (i)(B)	✓	✓	✓	✓	✓	✓	✓	✓
	For both liquid and nonliquid wastes, containers must meet all substantive requirements pertaining to nuclear criticality safety. Acceptable container materials include polyethylene and stainless steel provided that the container material is chemically compatible with the waste being stored. Other containers may be used if the use of such containers is protective of health		40 *CFR* § 761.65(c)(6) (i)(C)	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	and the environment as well as public health and safety.										
Temporary storage of bulk PCB remediation waste or PCB bulk product waste in a waste pile	May be stored at the clean-up site or site of generation subject to the following conditions: • waste must be placed in a pile designed and operated to control dispersal by wind, where necessary, by means other than wetting; • waste must not generate leachate through decomposition or other reactions.	Storage of PCB remediation waste or PCB bulk product waste in a waste pile—**applicable**.	40 *CFR* § 761.65(c)(9)(i) 40 *CFR* § 761.65(c)(9)(ii)					✓	✓	✓	
	Storage site must have a liner designed, constructed, and installed to prevent any migration of wastes off or through liner into adjacent subsurface soil, groundwater or surface water at any time during the active life (including closure period) of the storage site.		40 *CFR* § 761.65(c)(9)(iii)(A)					✓	✓	✓	
	Liner must be: • constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure because of pressure gradients, physical contact with waste or leachate to which they are exposed, climatic conditions, the stress of installation, and the stress of daily operation;		40 *CFR* § 761.65(c)(9)(iii)(A)(*1*)					✓	✓	✓	
	• placed on foundation or base capable of providing support to liner and resistance to pressure gradients above and below the liner to present failure because of settlement compression or uplift;		40 *CFR* § 761.65(c)(9)(iii)(A)(*2*)					✓	✓	✓	
	• installed to cover all surrounding earth likely to be in contact with waste.		40 *CFR* § 761.65(c)(9)(iii)(A)(*3*)					✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	Has a cover that meets the above requirements and installed to cover all of the stored waste likely to be contacted by precipitation, and is secured so as not to be functionally disabled by winds expected under normal weather conditions at the storage site; and	Storage of PCB remediation waste or PCB bulk product waste in a waste pile—**applicable**.	40 *CFR* § 761.65(c)(9) (iii)(B)					✓	✓	✓	
	Has a run-on control system designed, constructed, operated and maintained such that: • It prevents flow on the stored waste during peak discharge from at least a 25-year storm; • It collects and controls at least the water volume resulting from a 24-hour, 25-year storm. Collection and holding facilities (e.g., tanks or basins) must be emptied or otherwise managed expeditiously after storms to maintain design capacity of the system.		40 *CFR* § 761.65(c)(9) (iii)(C) 40 *CFR* § 761.65(c)(9) (iii)(C)(*1*) 40 *CFR* § 761.65(c)(9) (iii)(C)(*2*)					✓	✓	✓	
	Requirements of 40 *CFR* § 761.65(c)(9) may be modified under the risk-based disposal option of 40 *CFR* § 761.61(c).		40 *CFR* § 761.65(c)(9) (iv)					✓	✓	✓	
Temporary storage of bulk PCB remediation waste in a waste pile	Waste must be placed in a pile that • is designed and operated to control dispersal by wind, where necessary, by means other than wetting; • does not generate leachate through decomposition or other reactions; • is at a storage site with a liner designed, constructed, and installed to prevent any migration of wastes off or through liner into adjacent subsurface soil, groundwater, or surface water.	Storage of PCB remediation waste or PCB bulk product waste in waste pile at cleanup site or site of generation—**applicable**.	40 *CFR* § 761.65(c)(9) (i)					✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	Liner must be • constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure because of pressure gradients, physical contact with waste or leachate to which they are exposed, climatic conditions, the stress of installation, and the stress of daily operation; • placed on foundation or base capable of providing support to liner and resistance to pressure gradients above and below the liner to present failure because of settlement compression or uplift; • installed to cover all surrounding earth likely to be in contact with waste.		40 *CFR* § 761.65(c)(9)(iii)(A)(1) – (3)					✓	✓	✓	
	The storage site must have a cover that meets the above requirements and installed to cover all of the stored waste likely to be contacted by precipitation, and is secured so as not to be functionally disabled by winds expected under normal weather conditions; and		40 *CFR* § 761.65(c)(9) (iii)(B)					✓	✓	✓	
	Have a run-on control system designed, constructed, operated, and maintained such that it prevents flow on the stored waste during peak discharge from at least a 25-year storm.		40 *CFR* § 761.65(c)(9) (iii)(C)(1)					✓	✓	✓	
	It collects and controls at least the water volume resulting from a 24-hour, 25-year storm. Collection and holding facilities (e.g., tanks or basins) must be emptied or otherwise managed expeditiously after storms to maintain design capacity of the system.		40 *CFR* § 761.65(c)(9) (iii)(C)(2)					✓	✓	✓	
	Requirements of 40 *CFR* § 761.65(c)(9)		40 *CFR* §					✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	may be modified under the risk-based disposal option of 40 *CFR* § 761.61(c).		761.65(c)(9) (iv)								
Staging of LLW	Shall be for the purpose of the accumulation of such quantities of wastes necessary to facilitate transportation, treatment, and disposal.	Staging of LLW at a DOE facility—**TBC**.	DOE M 435.1-1 (IV)(N)(7)	✓	✓	✓	✓	✓	✓	✓	✓
Temporary storage of LLW	Shall not be readily capable of detonation, explosive decomposition, reaction at anticipated pressures and temperatures, or explosive reaction with water.	Temporary storage of LLW at a DOE facility—**TBC**.	DOE M 435.1-1 (IV)(N)(1)	✓	✓	✓	✓	✓	✓	✓	✓
	Shall be stored in a location and manner that protects the integrity of waste for the expected time of storage.		DOE M 435.1-1 (IV)(N)(3)	✓	✓	✓	✓	✓	✓	✓	✓
	Shall be managed to identify and segregate LLW from mixed waste.		DOE M 435.1-1 (IV)(N)(6)	✓	✓	✓	✓	✓	✓	✓	✓
Packaging of LLW for storage	Shall be packaged in a manner that provides containment and protection for the duration of the anticipated storage period and until disposal is achieved or until the waste has been removed from the container.	Storage of LLW in containers at a DOE facility—**TBC**.	DOE M 435.1-1(IV)(L)(1)(a)	✓	✓	✓	✓	✓	✓	✓	✓
	Vents or other measures shall be provided if the potential exists for pressurizing or generating flammable or explosive concentrations of gases within the waste container.		DOE M 435.1-1(IV)(L)(1) (b)	✓	✓	✓	✓	✓	✓	✓	✓
	Containers shall be marked such that their contents can be identified.		DOE M 435.1-1(IV)(L)(1)(c)	✓	✓	✓	✓	✓	✓	✓	✓
Packaging of LLW for off-site disposal	Waste shall not be packaged for disposal in a cardboard or fiberboard box.	Packaging of LLW for off-site shipment of LLW to a commercial NRC or Agreement State licensed disposal facility—**relevant**	10 *CFR* § 61.56 902 *KAR* 100:021 § 7 (1)(b)	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
		and appropriate.									
	Liquid waste shall be solidified or packaged in sufficient absorbent material to absorb twice the volume of the liquid.	Preparation of liquid LLW for off-site shipment of LLW to a commercial NRC or Agreement State licensed disposal facility—**relevant and appropriate**.	10 *CFR* § 61.56 902 *KAR* 100:021 § 7 (1)(c)	✓	✓	✓	✓	✓	✓	✓	✓
	Solid waste containing liquid shall contain as little freestanding and noncorrosive liquid as is reasonably achievable. The liquid shall not exceed one (1) percent of the volume.	Preparation of solid LLW containing liquid for off-site shipment of LLW to a commercial NRC or Agreement State licensed disposal facility—**relevant and appropriate**.	10 *CFR* § 61.56 902 *KAR* 100:021 § 7 (1)(d)	✓	✓	✓	✓	✓	✓	✓	✓
	Waste shall not be readily capable of • Detonation; • Explosive decomposition or reaction at normal pressures and temperatures; or • Explosive reaction with water.	Packaging of LLW for off-site shipment of LLW to a commercial NRC or Agreement State licensed disposal facility—**relevant and appropriate**.	10 *CFR* § 61.56 902 *KAR* 100:021 § 7 (1)(e)	✓	✓	✓	✓	✓	✓	✓	✓
	Waste shall not contain, or be capable of generating, quantities of toxic gases, vapors, or fumes harmful to a person transporting, handling, or disposing of the waste.	Packaging of LLW for off-site shipment of LLW to a commercial NRC or Agreement State licensed disposal facility—**relevant and appropriate**.	10 *CFR* § 61.56 902 *KAR* 100:021 § 7 (1)(f)	✓	✓	✓	✓	✓	✓	✓	✓
	Waste shall not be pyrophoric.	Packaging of pyrophoric LLW for off-site shipment of LLW to a commercial NRC or Agreement State licensed disposal facility—**relevant and appropriate**.	10 *CFR* § 61.56 902 *KAR* 100:021 § 7 (1)(g)	✓	✓	✓	✓	✓	✓	✓	✓
Waste treatment and disposal											
Transport or conveyance of collected RCRA	Any dedicated tank systems, conveyance systems, and ancillary equipment used to treat, store or convey wastewater to an on-	On-site wastewater treatment unit (as defined in 40 *CFR* § 260.10) subject to regulation	40 *CFR* § 264.1(g)(6) 401 *KAR*			✓	✓	✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
wastewater to a WWTU located on the facility	site KPDES-permitted wastewater treatment facility are exempt from the requirements of RCRA Subtitle C standards. *NOTE:* For purposes of this exclusion, any dedicated tank systems, conveyance systems, and ancillary equipment used to treat, store or convey CERCLA remediation wastewater to a CERCLA on-site wastewater treatment unit that meets all of the identified CWA ARARs for point source discharges from such a facility, are exempt from the requirements of RCRA Subtitle C standards.	under § 402 or § 307(b) of the CWA (i.e.,KPDES-permitted) that manages hazardous wastewaters—**applicable**.	34:010 § 1								
Treatment of hazardous waste in a miscellaneous treatment unit	Unit must be located, designed, constructed, operated and maintained, and closed in a manner that will ensure protection of human health and the environment.	Treatment of RCRA hazardous waste in miscellaneous units, unless exempt in 40 *CFR* § 264.1, (e.g., thermal desorber not meeting the definition of a hazardous waste incinerator in 40 *CFR* § 260.10)—**applicable**.	40 *CFR* § 264.601					✓	✓	✓	
	Protection of human health and the environment includes, but is not limited to: prevention of any release that may have adverse effects on human health or the environment due to migration of waste constituents in the air, considering the factors listed in 40 *CFR* § 264.601(c)(1) thru (7).		40 *CFR* § 264.601(c)					✓	✓	✓	
Release of property with residual radioactive material to an off-site commercial facility	Prior to being released, property shall be surveyed to determine whether both removable and total surface contamination (including contamination present on and under any coating) are in compliance with the levels given in Figure IV-1 of DOE O 5400.5 and the contamination has been subjected to the ALARA process.	Generation of DOE materials and equipment with surface residual radioactive contamination—**TBC**.	DOE O 5400.5 (II)(5)(c)(1) and 5400.5(IV)(4)(d)	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	Material that has been radioactively contaminated in depth, may be released if criteria and survey techniques are approved by DOE EH-1.	Generation of DOE materials and equipment that are volumetrically contaminated with radionuclides—**TBC**.	DOE O 5400.5 (II)(5)(c)(6)	✓	✓	✓	✓	✓	✓	✓	✓
Discharge of Treated Water to Surface Water											
General duty to mitigate for discharge of wastewater from groundwater treatment system	Take all reasonable steps to minimize or prevent any discharge or sludge use or disposal in violation of effluent standards which has a reasonable likelihood of adversely affecting human health or the environment.	Discharge of pollutants to surface waters—**applicable**.	401 *KAR* 5:065 § 2(1) 40 *CFR* §122.41(d)			✓		✓	✓	✓	
Operation and maintenance of treatment system	Properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used to achieve compliance with the effluent standards. Proper operation and maintenance also includes adequate laboratory controls and appropriate quality assurance procedures.	Discharge of pollutants to surface waters—**relevant and appropriate**.	401 *KAR* 5:065 § 2(1) 40 *CFR* § 122.41(e)			✓		✓	✓	✓	
Technology-based treatment requirements for wastewater discharge	To the extent that EPA promulgated effluent limitations are inapplicable, shall develop on a case-by-case Best Professional Judgment (BPJ) basis under § 402(a)(1)(B) of the CWA, technology based effluent limitations by applying the factors listed in 40 *CFR* § 125.3(d) and shall consider: • The appropriate technology for this category or class of point sources, based upon all available information; and • Any unique factors relating to the discharger.	Discharge of pollutants to surface waters from other than a POTW—**applicable**.	40 *CFR* § 125.3(c)(2)			✓		✓	✓	✓	
Water quality-based effluent limits for wastewater discharge	Must develop water quality based effluent limits that ensure that: • The level of water quality to be achieved by limits on point source(s) established	Discharge of pollutants to surface waters that causes, or has reasonable potential to cause, or contributes to an instream excursion above a	40 *CFR* § 122.44(d)(1)(vii) 401 *KAR*			✓		✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	under this paragraph is derived from, and complies with all applicable water quality standards; and • Effluent limits developed to protect narrative or numeric water quality criteria are consistent with the assumptions and any available waste load allocation for the discharge prepared by the State and approved by EPA pursuant to 40 *CFR* § 130.7.	narrative or numeric criteria within a State water quality standard established under § 303 of the CWA—**applicable**.	5:065 § 2(4)								
	Must attain or maintain a specified water quality through water quality related effluent limits established under § 302 of the CWA.	Discharge of pollutants to surface waters that causes, or has reasonable potential to cause, or contributes to an instream excursion above a narrative or numeric criteria within a State water quality standard—**applicable**.	40 *CFR* § 122.44(d)(2) 401 *KAR* 5:065 § 2(4)			✓		✓	✓	✓	
	If a discharge causes, has the reasonable potential to cause, or contribute to an in-stream excursion above the numeric ctiterion for whole effluent toxicity using the procedures in paragraph (d)(1)(ii), must develop effluent limits for whole effluent toxicity.	Discharge of wastewater that causes, has the reasonable potential to cause, or contributes to an in-stream excursion above the numeric criterion for whole effluent toxicity**—applicable**.	40 *CFR* § 122.44(d)(1) (iv) 401 *KAR* § 5:065 2(4)			✓		✓	✓	✓	
Monitoring requirements for groundwater treatment system discharges	All effluent limitations, standards and prohibitions shall be established for each outfall or discharge point, except as provided under § 122.44(k)	Discharge of pollutants to surface waters—**applicable**.	40 *CFR* § 122.45(a) 401 *KAR* § 5:065 2(5)			✓		✓	✓	✓	
	All effluent limitations, standards and prohibitions, including those necessary to achieve water quality standards, shall unless impracticable be stated as: • Maximum daily and average monthly discharge limitations for all discharges.	Continuous discharge of pollutants to surface waters—**applicable**.	40 *CFR* § 122.45(d)(1) 401 *KAR* § 5:065 2(5)			✓		✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
Mixing zone requirements for discharge of pollutants to surface water	The relevant requirements provided in 401 *KAR* 10:029 § 4 shall apply to a mixing zone for a discharge of pollutants. *NOTE*: Determination of the appropriate mixing zone will, if necessary, involve consultation with KDEP and will be documented in the CERCLA Remedial Design or other appropriate FFA CERCLA document.	Discharge of pollutants to surface waters of the Commonwealth [*Bayou Creek*]—**applicable**.	401 *KAR* 10:029 § 4			✓		✓	✓	✓	
Minimum criteria applicable to all surface waters	Surface waters shall not be aesthetically or otherwise degraded by substances that: • Settle to form objectionable deposits; • Float as debris, scum, oil, or other matter to form a nuisance; • Produce objectionable color, odor, taste, or turbidity; • Injure, are chronically or acutely toxic to or produce adverse physiological or behavioral responses in humans, animals, fish, and other aquatic life; • Produce undesirable aquatic life or result in the dominance of nuisance species; 1. Cause fish flesh tainting. 2. The concentration of phenol shall not exceed 300 mg/l as an in stream value.	Discharge of pollutants to surface waters of the Commonwealth [*Bayou Creek*]—**applicable**.	401 *KAR* 10:031 § 2(1)(a-f)			✓		✓	✓	✓	
	The water quality criteria for the protection of human health related to fish consumption in Table 1 of 401 *KAR* 10:031 § 6 are applicable to all surface water at the edge of assigned mixing zone except for those points where water is withdrawn for domestic water supply use. (a) The criteria are established to protect human health from the consumption of fish tissue and shall not be exceeded. (b) For those substances associated with a		401 *KAR* 10:031 § 2 (2)(a) and (b)			✓		✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	cancer risk, an acceptable risk level of not more than one (1) additional cancer case in a population of 1,000,000 people, (or 1 x 10^{-6}) shall be utilized to establish the allowable concentration.										
Criteria for surface water designated as *Warm Water Aquatic Life Habitat*	The following parameters and associated criteria shall apply for the protection of productive warm water aquatic communities, fowl, animal wildlife, arboreous growth, agricultural, and industrial uses: • Natural alkalinity as $CaCO3$ shall not be reduced by more than 25 percent; • pH shall not be less than 6.0 nor more than 9.0 and shall not fluctuate more than 1.0 pH units over a period of 24 hours; • Flow shall not be altered to a degree that will adversely affect the aquatic community; • Temperature shall not exceed 31.7^{o}C (89^{o}F); • Dissolved oxygen shall be maintained at a minimum concentration of 5.0 mg/l as a 24 hour average; instantaneous minimum shall not be less than 4.0 mg/l; • Total dissolved solids or specific conductance shall not be changed to the extent that the indigenous aquatic community is adversely affected; • Total suspended solids shall not be changed to the extent that the indigenous aquatic community is adversely affected; • Addition of settleable solids that may alter the stream bottom so as to adversely affect productive aquatic communities shall be prohibited;	Discharge of pollutants to surface waters of the Commonwealth designated as *Warm Water Aquatic Life Habitat*—**applicable**.	401 *KAR* 10:031 § 4(1)(a)-(i) and (k)			✓		✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	• Concentration of the un-ionized ammonia shall not be greater than 0.05 mg/l at any time instream after mixing; • Instream concentrations for total residual chlorine shall not exceed an acute criteria value of 19 µg/l or a chronic criteria value of 11 µg/l.										
Criteria for surface water designated as *Warm Water Aquatic Life Habitat*	The allowable instream concentration of toxic substances, or whole effluents containing toxic substances, which are noncumulative or nonpersistent with a half-life of less than 96 hours, shall not exceed: a. 0.1 of the 96 hour median LC_{50} of representative indigenous or indicator aquatic organisms; or b. A chronic toxicity unit of 1.00 utilizing the 25 percent inhibition concentration, or LC_{25}.	Discharge of toxic pollutants to surface waters of the Commonwealth designated as *Warm Water Aquatic Life Habitat*—**applicable**.	401 *KAR* 10:031 § 4(1)(j)(1)			✓		✓	✓	✓	
	The allowable instream concentration of toxic substances, or whole effluents containing toxic substances, which are bioaccumulative or persistent, including pesticides, if not otherwise regulated, shall not exceed: a. 0.01 of the 96 hour median LC_{50} of representative indigenous or indicator aquatic organisms; or b. A chronic toxicity unit of 1.00 utilizing the LC_{25}.		401 *KAR* 10:031 § 4(1)(j)(2)			✓		✓	✓	✓	
	In the absence of acute criteria for pollutants listed in Table 1 of 401 *KAR* 10:031 § 6, for other substances known to be toxic but not listed in this regulation, or for whole effluents that are acutely toxic, the allowable instream concentration shall not exceed the LC1 or 1/3 LC50 concentration derived from toxicity tests on		401 *KAR* 10:031 § 4(1)(j)(3)			✓		✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	representative indigenous or indicator aquatic organisms or exceed 0.3 acute toxicity units.										
	If specific factors have been determined for a toxic substance or whole effluent such as an acute to chronic ratio or water effect ratio, they may be used instead of the 0.1 and 0.01 factors upon demonstration that such factors are scientifically defensible. NOTE: Demonstration that such factors are scientifically defensible will be reflected in an appropriate FFA CERCLA document.		401 *KAR* 10:031 § 4(1)(j)(4)			✓		✓	✓	✓	
	Allowable instream concentrations for specific pollutants for the protection of warm water aquatic habitat are listed in Table 1 of 401 *KAR* 10:031 § 6 shall not be exceeded.		401 *KAR* 10:031 § 4(1)(j)(5)			✓		✓	✓	✓	
	Table 1 of 401 *KAR* 10:031 § 6(1) provides allowable instream concentrations of pollutants that may be found in surface waters or discharged into surface waters.	Discharge of pollutants to surface waters of the Commonwealth designated as *Warm Water Aquatic Life Habitat*—**applicable**.	401 *KAR* 10:031 § 6(1)			✓		✓	✓	✓	
Surface Water Standards	Provides chemical-specific numeric standards for pollutants discharged or found in surface waters.	Discharge of pollutants to surface waters—**applicable**.	401 *KAR* 10:031 § 6(1)			✓		✓	✓	✓	
	Monitoring location and frequency will be conducted in accordance with the substantive provisions of the KPDES Permit.	Discharge of pollutants to surface waters—**TBC**.	KPDES Permit KY0004049			✓		✓	✓	✓	
Discharge of radionuclides into surface water	Absorbed dose to native animal aquatic organisms must not exceed 1 rad/day.	Discharge of radioactive materials in liquid waste to surface water at a DOE facility—**TBC**.	DOE O 5400.5(II)(3) (a)(1)(1)			✓		✓	✓	✓	
	For liquid wastes containing radionuclides from DOE activities which are discharged to surface water, the best available	Discharge of radioactive materials in liquid waste to surface water at a DOE	DOE O 5400.5			✓		✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	technology (BAT) is the prescribed level of treatment if the surface waters otherwise would contain, at the point of discharge and prior to dilution, radioactive material at annual average concentrations greater than the DCG values in liquids given in Chapter III of DOE Order 5400.5. The BAT selection process shall be implemented in accordance with II(3)(a)(1)(a) and (b) of the Order 5400.5 .	facility—**TBC**.	(II)(3)(a)(1)								
	For purposes of DOE O 5400.5 (II)(3)(a)(1), above, the DCG for liquid waste streams containing more than one type of radionuclide shall be the sum of the fractional DCG values.		DOE O 5400.5 (II)(3)(a)(3)			✓		✓	✓	✓	
	Selection of the best available technology for a specific application will be made from among candidate alternative treatment technologies which are identified by an evaluation process that includes factors related to technology, economics, and public policy considerations. Factors that are to be considered in selecting BAT, at a minimum, shall include: • the age of equipment and facilities involved; • the process employed; • the engineering aspects of the application of various types of control techniques; • process changes; • the cost of achieving such effluent reduction; • non-water quality environmental impact (including energy requirements); • safety considerations; and public policy considerations.		DOE O 5400.5 (II)(3)(a)(1) (a)			✓		✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	Implementation of the BAT process for liquid radioactive wastes is not required where radionuclides are already at a low level, i.e., the annual average concentration is less than DCG level. Additional treatment will not be required for waste streams that contain radionuclide concentrations of not more than the DCG values in Chapter III of DOE Order 5400.5 at the point of discharge to a surface waterway. However, the ALARA provisions are applicable.		DOE O 5400.5 (II)(3)(a)(2)			✓		✓	✓	✓	
	To prevent the buildup of radionuclide concentrations in sediments, liquid process waste streams containing radioactive material in the form of settleable solids may be released to natural waterways if the concentration of radioactive material in the solids present in the waste stream does not exceed 5 pCi (O.2 Bq) per gram above background level, of settleable solids for alpha-emitting radionuclides or 50 pCi (2 Bq) per gram above background level, of settleable solids for beta gamma- emitting radionuclides.	Discharge of radioactive concentrations in sediments to surface water from a DOE facility—**TBC**.	DOE O 5400.5 (II)(3)(a)(4)			✓		✓	✓	✓	
	To protect native animal aquatic organisms, the absorbed dose to these organisms shall not exceed 1 rad per day from exposure to the radioactive material in liquid wastes discharged to natural waterways.		DOE O 5400.5 (II)(3)(a)(5)			✓		✓	✓	✓	
Treatment of LLW	Treatment to provide more stable waste forms and to improve the long-term performance of a LLW disposal facility shall be implemented as necessary to meet the performance objectives of the disposal facility.	Treatment of LLW for disposal at a LLW disposal facility—**TBC**.	DOE M 435.1-1(IV)(O)	✓	✓	✓	✓	✓	✓	✓	✓
Treatment of RCRA hazardous waste soil	Prior to land disposal, all “constituents subject to treatment” as defined in 40 *CFR*	Treatment of restricted hazardous waste soils—	40 *CFR* § 268.49(c)(1)	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	§ 268.49(d) must be treated as follows.	**applicable**.	401 *KAR* 37:040 § 10								
	For non-metals (except carbon disulfide, cyclohexanone, and methanol), treatment must achieve a 90 percent reduction in total constituent concentrations, except as provided in 40 *CFR* § 268.49(c)(1)(C).		40 *CFR* § 268.49(c)(1) (A) 401 *KAR* 37:040 § 10	✓	✓	✓	✓	✓	✓	✓	✓
	For metals and carbon disulfide, cyclohexanone, and methanol,), treatment must achieve a 90 percent reduction in total constituent concentrations as measured in leachate from the treated media (tested according to TCLP) <u>or</u> 90 percent reduction in total constituent concentrations (when a metal removal technology is used), except as provided in 40 *CFR* § 268.49(c)(1)(C).		40 *CFR* § 268.49(c)(1) (B) 401 *KAR* 37:040 § 10	✓	✓	✓	✓	✓	✓	✓	✓
	When treatment of any constituent subject to treatment to a 90 percent reduction standard would result in a concentration less than 10 times the Universal Treatment Standard for that constituent, treatment to achieve constituent concentrations less than 10 times the universal treatment standard is not required. [Universal Treatment Standards are identified in 40 *CFR* § 268.48 Table UTS].		40 *CFR* § 268.49(c)(1) (C) 401 *KAR* 37:040 § 10	✓	✓	✓	✓	✓	✓	✓	✓
	In addition to the treatment requirement required by paragraph (c)(1) of 40 *CFR* § 268.49, soils must be treated to eliminate these characteristics.	Treatment of soils that exhibit the hazardous characteristic of ignitability, corrosivity, or reactivity—**applicable**.	40 *CFR* § 268.49(c)(2) 401 *KAR* 37:040 § 10	✓	✓	✓	✓	✓	✓	✓	✓
	Provides methods on how to demonstrate compliance with the alternative treatment standards for contaminated soils that will be land disposed.	Treatment of restricted hazardous waste soils—**TBC**.	*Guidance on Demonstrating Compliance with the LDR*	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
			Alternative Soil Treatment Standards [EPA 530-R-02-003, July 2002]								
Disposal of prohibited RCRA hazardous waste in a land-based unit	Are not prohibited if the wastes no longer exhibit a prohibited characteristic at the point of land disposal, unless the wastes are subject to a specified method of treatment other than DEACT in 40 *CFR* § 268.40, or are D003 reactive cyanide.	Land disposal of restricted RCRA hazardous wastes that are hazardous only because they exhibit a hazardous characteristic—**applicable**.	40 *CFR* § 268.1(c)(4)(iv) 401 *KAR* 37:010 § 2	✓	✓	✓	✓	✓	✓	✓	✓
	May be land disposed if it meets the requirements in the table "Treatment Standards for Hazardous Waste" at 40 *CFR* § 268.40 before land disposal.	Land disposal, as defined in 40 *CFR* § 268.2, of prohibited RCRA waste—**applicable**.	40 *CFR* § 268.40(a) 401 *KAR* 37:040 § 2	✓	✓	✓	✓	✓	✓	✓	✓
	All underlying hazardous constituents [as defined in 40 *CFR* § 268.2(i)] must meet the Universal Treatment Standards, found in 40 *CFR* § 268.48 Table UTS prior to land disposal.	Land disposal of restricted RCRA characteristic wastes (D001-D043) that are not managed in a wastewater treatment system that is regulated under the CWA, that is CWA equivalent, or that is injected into a Class I nonhazardous injection well—**applicable**.	40 *CFR* § 268.40(e) 401 *KAR* 37:040 § 2	✓	✓	✓	✓	✓	✓	✓	✓
Disposal of RCRA hazardous waste soil in a land-based unit	Must be treated according to the alternative treatment standards of 40 *CFR* § 268.49(c) or according to the UTSs specified in 40 *CFR* § 268.48 applicable to the listed and/or characteristic waste contaminating the soil prior to land disposal.	Land disposal, as defined in 40 *CFR* § 268.2, of restricted hazardous soils—**applicable**.	40 *CFR* § 268.49(b) 401 *KAR* 37:040 § 10	✓	✓	✓	✓	✓	✓	✓	✓
Disposal of RCRA hazardous debris in a land-based unit	Must be treated prior to land disposal as provided in 40 *CFR* § 268.45(a)(1)-(5) unless EPA determines under 40 *CFR* §	Land disposal, as defined in 40 *CFR* § 268.2, of RCRA-hazardous debris—	40 *CFR* § 268.45(a) 401 *KAR*			✓		✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	261.3(f)(2) that the debris no longer contaminated with hazardous waste <u>or</u> the debris is treated to the waste-specific treatment standard provided in 40 *CFR* § 268.40 for the waste contaminating the debris.	**applicable**.	37:040 § 7								
Disposal of treated hazardous debris	Debris treated by one of the specified extraction or destruction technologies on Table 1 of 40 *CFR* § 268.45 and which no longer exhibits a characteristic is not a hazardous waste and need not be managed in RCRA Subtitle C facility. Hazardous debris contaminated with listed waste that is treated by immobilization technology must be managed in a RCRA Subtitle C facility.	Treated debris contaminated with RCRA-listed or characteristic waste—**applicable**.	40 *CFR* § 268.45(c) 401 *KAR* 37:040 § 7			✓		✓	✓	✓	
Disposal of hazardous debris treatment residues	Except as provided in 268.45(d)(2) and (d)(4), must be separated from debris by simple physical or mechanical means, and such residues are subject to the waste-specific treatment standards for the waste contaminating the debris.	Residue from treatment of hazardous debris —**applicable**.	40 *CFR* § 268.45(d)(1) 401 *KAR* 37:040 § 7			✓		✓	✓	✓	
Disposal of bulk PCB remediation waste off-site (self-implementing)	May be sent off-site for decontamination or disposal provided the waste either is dewatered on-site or transported off-site in containers meeting the requirements of DOT HMR at 49 *CFR* Parts 171-180.	Generation of bulk PCB remediation waste (as defined in 40 *CFR* § 761.3) for off-site disposal—**relevant and appropriate**.	40 *CFR* § 761.61(a)(5) (i)(B)	✓	✓	✓	✓	✓	✓	✓	✓
	Must provide written notice including the quantity to be shipped and highest concentration of PCBs [using extraction EPA Method 3500B/3540C or Method 3500B/3550B followed by chemical analysis using Method 8082 in SW-846 or methods validated under 40 *CFR* § 761.320-26 (Subpart Q)] before the first shipment of waste to each off-site facility where the waste is destined for an area not	Bulk PCB remediation waste (as defined in 40 *CFR* § 761.3) destined for an off-site facility not subject to a TSCA PCB Disposal Approval—**relevant and appropriate**.	40 *CFR* § 761.61(a)(5) (i)(B)(2)*(iv)*	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	subject to a TSCA PCB Disposal Approval.										
	Shall be disposed of in accordance with the provisions for cleanup wastes at 40 *CFR* § 761.61(a)(5)(v)(A).	Off-site disposal of dewatered bulk PCB remediation waste with a PCB concentration < 50 ppm—**relevant and appropriate**.	40 *CFR* § 761.61(a)(5) (i)(B)(2)*(ii)*	✓	✓	✓	✓	✓	✓	✓	✓
	Shall be disposed of • in a hazardous waste landfill permitted by EPA under §3004 of RCRA; • in a hazardous waste landfill permitted by a State authorized under §3006 of RCRA; or • in a PCB disposal facility approved under 40 *CFR* § 761.60.	Off-site disposal of dewatered bulk PCB remediation waste with a PCB concentration ≥ 50 ppm—**relevant and appropriate**.	40 *CFR* § 761.61(a)(5) (i)(B)(2)*(iii)*	✓	✓	✓	✓	✓	✓	✓	✓
Disposal of PCB-contaminated nonporous surfaces on-site	Shall be cleaned on-site or off-site to levels in 40 *CFR* § 761.61(a)(4)(ii) using • Decontamination procedures under 40 *CFR* § 761.79, • Technologies approved under 40 *CFR* § 761.60(e), or • Risk-based procedures/technologies under 40 *CFR* § 761.61(c).	PCB remediation waste porous surfaces as defined in 40 *CFR* § 761.3—**applicable**.	40 *CFR* § 761.61(a)(5) (ii)(A)			✓		✓	✓	✓	
Disposal of PCB-contaminated nonporous surfaces off-site	Shall be disposed of in accordance with 40 *CFR* § 761.61(a)(5)(i)(B)(3)(ii) [sic] 40 *CFR* § 761.61(a)(5)(i)(B)(2)(ii). Metal surfaces may be thermally decontaminated in accordance with 40 *CFR* § 761.79(c)(6)(i).	PCB remediation waste nonporous surfaces as defined in 40 *CFR* § 761.3 having surface concentrations < 100 µg/100 cm^2—**applicable**.	40 *CFR* § 761.61(a)(5) (ii)(B)(1)			✓		✓	✓	✓	
	Shall be disposed of in accordance with 40 *CFR* § 761.61(a)(5)(i)(B)(3)(iii) [sic] [40 *CFR* § 761.61(a)(5)(i)(B)(2)(iii)]. Metal surfaces may be thermally decontaminated in accordance with	PCB remediation waste nonporous surfaces having surface concentrations ≥ 100 µg/100 cm^2—**applicable**.	40 *CFR* § 761.61 (a)(5)(ii)(B) (2)			✓		✓	✓	✓	

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	40 *CFR* § 761.79(c)(6)(ii).										
Disposal of PCB-contaminated porous surfaces	Shall be disposed on-site or off-site as bulk PCB-remediation waste according to 40 *CFR* § 761.61(a)(5)(i) or decontaminated for use according to 40 *CFR* § 761.79(b)(4).	PCB remediation waste porous surfaces (as defined in 40 *CFR* § 761.3)—**applicable**.	40 *CFR* § 761.61(a)(5) (iii)			✓		✓	✓	✓	
Disposal of liquid PCB remediation waste (self-implementing)	Shall either • decontaminate the waste to the levels specified in 40 *CFR* § 761.79(b)(1) or (2); or	Liquid PCB remediation waste (as defined in 40 *CFR* § 761.3)—**applicable**.	40 *CFR* § 761.61(a)(5) (iv)(A)	✓	✓	✓	✓	✓	✓	✓	✓
	• dispose of the waste in accordance with the performance-based requirements of 40 *CFR* § 761.61(b) or in accordance with a risk-based approval under 40 *CFR* § 761.61(c).		40 *CFR* § 761.61(a)(5) (iv)(B)	✓	✓	✓	✓	✓	✓	✓	✓
Disposal of PCB cleanup wastes (e.g., PPE, rags, non-liquid cleaning materials) (self-implementing)	Shall be either decontaminated in accordance with 40 *CFR* § 761.79((b) or (c), or disposed of in one of the following facilities: • a facility permitted, licensed or registered by a State to manage municipal solid waste under 40 *CFR* § 258; • a facility permitted, licensed, or registered by a State to manage non-municipal non-hazardous waste subject to 40 *CFR* § 257.5 thru 257.30, as applicable; or • a hazardous waste landfill RCRA permitted by EPA under Section 3004 of RCRA, or a State authorized under Section 3006 of RCRA; or • in a PCB disposal facility approved under 40 *CFR* § 761; or	Generation of non-liquid cleaning materials at any PCB concentration resulting from the cleanup of PCB remediation waste—**applicable**.	40 *CFR* § 761.61(a)(5) (v)(A)	✓	✓	✓	✓	✓	✓	✓	✓
Reuse of PCB cleaning solvents, abrasives and	May be reused after decontamination under 40 *CFR* § 761.79.	Generation of PCB wastes from the cleanup of PCB remediation waste—	40 *CFR* § 761.61(a)(5) (v)(B)	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
equipment		**applicable**.									
Performance-based disposal of PCB remediation waste	May dispose by one of the following methods • in a high-temperature incinerator under 40 *CFR* § 761.70(b); • by an alternate disposal method under 40 *CFR* § 761.60(e); • in a chemical waste landfill under 40 *CFR* § 761.75; • in a facility under 40 *CFR* § 761.77; or	Disposal of non-liquid PCB remediation waste (as defined in 40 *CFR* § 761.3)—**applicable**.	40 *CFR* § 761.61(b)(2) 40 *CFR* § 761.61(b)(2)(i)	✓	✓	✓	✓	✓	✓	✓	✓
	• through decontamination in accordance with 40 *CFR* § 761.79.		40 *CFR* § 761.61(b)(2)(ii)	✓	✓	✓	✓	✓	✓	✓	✓
	Shall be disposed according to 40 *CFR* § 761.60(a) or (e), or decontaminate in accordance with 40 *CFR* § 761.79.	Disposal of liquid PCB remediation waste—**applicable**.	40 *CFR* § 761.61(b)(1)	✓	✓	✓	✓	✓	✓	✓	✓
Risk-based disposal of PCB remediation waste	May dispose of in a manner other than prescribed in 40 *CFR* § 761.61(a) or (b) if approved in writing from EPA and method will not pose an unreasonable risk of injury to [sic] human health or the environment. *NOTE:* EPA approval of alternative disposal method will be obtained by approval of the FFA CERCLA document.	Disposal of PCB remediation waste—**applicable**.	40 *CFR* § 761.61(c)	✓	✓	✓	✓	✓	✓	✓	✓
Disposal of PCB decontamination waste and residues	Such waste shall be disposed of at their existing PCB concentration unless otherwise specified in 40 *CFR* § 761.79(g)(1-6).	PCB decontamination waste and residues—**applicable**.	40 *CFR* § 761.79(g)	✓	✓	✓	✓	✓	✓	✓	✓
Disposal of LLW	LLW shall be certified as meeting waste acceptance requirements before it is transferred to the receiving facility.	Disposal of LLW at a DOE facility—**TBC**.	DOE M 435.1-1(IV)(J)(2)	✓	✓	✓	✓	✓	✓	✓	✓
Decontamination/Cleanup											

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
Decontamination of PCB-contaminated water	For discharge to a treatment works as defined in 40 *CFR* § 503.9 (aa), or discharge to navigable waters, meet standard of < 3 ppb PCBs; or	Water containing PCBs regulated for disposal—**applicable**.	40 *CFR* § 761.79 (b)(1)(ii)	✓	✓	✓	✓	✓	✓	✓	✓
	For unrestricted use, meet standard of 0.5 ppb PCBs.		40 *CFR* § 761.79(b)(1) (iii)	✓	✓	✓	✓	✓	✓	✓	✓
Decontamination of PCB-contaminated liquids	Meet standard of < 2 ppm PCBs.	Organic liquids and nonaqueous inorganic liquids containing PCBs—**applicable**.	40 *CFR* § 761.79(b)(2)	✓	✓	✓	✓	✓	✓	✓	✓
Decontamination of PCB containers (self-implementing option)	Must flush the internal surfaces of the container three times with a solvent containing < 50 ppm PCBs. Each rinse shall use a volume of the flushing solvent equal to approximately 10% of the PCB container capacity.	Decontaminating a PCB Container as defined in 40 *CFR* § 761.3—**applicable**.	40 *CFR* § 761.79(c)(1)	✓	✓	✓	✓	✓	✓	✓	✓
Decontamination of movable equipment contaminated by PCBs (self-implementing option)	May decontaminate by • swabbing surfaces that have contacted PCBs with a solvent; • a double wash/rinse as defined in 40 *CFR* § 761.360-378; or • another applicable decontamination procedure under 40 *CFR* § 761.79.	Decontaminating movable equipment contaminated by PCB, tools and sampling equipment—**applicable**.	40 *CFR* § 761.79(c)(2)	✓	✓	✓	✓	✓	✓	✓	✓
Decontamination of metal surfaces in contact with PCBs	For surfaces in contact with liquid or non-liquid PCBs < 500 ppm, may be decontaminated in an industrial furnace for purposes of disposal in accordance with 40 *CFR* § 761.72.	Use of thermal processes to decontaminate metal surfaces, as required by 40 *CFR* § 761.61 (a)(6) —**applicable**.	40 *CFR* § 761.79 (c)(6)(i)	✓	✓	✓	✓	✓	✓	✓	✓
	For surfaces in contact with liquid or non-liquid PCBs ≥ 500 ppm, may be smelted in an industrial furnace operating in accordance with 40 *CFR* § 761.72(b), but		40 *CFR* § 761.79 (c)(6)(ii)	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	must first be decontaminated in accordance with 40 *CFR* § 761.72(a) or to a surface concentration of < 100 µg/100 cm^2.										
Unit Closure											
Closure performance standard for RCRA container storage unit	Must close the facility (e.g., container storage unit) in a manner that: • Minimizes the need for further maintenance; • Controls minimizes or eliminates to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated run-off, or hazardous waste decomposition products to the ground or surface waters or the atmosphere; and • Complies with the closure requirements of part G, but not limited to, the requirements of 40 *CFR* § 264.178 for containers.	Storage of RCRA hazardous waste in containers —**applicable**.	40 *CFR* § 264.111 401 *KAR* 34:070 § 2	✓	✓	✓	✓	✓	✓	✓	✓
Closure of RCRA container storage unit	At closure, all hazardous waste and hazardous waste residues must be removed from the containment system. Remaining containers, liners, bases, and soils containing or contaminated with hazardous waste and hazardous waste residues must be decontaminated or removed. [Comment: At closure, as throughout the operating period, unless the owner or operator can demonstrate in accordance with 40 *CFR* § 261.3(d) of this chapter that the solid waste removed from the containment system is not a hazardous waste, the owner or operator becomes a generator of hazardous waste and must manage it in accordance with all applicable requirements of parts 262 through 266 of	Storage of RCRA hazardous waste in containers in a unit with a containment system—**applicable**.	40 *CFR* § 264.178 401 *KAR* 34:180 § 9	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	this chapter]										
Closure of staging piles of remediation waste	Must be closed by removing or decontaminating all remediation waste, contaminated containment system components, and structures and equipment contaminated with waste and leachate.	Storage of remediation waste in staging pile located in previously contaminated area—**relevant and appropriate**.	40 *CFR* § 264.554(j)(1) 401 *KAR* 34:287 § 5					✓	✓	✓	
	Must decontaminate contaminated sub-soils in a manner that will protect human and the environment.		40 *CFR* § 264.554(j)(2) 401 *KAR* 34:287 § 5					✓	✓	✓	
	Must be closed according to substantive requirements in 40 *CFR* § 264.258(a) and 264.111.	Storage of remediation waste in staging pile located in uncontaminated area—**relevant and appropriate**.	40 *CFR* § 264.554(k) 401 *KAR* 34:287 § 5					✓	✓	✓	
Closing a hazardous waste incinerator	At closure must remove all hazardous waste and hazardous waste residues (including, but not limited to, ash, scrubber waters, and scrubber sludges) from the incinerator site.	Closing a thermal desorber that meets the definition of a hazardous waste incinerator—**applicable**.	40 *CFR* § 264.351 401 *KAR* 34:240 § 8					✓	✓	✓	
Clean closure of TSCA storage facility	A TSCA/RCRA storage facility closed under RCRA is exempt from the TSCA closure requirements of 40 *CFR* § 761.65(e).	Closure of TSCA/RCRA storage facility—**relevant and appropriate**.	40 *CFR* § 761.65(e)(3)	✓	✓	✓	✓	✓	✓	✓	✓
		Waste Transportation									
Transportation of samples (i.e. contaminated soils and wastewaters)	Are not subject to any requirements of 40 *CFR* Parts 261 through 268 or 270 when: • The sample is being transported to a laboratory for the purpose of testing; or • The sample is being transported back to the sample collector after testing.	Samples of solid waste <u>or</u> a sample of water, soil for purpose of conducting testing to determine its characteristics or composition—**applicable**.	40 *CFR* § 261.4(d)(1)(i) and (ii) 401 *KAR* 31:010 § 4	✓	✓	✓	✓	✓	✓	✓	✓
	In order to qualify for the exemption in paragraphs (d)(1)(i) and (ii), a sample collector shipping samples to a laboratory		40 *CFR* § 261.4(d)(2)(i) 401 *KAR*	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	must: • Comply with U.S. DOT, U.S. Postal Service, or any other applicable shipping requirements. • Assure that the information provided in (1) thru (5) of this section accompanies the sample. • Package the sample so that it does not leak, spill, or vaporize from its packaging.		31:010 § 4 40 *CFR* § 261.4(d)(2)(i) (A) 401 *KAR* 31:010 § 4 40 *CFR* § 261.4(d)(2)(i) (B) 401 *KAR* 31:010 § 4								
Transportation of RCRA hazardous waste on-site	The generator manifesting requirements of 40 *CFR* § 262.20–262.32(b) do not apply. Generator or transporter must comply with the requirements set forth in 40 *CFR* § 263.30 and 263.31 in the event of a discharge of hazardous waste on a private or public right-of-way.	Transportation of hazardous wastes on a public or private right-of-way within or along the border of contiguous property under the control of the same person, even if such contiguous property is divided by a public or private right-of-way—**applicable**.	40 *CFR* § 262.20(f) 401 *KAR* 32:020 § 1	✓	✓	✓	✓	✓	✓	✓	✓
Transportation of RCRA hazardous waste off-site	Must comply with the generator requirements of 40 *CFR* § 262.20–23 for manifesting, Sect. 262.30 for packaging, Sect. 262.31 for labeling, Sect. 262.32 for marking, Sect. 262.33 for placarding, Sect. 262.40, 262.41(a) for record keeping requirements, and Sect. 262.12 to obtain EPA ID number.	Preparation and initiation of shipment of hazardous waste off-site—**applicable**.	40 *CFR* § 262.10(h) 401 *KAR* 32:010 § 1	✓	✓	✓	✓	✓	✓	✓	✓
Transportation of PCB wastes off-site	Must comply with the manifesting provisions at 40 *CFR* § 761.207 through 218.	Relinquishment of control over PCB wastes by transporting, or offering for transport—**applicable**.	40 *CFR* § 761.207(a)	✓	✓	✓	✓	✓	✓	✓	✓
Determination of radionuclide concentration	The concentration of a radionuclide may be determined by an indirect method, such as use of a scaling factor which relates the inferred concentration of one (1) radionuclide	Preparation for off-site shipment of LLW to a commercial NRC or Agreement State licensed	10 *CFR* § 61.55 (a)(8) 902 *KAR*	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	to another that is measured or radionuclide material accountability if there is reasonable assurance that an indirect method may be correlated with an actual measurement. The concentration of a radionuclide may be averaged over the volume or weight of the waste if the units are expressed as nanocuries per gram.	disposal facility—**relevant and appropriate**.	100:021 § 6(8)(a) and (b)								
Labeling of LLW packages	Each package of waste shall be clearly labeled to identify if it is Class A, Class B, or Class C waste, in accordance with 10 *CFR* § 61.55 or Agreement State waste classification requirements.	Preparation for off-site shipment of LLW to a commercial NRC or Agreement State licensed disposal facility—**relevant and appropriate**.	10 *CFR* § 61.57 902 *KAR* 100:021 § 8	✓	✓	✓	✓	✓	✓	✓	✓
Transportation of radioactive waste	Shall be packaged and transported in accordance with DOE Order 460.1B and DOE Order 460.2.	Preparation of shipments of radioactive waste—**TBC**.	DOE M 435.1-(I)(1)(E)(11)	✓	✓	✓	✓	✓	✓	✓	✓
Transportation of LLW	To the extent practicable, the volume of the waste and the number of the shipments shall be minimized.	Preparation of shipments of LLW—**TBC**.	DOE M 435.1-1(IV)(L)(2)	✓	✓	✓	✓	✓	✓	✓	✓
Transportation of hazardous materials	Shall be subject to and must comply with all applicable provisions of the HMR at 49 *CFR* §§ 171–180 related to marking, labeling, placarding, packaging, emergency response, etc.	Any person who, under contract with a department or agency of the federal government, transports "in commerce," or causes to be transported or shipped, a hazardous material—**applicable**.	49 *CFR* § 171.1(c)	✓	✓	✓	✓	✓	✓	✓	✓
Transportation of hazardous materials on-site	Shall comply with 49 *CFR* Parts 171-174, 177, and 178 or the site- or facility-specific Operations of Field Office approved Transportation Safety Document that describes the methodology and compliance process to meet equivalent safety for any deviation from the HMR [i.e., *Transportation Safety Document for On-*	Any person who, under contract with the DOE, transports a hazardous material on the DOE facility—**TBC**.	DOE O 460.1B(4)(b)	✓	✓	✓	✓	✓	✓	✓	✓

Table F.2. Action-Specific ARARs and TBC Guidance for BGOU FS (Continued)

Action	Requirement	Prerequisite	Citation	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
	Site Transport within the Paducah Gaseous Diffusion Plant, PRS-WSD-0661, (PRS 2007b)].										
Transportation of hazardous materials off-site	Off-site hazardous materials packaging and transfers shall comply with 49 *CFR* Parts 171-174, 177, and 178 and applicable tribal, State, and local regulations not otherwise preempted by DOT and special requirements for Radioactive Material Packaging.	Preparation of off-site transfers of LLW—**TBC**.	DOE O 460.1B(4)(a)	✓	✓	✓	✓	✓	✓	✓	✓

ALARA = as low as reasonably achievable
ARAR = applicable or relevant and appropriate requirement
BAT = best available technology
BMP = Best Management Practices
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR = *Code of Federal Regulations*
CWA = Clean Water Act
DCG = Derived Concentration Guide
DOE = U.S. Department of Energy
DOE M = DOE Manual
DOE O = DOE Order
DOT = U.S. Department of Transportation
EDE = effective dose equivalent
E.O. = Executive Order
EPA = U.S. Environmental Protection Agency
FFA = federal facility agreement
HAP = hazardous air pollutant
HMR = Hazardous Material Regulations
KAR = Kentucky Administrative Regulations
KPDES = Kentucky Pollutant Discharge Elimination System
LDR = land disposal restrictions
LLW = low-level (radioactive) waste
mrem = millirem
NAAQS = National Ambient Air Quality Standards
NESHAP = National Emissions Standards for Hazardous Air Pollutant
NRC = Nuclear Regulatory Commission
NSPR = New Source Performance Standards
NSR = new source review
NWP = Nationwide Permits
PCB = polychlorinated biphenyl
PGDP = Paducah Gaseous Diffusion Plant
PPE = personal protective equipment
RCRA = Resource Conservation and Recovery Act
SWMU = solid waste management unit
TBC = to be considered
TCLP = Toxicity Characteristic Leaching Procedure
TOC = total organic compound
TSCA = Toxic Substances Control Act
UTS = Universal Treatment Standards
VOC = Volatile organic compound
VOHAP = volatile organic hazardous air pollutant
WAC = waste acceptance criteria
WWTU = wastewater treatment unit

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX G

GROUPING BGOU SWMUs TO ESTABLISH

WASTE MANAGEMENT AREAS

THIS PAGE INTENTIONALLY LEFT BLANK

CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

G.1. BACKGROUND

The Burial Grounds Operable Unit (BGOU) remedial investigation (RI) assessed contamination associated with eight solid waste management units (SWMUs) that include the Paducah Gaseous Diffusion Plant's (PGDP's) landfills and burial grounds. Seven SWMUs (2, 3, 4, 5, 6, 7, and 30) are located within the main PGDP secure area and one SWMU (145) is located within a controlled access area to the north of the main PGDP area. An investigation for SWMU 13 (C-746-P and C-746-P1 scrap yards) is planned and the findings will be documented separately. SWMUs 9 and 10 are documented in the Site Management Plan as sites requiring no further action.

The following describes the potential source units that were addressed by the BGOU RI.

- SWMU 2 — C-749 Uranium Burial Ground
- SWMU 3 — C-404 Low-Level Radioactive Waste Burial Ground
- SWMU 4 — C-747 Contaminated Burial Yard and C-748-B Burial Area
- SWMU 5 — C-746-F Burial Yard
- SWMU 6 — C-747-B Burial Ground
- SWMUs 7 and 30 — C-747-A Burial Ground and Burn Area (which includes an area beneath SWMU 12)
- SWMU 145 — Area P (residential/inert borrow area) and old North-South Diversion Ditch disposal trench (the area for SWMU 145 includes that beneath SWMUs 9 and 10)

Field characterization activities were conducted during the winter and spring of 2007, as detailed in the *Work Plan for the Burial Grounds Operable Unit Remedial Investigation/Feasibility Study at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2179&D2/R1 (DOE 2006). This work principally involved the collection and analysis of subsurface soil and groundwater samples from the areas of the SWMUs, including sampling from angle borings beneath the burial cells.

The *Remedial Investigation Report for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0030&D2/R1, (DOE 2010) that presents and summarizes the findings from the BGOU RI has been submitted to U.S. Environmental Protection Agency (EPA) and the Commonwealth of Kentucky.

This feasibility study (FS) evaluates remedial alternatives for each SWMU to address disposed wastes, contaminated soil commingled with disposed wastes, and secondary sources in soil originating from the disposed waste that poses a threat to groundwater [e.g., dense nonaqueous-phase liquid (DNAPL)] and has the potential to result in an unacceptable cancer risk or noncancer hazard to off-site residential groundwater users.

G.2. COMBINED RESPONSE ACTIONS

The BGOU SWMUs could be grouped into waste management areas (WMA) for application of combined response actions during remediation. This approach could be more effective, accomplished more quickly, and incur less cost than addressing each SWMU individually. Along with the creation of WMAs is the establishment of revised administrative boundaries for the WMAs based on the SWMUs that are grouped together.

Comprehensive Environmental Response, Composition, and Liability Act (CERCLA) allows EPA to treat noncontiguous facilities as one site for the purpose of taking response actions when the facilities are related on the basis of geography, or on the basis of the threat or potential threat to the public health or welfare or the environment. A combined response action may combine separate sites into one large study area for development of a joint RI/FS and remediation. Combined response actions may be more cost effective and expeditious to undertake, since one set of resources is used to carry out two or more related (but distinct) cleanups. In addition, the permit waiver in CERCLA section 121(e) (1) applies to response activities conducted “on-site,” including all portions of an aggregated site; therefore, the management of wastes between aggregated noncontiguous sites may be conducted without a permit (EPA 1992).

EPA may consider adopting a combined response action approach based on geography. For example, noncontiguous sites may represent sources of contamination to a common groundwater aquifer. The decision to combine the RI/FS and remedial action for these facilities may be based on their contribution to a commingled contaminant plume.

There are several potential benefits associated with a combined response approach.

1. It may be more cost effective to apply treatment at a central location rather than at numerous individual sites.

2. A combined response action approach may be highly favored by the state and public in cases where sites are near residential areas and where wastes will be transported to a different CERCLA site for treatment and disposal.

3. The treatment zone used for monitoring sites can be established at the most downgradient edge of the combined SWMUs allowing reduced monitoring costs and consideration of distance to this point when deriving remedial goals consistent with the remedial action objectives.

4. A more effective groundwater monitoring program can be established by installing fewer and more strategically located monitoring wells to monitor the effectiveness of remedial action for the group of SWMUs, and to observe changes in groundwater conditions over time.

5. Applying this type of approach during cleanup allows wastes from several sites to be managed in a coordinated method at one site and to be considered an on-site action falling within the permit waiver criteria of CERCLA section 121(e)(1). For example, if noncontiguous sites A, B, and C are aggregated, then an on-site treatment facility built on site A can accept and treat hazardous wastes from sites B and C without obtaining a Resource Conservation and Recovery Act (RCRA) permit for the treatment unit (EPA 1992).

In addition, it is desirable for remedial action to consider sustainable concepts throughout the remediation process while providing long-term protection of human health and the environment and achieving public and regulatory acceptance. The metrics for a sustainable remedy include elements such as water use, worker safety, community impact, and the net environmental benefit. A combined response action is more likely to meet goals for a sustainable remedy than approaching each SWMU individually (Remediation Journal 2009).

In certain situations it may be appropriate to address the contamination as one WMA for purposes of the groundwater protection. For example, this may be protective of public health and the environment at certain sites where there are multiple sources from closely spaced WMAs. In such cases, the most feasible and effective remediation strategy may be to address the problem as a whole, rather than source-by-source and to draw the treatment zone to encompass the sources of release. In determining where to draw the treatment zone in such situations, it is necessary to consider factors such as the proximity of the sources, the technical practicability of remediation at that specific site, the vulnerability of the groundwater and its possible uses, and exposure and likelihood of exposure.

It is an National Oil and Hazardous Substances Pollution Contingency Plan (NCP) expectation to return groundwater back to its beneficial use throughout the plume or at the edge of the WMA, depending on whether the source is removed. For the "excavation alternative," the treatment zone is directly beneath the unit since no visible waste is being left in place. The goal of excavation at the BGOU would be to remove the source and achieve target contaminant of concern (COC) concentrations in the remaining soil (remediation goals) that are protective of the groundwater at the edge of the unit. For alternatives where waste will remain in place, the treatment zone will be at the edge of the WMA. If multiple SWMUs are to be covered, leaving waste in place, and these SWMUs are located in proximity to one another, then the NCP preamble guidance allows for grouping those areas together for the purpose of defining the "waste management area." In those cases, target soil cleanup levels (i.e., residual COC concentrations that can remain in place and still be protective of groundwater) can be back-calculated from the treatment zone, which would be the WMA boundary.

In summary, CERCLA recognizes the potential utility of establishing a treatment zone to encompass multiple distinct sources of release that are in proximity and source a common plume. This approach eliminates redundancy that would occur if each SWMU were to be remediated and monitored individually.

G.3. GROUPINGS TO FORM WASTE MANAGEMENT AREAS

Potential WMAs for the BGOU are described below and are presented graphically in Figure G.1. The advantages and disadvantages of forming these WMAs also are discussed.

- WMA A—SWMUs 2, 3 and 4

An EE/CA recommending remedial action of excavation and disposal for SWMU 4 is currently under review by the regulators. If the excavation is performed, it is likely that there would be some form of DNAPL treatment required at SWMU 4 following excavation and removal of the primary trichloroethene (TCE) source.

The data for SWMU 2 indicate that a RCRA cap and hydraulic isolation barrier to prevent lateral migration will contain the contamination at SWMU 2, prevent direct contact with buried waste and contamination, and protect groundwater. The RI Report suggests that there may be a DNAPL source present at SWMU 2 that requires action but, based on the data, a RCRA cap and vertical barrier will contain the contamination and be protective of groundwater. SWMU 3 is a closed RCRA unit and is a

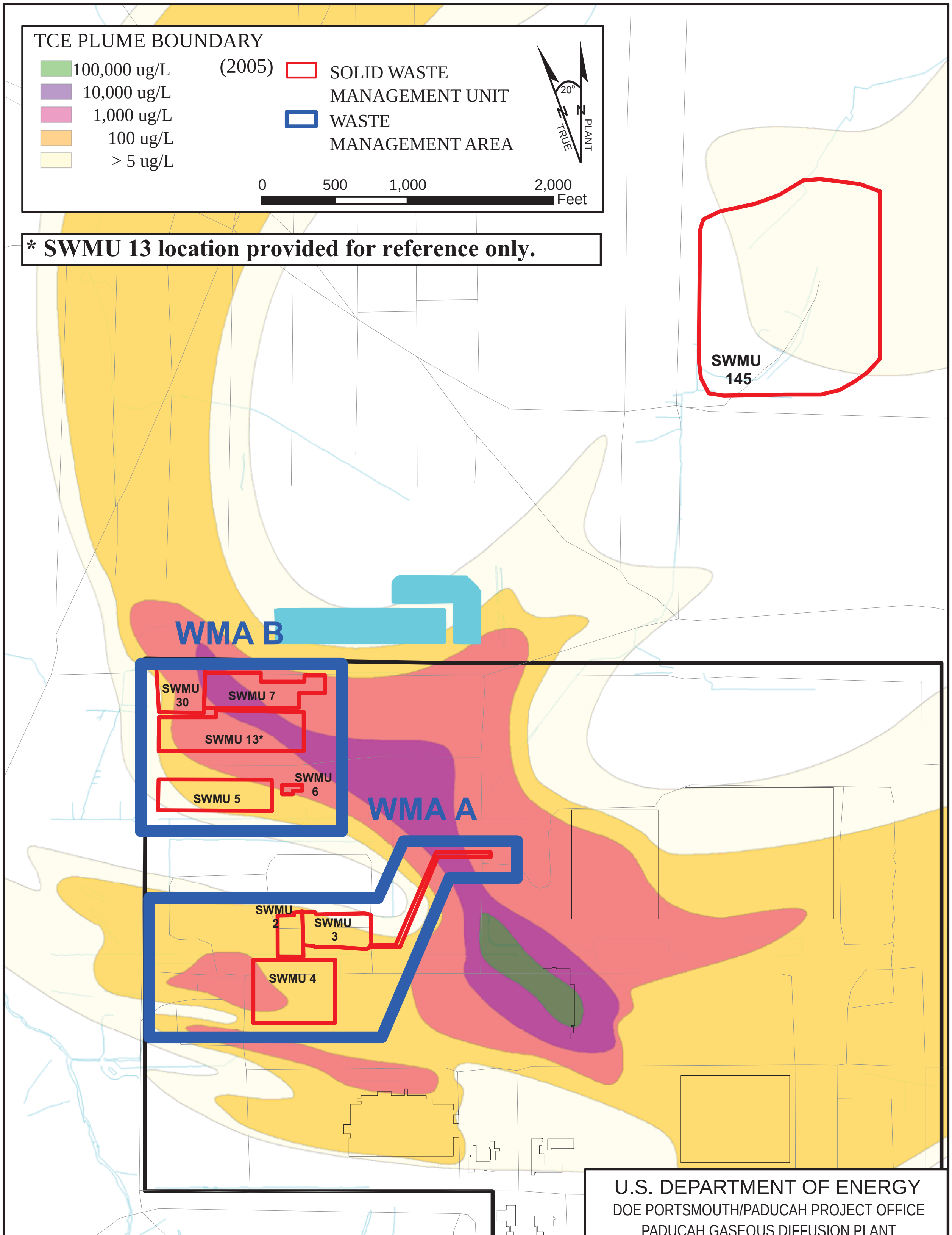


Figure G.1. Grouping WMAs for BGOU FS

Figure No. bgou\FS_Alternative Options R6logo.mxd
DATE 03-12-10

candidate for no action, which would include continued management and monitoring in accordance with the RCRA post-closure permit for the unit, but under the jurisdiction of the CERCLA program.

- WMA B—SWMUs 5, 6, 7, and 30

SWMUs 5, 6, 7, and 30 are located in proximity to one another. Contamination at these units is either insignificant (SWMU 6), or limited primarily to the surface and shallow subsurface soils (SWMUs 5, 7 and 30). Probable remedial actions for WMA B would consist of monitoring for SWMU 6 and installation of a soil cover at SWMUs 5, 7, 30.

There is some uncertainty as to whether TCE is present beneath SWMU 7 as DNAPL; however, data collected in support of remedial design should determine if it is present and, if so, the extent of DNAPL contamination. Identification of a secondary DNAPL source at SWMU 7 would result in the implementation of a remedial alternative to address the DNAPL contamination prior to installation of a soil cover.

An effective groundwater monitoring network could be established for the four SWMUs that would comprise WMA B. The network would be comprised of fewer wells than if each SWMU were addressed individually, but it would be equally as effective.

- SWMU 145

Portions of SWMU 145 lie beneath SWMUs 9 and 10, which have both been closed under RCRA Subtitle D. It is outside the secure plant area of PGDP and it is relatively far away from the other SWMUs that comprise the BGOU. There is little advantage to combining SWMU 145 with any other BGOU SWMUs for remediation.

G.4. WASTE MANAGEMENT AREA EVALUATION

The creation of WMAs results in a number of advantages that can be realized throughout the lifecycle of a remedial action including the phases of design, mobilization, implementation, and postclosure monitoring and stewardship. The advantages and disadvantages are both presented in Table G.1.

The primary benefits of grouping SWMUs into WMAs for remediation are as follows:

- Reduced effort in preparing and reviewing planning documents and expedited schedule.
- Reduced effort in remedial design, development of specifications, procurement, and corresponding reviews. Expedited schedule for these activities.
- A single mobilization of personnel and equipment.
- Efficiency gains during project implementation.
- More cost-effective postclosure monitoring and long-term stewardship.

A treatment zone would be established at the downgradient edge of the WMA since wastes will be left in place rather than having a treatment zone for each individual SWMU. This WMA treatment zone will provide some limited opportunity for natural attenuation processes to supplement the containment provided during remediation to protect groundwater. Based on the geographical orientation of the SWMUs to the existing contaminant plumes and prevailing groundwater flow directions, the supplemental benefits of attenuation processes in meeting groundwater-protection goals at the WMA treatment zone is minimal.

The existing SWMU boundaries for SWMUs 2 and 3 coincide with the new boundary that would be established for WMA A; therefore the RGs established for SWMUs 2 and 3 would not change if a WMA were established. There is additional opportunity for natural attenuation processes to supplement remedial actions at SWMU 4, but the nature and extent of contamination at SWMU 4 are such that waste likely will not be left in place, negating the supplemental remediation benefits of natural attenuation processes.

Excavation and disposal of SWMU 4, if selected, would present a unique opportunity to combine both SWMUs 2 and 3 into a single unit for *in situ* containment and long-term monitoring. This technology, described in the main text of the FS as Alternative 9, provides an opportunity for full containment and management of the wastes contained in these units. A conceptual drawing showing how this alternative could be applied to both units is presented in Figure G.2.

Employing this approach allows any potential pyrophoric uranium present in SWMU 2 to remain in place without being disturbed, avoiding the potential hazards to workers and community that may arise from excavation. The immobility of uranium coupled with the application of technology that provides for full *in situ* containment of the waste represents an attractive option for these sites. In addition, long-term groundwater monitoring, inspection and maintenance, land use controls, and, if required, leachate collection and treatment all will be in place to confirm the effectiveness of the remedial action and to protect future site workers and off-site residents.

For SWMUs 7 and 30, the existing boundaries coincide with the new boundary that would be established for WMA B; therefore, the RGs established for SWMUs 7 and 30 would not change if a WMA were established. The proximity of SWMUs 5 and 6 to the downgradient treatment zone for WMA B is such that there could be some benefit from the supplemental remediation provided by natural attenuation processes; however, SWMUs 5 and 6 are minimally contaminated and are not contributing to groundwater contamination so the additional remediation benefits derived from natural attenuation processes are minimal.

The cost and schedule benefits of developing and employing WMAs within the BGOU are summarized in Table G.2. Costs for implementing *in situ* containment for SWMUs 2 and 3 as a single unit are presented in Attachment G.1.

Table G.1. Advantages and Disadvantages of WMAs

	WMA A	WMA A	WMA B	WMA B
Activity	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**
Data collection to support detailed technology design, sizing, and optimization	One integrated data collection activity. Save time and cost.	None	Same as WMA A	None
Remedial Design	Integrated engineering design effort. Increased efficiency saving both time and cost.	None	Same as WMA A	None
	One set of documents, plans and specifications. Ease of review and expedited schedule.	None	Same as WMA A	None
Procurement	Reduced quantities and redundancy of vendors, equipment, materials, and supplies. Reduced deliveries onsite.	None	Same as WMA A	None
	Expedite schedule by performing one round of procurement for the WMA rather than multiple rounds, one for each SWMU.	None	Same as WMA A	None
Mobilization	Single mobilization. Single set up of utilities and infrastructure, administrative and technical support facilities, construction of support unit operations (e.g., WWTP and materials handling facilities), and equipment mobilization.	None	Same as WMA A	None
	Continuity in trained field, radcon, ESH, shipping, and quality personnel ensuring consistency in project performance. Also reduced training cost and schedule.	None	Same as WMA A	None

Table G.1. Advantages and Disadvantages of WMAs (Continued)

	WMA A	WMA A	WMA B	WMA B
Activity	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**
Implementation	Integrated remedial action maximizing efficiency of equipment, personnel, and support infrastructure.	None	Same as WMA A	None
	As appropriate, a single set of unit operations for processing, treating, and managing waste and residuals prior to disposal could be established and designed.	None	N/A	
	Avoidance of SWMU 3 and its existing RCRA cover could be more easily accomplished if SWMUs 2 and 4 were addressed as part of a combined response action within WMA A. SWMU 3 could be physically tied to SWMU 2 under an integrated RCRA cap for the two units. They could also be isolated from SWMU 4 so as not to compromise the integrity of its cover and containment.	None	N/A	
	A more coordinated and aggressive application of remedial technologies under a combined response action to expedite remediation of waste, contaminated soil, and produced water compared to addressing each SWMU individually.	None	N/A	
	N/A			Covering SWMUs 5, 7, and 30 as a single WMA B will impact, and may preclude, the option to recover nickel contained in SWMU 5.

Table G.1. Advantages and Disadvantages of WMAs (Continued)

	WMA A	WMA A	WMA B	WMA B
Activity	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**
Post Closure Monitoring and Stewardship	SWMUs within WMA A are co-located within the Southwest TCE plume. Establishment of a common treatment zone for SWMUs in a WMA that source a common plume may simplify long-term monitoring.		SWMUs within WMA B are co-located within the Northwest TCE plume. Establishment of a common treatment zone for SWMUs in a WMA that source a common plume may simplify long-term monitoring. SWMU 6 is likely a no further action site and SWMUs 5, 7, and 30 are likely to be covered.	None
	Reduced number of monitoring wells in an effective network compared to number of wells required to monitor each SWMU individually. Lower costs for establishing monitoring well network and reduced long-term monitoring, sampling, analytical, and reporting costs.	None	Same as WMA A	None
	N/A		Opportunity to develop a revised treatment zone based on creating a WMA boundary around the perimeter of the combined group of SWMUs. Provides a greater opportunity for natural attenuation processes to positively impact compliance with groundwater quality criteria.	None
	More effective mechanisms can be developed and emplaced for long-term stewardship and effective land use controls, as necessary.		Same as WMA A	None

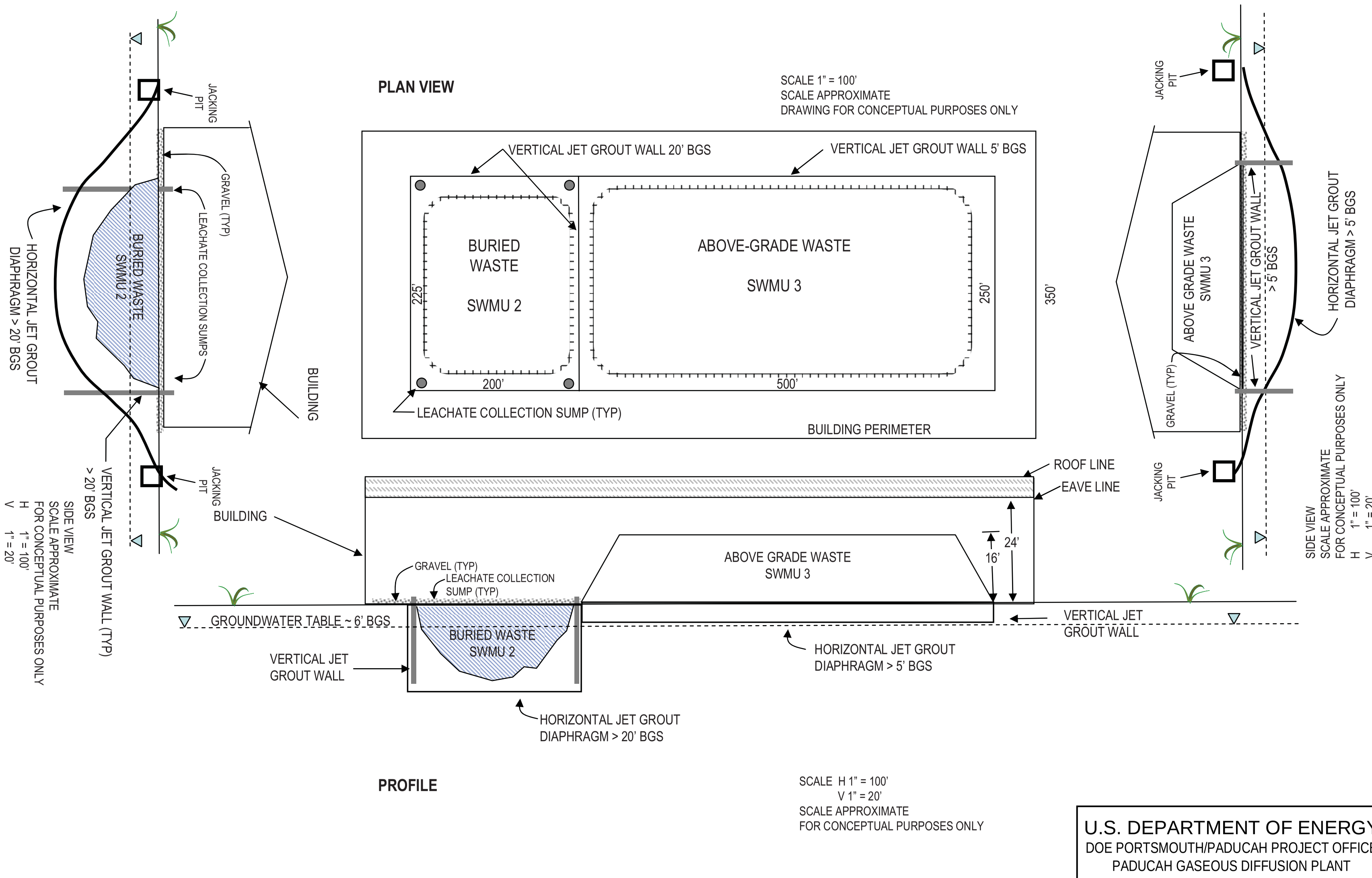


Figure G.2. ***In situ*** **Containment SWMUs 2 and 3 Combined**

Table G.2. Combined SWMUs Comparison Summary

COST ESTIMATE
WMA A SWMU 2,3, and 4

Task Description	SWMU 2 Alternative 7 Excavate & Disposal w/ In Situ DNAPL Source Treatment & LTM	SWMU 3 Alternative 2 Limited Action	SWMU 4 Alternative 7 Excavate & Disposal w/ In Situ DNAPL Source Treatment & LTM	Combined Total	Combined Estimated Efficiency Savings	Combined Total with Efficiency Savings Applied	Combined Percent Reduction
Cost Estimate Summary							
Capital Cost							
1.0 Project Plans	$2,220,000	$0	$3,788,000	$6,008,000	50%	$3,004,000	
2.0 Engineering Design	$2,140,000	$0	$4,608,000	$6,748,000	50%	$3,374,000	
3.0 Work Package Prep./Readiness Review	$1,050,000	$0	$2,100,000	$3,150,000	50%	$1,575,000	
4.0 Training	$126,000	$0	$230,000	$356,000	50%	$178,000	
5.0 Mobilization	$785,000	$0	$1,689,000	$2,474,000	50%	$1,237,000	
6.0 Site Preparation / Construct Laydown & Staging Areas	$1,411,000	$0	$3,150,000	$4,561,000	25%	$3,421,000	
7.0 Excavation	$7,181,000	$0	$31,025,000	$38,206,000	10%	$34,385,000	
8.0 Waste Treatment, Transportation & Disposal	$20,633,000	$0	$96,968,000	$117,601,000	10%	$105,841,000	
9.0 Backfill and Equipment Decontamination.	$1,387,000	$0	$4,406,000	$5,793,000	25%	$4,345,000	
10.0 ERH System Installation and Operation	$6,346,000	$0	$74,429,000	$80,775,000	25%	$60,581,000	
11.0 Well Installation, Baseline Sampling	$0	$0	$0	$0	25%	$0	
12.0 Post Operation Sampling	$0	$0	$0	$0	25%	$0	
13.0 Site Restoration	$52,000	$0	$81,000	$133,000	50%	$67,000	
14.0 Remedial Action Completion Report	$225,000	$0	$275,000	$500,000	30%	$350,000	
Project Management	$2,177,000	$0	$4,455,000	$6,632,000	25%	$4,974,000	
CAPITAL TOTAL	**$45,733,000**	**$0**	**$227,204,000**	**$272,937,000**		**$223,332,000**	18%

Table G.2. Combined SWMUs Comparison Summary (Continued)

COST ESTIMATE
WMA A SWMU 2,3, and 4 (Continued)

Task Description	SWMU 2 Alternative 7 Excavate & Disposal w/ In Situ DNAPL Source Treatment & LTM	SWMU 3 Alternative 2 Limited Action	SWMU 4 Alternative 7 Excavate & Disposal w/ In Situ DNAPL Source Treatment & LTM	Combined Total	Combined Estimated Efficiency Savings	Combined Total with Efficiency Savings Applied	Combined Percent Reduction
Cost Estimate Summary							
Annual Cost (Present Worth)							
Annual Post Closre Care (Years 1-30)	$0	$1,129,000	$0	$1,129,000	25%	$847,000	
Semi-Annual Groundwater LTM (Years 1-30)	$0	$707,000	$0	$707,000	25%	$530,000	
Quarterly Groundwater LTM (Years 1 - 5)	$369,000	$0	$369,000	$738,000	25%	$554,000	
Semi Annual Groundwater LTM (Years 6 - 10)	$132,000	$0	$132,000	$264,000	25%	$198,000	
Annual Groundwater LTM (Years 11 - 30)	$124,000	$0	$124,000	$248,000	25%	$186,000	
Five Year Review Yr 5	$36,000	$36,000	$36,000	$108,000	25%	$81,000	
Five Year Review Yr 10	$25,000	$25,000	$25,000	$75,000	25%	$56,000	
Five Year Review Yr 15	$18,000	$18,000	$18,000	$54,000	25%	$41,000	
Five Year Review Yr 20	$13,000	$13,000	$13,000	$39,000	25%	$29,000	
Five Year Review Yr 25	$9,000	$9,000	$9,000	$27,000	25%	$20,000	
Five Year Review Yr 30	$7,000	$7,000	$7,000	$21,000	25%	$16,000	
ANNUAL TOTAL	**$733,000**	**$1,944,000**	**$733,000**	**$3,410,000**		**$2,558,000**	25%
TOTALS	**$46,466,000**	**$1,944,000**	**$227,937,000**	**$276,347,000**		**$225,890,000**	18%

Table G.2. Combined SWMUs Comparison Summary (Continued)

COST ESTIMATE
WMA B - SWMUs 5,6,7, and 30

	SWMU 5	SWMU 6	SWMU 7	SWMU 30	COMBINED			
Task Description	Alternative 3 Soil Cover & LTM	Alternative 1 No Action	Alternative 4 Soil Cover combined with In Situ DNAPL Source Treatment & LTM	Alternative 3 Soil Cover & LTM	Total	Estimated Efficiency Savings	Total with Efficiency Savings Applied	Percent Reduction
Cost Estimate Summary								
Capital Cost								
1.0 Project Plans	$535,000	$0	$2,275,000	$600,000	$3,410,000	50%	$1,705,000	
2.0 Engineering Design	$424,000	$0	$1,306,000	$332,000	$2,062,000	50%	$1,031,000	
3.0 Work Package Prep./Readiness Review	$700,000	$0	$1,200,000	$500,000	$2,400,000	50%	$1,200,000	
4.0 Training	$145,000	$0	$140,000	$138,000	$423,000	50%	$212,000	
5.0 Mobilization	$313,000	$0	$986,000	$90,000	$1,389,000	50%	$695,000	
6.0 Site Preparation	$289,000	$0	$880,000	$104,000	$1,273,000	30%	$891,000	
7.0 Excavation	$0	$0	$1,843,000	$0	$1,843,000	0%	$1,843,000	
8.0 Waste Treatment Transportation & Disposal	$0	$0	$4,316,000	$0	$4,316,000	0%	$4,316,000	
9.0 Backfill & Equipment Decon	$0	$0	$376,000	$0	$376,000	0%	$376,000	
10.0 ERH System Installation & Operation	$0	$0	$6,346,000	$0	$6,346,000	0%	$6,346,000	
11.0 Baseline Sampling	$0	$0	$78,000	$0	$78,000	0%	$78,000	
12.0 Post Op Sampling	$0	$0	$174,000	$0	$174,000	0%	$174,000	
13.0 Soil Cover Construction	$643,000	$0	$555,000	$327,000	$1,525,000	10%	$1,373,000	
14.0 Well Installation and Site Restoration	$699,000	$0	$542,000	$668,000	$1,909,000	10%	$1,718,000	
15.0 O&M Manual and Remedial Action Completion Report	$150,000	$0	$225,000	$210,000	$585,000	25%	$439,000	
Project Mgmt	$390,000	$0	$1,098,000	$297,000	$1,785,000	25%	$1,339,000	
CAPITAL TOTAL	**$4,288,000**	**$0**	**$22,340,000**	**$3,266,000**	**$29,894,000**		**$23,736,000**	21%

Table G.2. Combined SWMUs Comparison Summary (Continued)

COST ESTIMATE
WMA B - SWMUs 5,6,7, and 30 (Continued)

Task Description	SWMU 5 Alternative 3 Soil Cover & LTM	SWMU 6 Alternative 1 No Action	SWMU 7 Alternative 4 Soil Cover combined with In Situ DNAPL Source Treatment & LTM	SWMU 30 Alternative 3 Soil Cover & LTM	COMBINED Total	Estimated Efficiency Savings	Total with Efficiency Savings Applied	Percent Reduction
Cost Estimate Summary								
Annual Cost (Present Worth)								
Annual Cap O&M (Years 1 - 30)	$682,000	$0	$1,228,000	$608,000	$2,518,000	50%	$1,259,000	
Quarterly Groundwater LTM (Years 1 - 5)	$369,000	$0	$418,000	$418,000	$1,205,000	30%	$844,000	
Semi Annual Groundwater LTM (Years 6 - 10)	$132,000	$0	$149,000	$149,000	$430,000	25%	$323,000	
Annual Groundwater LTM (Years 11 - 30)	$124,000	$0	$140,000	$140,000	$404,000	25%	$303,000	
Five Year Review Year 5	$36,000	$0	$36,000	$36,000	$108,000	25%	$81,000	
Five Year Review Year 10	$25,000	$0	$25,000	$25,000	$75,000	25%	$56,000	
Five Year Review Year 15	$18,000	$0	$18,000	$18,000	$54,000	25%	$41,000	
Five Year Review Year 20	$13,000	$0	$13,000	$13,000	$39,000	25%	$29,000	
Five Year Review Year 25	$9,000	$0	$9,000	$9,000	$27,000	25%	$20,000	
Five Year Review Year 30	$7,000	$0	$7,000	$7,000	$21,000	25%	$16,000	
ANNUAL TOTAL	**$1,415,000**	**$0**	**$2,043,000**	**$1,423,000**	**$4,881,000**		**$2,972,000**	39%
TOTALS	**$5,703,000**	**$0**	**$24,383,000**	**$4,689,000**	**$34,775,000**		**$26,708,000**	23%

G.5. REFERENCES

DOE (U.S. Department of Energy) 2006. *Work Plan for the Burial Grounds Operable Unit Remedial Investigation/Feasibility Study at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2179&D2/R1, August.

DOE 2010. *Remedial Investigation Report for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0030&D2, October.

EPA 1992. *Selecting a Combined Response Action Approach for Noncontiguous CERCLA Facilities to Expedite Cleanups*, Superfund Publication: 9355.3-14FS, April.

Remediation Journal 2009. "The Sustainable Remediation Forum White Paper: Integrating Sustainable Principles, Practices, and Metrics into Remediation Projects," Published in a special edition of the *Remediation Journal*, June.

THIS PAGE INTENTIONALLY LEFT BLANK

ATTACHMENT G.1

SWMUs 2 & 3 REMEDIAL ALTERNATIVES COST ESTIMATES

THIS PAGE INTENTIONALLY LEFT BLANK

SWMUs 2 & 3 Combined Remedial Alternatives Cost Estimate Summary

			PRESENT WORTH [1]		ESCALATED	
Alternative Description	Annual Time Period, yrs	Capital $ (2010 Constant Dollars)	Total Annual $	Total $ (Capital & Annual)	Total Annual $	Total $ (Capital & Annual)
In Situ Containment with Long-Term Monitoring	30	$34,221,000	$4,003,000	$38,224,000	$15,968,000	$52,274,000

Notes:
(1) Not used for budgeting or planning purposes because value is based on investing funds for out year expenditures.

ESTIMATE BASIS
SWMU 2 (C-749 Uranium Burial Ground) and
Alternative 9 - In Situ Containment with Long-Term Monitoring

A. Given SWMU Dimensions
SWMU 2
Depth of burial pits are 7 to 17 feet bgs.
Area covered with 6 inch clay cap and 18 inch thick soil cover after the site was no longer used.
Reference: DOE, 2010
SWMU 3
Originally constructed as an above ground holding pond, with an on-grade tamped earth floor
and 6-ft high clay dike walls. Later the site was used for waste disposal; the site covered with a RCRA multilayered cap.
The SWMU dimensions are reported as 387ft x 137 ft.
Reference: DOE, 2010

Description	Length, ft	Width, ft	Area, sf
SWMU 2	200	160	32,000
SWMU 3	387	137	53,000
Total Waste Disposal			85,000

B. Quantifiable Disposal Items
SWMU 2

Item	Quantity	Units
Uranium	270	tons
Oils	59,000	gallons
TCE	450	gallons

Reference: DOE, 1998

SWMU 3

Item	Quantity	Units
Uranium-contaminated Waste	6,615,000	lb
Precipitation Filter Cake (end projects from the gold dissolver process)	645	drums
Total Waste Disposal	260,000 9,600	cf cy

Reference: DOE, 1999

C. Unquantifiable Disposal Items
SWMU 2
Drummed waste consist primarily of uranium metal from machine shop turnings, shavings, and sawdust.
Pyrophoric uranium metal in 20-, 30-, or 55-gal drums, PCB oils, TC-99 possibly disposed at site.
Reference: DOE, 2010

SWMU 3

Primary disposal area for Tc99 and uranium-contaminated effluent, which was removed prior to disposing of uranium -contaminated bulk wastes.
Contains bulk solid waste.
Upper portion used for the disposal of bulk and containerized uranium-contaminated solid waste.
Contains drummed waste similar to that collected in the impoundment plus smelter furnace liners and drums of hazardous waste (cadmium, lead, selenium).
Waste uranium precipitated from aqueous solutions, uranium tetrafluoride, uranium metal, uranium oxides, degreasing sludge, and radioactively contaminated trash.
Fluoride, TCE, PCBs, neptunium, technetium-99, and uranium-238 found in leachate.
33 percent of the surface area is covered with drums ((DOE, 1978).

Assumed Volume of PCB Oil 50,000 gallon

E. Dewatering Estimate
SWMU 2

Assumed depth to groundwater (based on Fig 3.16, DOE, 2010) =	6	ft
Assumed bottom of Excavation =	20	ft
Groundwater Thickness =	14	ft
Assumed Average Site Soil Porosity =	0.2	
Area to be Dewatered =	18850	sf

ESTIMATE BASIS
SWMU 2 (C-749 Uranium Burial Ground) and
Alternative 9 - In Situ Containment with Long-Term Monitoring

Initial Pore Volume = Area x Groundwater Thickness x Porosity

Estimate of Initial Pore Volume to Dewater				
area (sf)	depth (ft)	porosity	Volume (cubic ft)	Volume (gallon)
surface area is covered with dru	14	0.2	52,780	400,000

Assumed removal rate achieved for dewatering initial pore volume = 30 gpm
Assumed dewatering rate after removal of initial pore volume = 7.9 gpm
(DOE, 1998, pg 17)

SWMU 3
Assume SWMU 3 sits 16 ft above normal grade; therefore, if the excavation is 26 ft thick, then only 10 ft of the excavation will be below grade.

Sheet pile installed around perimeter of excavation =	930	lf
Height of SWMU above grade =	16	ft
Assumed datum elevation at grade =	0	ft
Assumed depth to groundwater (DOE, 2010) =	5	ft
Assumed bottom of Excavation based on datum elev. at grade =	10	ft
Groundwater Thickness =	5	ft
Assumed Average Site Soil Porosity =	0.2	
Area to be Dewatered =	53,000	sf

Initial Pore Volume = Area x Groundwater Thickness x Porosity

Estimate of Initial Pore Volume to Dewater				
area (sf)	thickness (ft)	porosity	Volume (cubic ft)	Volume (gallon)
53,000	5	0.2	53,000	400,000

Assumed removal rate achieved for dewatering initial pore volume =	30	gpm
Assumed dewatering rate after removal of initial pore volume (DOE, 1998, pg 17) =	7.9	gpm
Leachate Generation =	2,200	gal/yr

F. References

DOE, 2010, BGOU Remedial Investigation Report.
DOE, 1998, Feasibility Study for Final Action at SWMU 2 of WAG 22 at the Paducah GDP, KY, Sept.

CONCEPTUAL DESIGN CALCULATIONS

BGOU SWMU 2 &3 Combined

Alternative 9 - In Situ Containment with Long-Term Monitoring

Parameter			Total	Units	Basis
SWMU Dimensions					
	Containment Dimensions				
		SWMU 2			
		Containment Width	200	ft	DOE, 2010
		Containment Length	250	ft	DOE, 2010
		Containment Depth	20	ft	DOE, 2010
		SWMU 3			
		Containment Width	250	ft	DOE, 2010
		Containment Length	500	ft	DOE, 2010
		Containment Depth	5	ft	DOE, 2010
	Jet Grouting for Vertical Containment Wall				
		Assume common wall between SWMUs 2 & 3 from 0 to 20 ft bgs.			
		Outer Containment Wall Perimeter around SWMU 2	900	ft	calc
		Outer Containment Wall depth around SWMU 2	20	ft	Engr est.
		Outer Containment Wall Perimeter around SWMU 3	1,250	ft	calc
		Outer Containment Wall Depth around SWMU 3	5		Engr est.
		Common Containment Wall Length Between SWMU's 2 & 3	250	ft	calc
		Common Containment Wall Depth Between SWMU's 2 & 3, i.e., installed to 20 ft bgs to compartmentalize the SWMUs.	20	ft	calc
		Thickness of Containment Wall	3	ft	Hayward Baker
		Approx Cross Sectional Area	29,250	sf	calc
		Overlap Factor	1.25		Hayward Baker
		Approx. Volume of Jet Grouting	109,688	cf	calc
		Approx. Volume of Jet Grouting	4,100	cy	calc
	Jet Grouting for Horizontal Containment				
		Setback for SWMU 2	100	ft	
		Width SWMU 2	400	ft	
		Setback for SWMU 3	50		
		Width SWMU 3	320	ft	
		SWMU 2 Area	100,000	sf	calc
		SWMU 3 Area	160,000	sf	calc
		Total Area	260,000	sf	calc
		Thickness of Containment Bottom	3	ft	Engr est.
		Overlap Factor	1.25		Engr est.
		Approx. Volume of Jet Grouting	975,000	cf	calc
		Approx. Volume of Jet Grouting	37,000	cy	calc
	Spoil Return				
		Estimated Fraction of Spoil Return	0.10	unit less	Engr est.
		Est. Spoil Return Based on Vol of Jet Grouting	4,100	cy	calc

CONCEPTUAL DESIGN CALCULATIONS

BGOU SWMU 2 &3 Combined

Alternative 9 - In Situ Containment with Long-Term Monitoring

Parameter			Total	Units	Basis
	Groundwater Pore Volume				
		Containment Area with Groundwater	100,000	sf	calc
		Depth to Groundwater	6	ft	Engr Est
		Depth to be dewatered	20	ft	Engr Est.
		Volume to be dewatered	1,400,000	cf	calc
		Assumed landfill porosity	0.30		Engr Est.
		Groundwater Pore Volume	420,000	cf	calc
		Conversion	7.48	gal/cf	Lindeburg, 1990
		Groundwater Pore Volume beneath Cap	3,100,000	gal	calc
		Initial Dewatering Rate	30.0	gpm	Engr Est
		Time to remove one pore volume	1,722	hours	calc
		Time to remove one pore volume	72	days	Calc
	Groundwater Sumps for SWMU 2				
		Assumed ROI for dewatering/leachate sumps	60	ft	Engr Est.
		Perimeter of RCRA Cap	11,304	sf/sump	calc
		No. of Sumps required for dewatering/long-term leachate collection for SWMU 2	4	sumps	calc
	Leachate Collection				
		Annually Fraction of Pore Vol Collected	0.006	fraction	calc
		Pore Volume	3,100,000	gal	calc
		Est. Annual Leachate Production from SWMU 2	20,000	gal	calc
		Pore Volume SWMU 3	400,000	gal	calc
		Annual Leachate Production from SWMU 3	2200	gal	DOE Operation Records

References:

DOE, 2010, BGOU Remedial Investigation Report
Lindeburg, 1990, Engineering Unit Conversions

COST ESTIMATE
BGOU SWMUs 2 & 3 Combined
Alternative 9 - In Situ Containment with Long-Term Monitoring

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
Cost Estimate Summary									
Capital Cost									
1.0 Project Plans	1	ls	$1,160,000	$1,160,000					
2.0 Engineering Design	1	ls	$794,000	$794,000					
3.0 Work Package Prep./Readiness Review	1	ls	$500,000	$500,000					
4.0 Training	1	ls	$138,000	$138,000					
5.0 Mobilization	1	ls	$321,000	$321,000					
6.0 Site Preparation/Construct Laydown & Staging Areas	1	ls	$344,000	$344,000					
7.0 Vertical and Horizontal Containment Construction	1	ls	$28,947,000	$28,947,000					
8.0 Site Restoration	1	ls	$142,000	$142,000					
9.0 Remedial Action Completion Reporting	1	ls	$245,000	$245,000					
Project Management			5%	$1,630,000					
		TOTAL CAPITAL COST		**$34,221,000**					
Construction Schedule	**10**	**Months**							
Annual Cost									
Annual O&M (Years 1 - 30)	30	ls	$263,000	$7,890,000					
Quarterly Groundwater LTM (Years 1 - 5)	5	ls	$91,000	$455,000					
Semi-Annual Groundwater LTM (Years 6 - 10)	5	ls	$46,000	$230,000					
Annual Groundwater LTM (Years 11 - 30)	20	ls	$23,000	$460,000					
Five Year Review Yr 5	1	ls	$50,000	$50,000					
Five Year Review Yr 10	1	ls	$50,000	$50,000					
Five Year Review Yr 15	1	ls	$50,000	$50,000					
Five Year Review Yr 20	1	ls	$50,000	$50,000					
Five Year Review Yr 25	1	ls	$50,000	$50,000					
Five Year Review Yr 30	1	ls	$50,000	$50,000					
		TOTAL ANNUAL COST		**$9,335,000**					
			TOTAL	**$43,556,000**					

COST ESTIMATE
BGOU SWMUs 2 & 3 Combined
Alternative 9 - In Situ Containment with Long-Term Monitoring

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
Present Worth Value									
	Quantity	**Unit**	**Unit Cost**	**Total**				**Present Worth**	
Total Capital Cost	1	ls	$34,221,000	$34,221,000				**$34,221,000**	
Annual Containment O&M (Years 1 - 30)	30	ls	$263,000	$7,890,000				**$3,264,000**	7% discount rate
Quarterly Groundwater LTM (Years 1 - 5)	5	ls	$91,000	$455,000				**$373,000**	7% discount rate
Semi-Annual Groundwater LTM (Years 6 - 10)	5	ls	$46,000	$230,000				**$134,000**	7% discount rate
Annual Groundwater LTM (Years 11 - 30)	20	ls	$23,000	$460,000				**$124,000**	7% discount rate
Five Year Review Yr 5	1	ls	$50,000	$50,000				**$36,000**	7% discount rate
Five Year Review Yr 10	1	ls	$50,000	$50,000				**$25,000**	7% discount rate
Five Year Review Yr 15	1	ls	$50,000	$50,000				**$18,000**	7% discount rate
Five Year Review Yr 20	1	ls	$50,000	$50,000				**$13,000**	7% discount rate
Five Year Review Yr 25	1	ls	$50,000	$50,000				**$9,000**	7% discount rate
Five Year Review Yr 30	1	ls	$50,000	$50,000				**$7,000**	7% discount rate
							Capital Costs	**$34,221,000**	
						Present Worth Values	**Annual**	**$4,003,000**	
							Avg. Annual	**$133,433**	
							Total	**$38,224,000**	
This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 percent of the actual project cost.									
Not used for budgeting or planning purposes because value is based on investing funds for out year expenditures.									

COST ESTIMATE
BGOU SWMUs 2 & 3 Combined
Alternative 9 - In Situ Containment with Long-Term Monitoring

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
1.0 Project Plans									
Documented Safety Analysis	1	LS	$500,000	$500,000					PRS, 2009
Remedial Design Work Plan	1	LS	$350,000	$350,000					Engr Est.
Remedial Action Work Plan	1	LS	$110,000	$110,000					Engr Est., PRS
Health & Safety Plan	1	LS	$50,000	$50,000					Engr Est.
QA Plan	1	LS	$50,000	$50,000					Engr Est.
Sampling & Analysis Plan	1	LS	$50,000	$50,000					Engr Est.
Waste Management Plan	1	LS	$50,000	$50,000					Engr Est.
TASK TOTAL				**$1,160,000**			**0**	**$1,160,000**	
2.0 Engineering Design									
Civil Surveying	1	LS	$50,000	$50,000					Engr Est.
Design	1	LS	$743,850	$743,850					2.5% of Construction Costs
TASK TOTAL				**$793,850**			**0**	**$794,000**	
3.0 Work Package Prep./Readiness Review									
Remedial Work Plan									
Work Instructions									
Training									
USD/USQD									
Lessons Learned									
Procedures									
AHA									
Work Authorization									
Excavation/Penetration Permits									
Team Meeting Documentation									
Emergency Response Plan									
Hoisting & Rigging Plan									
Transportation Plan									
Project Org. Chart									
TASK TOTALS	1	LS	$500,000	**$ 500,000**			**0**	**$500,000**	Engr Est.

COST ESTIMATE
BGOU SWMUs 2 & 3 Combined
Alternative 9 - In Situ Containment with Long-Term Monitoring

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
4.0 Training									
Labor									
Assumptions: Assume 10 hrs/workday, 16 workday/month. 100% cleared workers, no travel.									
Training Specialist					0	$56	$0		Engr Est., paid for by other funding
Training Data Clerk					192	$37	$7,104		Engr Est.
Operations Supervisor					192	$56	$10,752		Engr Est., PRS Labor Rate
HEO					192	$45	$8,640		Engr Est., PRS Labor Rate
HEO					192	$45	$8,640		Engr Est., PRS Labor Rate
Laborer					192	$42	$8,064		Engr Est., PRS Labor Rate
Laborer					192	$42	$8,064		Engr Est., PRS Labor Rate
Health & Safety Tech					192	$56	$10,752		Engr Est., PRS Labor Rate
QA Specialist					192	$56	$10,752		Engr Est., PRS Labor Rate
Senior Rad Control Tech					192	$56	$10,752		Engr Est., PRS Labor Rate
Senior Rad Control Tech					192	$56	$10,752		Vendor quote for similar work
Health Physicist					192	$74	$14,208		Vendor quote for similar work
Junior Rad Control Tech					192	$42	$8,064		Vendor quote for similar work
Training Modules									paid for by overhead acct
Security Training	13	person	$0	$0					No training fee, No cost, 28 hrs
Pyrophorics	13	person	$0	$0					$1000 typ. training fee/person, 16hrs, financed by other funding
Hazwoper 40 Hr	13	person	$0	$0					No training fee, 40 hrs
Hazwoper 8 hr refresher	13	person	$0	$0					No training fee, 2nd Yr, 8 hrs
Safety Meetings	13	person	$0	$0					No training fee, 2hrs/wk/person, assume 100 hrs
Medical Exams/Tests									
Med Exam & Respirator Fit	26	test	$365	$9,490					once per year for 2yr , 4 hrs labor
Fecal Sampling	104	test	$30	$3,120					8 qtrs
Urinalysis	104	test	$22	$2,236					8 qtrs
Beta Gamma Monitoring	104	test	$68	$7,020					8 qtrs
TASK TOTALS				**$21,866**	**2,304**		**$116,544**	**$138,000**	

COST ESTIMATE
BGOU SWMUs 2 & 3 Combined
Alternative 9 - In Situ Containment with Long-Term Monitoring

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
5.0 Mobilization									
Duration: Assume one month for mobilization.									
Assumptions: For Non-Union personnel assume 10 hrs/workday, 22 workday/month straight time.									
For Union personnel assume 10 hrs/workday, 16 workday/month straight time and 6 workday/month overtime totaling 22 workdays/month.									
100% cleared workers, no travel.									
Schedule	**1**	**Month**							
Labor									
Non Union									
Operations Supervisor					220	$56	$12,320		Engr Est., PRS Labor Rate
Health & Safety Tech					220	$56	$12,320		Engr Est., PRS Labor Rate
QA Specialist					220	$56	$12,320		Engr Est., PRS Labor Rate
Health Physicist					220	$74	$16,280		Vendor quote for similar work
Union									
HEO					160	$45	$7,200		Engr Est., PRS Labor Rate
HEO					160	$45	$7,200		Engr Est., PRS Labor Rate
Laborer					160	$42	$6,720		Engr Est., PRS Labor Rate
Laborer-Union					160	$42	$6,720		Engr Est., PRS Labor Rate
Senior Rad Control Tech					160	$56	$8,960		Vendor quote for similar work
Junior Rad Control Tech					160	$42	$6,720		Vendor quote for similar work
Union OT 1.5x									
HEO					60	$68	$4,050		Engr Est., PRS Labor Rate
HEO					60	$68	$4,050		Engr Est., PRS Labor Rate
Laborer					60	$63	$3,780		Engr Est., PRS Labor Rate
Laborer-Union					60	$63	$3,780		Engr Est., PRS Labor Rate
Senior Rad Control Tech					60	$84	$5,040		Vendor quote for similar work
Junior Rad Control Tech					60	$63	$3,780		Vendor quote for similar work
Part Time									
RADCON Supervisor					55	$74	$4,070		Vendor quote for similar work
Criticality Safety Engineer					55	$74	$4,070		Engr Est.

COST ESTIMATE
BGOU SWMUs 2 & 3 Combined
Alternative 9 - In Situ Containment with Long-Term Monitoring

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
Radcon Instruments									
Survey Meters	1	ls	$12,000	$12,000					Vendor Quotes: 2-portable scalar, 5-digital scalar rate meter
Dose Rate Meters	1	ls	$22,000	$22,000					Vendor Quotes: 1-nuetron counter, 1-stretch scope, 1-teletector, 2-micron rem meter.
Alpha/Beta/Gamma Detectors	1	ls	$17,000	$17,000					Vendor Quotes: 1-gas proportional detector, 1-dual scintillator alpha/beta detector, 2-NaI scintillator, 2-fidler probes, 2-pancake GM detector.
Counters	1	ls	$10,000	$10,000					Vendor Quotes: 2 sample counters
Specialty Equipment	1	ls	$60,000	$60,000					Vendor Quotes: 1-low background smear counter, 1-GPS
Industrial Hygiene	1	ls	$13,000	$13,000					Vendor Quotes: 1- Acoustic /Noise Calibrator, 1- audio dosimeter, 1-airflow calibrator, 1- dragger bellows pump, 1-gas monitor, 1-noise dosimeter, 1-scale, 1- gas monitor with pump.
Air Samplers/Monitors	1	ls	$50,000	$50,000					Vendor Quotes: 2- low volume, 1- station charger, 4-high volume, 4-air particulate continuous air monitor.
Sources	1	ls	$6,000	$6,000					Vendor Quotes: Th-23, SrY90, Cs137.
Equipment									
Pickup Truck, crew cab, F250	2	mob fee	$150	$300					Hertz
Front End Loader	1	mob fee	$150	$150					Hertz
Excavator	1	mob fee	$151	$151					Hertz
Dozer	1	mob fee	$150	$150					Hertz
Water Truck, 2000 gal	1	mob fee	$150	$150					Hertz
Compactor/12 ton/pad foot	1	mob fee	$150	$150					Hertz
Compactor/12 ton/smooth drum	1	mob fee	$150	$150					Hertz
Generator, 150 KW	1	mob fee	$150	$150					Hertz
Supply Trailer	1	mob fee	$150	$150					Hertz
TASK TOTALS				**$191,501**	**2,310**		**$129,380**	**$321,000**	

COST ESTIMATE
BGOU SWMUs 2 & 3 Combined
Alternative 9 - In Situ Containment with Long-Term Monitoring

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
6.0 Site Preparation/Construct Laydown & Staging Areas									
Duration: Assume two months for site preparation and construction laydown and staging areas.									
Assumptions: 100% cleared, no travel.									
Also install stormwater control measures including cleaning ditches, repairing culverts and drains, and diverting water from the treatment area.									
Includes geophysical survey of areas where ground penetration is planned.									
Schedule	**2**	**Month**							
Non Union									
Operations Supervisor					440	$56	$24,640		Engr Est., PRS Labor Rate
Health & Safety Tech					440	$56	$24,640		Engr Est., PRS Labor Rate
QA Specialist					440	$56	$24,640		Engr Est., PRS Labor Rate
Health Physicist					440	$74	$32,560		Vendor quote for similar work
Union									
HEO					320	$45	$14,400		Engr Est., PRS Labor Rate
HEO					320	$45	$14,400		Engr Est., PRS Labor Rate
Laborer					320	$42	$13,440		Engr Est., PRS Labor Rate
Laborer-Union					320	$42	$13,440		Engr Est., PRS Labor Rate
Senior Rad Control Tech					320	$56	$17,920		Vendor quote for similar work
Junior Rad Control Tech					320	$42	$13,440		Vendor quote for similar work
Union OT 1.5x									
HEO					120	$68	$8,100		Engr Est., PRS Labor Rate
HEO					120	$68	$8,100		Engr Est., PRS Labor Rate
Laborer					120	$63	$7,560		Engr Est., PRS Labor Rate
Laborer-Union					120	$63	$7,560		Engr Est., PRS Labor Rate
Senior Rad Control Tech					120	$84	$10,080		Vendor quote for similar work
Junior Rad Control Tech					120	$63	$7,560		Vendor quote for similar work
Part Time									
RADCON Supervisor					110	$74	$8,140		Vendor quote for similar work
Criticality Safety Engineer					110	$74	$8,140		Engr Est.
Equipment									
Pickup Truck, crew cab, F250	2	month	$1,300	$2,600					Hertz
Pickup Truck, crew cab, F250	2	month	$1,300	$2,600					Hertz
Front End Loader, 3.5CY	2	month	$4,150	$8,300					Hertz
Dozer	2	month	$2,800	$5,600					Hertz
Water Truck, 2000 gal	2	month	$1,850	$3,700					Hertz
Equipment Trailer	2	month	$300	$600					Hertz
Generator, 150 KW	2	month	$2,006	$4,012					Hertz
Two Portable Toilets	2	month	$300	$600					DOE, 2007
FOGM	2	month	$1,000	$2,000					Engr Est
Subcontractor									
Geophysics Survey	1	ls	$50,000	$50,000					Engr Est.
Materials									
Rip Rap delivered	200	ton	$17	$3,400					Carver Sand & Gravel
Geotextile delivered	2	roll	$600	$1,200					AH Harris, 500cy roll
Silt Fence	15	roll	$50	$750					AH Harris, 100 ft roll
TASK TOTAL				**$ 85,362**	**0**		**$258,760**	**$344,000**	

COST ESTIMATE
BGOU SWMUs 2 & 3 Combined
Alternative 9 - In Situ Containment with Long-Term Monitoring

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
7.0 Vertical and Horizontal Containment Construction									
Duration: Six months construction									
Assumptions: Construction Labor included in Unit Pricing.									
Installation will consist of constructiong horizontal and vertical containment barriers by Jet Grounting									
Spoil return from Jet Grouting will be U Landfill WAC acceptable.									
Dewatering of one pore volume will be performed during construction									
Treatment of Dewatering water may include filtration, air stripping, ion exchange, and liquid phase carbon and direct discharged.									
Prefabricated metal building will be erected over the contained area.									
Install four nested well pairs (8 wells total) in the RGA and UCRS.									
Used 10 hour work-day; 22 work-days per month.									
Schedule	**6**	**Month**							
Labor									
Non Union									
Operations Supervisor					1760	$56	$98,560		Engr Est., PRS Labor Rate
Health & Safety Tech					1760	$56	$98,560		Engr Est., PRS Labor Rate
QA Specialist					1760	$56	$98,560		Engr Est., PRS Labor Rate
Health Physicist					1760	$74	$130,240		Vendor quote for similar work
Union									
HEO					1280	$45	$57,600		Engr Est., PRS Labor Rate
HEO					1280	$45	$57,600		Engr Est., PRS Labor Rate
Laborer					1280	$42	$53,760		Engr Est., PRS Labor Rate
Laborer-Union					1280	$42	$53,760		Engr Est., PRS Labor Rate
Senior Rad Control Tech					1280	$56	$71,680		Vendor quote for similar work
Junior Rad Control Tech					1280	$42	$53,760		Vendor quote for similar work
Union OT 1.5x									
HEO					480	$68	$32,400		Engr Est., PRS Labor Rate
HEO					480	$68	$32,400		Engr Est., PRS Labor Rate
Laborer					480	$63	$30,240		Engr Est., PRS Labor Rate
Laborer-Union					480	$63	$30,240		Engr Est., PRS Labor Rate
Senior Rad Control Tech					480	$84	$40,320		Vendor quote for similar work
Junior Rad Control Tech					480	$63	$30,240		Vendor quote for similar work
Part Time									
RADCON Supervisor					440	$74	$32,560		Vendor quote for similar work
Criticality Safety Engineer					88	$74	$6,512		Engr Est.

COST ESTIMATE
BGOU SWMUs 2 & 3 Combined
Alternative 9 - In Situ Containment with Long-Term Monitoring

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
Subcontractors/Unit Pricing									
Vertical Containment Wall - Jet Grouting	4,100	cy	$250	$1,025,000					Hayward Baker
Horizontal Containment Wall - Jet Grouting	37,000	cy	$250	$9,250,000					Hayward Baker
Dewater/Wastewater Trmt and Disposal	3,100,000	gal	$3	$9,300,000					RSMeans ECHOS 33 19 7104, Rad water, 10,000 gal/day
RGA & UCRS Nested Monitoring Well Installation	4	ea	$125,000	$500,000					2 wells/nest, 4 nests, 65 & 100 ft deep
Pre-Engineered Building 350' x 800', 24' tall at eave.	280,000	sf	$25	$7,000,000					RSMeans 13128 700 5100
Gravel floor for Pre-Engineered Bldg, 6" thick	14,400	sy	$7	$100,800					RSMeans 02720 200 0100
Fence, 8', barbed wire	2,900	lf	$35	$101,500					8' tall with barb wire, RSMeans 02820-528-0920
Double Swing Gate, 8'	2	ea	$1,475	$2,950					RSMeans 0280-528-5070
Sumps	80	lf	$200	$18,949					30 ft deep, 12 inch dia, Sch 80 PVC, RSMeans 33 23 0117
Laboratory Analytical									
Off Gas									
TO14	60	sample	$450	$27,000					Assume treated offgas and ground
Shipping	60	ea	$20	$1,200					water effluent samples taken daily
Treated GW Effluent									during startup.
Metals 6010	60	sample	$165	$9,900					
VOA 8260	60	sample	$165	$9,900					
SVOA 8270	60	sample	$352	$21,120					
RAD	60	sample	$1,047	$62,820					
Shipping	60	ls	$100	$6,000					
Waste Transportaion and Disposal									
Spoil Return from Jet Grouting, assume U Landfill WAC Compliant	4,100	cy	$75	$307,500					Onsite existing U Landfill - Subtitle D, assume 10 cy dump trucks, round trip is 10 miles, RS Means ECHOS 33 19 0209

COST ESTIMATE
BGOU SWMUs 2 & 3 Combined
Alternative 9 - In Situ Containment with Long-Term Monitoring

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
Equipment									
Pickup Truck, crew cab, F250	8	month	$1,300	$10,400					Hertz
Pickup Truck, crew cab, F250	8	month	$1,300	$10,400					Hertz
Front End Loader	8	month	$4,150	$33,200					Hertz
Excavator	8	month	$4,350	$34,800					Hertz
Dozer	8	month	$2,800	$22,400					Hertz
Compactor/12 ton/pad foot	8	month	$3,090	$24,720					Hertz
Compactor/12 ton/smooth drum	8	month	$2,920	$23,360					Hertz
Water Truck, 2000 gal	8	month	$1,850	$14,800					Hertz
Equipment Trailer	8	month	$300	$2,400					Hertz
Generator, 15KW	8	month	$2,006	$16,048					Hertz
Portable Toilet	8	month	$150	$1,200					Engr Est
TASK TOTAL				**$27,938,367**	**18128**		**$1,008,992**	**$28,947,000**	

COST ESTIMATE
BGOU SWMUs 2 & 3 Combined
Alternative 9 - In Situ Containment with Long-Term Monitoring

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
8.0 Site Restoration									
Duration: Approximately one month for site restoration.									
Assumptions: Used 10 hour work-day; 22 work-days per month.									
Schedule	**1**	**Month**							
Labor									
Non Union									
Operations Supervisor					220	$56	$12,320		Engr Est., PRS Labor Rate
Health & Safety Tech					220	$56	$12,320		Engr Est., PRS Labor Rate
Health Physicist					220	$74	$16,280		Vendor quote for similar work
Union									
HEO					160	$45	$7,200		Engr Est., PRS Labor Rate
HEO					160	$45	$7,200		Engr Est., PRS Labor Rate
Laborer					160	$42	$6,720		Engr Est., PRS Labor Rate
Laborer-Union					160	$42	$6,720		Engr Est., PRS Labor Rate
Senior Rad Control Tech					160	$56	$8,960		Vendor quote for similar work
Junior Rad Control Tech					160	$42	$6,720		Vendor quote for similar work
Union OT 1.5x									
HEO					60	$68	$4,050		Engr Est., PRS Labor Rate
HEO					60	$68	$4,050		Engr Est., PRS Labor Rate
Laborer					60	$63	$3,780		Engr Est., PRS Labor Rate
Laborer-Union					60	$63	$3,780		Engr Est., PRS Labor Rate
Senior Rad Control Tech					60	$84	$5,040		Vendor quote for similar work
Junior Rad Control Tech					60	$63	$3,780		Vendor quote for similar work
Part Time									
RADCON Supervisor					55	$74	$4,070		Vendor quote for similar work
Criticality Safety Engineer					55	$74	$4,070		Engr Est.
QA Specialist					55	$56	$3,080		Engr Est.
Travel									USGSA
Labor Travel Expenses	0	days	$109	$0					
Equipment									
Pickup Truck, crew cab, F250	1	month	$1,300	$1,300					Hertz
Front End Loader	1	month	$4,150	$4,150					Hertz
Water Truck, 2000 gal	1	month	$1,850	$1,850					Hertz
Equipment Trailer	1	month	$2,000	$2,000					Williams Scotsman
Generator 150KW	1	month	$2,006	$2,006					Hertz
Portable Toilet	1	month	$150	$150					Engr Est
Subcontractors									
Hydroseed Bluegrass	200	MSF	$50	$10,000					Assume entire capped area plus 50%; RSMeans 02920-320-1000
TASK TOTAL				**$21,456**			**$120,140**	**$142,000**	
9.0 Remedial Action Completion Reporting									Engr Est.
Reports									
As-Built Drawings	1	ls	$35,000	$35,000					Engr Est.
O&M Plan	1	ls	$50,000	$50,000					Engr Est.
Remedial Action Completion Report and Reviews	1	ls	$160,000	$160,000					PRS, 2009
TASK TOTAL				**$245,000**			**$0**	**$245,000**	
							SUBTOTAL CAPITAL COST	**$32,591,000**	

COST ESTIMATE
BGOU SWMUs 2 & 3 Combined
Alternative 9 - In Situ Containment with Long-Term Monitoring

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
Annual Containment O&M (Years 1 - 30)									
Duration: Annual for thirty years.									
Assumptions: Includes O&M for waste containment system including building and fence.									
All process waste accepted by onsite U Landfill.									
Assume 5 days per month labor on O&M with no overtime.									
8 hr/work day and 22 workdays/month.									
5	days/month								
Labor									
Non Union									
Operations Supervisor					480	$56	$26,880		Engr Est., PRS Labor Rate
Union									
HEO					480	$45	$21,600		Engr Est., PRS Labor Rate
Laborer					480	$42	$20,160		Engr Est., PRS Labor Rate
Part Time									
RADCON Supervisor					96	$74	$7,104		Vendor quote for similar work
Junior Rad Control Tech					96	$42	$4,032		Vendor quote for similar work
QA Specialist					96	$56	$5,376		Engr Est.
Health Physicist					96	$74	$7,104		Vendor quote for similar work
Health & Safety Tech					96	$56	$5,376		Engr Est., PRS Labor Rate
Equipment									
Pickup Truck, crew cab, F250	2	month	$1,300	$2,600					Hertz
FOGM	2	month	$100	$200					Engr Est
Materials									
Miscellaneous Supplies	1	ls	$2,500	$2,500					Engr Est.
Power Consumption	200,000	KW-hr	$0.05	$10,000					Engr Est.
Laboratory Analytical									
Subcontractor									
Building Maintenance	1	ls	$10,000	$10,000					Engr Est.
Cap Maintenance	1	ls	$10,000	$10,000					Engr Est.
Site Maintenance	1	ls	$10,000	$10,000					Engr Est.
SWMU 2 Leachate Treatment & Disp	20,000	gal	$3	$60,000					RSMeans ECHOS 33 19 7104, Rad water, 10,000 gal/day
SWMU 3 Leachate Treatment & Disp	2,200	gal	$3	$6,600					RSMeans ECHOS 33 19 7104, Rad water, 10,000 gal/day
Laboratory Analytical									
Off Gas									
TO14	52	sample	$450	$23,400					Collect weekly treated off-gas
Shipping	12	sample	$100	$1,200					sample and monthly effluent sample
Treated Water									from groundwater treatment
Total Volatiles	12	sample	$165	$1,980					system.
Shipping	12	ls	$100	$1,200					
Reporting									
Annual Report	1	ls	$25,000	$25,000					
TASK TOTAL				**$165,000**	**1920**		**$98,000**	**$263,000**	

COST ESTIMATE
BGOU SWMUs 2 & 3 Combined
Alternative 9 - In Situ Containment with Long-Term Monitoring

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
Quarterly Groundwater LTM (Years 1 - 5)									
Duration: First five years.									
Assumptions: Quarterly monitoring well sampling. Sample time is 5 hours per well,									
eight wells total, four times a year. IDW is non hazardous and acceptable to U Landfill.									
Labor									
Union									
Senior Rad Control Tech					160	$56	$8,960		Vendor quote for similar work
Field Technician					160	$46	$7,360		Engr Est., PRS Labor Rate
Part-Time									
Radcon Supervisor					40	$74	$2,960		Vendor quote for similar work
Equipment									
Pickup Truck, crew cab, F250	1	month	$1,300	$1,300					Hertz
Laboratory Analytical									Analytical rates from PRS Lab Coord.
Metals 6010	36	sample	$165	$5,940					Samples collected from eight wells
VOA 8260	36	sample	$165	$5,940					QA/QC 10%.
Rad	36	sample	$1,041	$37,476					
Shipping	4	ls	$100	$400					Engr Est.
Reporting									
Report of Findings	4	ls	$5,000	$20,000					Engr Est.
TASK TOTAL				**$71,056**	**360**		**$19,280**	**$91,000**	
Semi-Annual Groundwater LTM (Years 6 - 10)									
Duration: Years six through ten.									
Assumptions: Semi Annual monitoring well sampling. Sample time is 5 hours per well,									
eight wells total, two times a year. IDW is non hazardous and acceptable to U Landfill.									
Labor									
Union									
Senior Rad Control Tech					80	$56	$4,480		Vendor quote for similar work
Field Technician					80	$46	$3,680		Engr Est., PRS Labor Rate
Part-Time									
Radcon Supervisor					20	$74	$1,480		Vendor quote for similar work
Equipment									
Pickup Truck, crew cab, F250	0.5	month	$1,300	$650					Hertz
Laboratory Analytical									Analytical rates from PRS Lab Coord.
Metals 6010	18	sample	$165	$2,970					Samples collected from eight wells
VOA 8260	18	sample	$165	$2,970					QA/QC 10%.
Rad	18	sample	$1,041	$18,738					
Shipping	2	ls	$100	$200					Engr Est.
Reporting									
Report of Findings	2	ls	$5,000	$10,000					Engr Est.
TASK TOTAL				**$35,528**	**0**		**$9,640**	**$46,000**	

COST ESTIMATE
BGOU SWMUs 2 & 3 Combined
Alternative 9 - In Situ Containment with Long-Term Monitoring

	Other Direct Costs				Labor				
Task Description	**Qty**	**Unit**	**Unit Price**	**Total**	**Hours**	**Rate**	**Total**	**Total Cost**	**Basis of Estimate**
Annual Groundwater LTM (Years 11 - 30)									
Duration: Years eleven through thirty.									
Assumptions: Annual monitoring well sampling. Sample time is 5 hours per well,									
eight wells total, once a year. IDW is non hazardous and acceptable to U Landfill.									
Labor									
Union									
Senior Rad Control Tech					40	$56	$2,240		Vendor quote for similar work
Field Technician					40	$46	$1,840		Engr Est., PRS Labor Rate
Part-Time									
Radcon Supervisor					10	$74	$740		Vendor quote for similar work
Equipment									
Pickup Truck, crew cab, F250	0.25	month	$1,300	$325					Hertz
Laboratory Analytical									Analytical rates from PRS Lab Coord.
Metals 6010	9	sample	$165	$1,485					Samples collected from eight wells
VOA 8260	9	sample	$165	$1,485					QA/QC 10%.
Rad	9	sample	$1,041	$9,369					
Shipping	1	ls	$100	$100					Engr Est.
Reporting									
Report of Findings	1	ls	$5,000	$5,000					Engr Est.
TASK TOTAL				**$17,764**	**90**		**$4,820**	**$23,000**	
Five Year Review (5, 10, 15, 20, 25, & 30)									
Five Year Review	1	ls	$50,000	$50,000					Engr Est.
TASK TOTAL				**$50,000**			**$0**	**$50,000**	

Escalated Costs
BGOU SWMUs 2 & 3 Combined
Alternative 9 - In Situ Containment with Long-Term Monitoring

Escalated

Date	Yr	Esca-lation	Esca-lation Factor	Capital	Trmt System and RCRA Cap O&M (Years 1 - 30)	Quarterly GW LTM (Yrs 1 - 5)	Semi-Annual GW LTM (Yrs 6 - 10)	Annual GW LTM (Yrs 11 - 30)	Five Year Reviews	TOTALS
2010		1	1	$34,221,000	$263,000	$91,000	$46,000	$23,000	$50,000	
2011		1.03	1.03							
2012	0	1.03	1.06	$36,305,059						$36,305,059
2013	1	1.03	1.09		$287,387	$99,438				$386,825
2014	2	1.03	1.13		$296,009	$102,421				$398,430
2015	3	1.03	1.16		$304,889	$105,494				$410,383
2016	4	1.03	1.19		$314,036	$108,659				$422,695
2017	5	1.03	1.23		$323,457	$111,919			$61,494	$496,869
2018	6	1.03	1.27		$333,161		$58,271			$391,432
2019	7	1.03	1.30		$343,155		$60,020			$403,175
2020	8	1.03	1.34		$353,450		$61,820			$415,270
2021	9	1.03	1.38		$364,054		$63,675			$427,728
2022	10	1.03	1.43		$374,975		$65,585		$71,288	$511,848
2023	11	1.03	1.47		$386,224			$33,776		$420,001
2024	12	1.03	1.51		$397,811			$34,790		$432,601
2025	13	1.03	1.56		$409,745			$35,833		$445,579
2026	14	1.03	1.60		$422,038			$36,908		$458,946
2027	15	1.03	1.65		$434,699			$38,015	$82,642	$555,357
2028	16	1.03	1.70		$447,740			$39,156		$486,896
2029	17	1.03	1.75		$461,172			$40,331		$501,503
2030	18	1.03	1.81		$475,007			$41,541		$516,548
2031	19	1.03	1.86		$489,257			$42,787		$532,044
2032	20	1.03	1.92		$503,935			$44,070	$95,805	$643,811
2033	21	1.03	1.97		$519,053			$45,392		$564,446
2034	22	1.03	2.03		$534,625			$46,754		$581,379
2035	23	1.03	2.09		$550,664			$48,157		$598,820
2036	24	1.03	2.16		$567,184			$49,602		$616,785
2037	25	1.03	2.22		$584,199			$51,090	$111,064	$746,353
2038	26	1.03	2.29		$601,725			$52,622		$654,347
2039	27	1.03	2.36		$619,777			$54,201		$673,978
2040	28	1.03	2.43		$638,370			$55,827		$694,197
2041	29	1.03	2.50		$657,521			$57,502		$715,023
2042	30	1.03	2.58		$677,247			$59,227	$128,754	$865,228
TOTAL				$36,305,059	#########	$527,931	$309,371	$907,581	$551,048	$52,274,000

Escalated Costs
BGOU SWMUs 2 & 3 Combined
Alternative 9 - In Situ Containment with Long-Term Monitoring

Unescalated

Date	Yr	Esca-lation	Esca-lation Factor	Capital	Trmt System and RCRA Cap O&M (Years 1 - 30)	Quarterly GW LTM (Yrs 1 - 5)	Semi-Annual GW LTM (Yrs 6 - 10)	Annual GW LTM (Yrs 11 - 30)	Five Year Reviews	TOTALS
2010		1	1	$34,221,000	$263,000	$91,000	$46,000	$23,000	$50,000	
2011		1	1.00							
2012	0	1	1.00	$34,221,000						$34,221,000
2013	1	1	1.00		$263,000	$91,000				$354,000
2014	2	1	1.00		$263,000	$91,000				$354,000
2015	3	1	1.00		$263,000	$91,000				$354,000
2016	4	1	1.00		$263,000	$91,000				$354,000
2017	5	1	1.00		$263,000	$91,000			$50,000	$404,000
2018	6	1	1.00		$263,000		$46,000			$309,000
2019	7	1	1.00		$263,000		$46,000			$309,000
2020	8	1	1.00		$263,000		$46,000			$309,000
2021	9	1	1.00		$263,000		$46,000			$309,000
2022	10	1	1.00		$263,000		$46,000		$50,000	$359,000
2023	11	1	1.00		$263,000			$23,000		$286,000
2024	12	1	1.00		$263,000			$23,000		$286,000
2025	13	1	1.00		$263,000			$23,000		$286,000
2026	14	1	1.00		$263,000			$23,000		$286,000
2027	15	1	1.00		$263,000			$23,000	$50,000	$336,000
2028	16	1	1.00		$263,000			$23,000		$286,000
2029	17	1	1.00		$263,000			$23,000		$286,000
2030	18	1	1.00		$263,000			$23,000		$286,000
2031	19	1	1.00		$263,000			$23,000		$286,000
2032	20	1	1.00		$263,000			$23,000	$50,000	$336,000
2033	21	1	1.00		$263,000			$23,000		$286,000
2034	22	1	1.00		$263,000			$23,000		$286,000
2035	23	1	1.00		$263,000			$23,000		$286,000
2036	24	1	1.00		$263,000			$23,000		$286,000
2037	25	1	1.00		$263,000			$23,000	$50,000	$336,000
2038	26	1	1.00		$263,000			$23,000		$286,000
2039	27	1	1.00		$263,000			$23,000		$286,000
2040	28	1	1.00		$263,000			$23,000		$286,000
2041	29	1	1.00		$263,000			$23,000		$286,000
2042	30	1	1.00		$263,000			$23,000	$50,000	$336,000
TOTAL				$34,221,000	$7,890,000	$455,000	$230,000	$460,000	$300,000	$43,556,000

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX H

SWMU 3 RCRA POST-CLOSURE PERMIT CONDITIONS SUMMARY

(The following is a historical document reprinted in its original format. Pagination and formatting from original document retained.)

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX I-2

C-404 LANDFILL POST CLOSURE PLAN

1. POSTCLOSURE CARE PLAN
C-404 LANDFILL

This plan identifies all steps that will be necessary for the U.S. Department of Energy (DOE) Paducah Gaseous Diffusion Plant (PGDP) to perform postclosure care meeting requirements of 401 *KAR* 34:070, Section 8 (incorporating 40 *CFR* § 264.117) at the C-404 Landfill. The C-404 Landfill began postclosure care under the permit issued in 1992 and will continue for a minimum of 30 years after landfill closure.

The C-404 Low-Level Radioactive Burial Ground is located in the west-central portion of the security-fenced area of PGDP. The C-404 unit originally was constructed in the early 1950s as a rectangular aboveground surface impoundment with a floor area of approximately 53,000 ft^2 (387 ft by 137 ft). The floor of the surface impoundment was constructed of well-tamped earth, and clay dikes provide liquid containment to an operating depth of 6 ft. From 1952 through 1957, the surface impoundment was operated as a neutralization/sedimentation treatment facility for uranium-contaminated waste water generated at the C-400 decontamination facility. From 1957 through 1976, the impoundment was used for the bulk disposal of uranium-contaminated solid waste. The surface impoundment thus was filled with bulk solid wastes to within 1–2 ft of the top of the original dikes. The facility then was covered with compacted earth to the top of the original dikes and sloped to facilitate runoff. The exit weir was converted to an enclosed concrete basin for use as a leachate collection sump.

In 1977, bulk and containerized uranium-contaminated solid wastes were placed on top of the previously filled area. These wastes were then covered with earth. In 1983, the eastern quarter of the site was covered with a clay cap that extends over the out-slope of the dike. One of the types of containerized solid wastes disposed of in the upper portion of the facility was gold dissolver precipitate, a solid waste containing no free liquid. During a routine testing program, the gold dissolver precipitate disposed of in early 1986 was found to be hazardous based upon the Extraction Procedure Toxicity. The C-404 Landfill subsequently was closed by placement of a final cover over the facility.

Postclosure use of the C-404 Landfill never will be allowed to disturb the integrity of the final cover, liner(s), or any other component of the containment system or the function of the facility's monitoring systems, unless the disturbance is necessary and 1) will not increase the potential hazard to human health or the environment or 2) is necessary to reduce a threat to human health or the environment. Access to the landfill will be restricted and maintained through existing security measures including checkpoints, fences, and postings.

1.1 GENERAL FACILITY INSPECTION AND MAINTENANCE

The primary objective of routine inspection is to identify potential problems at an early stage prior to the need for significant maintenance. General facility inspections will be performed on security fences, gates, locks, and HWFP required warning signs quarterly, as applicable. Possible problems may include deterioration, erosion, frost heaves of fence post anchors, normal wear, or vandalism. Maintenance activities may include erosion or sediment control and the repair or replacement of damaged fences, locks, or warning signs.

1.1.1 Landfill Cover

As described in the C-404 Closure Plan, the synthetic liner and vegetative cover installed on the C-404 Landfill is designed to minimize maintenance requirements. The cover shall be inspected quarterly and following any major precipitation event approaching or exceeding a 24-hour, 25-year storm (5.8 inches within 24-hours). The cover will be inspected for surface cracks, erosion, depressions or subsidence, damage to cover by burrowing animals, vegetative stress, or any other factors that might adversely affect proper functioning of the vegetative and landfill cover.

The vegetative cover shall be mowed regularly during the active growing season to discourage the growth of weeds, competitive species, or deep-rooted vegetation. Since C-404 has been designated a radiological contaminated area, mowing will be conducted in such a way as to prevent airborne contaminants.

Damage to the cover by erosion greater than 6-inches deep will be repaired by restoring the cover to its original grade with soil and reseeding. Differential settlement or subsidence will be repaired by restoring the site to its original grade with soil and reseeding. Other repairs, such as eradicating burrowing animals, will be performed as necessary.

1.1.2 Cover Drainage System

The synthetic liner is anchored using a French-type drainage system. Construction details are described in the C-404 Closure Plan. The area surrounding the C-404 Landfill will be inspected quarterly and following any precipitation event approaching or exceeding a 24-hour, 25-year storm (5.8 inches within 24-hours). The area will be inspected for washouts or depressions, which could indicate that the system is plugged or that the drainage pipe has ruptured or collapsed. Drainage pipe failures shall be repaired by removing the failed piece, installing a new section, and replacing the fill material as necessary.

The drain exits shall be monitored following one rainfall event each quarter to check for unusual flow or lack of discharge.

1.2 OPERATION OF THE LEACHATE COLLECTION SYSTEM

The leachate collection system shall be maintained until leachate no longer is generated by the landfill. The quantity of liquid in the leachate collection system shall be monitored at least monthly. Preparation to remove the leachate shall begin when the depth of leachate in the sump exceeds 3 ft. The removed leachate shall be sampled and analyzed for the parameters in Table 1. The results of the leachate analysis will be reviewed prior to proper disposal. Sampling and analytical procedures shall be conducted according to Part C, Waste Analysis Plan, of the HWFP application.

Table 1. List of C-404 Leachate Characterization Analytes

Mercury	Fluoride
Arsenic	Ammonia Nitrate
Selenium	pH
Silver	Trichloroethylene
Barium	Neptunium 237
Cadmium	Technetium 99
Chromium	Thorium 230
Copper	Uranium 234
Iron	Uranium 235
Nickel	Uranium 238
Lead	Plutonium 239
Zinc	

The leachate shall be pumped to a portable tank(s) and stored awaiting appropriate treatment and/or disposition. The leachate collection pit will be inspected quarterly including when the leachate is removed for any major structural deterioration. Cracks and other damage will be repaired as necessary. A leachate sump integrity test will be conducted annually.

1.3 MAINTENANCE OF THE LEAK DETECTION SYSTEM

The C-404 Landfill does not have a leak detection system.

1.4 MAINTAIN AND OPERATE THE GROUNDWATER MONITORING SYSTEM

All groundwater monitoring wells at C-404 will be inspected annually during the third quarter of the calendar year. The wells will be inspected for the condition of the AKGWA identification, the outer casing, the concrete pad, the bumper posts, painting, the well cap, the lettering and numbers, lock and hasp, well access, vegetation control, and well fittings and tubing. Items will be repaired as necessary.

The wells will be inspected annually for excessive sedimentation by performing a depth sounding at each monitoring well.

1.5 RUN ON AND RUNOFF CONTROL SYSTEM

Run on and runoff control is provided by a series of ditches surrounding the C-404 Landfill. This system is discussed in detail in the C-404 Closure Plan. These ditches shall be inspected quarterly and following any major precipitation event approaching or exceeding a 24-hour, 25-year storm (5.8-inches in 24-hours) for obstructions such as debris, excessive sediment, erosion, or any deterioration that might adversely affect the drainage from the landfill cover. Repairs or maintenance may include removal of accumulated debris, sediment, and restoration of the ditch to the original grade. Ditches will be reseeded or additional gravel placed as needed.

1.6 PROTECT AND MAINTAIN SURVEY BENCHMARKS

Benchmarks have been permanently installed at the groundwater monitoring wells. Benchmarks will be inspected annually with the groundwater monitoring wells, and new benchmarks will be installed if necessary.

1.7 RECORDKEEPING AND REPORTING

Inspection records will be recorded on an inspection log or summary. The records will include the date and time of inspection, the name of the inspector, a notation of the observation, and the date and nature of any repairs. Inspection records will be maintained for three years from the date of inspection. Records concerning the operation of the leachate system, including inspection, leachate removal volumes, damage assessment, and repairs undertaken, will be maintained at the facility during the postclosure care period and available for inspection by Kentucky Division of Waste Management (KDWM.)

The annual groundwater flow rate and direction shall be submitted by November 30 of each year of the postclosure period. Analytical results of leachate sampling will be submitted to the KDWM along with semiannual groundwater sampling results. Copies of these groundwater reports, containing analytical data, will be maintained for inspection at the facility.

All Resource Conservation and Recovery Act permitted treatment and storage facilities at the PGDP are owned by DOE. The DOE point of contact during the postclosure care period is as follows.

Mr. William E. Murphie, Manager
Portsmouth/Paducah Project Office
U.S. Department of Energy
1017 Majestic Drive, Suite 200
Lexington, Kentucky 40513

1.8 EXAMPLE INSPECTION FORMS

Attached are examples of the inspection forms that will be used for C-404 inspections.

C-404 Monthly Inspection Summary[1]

Period of Inspection: ____

Leachate Level	Date (M/D/YY)	Level (inches deep)*	Inspector(s)
First monthly leachate level determination			
Second monthly leachate level determination			
Third monthly leachate level determination			

* If the leachate level in the sump is at **3 feet (36 inches)**, then contact the appropriate personnel to initial removal and sampling of leachate AND when leachate is removed, complete the "**C-404 Inspection Checklist for Leachate Removal**."

Notes:

1. If any item is found to be unacceptable and cannot be explained in the space available, the inspector must identify the specific observation and nature of the problem on the "C-404 Inspection Addendum" Form.

C-404 Quarterly Inspection Checklist[1]

Item No.	Inspection Item	Item Description	Inspection Results		Comments/Observations
			A	U	
A	Warning Signs	Four signs around landfill			
B	Vegetative Cover	Gully erosion depth > 6 inches			
		Vegetative die-off			
		Varmint intrusion/burrowing from animals			
		Overgrowth			
		Depressions			
C	Ditches	Debris in ditches			
		Excessive sediment			
		Drainage			
		Erosion			
D	Anchor Trench	Washouts or depressions			
		Lack of discharge			
		Unusual volume or color			
		Drainage (4 drains from landfill)			
E	Leachate System	Level			
		Cracks or damage			

Inspector: ______________________________
(Printed Name)

Signature: ______________________________
Date:_______________Time:____________

A=Acceptable
U=Unacceptable

Notes:

1. If any item is found to be unacceptable, the inspector must identify the specific observation and nature of the problem on the "C-404 Inspection Addendum" Form.

C-404 Annual Inspection Checklist[1,2,3]

Item No.	Inspection Item	Item Description	Inspection Results A	Inspection Results U	Comments
A	Wells	Attach well inspection form			
B	Leachate Pit	Interior malformations			
		Exterior malformations			
		Integrity test (attach data)			
Inspector: ____________ (Printed Name)			Signature:____________ Date:__________ Time:________		

A=Acceptable
U=Unacceptable

Notes:

1. If any item is found to be unacceptable, the inspector must identify the specific observation and nature of the problem on the "C-404 Inspection Addendum" Form.
2. Annual inspection performed during the third quarter of the calendar year.
3. For the integrity test of the leachate pit during the annual inspection, data from the datalogger is downloaded electronically and printed annually, and the attached to the annual inspection checklist for maintaining in the file.

C-404 Inspection Checklist for a 24-Hour Rain Event[1]

Item No.	Inspection Item	Item Description	Inspection Results		Comments/Observations
			A	U	
A	Vegetative Cover	Gully erosion depth > 6 inches			
		Vegetative die-off			
		Varmint intrusion/burrowing from animals			
		Overgrowth			
		Depressions			
B	Ditches	Debris in ditches			
		Excessive sediment			
		Drainage			
		Erosion			
C	Anchor Trench	Washouts or depressions			
		Lack of discharge			
		Unusual volume or color			
		Drainage (4 drains from landfill)			
Inspector:______________________ (Printed Name)			Signature: ______________________ Date:____________ Time:____________		

A=Acceptable
U=Unacceptable

Notes:

1. If any item is found to be unacceptable, the inspector must identify the specific observation and nature of the problem on the "C-404 Inspection Addendum" Form.

C-404 Inspection Checklist for Leachate Removal[1,2]

Leachate Removal Inspection	YES	NO	N/A	Date (M/D/YY)	Volume (gallons)
Was any removal necessary during the quarter?					
Has any leachate removed during the quarter been sampled?					
Date of superficial inspection upon removal of leachate.					
Date of sampling of leachate after removal.					

Item No.	Inspection Item	Item Description	Inspection Results		Comments
			A	U	
A	Leachate Pit	Interior malformations			
		Exterior malformations			

Inspector: ______________________________ (Printed Name)	Signature: ______________________ Date:____________ Time:__________

A=Acceptable
U=Unacceptable

Notes:

1. This form is completed if the leachate level in the sump is at **3 feet (36 inches)** and is being removed.
2. If any item is found to be unacceptable, the inspector must identify the specific observation and nature of the problem on the "C-404 Inspection Addendum" Form.

C-404 Inspection Addendum

Date	Item No.	Observation	Repairs Completed

INSPECTIONS FORM

Inside

SAMPLE POINT :
Location: C-404 Landfill
AKGWA Number:

	Accept	Reject	N/A
AKGWA Number Tag			
Stamped AKGWA Number			
Outer Casing			
Concrete Pad			
Bumper Post			
Painting			
Cap			
Road Access			
Brush/Weed eating/Mowing			
Fittings/Tubing/Pump Repair			
Lettering/Numbers			
Lock and Hasp			

Comments:

Signature: ______________________ Time: __________ Date: ______________

APPENDIX I

RISK ASSESSMENT FOR C-404 (SWMU 3) DISCHARGE DITCH

Subsequent to incorporation of this appendix into the PGDP BGOU Feasibility Study, the Excavation Worker Scenario was renamed to the Outdoor Worker Scenario.

All references to the Excavation Worker Scenario and related exposure assessments and risk characterization assessments made for the Excavation Worker are intended to be applicable to the Outdoor Worker Scenario described in the main body of document and in Appendices A through H.

THIS PAGE INTENTIONALLY LEFT BLANK

I. RISK ASSESSMENT SUMMARY FOR C-404 (SOLID WASTE MANAGEMENT UNIT 3) DISCHARGE DITCH

Future Industrial Worker Scenario (0–1 ft)

Risk assessment calculations have been completed for a future industrial worker scenario, using 2007 surface soil data collected from solid waste management unit (SWMU) 3 ditch locations (003-005 through 003-010) (Figure I.1). The total excess lifetime cancer risk (ELCR), based on maximum concentrations, was computed to be 3.68E-06, with uranium-238 contributing 95.4% of the total risk. The total hazard index (HI) for the site was computed to be 4.37, with antimony contributing 94.9% of the hazard. Both the ELCR and the HI exceed *de minimis* risk levels for an industrial worker. Calculations for the ELCR and HI are attached (Attachment I.1). They were completed using guidance from the 2001 Paducah Gaseous Diffusion Plant (PGDP) Risk Methods Document.

To understand the results of this assessment, the following summary information is provided. It summarizes the technical basis and criteria used to screen the data prior to its use in the risk and hazard calculations.

- *Soil samples*. Only surface samples (0–1 ft bgs) apply to the industrial worker scenario, per the 2001 Risk Methods Document, Section 3.3.4.3. All subsurface samples were removed from the data set.

- *Units of measure*. All inorganic and organic chemicals were converted to mg/kg units and all radionuclides were converted to pCi/g prior to performing risk and hazard calculations.

- *Detect/nondetect status.* Each data point was assigned a detected or nondetected status. Any data with a "U" or "UJ" lab or validation flag was classified as nondetect; all other data points were classified as detects.

- *Essential nutrients.* The seven analytes listed in Section 3.3.3.2 of the 2001 Risk Methods Document (calcium, chloride, iodine, magnesium, potassium, sodium, and phosphorous) were removed from the data set as they are essential nutrients.

- *^{234}Thorium.* ^{234}Thorium, which has a short half-life, was removed from the data set based on previous comments from the regulatory agencies. Protactinium-234, and potassium-40 also would be removed, but were not included in the data set.

- *Nondetects.* Any analyte that was not detected in <u>*any*</u> surface sample (0–1 ft bgs) was removed from the data set.

- *Background Comparison.* The maximum concentration of each of the analytes exhibiting at least one detection was then compared to applicable background concentrations. Background concentrations for surface soils from Table A.12 of the 2001 Risk Methods Document were used in this comparison.

Analytes with at least one detection, and which exceeded background, were retained as chemicals of potential concern (COPCs) and carried through the risk and hazard calculations. The COPCs for the SWMU 3 ditch surface soils include antimony, molybdenum, uranium, trichloroethene (TCE), plutonium-239/240, technetium-99 and uranium-238. Because each COPC had a maximum of six data points, the 95% upper confidence limit (UCL) was not appropriate to compute. Instead, the maximum concentration for each COPC was used as the exposure point concentration (EPC).

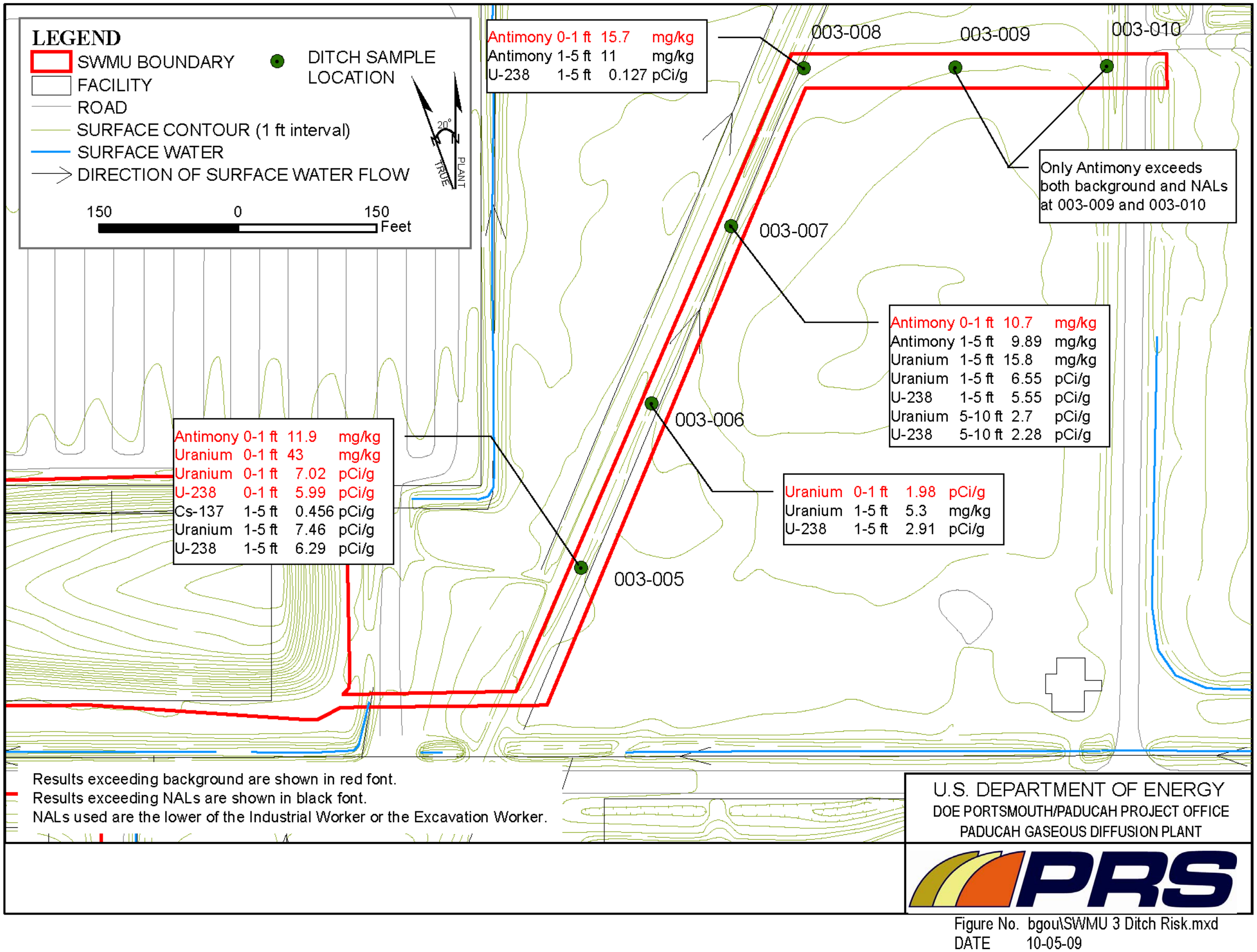


Figure I.1. Analytes Exceeding Background and No Action Limits Within SWMU 3 Ditch

Chronic daily intakes (CDIs) for the following exposure routes were calculated using the equations and default values shown in Appendix D of the 2001 Risk Methods Document:

- Incidental ingestion of soil,
- Inhalation of vapors and particulates from soil,
- Dermal contact with soil, and
- External exposure to ionizing radiation from soil.

Exposure to groundwater was not included in this assessment as it was not considered to be a complete pathway for an industrial worker. The following information was employed in developing risk and hazard estimates.

- Toxicity values used in the risk and hazard calculations were the same as those used in the Burial Grounds Operable Unit (BGOU) Remedial Investigation (RI), with the exception of molybdenum and plutonium-239/240, which were not retained as groundwater COPCs in the BGOU RI.

- Toxicity values for molybdenum and plutonium-239/240 were obtained from the 2001 Risk Methods Document to facilitate development of risk and hazard estimates.

- Dermal slope factors (SFs) and reference doses (RfDs) were calculated as specified in U.S. Environmental Protection Agency (EPA's) Risk Assessment Guidance for Superfund (RAGS) Part E using gastrointestinal absorption factors (GIABS) from the 2001 Risk Methods Document.

- ELCRs and HIs were calculated using equations 10 through 15 in the 2001 Risk Methods Document.

There is always a degree of uncertainty associated with all risk assessments. The following details elements of uncertainty associated with the assessment of potential human health risks and hazards associated with industrial use of the SWMU 3 ditch.

1. As discussed above, maximum concentrations were used to compute human health risks and hazard indices, rather than upper confidence limits (UCLs). UCLs were not employed due to the very limited number of data points available (six). This is standard industry practice, as small data sets can greatly increase the uncertainty in estimating the mean/UCL. Use of the maximum value is in keeping with EPA and PGDP accepted guidance; however, end data users should be aware that using maximum concentrations is a health-protective conservative approach to developing risk and hazard estimates. On-site receptors would not constantly be exposed to the maximum concentration of a COPC, so using these values is likely to overestimate the receptor's exposure. An overestimate of exposure would lead to an overestimation of risk and hazard. The impact of using maximum values in the assessment is low.

2. It is also important for decision makers to note the difference in GIABS factors between the 2001 Risk Methods Document and the EPA RAGS Part E, particularly for antimony. The majority of the total HI for the industrial worker comes from dermal absorption of antimony (94.5%). The dermal RfD of 8.00E-06 mg/kg x day used in the hazard calculations was generated using the 2001 Risk Methods Document GIABS value for antimony (0.02). If the GIABS value for antimony from the EPA RAGS Part E (0.15) were used to calculate the dermal RfD, it becomes 6.00E-05 mg/kg x day. Using this dermal RfD lowers the total HI from 4.37 to 0.791 and below the *de minimis* hazard level of 1.0. The dermal ABS factor for antimony used in the risk assessment included here also differs the dermal ABS factor in current guidance from EPA Region 4. The dermal ABS in the Region 4C supplemental guidance suggests 0.1% dermal ABS; the dermal ABS from RAGS used in the existing risk assessment is 5% dermal ABS. Use of the Region 4 value would lower the dermally absorbed dose 50 fold from the current estimates; the HI would be lowered to 0.141 even without adjustment of the GIABS as discussed above. The uncertainty associated with the choice of dermal ABS factors is high, and use of the lower dermal ABS factor reduces the total HI below

the *de minimis* hazard level of 1.0. The uncertainty associated with GIABS and dermal ABS factors for antimony is medium to high.

3. The analytical method used by United States Enrichment Corporation (USEC) for determining uranium concentrations does not digest the uranium as fully as the method used to determine the uranium concentration for the PGDP background study. Therefore, comparisons of uranium concentrations that are less than 10 pCi/g to the background values may result in uranium isotopes being eliminated as below background when they are actually elevated slightly above background. Uranium-234 was not retained as a COPC as the maximum detected activity was less than background. However, uranium-234 would only contribute 0.1% of the total ELCR and does not change the total risk estimate. The effect of the difference in digestion recovery between the two methods is minimal and the uncertainty associated with the use of the two different methods is therefore small.

Future Excavation Worker Scenario (0 ft –10 ft)

Risk assessment calculations have also been completed for a future excavation worker scenario. The attached tables (Attachments I.1 and I.2) use 2007 surface (Table I.1) and subsurface (Table I.2) soil data collected from SWMU 3 ditch locations (003–005 through 003–008). The total ELCR, based on maximum concentrations, was computed to be 7.46E-06, with cesium-137 contributing 71.2% and uranium-238 contributing 25.2% of the total risk. The total HI for the site was computed to be 4.23, with antimony contributing 97.9% of the hazard. Both the ELCR and the HI exceed *de minimis* risk levels for an excavation worker. Calculations are attached (Attachment I.2). They were completed using guidance from the 2001 PGDP Risk Methods Document.

To understand the results of this cursory assessment, the following summary information is provided. It summarizes the technical basis and criteria used to screen the data prior to its use in the risk and hazard calculations.

- *Soil samples*. Both surface and subsurface (0–10 ft bgs) apply to the excavation worker scenario, per the 2001 Risk Methods Document, Section 3.3.4.3. All samples collected at depths below 10 ft bgs were removed from the data set.

- *Units of measure*. All inorganic and organic chemicals were converted to mg/kg units and all radionuclides were converted to pCi/g prior to performing risk and hazard calculations.

- *Detect/nondetect status.* Each data point was assigned a detected or non-detected status. Any data with a "U" or "UJ" lab or validation flag was classified as nondetect; all other data points were classified as detects.

- *Essential nutrients.* The seven analytes listed in Section 3.3.3.2 of the 2001 Risk Methods Document (calcium, chloride, iodine, magnesium, potassium, sodium, and phosphorous) were removed from the data set as they are essential nutrients.

- *Thorium.* Thorium-234, which has a short half-life, was removed from the data set based on previous comments from the regulatory agencies. Protactinium-234 and potassium-40 would also be removed, but were not included in the data set.

- *Nondetects.* Any analyte that was not detected in <u>any</u> surface or subsurface sample (0–10 ft bgs) was removed from the data set.

- *Background Comparison.* The maximum concentration for any analytes exhibiting at least one detection was compared to applicable background concentrations. Background concentrations from Table A.12 from the 2001 Risk Methods Document were used in this comparison.

Table I.1. Surface Soil Summary SWMU 3 Ditch (0–1 ft)
(Locations 003–005 through 003–010)

Analysis	Maximum Detection	Frequency of Detection[a]	Frequency Detected above Background[b]	Cleanup Value[c]
Metals (mg/kg)				
Antimony	15.7	4/6	4/6	NA
Molybdenum	6.21	4/6	NA	NA
Uranium	43	4/6	3/6	227
Organics—Volatiles (mg/kg)				
Trichloroethene	0.00633	1/5	NA	NA
Radionuclides (pCi/g)				
Plutonium-239/240	0.0562	1/6	1/6	108
Technetium-99	21.6	3/6	3/6	3,825
Uranium-238	5.99	6/6	2/6	94

NA—not applicable
[a] Frequency of detection is the number of detection of an analyte per number of analyses (includes regular and duplicate samples).
[b] Background values are taken from DOE 2001. Results of samples collected 0-1 ft were compared to surface background values. All other results were compared to subsurface values.
[c] Cleanup values are taken from the Surface Water Operable Unit (On-site) Removal Action (DOE 2009).

Table I.2. Subsurface Soil Summary SWMU 3 Ditch (0–10 ft)
(Locations 003–005 through 003–008)

Analysis	Maximum Detection	Frequency of Detection[a]	Frequency Detected above Background[b]	Cleanup Value[c]
Metals (mg/kg)				
Antimony	15.7	5/13	5/13	NA
Molybdenum	3.78	3/13	NA	NA
Uranium	43	8/13	7/13	227
Organics—Volatiles (mg/kg)				
Trichloroethene	0.00633	1/12	NA	NA
Radionuclides (pCi/g)				
Cesium-137	0.456	2/13	3/13	8
Plutonium-239/240	0.0562	2/13	2/13	108
Technetium-99	56.9	6/13	6/13	3,825
Uranium-238	6.29	10/13	6/13	94

NA—not applicable
[a] Frequency of detection is the number of detection of an analyte per number of analyses (includes regular and duplicate samples).
[b] Background values are taken from DOE 2001. Results of samples collected 0-1 ft were compared to surface background values. All other results were compared to subsurface values. All results for plutonium-239/240 were compared to surface background values for plutonium-239.
[c] Cleanup values are taken from the Surface Water Operable Unit (On-site) Removal Action (DOE 2009).

Those analytes with at least one detection and exceeding background were retained as COPCs and carried through the risk and hazard calculations. The COPCs for the SWMU 3 ditch surface soils include antimony, molybdenum, uranium, TCE, cesium-137, plutonium-239/240, technetium-99 and uranium-238. The 95% UCL was used as the EPC for total uranium and uranium-238, as there were a sufficient number of detections for these COPCs (eight and ten, respectively). The remaining COPCs each had seven or fewer detections, making computation of the 95% UCL inappropriate. For these COPCs, the maximum concentration was used as the EPC.

CDIs for the following exposure routes were calculated using the equations and default values shown in Appendix D of the 2001 Risk Methods Document:

- Incidental ingestion of soil,
- Inhalation of vapors and particulates from soil,
- Dermal contact with soil, and
- External exposure to ionizing radiation from soil.

Exposure to groundwater was not included in this assessment as it was not considered to be a complete pathway for an excavation worker. The following information was employed in developing risk and hazard estimates.

- Toxicity values used in the risk and hazard calculations were the same as those used in the BGOU RI, with the exception of molybdenum, cesium-137 and plutonium-239/240, which were not retained as groundwater COPCs in the BGOU RI.

- Toxicity values for molybdenum, cesium-137 and plutonium-239/240 were obtained from the 2001 Risk Methods Document to facilitate development of risk and hazard estimates.

- SFs and RfDs were calculated as specified in EPA's RAGS Part E using GIABS from the 2001 Risk Methods Document.

- ELCRs and HIs were calculated using equations 10 through 15 in the 2001 Risk Methods Document.

There is always a degree of uncertainty associated with all risk assessments. The following details elements of uncertainty associated with the assessment of potential human health risks and hazards associated with industrial use of the SWMU 3 ditch.

1. As discussed above, with the exception of total uranium and uranium-238, maximum concentrations were used to compute human health risks and hazard indices, rather than UCLs. UCLs were not employed due to the limited number of detections. This is standard industry practice, as small data sets can greatly increase the uncertainty in estimating the mean/CL. Use of the maximum value is in keeping with EPA and PGDP accepted guidance; however, end data users should be aware that using maximum concentrations is a conservative approach to developing risk and hazard estimates. On-site receptors would not constantly be exposed to the maximum concentration of a COPC, so using these values is likely to overestimate the receptor's exposure. An overestimate of exposure would lead to an overestimation of risk and hazard. The impact of using maximum values in the assessment is low.

2. It is also important for decision makers to note the difference in GIABS factors between the 2001 Risk Methods Document and the EPA RAGS Part E, particularly for antimony. The majority of the total HI for the excavation worker comes from dermal absorption of antimony (97.9%). The dermal RfD of 8.00E-06 mg/kg x day used in the hazard calculations was generated using the 2001 Risk Methods Document GIABS value for antimony (0.02). If the GIABS value for antimony from the EPA RAGS Part E (0.15) were used to calculate the dermal RfD, it becomes 6.00E-05 mg/kg x day. Using this dermal RfD lowers the total HI

from 4.23 to 0.657 and below the *de minimis* hazard level of 1.0. The dermal ABS factor for antimony used in the risk assessment included here also differs the dermal ABS factor in current guidance from EPA Region 4. The dermal ABS in the Region 4C supplemental guidance suggests 0.1% dermal ABS; the dermal ABS from KRAGS used in the existing risk assessment is 5% dermal ABS. Use of the Region 4 value would lower the dermally absorbed dose 50 fold from the current estimates; the HI would be lowered to 0.117 even without adjustment of the GIABS as discussed above. The uncertainty associated with the choice of dermal ABS factors is high, and use of the lower dermal ABS factor reduces the total HI below the *de minimis* hazard level of 1.0. The uncertainty associated with using GIABS and dermal ABS values for antimony is medium to high.

3. The analytical method used by USEC for determining uranium concentrations does not digest the uranium as fully as the method used to determine the uranium concentration for the PGDP background study. Comparisons of uranium concentrations that are less than 10 pCi/g to the background values may result in uranium isotopes being eliminated as below background when they are actually elevated slightly above background. Uranium-234 was not retained as a COPC, as the maximum detected activity was less than background. Uranium-234 does not contribute (i.e., 0.0% contribution) to the total ELCR and does not change the total risk estimate. The effect of the difference in digestion recovery between the two methods is minimal, and the uncertainty associated with the use of the two different methods is therefore small.

Conclusions

The risk assessment for the C-404 (SWMU 3) Discharge Ditch addresses cancer risk and noncancer hazard associated with potential exposure of future industrial workers to COCs located in surface soil (0-1 ft bgs) and potential future excavation workers to COCs in subsurface soil (1–10 ft bgs). The risk assessment was focused on antimony, molybdenum, uranium, TCE, plutonium-239/240, technetium-99, and uranium-238 that were identified as COPCs in surface soil and on antimony, molybdenum, uranium, TCE, cesium-137, plutonium-239/240, technetium-99, and uranium-238 in subsurface soil.

Future Industrial Worker Scenario

The risk assessment notes that ELCR to a future industrial worker at the SWMU 3 Ditch is estimated at 3.86E-06, with uranium-238 contributing 95.4% of the total risk, which is within the acceptable ELCR range of 1E-06 to 1E-04 specified in the National Contingency Plan (NCP) (EPA 1994) and below the target ELCR criterion described in Section 2.3.3 of this FS. The noncancer HI estimated for industrial worker exposures to surface soil is estimated at 4.37, with antimony contributing 94.9% of the total HI, which exceeds the acceptable value of 1 established in the NCP and the target HI criterion. The discussion of uncertainties associated with the assessment indicates that the high estimate for the noncancer hazard is related to uncertainties in the GIABS factor and the ABS for antimony used in the estimation of dermal exposures. The uncertainty in these factors arises from differences in the values provided in Table B.5 of the DOE Risk Methods Document (DOE 2001), and updated values provided in more recent EPA RAGS Part E guidance (EPA 2004a). The risk assessment notes that if the noncancer hazard HI value for antimony were based on the GIABS and ABS factors for antimony from the EPA (2004) guidance rather than the higher factors contained in the DOE (2001) Risk Methods Document, the noncancer HI for antimony would be lowered to 0.141, which is below the *de minimis* HI value of 1. Use of the updated GIABS and ABS factors would support a conclusion of no unacceptable cancer risk or noncancer hazard to the future industrial worker at the SWMU 3 Ditch. The use of updated information, as it becomes available, is consistent with the 2001 RMD.

Future Excavation Worker Scenario

The risk assessment notes that the ELCR to a future excavation worker exposed to subsurface soil at the SWMU 3 Ditch is estimated at 7.46E-06 with cesium-137 contributing 71.2% and uranium-238 contributing 25.2% of the total risk. The total ELCR is within the acceptable range of 1E-06 to 1E-04 specified in the NCP and below the target ELCR criterion for subsurface soil described in Section 2.3.3 of this FS.

The noncancer HI estimated for excavation worker exposures to subsurface soil is estimated at 4.23, with antimony contributing 97.9% of the total HI, which exceeds the acceptable value of 1 established in the NCP. As above, the assessment indicates that the high estimate for the noncancer hazard is related to uncertainties in the GIABS and ABS factors for antimony. The risk assessment notes that if the noncancer hazard HI value for antimony were based on the GIABS and ABS factors for antimony from the EPA (2004) guidance rather than the higher factors contained in the DOE (2001) Risk Methods Document, the noncancer HI for antimony would be lowered to 0.657, below the *de minimis* HI value of 1. Use of the updated GIABS and ABS factors would support a conclusion of no unacceptable cancer or noncancer hazard to the future excavation worker at the SWMU 3 Ditch.

Comparison to Cleanup Levels

Postexcavation Cleanup Levels for antimony, molybdenum, uranium, TCE, cesium-137, plutonium-239/240, technetium-99, and uranium-238 are given in *Removal Action Work Plan for Contaminated Sediment Associated with the Surface Water Operable Unit (On-Site) at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0221&D2, August 2009. With the exception of antimony, which is described above, the only COPCs exceeding either their background or NAL concentrations along the SWMU 3 Ditch were cesium-137, uranium-238 and uranium metal. The cleanup levels for these COPCs are provided in Appendix F, Table F.1 of that document as follows:

Contaminant of Concern	Cleanup Level
Cesium-137	8 pCi/g
Uranium-238	94 pCi/g
Uranium	227 mg/kg

The concentrations of these COPCs measured in both surface and subsurface soil at locations in the SWMU 3 Ditch are shown in the ditch sample location map (Appendix I, pg I-4). The maximum cesium-137 concentration shown in the figure is 0.456 pCi/g, the maximum uranium-238 concentration is 6.29 pCi/g, and the maximum uranium concentration is 43 mg/kg; therefore, these comparisons support a conclusion that no action for the SWMU 3 Ditch is required.

ATTACHMENT I.1

FUTURE INDUSTRIAL AND EXCAVATION WORK SCENARIO CALCULATIONS

THIS PAGE INTENTIONALLY LEFT BLANK

Hazard Index Calculation for Industrial Worker

						Chronic Toxicity (RfD)				SWMU 3 Ditch										
COPC	Ingestion Intake (II_{ing}) without Cs	ABS	Dermal Intake (DI) w/o ABS & Cs	Inhalation Intake (II_{inh}) without Cs	External exposure Intake (EI) w/o Cs	Ingestion	Dermal	Inhalation	External Exposure	EPC (C)	Ingestion Intake Hazard	Dermal Intake Hazard	Inhalation Intake Hazard	External Exposure Hazard	IngestionHQ	Dermal HQ	Inhalation HQ	External Exposure	Chemical HI	% Contribution
Inorganic Chemicals (Metals)																				
Antimony	4.89E-07	5.00E-02	4.21E-05	6.10E-12	NA	4.00E-04	8.00E-06	NA	NA	1.57E+01	7.68E-06	3.30E-05	9.57E-11	NA	1.92E-02	4.13E+00	NA	NA	4.15E+00	94.9%
Molybdenum	4.89E-07	5.00E-02	4.21E-05	6.10E-12	NA	5.00E-03	1.90E-03	NA	NA	6.21E+00	3.04E-06	1.31E-05	3.79E-11	NA	6.08E-04	6.88E-03	NA	NA	7.48E-03	0.2%
Uranium	4.89E-07	5.00E-02	4.21E-05	6.10E-12	NA	6.00E-04	5.10E-04	NA	NA	4.30E+01	2.10E-05	9.05E-05	2.62E-10	NA	3.51E-02	1.77E-01	NA	NA	2.12E-01	4.9%
Organic Compounds																				
TCE	4.89E-07	2.50E-01	4.21E-05	5.67E-05	NA	3.00E-04	4.50E-05	1.14E-02	NA	6.33E-03	3.10E-09	6.66E-08	3.59E-07	NA	1.03E-05	1.48E-03	3.15E-05	NA	1.52E-03	0.0%
Radionuclides																				
Plutonium-239/240	3.13E+02	NA	NA	3.89E-03	4.57E+00	NA	NA	NA	NA	5.62E-02	1.76E+01	NA	2.19E-04	2.57E-01	NA	NA	NA	NA	0.00E+00	0.0%
Technetium-99	3.13E+02	NA	NA	3.89E-03	4.57E+00	NA	NA	NA	NA	2.16E+01	6.75E+03	NA	8.41E-02	9.86E+01	NA	NA	NA	NA	0.00E+00	0.0%
Uranium-238	3.13E+02	NA	NA	3.89E-03	4.57E+00	NA	NA	NA	NA	5.99E+00	1.87E+03	NA	2.33E-02	2.74E+01	NA	NA	NA	NA	0.00E+00	0.0%
														Cumulative Values:	5.49E-02	4.31E+00	3.15E-05	0.00E+00	**4.37E+00**	**100.0%**
														% Contribution:	1.3%	98.7%	0.0%	0.0%	100.0%	

Ingestion Calculation

Chemical Intake [mg/(kg x day)] = [C*CF*EF*FI*ED*IR/(BW*AT)]
Radionuclide Intake (pCi) = [A*CF_{rad}*EF*ED*IR*FI]

Industrial Worker

A =	5.62E-02	pCi/g $^{239/240}$Pu
CF =	1.00E-06	kg/mg
EF =	250	d/yr
FI =	1	
ED =	25	yr
IR =	50	mg/d
BW =	70	kg
ATnc = ED x 365 =	9125	yr-day/yr
CF_{rad} =	1.00E-03	g/mg
$II_{ing-chemical}$ =	4.89E-07	
$II_{ing-rad}$ =	3.13E+02	
Radionuclide Intake $^{239/240}$Pu =	1.76E+01	**Cell L13**

Dermal Contact Calculation

Absorbed Dose [mg/(kg x day)] = [C*CF_d*SA*AF*ABS*EF*ED/(BW*AT)]

Industrial Worker

C =	1.57E+01	mg/kg as Antimony
CF_d =	1.00E-02	kg-cm^2/mg-m^2
SA =	0.43	m^2/d
AF =	1	mg/cm^2
ABS =	5.00E-02	for Antimony
EF =	250	d/yr
ED =	25	yr
BW =	70	kg
ATnc = ED x 365 =	9125	yr-day/yr
DI w/o Cs & ABS =	4.21E-05	
Absorbed Dose Antimony =	3.30E-05	**Cell M7**

Inhalation Calculation

Chemical Intake [mg/(kg x day)] = [C*EF*ED*ET*(1/VF+1/PEF)*IR_{air}] / (BW * AT)
Radionuclide Intake (pCi) = [A*EF*ED*ET*CF*(1/VF+1/PEF)*IR_{air}]

Industrial Worker

A =	5.62E-02	pCi/g $^{239/240}$Pu
EF =	250	d/yr
ED =	25	yr
ET =	8	hr/d
VF_{TCE}=	3.45E+03	m^3/kg
PEF =	3.21E+10	m^3/kg
IR_{air} =	2.5	m^3/hr
BW =	70	kg
ATnc = ED x 365 =	9125	yr-day/yr
CF =	1.00E+03	g/kg
$II_{inh-TCE}$ =	5.67E-05	
$II_{inh-metals}$ =	6.10E-12	
$II_{inh-rad}$=	3.89E-03	
Radionuclide Intake $^{239/240}$Pu =	2.19E-04	**Cell N13**

Absorbed Dose Calculation

Absorbed Dose = [A_s*ED*EF*(1-S_e)*T_e]

Industrial Worker

A_s =	5.62E-02	pCi/g $^{239/240}$Pu
EF =	6.85E-01	d/d
ED =	25	yr
S_e =	0.2	
T_e	3.33E-01	hr/hr
EI =	4.57E+00	yr
Absorbed Dose $^{239/240}$Pu =	2.57E-01	**Cell O13**

Attachment I.1. Future Industrial Worker Scenario Calculations

Risk Calculation for Industrial Worker

COPC	Ingestion Intake (II_{ing}) without Cs	ABS	Dermal Intake (DI) w/o ABS & Cs	Inhalation Intake (II_{inh}) without Cs	External exposure Intake (EI) w/o Cs	Cancer Toxicity (SF) Ingestion	Dermal	Inhalation	External Exposure	SWMU 3 Ditch EPC (C)	Ingestion Intake Risk	Dermal Intake Risk	Inhalation Intake Risk	External Exposure Risk	IngestionELCR	Dermal ELCR	Inhalation ELCR	External Exposure	Chemical ELCR	% Contribution
Inorganic Chemicals (Metals)																				
Antimony	1.75E-07	5.00E-02	1.50E-05	2.18E-12	NA	NA	NA	NA	NA	1.57E+01	2.74E-06	1.18E-05	3.42E-11	NA	NA	NA	NA	NA	0.00E+00	0.0%
Molybdenum	1.75E-07	5.00E-02	1.50E-05	2.18E-12	NA	NA	NA	NA	NA	6.21E+00	1.09E-06	4.67E-06	1.35E-11	NA	NA	NA	NA	NA	0.00E+00	0.0%
Uranium	1.75E-07	5.00E-02	1.50E-05	2.18E-12	NA	NA	NA	NA	NA	4.30E+01	7.51E-06	3.23E-05	9.36E-11	NA	NA	NA	NA	NA	0.00E+00	0.0%
Organic Compounds																				
TCE	1.75E-07	2.50E-01	1.50E-05	2.03E-05	NA	3.22E-01	2.67E+00	3.22E-01	NA	6.33E-03	1.11E-09	2.38E-08	1.28E-07	NA	3.56E-10	6.35E-08	4.13E-08	NA	1.05E-07	2.9%
Radionuclides																				
Plutonium-239/240	3.13E+02	NA	NA	3.89E-03	4.57.E+00	2.77E-10	NA	3.33E-08	2.00E-10	5.62E-02	1.76E+01	NA	2.19E-04	2.57E-01	4.86E-09	NA	7.29E-12	5.13E-11	4.92E-09	0.1%
Technetium-99	3.13E+02	NA	NA	3.89E-03	4.57.E+00	7.66E-12	NA	1.41E-11	8.14E-11	2.16E+01	6.75E+03	NA	8.41E-02	9.86E+01	5.17E-08	NA	1.19E-12	8.03E-09	5.97E-08	1.6%
Uranium-238	3.13E+02	NA	NA	3.89E-03	4.57.E+00	2.10E-10	NA	9.35E-09	1.14E-07	5.99E+00	1.87E+03	NA	2.33E-02	2.74E+01	3.93E-07	NA	2.18E-10	3.12E-06	3.51E-06	95.4%
														Cumulative Values:	4.50E-07	6.35E-08	4.15E-08	3.13E-06	**3.68E-06**	**100.0%**
														% Contribution:	12.2%	1.7%	1.1%	84.9%	100.0%	

Ingestion Calculation

Chemical Intake [mg/(kg x day)] = [C*CF*EF*FI*ED*IR/(BW*AT)]
Radionuclide Intake (pCi) = [A*CF_{rad}*EF*ED*IR*FI]

Industrial Worker

A =	5.62E-02	pCi/g $^{239/240}$Pu
CF =	1.00E-06	kg/mg
EF =	250	d/yr
FI =	1	
ED =	25	yr
IR =	50	mg/d
BW =	70	kg
ATc = 70 x 365 =	25550	yr-day/yr
CF_{rad} =	1.00E-03	g/mg
$II_{ing\text{-}chemical}$ =	1.75E-07	
$II_{ing\text{-}rad}$ =	3.13E+02	
Radionuclide Intake $^{239/240}$Pu =	1.76E+01	**Cell L13**

Dermal Contact Calculation

Absorbed Dose [mg/(kg x day)] = [C*CF_d*SA*AF*ABS*EF*ED/(BW*AT)]

Industrial Worker

C =	1.57E+01	mg/kg as Antimony
CF_d =	1.00E-02	kg-cm^2/mg-m^2
SA =	0.43	m^2/d
AF =	1	mg/cm^2
ABS =	5.00E-02	for Antimony
EF =	250	d/yr
ED =	25	yr
BW =	70	kg
ATc = 70 x 365 =	25550	yr-day/yr
DI w/o Cs & ABS =	1.50E-05	
Absorbed Dose Antimony =	1.18E-05	**Cell M7**

Inhalation Calculation

Chemical Intake [mg/(kg x day)] = [C*EF*ED*ET*(1/VF+1/PEF)*IR_{air}] / (BW * AT)
Radionuclide Intake (pCi) = [A*EF*ED*ET*CF*(1/VF+1/PEF)*IR_{air}]

Industrial Worker

A =	5.62E-02	pCi/g $^{239/240}$Pu
EF =	250	d/yr
ED =	25	yr
ET =	8	hr/d
VF_{TCE}=	3.45E+03	m^3/kg
PEF =	3.21E+10	m^3/kg
IR_{air} =	2.5	m^3/hr
BW =	70	kg
AT =	25550	yr-day/yr
CF =	1.00E+03	g/kg
$II_{inh\text{-}TCE}$ =	2.03E-05	
$II_{inh\text{-}metals}$ =	2.18E-12	
$II_{inh\text{-}rad}$=	3.89E-03	
Radionuclide Intake $^{239/240}$Pu =	2.19E-04	**Cell N13**

Absorbed Dose Calculation

Absorbed Dose = [A_s*ED*EF*(1-S_e)*T_e]

Industrial Worker

A_s =	5.62E-02	pCi/g $^{239/240}$Pu
EF =	6.85E-01	d/d
ED =	25	yr
S_e =	0.2	
T_e	3.33E-01	hr/hr
EI =	4.57E+00	yr
Absorbed Dose$^{239/240}$Pu =	2.57E-01	**Cell O13**

Attachment I.1. Future Industrial Worker Scenario Calculations (Continued)

Hazard Index Calculation for Excavation Worker

						Chronic Toxicity (RfD)				SWMU 3 Ditch										
COPC	Ingestion Intake (II_{ing}) without Cs	ABS	Dermal Intake (DI) w/o ABS & Cs	Inhalation Intake (II_{inh}) without Cs	External exposure Intake (EI) w/o Cs	Ingestion	Dermal	Inhalation	External Exposure	EPC (C)	Ingestion Intake Hazard	Dermal Intake Hazard	Inhalation Intake Hazard	External Exposure Hazard	IngestionHQ	Dermal HQ	Inhalation HQ	External Exposure	Chemical HI	% Contribution
Inorganic Chemicals (Metals)																				
Antimony	4.89E-07	5.00E-02	4.21E-05	6.10E-12	NA	4.00E-04	8.00E-06	NA	NA	1.57E+01	7.68E-06	3.30E-05	9.57E-11	NA	1.92E-02	4.13E+00	NA	NA	4.15E+00	97.9%
Molybdenum	4.89E-07	5.00E-02	4.21E-05	6.10E-12	NA	5.00E-03	1.90E-03	NA	NA	3.78E+00	1.85E-06	7.95E-06	2.30E-11	NA	3.70E-04	4.19E-03	NA	NA	4.56E-03	0.1%
Uranium	4.89E-07	5.00E-02	4.21E-05	6.10E-12	NA	6.00E-04	5.10E-04	NA	NA	1.64E+01	8.03E-06	3.45E-05	1.00E-10	NA	1.34E-02	6.77E-02	NA	NA	8.11E-02	1.9%
Organic Compounds																				
TCE	4.89E-07	2.50E-01	4.21E-05	5.67E-05	NA	3.00E-04	4.50E-05	1.14E-02	NA	6.33E-03	3.10E-09	6.66E-08	3.59E-07	NA	1.03E-05	1.48E-03	3.15E-05	NA	1.52E-03	0.0%
Radionuclides																				
Cesium-137	3.13E+02	NA	NA	3.89E-03	4.57E+00	NA	NA	NA	NA	4.56E-01	1.43E+02	NA	1.78E-03	2.08E+00	NA	NA	NA	NA	0.00E+00	0.0%
Plutonium-239/240	3.13E+02	NA	NA	3.89E-03	4.57E+00	NA	NA	NA	NA	5.62E-02	1.76E+01	NA	2.19E-04	2.57E-01	NA	NA	NA	NA	0.00E+00	0.0%
Technetium-99	3.13E+02	NA	NA	3.89E-03	4.57E+00	NA	NA	NA	NA	5.69E+01	1.78E+04	NA	2.22E-01	2.60E+02	NA	NA	NA	NA	0.00E+00	0.0%
Uranium-238	3.13E+02	NA	NA	3.89E-03	4.57E+00	NA	NA	NA	NA	3.21E+00	1.00E+03	NA	1.25E-02	1.46E+01	NA	NA	NA	NA	0.00E+00	0.0%
														Cumulative Values:	3.30E-02	4.20E+00	3.15E-05	0.00E+00	**4.23E+00**	**100.0%**
														% Contribution:	0.8%	99.2%	0.0%	0.0%	100.0%	

Ingestion Calculation

Chemical Intake [mg/(kg x day)] = [C*CF*EF*FI*ED*IR/(BW*AT)]
Radionuclide Intake (pCi) = [A*CF_{rad}*EF*ED*IR*FI]

Industrial Worker

A =	5.62E-02	pCi/g $^{239/240}$Pu
CF =	1.00E-06	kg/mg
EF =	250	d/yr
FI =	1	
ED =	25	yr
IR =	50	mg/d
BW =	70	kg
ATnc = ED x 365 =	9125	yr-day/yr
CF_{rad} =	1.00E-03	g/mg
$II_{ing\text{-}chemical}$ =	4.89E-07	
$II_{ing\text{-}rad}$ =	3.13E+02	
Radionuclide Intake $^{239/240}$Pu =	1.76E+01	**Cell L13**

Dermal Contact Calculation

Absorbed Dose [mg/(kg x day)] = [C*CF_d*SA*AF*ABS*EF*ED/(BW*AT)]

Industrial Worker

C =	1.57E+01	mg/kg as Antimony
CF_d =	1.00E-02	kg-cm^2/mg-m^2
SA =	0.43	m^2/d
AF =	1	mg/cm^2
ABS =	5.00E-02	for Antimony
EF =	250	d/yr
ED =	25	yr
BW =	70	kg
ATnc = ED x 365 =	9125	yr-day/yr
DI w/o Cs & ABS =	4.21E-05	
Absorbed Dose Antimony =	3.30E-05	**Cell M7**

Inhalation Calculation

Chemical Intake [mg/(kg x day)] = [C*EF*ED*ET*(1/VF+1/PEF)*IR_{air}] / (BW * AT)
Radionuclide Intake (pCi) = [A*EF*ED*ET*CF*(1/VF+1/PEF)*IR_{air}]

Industrial Worker

A =	5.62E-02	pCi/g $^{239/240}$Pu
EF =	250	d/yr
ED =	25	yr
ET =	8	hr/d
VF_{TCE}=	3.45E+03	m^3/kg
PEF =	3.21E+10	m^3/kg
IR_{air} =	2.5	m^3/hr
BW =	70	kg
ATnc = ED x 365 =	9125	yr-day/yr
CF =	1.00E+03	g/kg
$II_{inh\text{-}TCE}$ =	5.67E-05	
$II_{inh\text{-}metals}$ =	6.10E-12	
$II_{inh\text{-}rad}$=	3.89E-03	
Radionuclide Intake $^{239/240}$Pu =	2.19E-04	**Cell N13**

Absorbed Dose Calculation

Absorbed Dose = [A_s*ED*EF*(1-S_e)*T_e]

Industrial Worker

A_s =	5.62E-02	pCi/g $^{239/240}$Pu
EF =	6.85E-01	d/d
ED =	25	yr
S_e =	0.2	
T_e	3.33E-01	hr/hr
EI =	4.57E+00	yr
Absorbed Dose $^{239/240}$Pu =	2.57E-01	**Cell O13**

Attachment I.2. Future Excavation Worker Scenario Calculations

Risk Calculation for Excavation Worker

						Cancer Toxicity (SF)				SWMU 3 Ditch										
COPC	Ingestion Intake (II_{ing}) without Cs	ABS	Dermal Intake (DI) w/o ABS & Cs	Inhalation Intake (II_{inh}) without Cs	External exposure Intake (EI) w/o Cs	Ingestion	Dermal	Inhalation	External Exposure	EPC (C)	Ingestion Intake Risk	Dermal Intake Risk	Inhalation Intake Risk	External Exposure Risk	IngestionELCR	Dermal ELCR	Inhalation ELCR	External Exposure	Chemical ELCR	% Contribution
Inorganic Chemicals (Metals)																				
Antimony	1.75E-07	5.00E-02	1.50E-05	2.18E-12	NA	NA	NA	NA	NA	1.57E+01	2.74E-06	1.18E-05	3.42E-11	NA	NA	NA	NA	NA	0.00E+00	0.0%
Molybdenum	1.75E-07	5.00E-02	1.50E-05	2.18E-12	NA	NA	NA	NA	NA	3.78E+00	6.60E-07	2.84E-06	8.23E-12	NA	NA	NA	NA	NA	0.00E+00	0.0%
Uranium	1.75E-07	5.00E-02	1.50E-05	2.18E-12	NA	NA	NA	NA	NA	1.64E+01	2.87E-06	1.23E-05	3.58E-11	NA	NA	NA	NA	NA	0.00E+00	0.0%
Organic Compounds																				
TCE	1.75E-07	2.50E-01	1.50E-05	2.03E-05	NA	3.22E-01	2.67E+00	3.22E-01	NA	6.33E-03	1.11E-09	2.38E-08	1.28E-07	NA	3.56E-10	6.35E-08	4.13E-08	NA	1.05E-07	1.4%
Radionuclides																				
Cesium-137	3.13E+02	NA	NA	3.89E-03	4.57.E+00	4.33E-11	NA	1.19E-11	2.55E-06	4.56E-01	1.43E+02	NA	1.78E-03	2.08E+00	6.17E-09	NA	2.11E-14	5.31E-06	5.32E-06	71.2%
Plutonium-239/240	3.13E+02	NA	NA	3.89E-03	4.57.E+00	2.77E-10	NA	3.33E-08	2.00E-10	5.62E-02	1.76E+01	NA	2.19E-04	2.57E-01	4.86E-09	NA	7.29E-12	5.13E-11	4.92E-09	0.1%
Technetium-99	3.13E+02	NA	NA	3.89E-03	4.57.E+00	7.66E-12	NA	1.41E-11	8.14E-11	5.69E+01	1.78E+04	NA	2.22E-01	2.60E+02	1.36E-07	NA	3.12E-12	2.11E-08	1.57E-07	2.1%
Uranium-238	3.13E+02	NA	NA	3.89E-03	4.57.E+00	2.10E-10	NA	9.35E-09	1.14E-07	3.21E+00	1.00E+03	NA	1.25E-02	1.46E+01	2.10E-07	NA	1.17E-10	1.67E-06	1.88E-06	25.2%
														Cumulative Values:	3.58E-07	6.35E-08	4.14E-08	7.00E-06	**7.46E-06**	**100.0%**
														% Contribution:	4.8%	0.9%	0.6%	93.8%	100.0%	

Ingestion Calculation

Chemical Intake [mg/(kg x day)] = [C*CF*EF*FI*ED*IR/(BW*AT)]
Radionuclide Intake (pCi) = [A*CF_{rad}*EF*ED*IR*FI]

Industrial Worker

A =	5.62E-02	pCi/g $^{239/240}$Pu
CF =	1.00E-06	kg/mg
EF =	250	d/yr
FI =	1	
ED =	25	yr
IR =	50	mg/d
BW =	70	kg
ATc = 70 x 365 =	25550	yr-day/yr
CF_{rad} =	1.00E-03	g/mg
$II_{ing\text{-}chemical}$ =	1.75E-07	
$II_{ing\text{-}rad}$ =	3.13E+02	
Radionuclide Intake $^{239/240}$Pu =	1.76E+01	**Cell L13**

Dermal Contact Calculation

Absorbed Dose [mg/(kg x day)] = [C*CF_d*SA*AF*ABS*EF*ED/(BW*AT)]

Industrial Worker

C =	1.57E+01	mg/kg as Antimony
CF_d =	1.00E-02	kg-cm^2/mg-m^2
SA =	0.43	m^2/d
AF =	1	mg/cm^2
ABS =	5.00E-02	for Antimony
EF =	250	d/yr
ED =	25	yr
BW =	70	kg
ATc = 70 x 365 =	25550	yr-day/yr
DI w/o Cs & ABS =	1.50E-05	
Absorbed Dose Antimony =	1.18E-05	**Cell M7**

Inhalation Calculation

Chemical Intake [mg/(kg x day)] = [C*EF*ED*ET*(1/VF+1/PEF)*IR_{air}] / (BW * AT)
Radionuclide Intake (pCi) = [A*EF*ED*ET*CF*(1/VF+1/PEF)*IR_{air}]

Industrial Worker

A =	5.62E-02	pCi/g $^{239/240}$Pu
EF =	250	d/yr
ED =	25	yr
ET =	8	hr/d
VF_{TCE}=	3.45E+03	m^3/kg
PEF =	3.21E+10	m^3/kg
IR_{air} =	2.5	m^3/hr
BW =	70	kg
AT =	25550	yr-day/yr
CF =	1.00E+03	g/kg
$II_{inh\text{-}TCE}$ =	2.03E-05	
$II_{inh\text{-}metals}$ =	2.18E-12	
$II_{inh\text{-}rad}$=	3.89E-03	
Radionuclide Intake $^{239/240}$Pu =	2.19E-04	**Cell N13**

Absorbed Dose Calculation

Absorbed Dose = [A_s*ED*EF*(1-S_e)*T_e]

Industrial Worker

A_s =	5.62E-02	pCi/g $^{239/240}$Pu
EF =	6.85E-01	d/d
ED =	25	yr
S_e =	0.2	
T_e	3.33E-01	hr/hr
EI =	4.57E+00	yr
Absorbed Dose $^{239/240}$Pu =	2.57E-01	**Cell O13**

Attachment I.2. Future Excavation Worker Scenario Calculations (Continued)