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

Volume 1. Main Text

I-04611-0119

Cleared for Public Release

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

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

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Internal Draft
Primary Document

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

Volume 1. Main Text

Date Issued—June 2001

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

by
Bechtel Jacobs Company LLC
managing the

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

for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-98OR22700

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DOE Contract No. DE-AC05-98OR22700
Job No. 23900
June 13, 2001

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

Subject: Transmittal of the *Feasibility Study for the Groundwater Operable Unit at Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* (DOE/OR/07-1857) Internal Draft Primary Document

Dear Mr. Seaborg:

At the direction of the Department of Energy (DOE), 13 copies of the subject document for review and approval are enclosed. The subject document consists of five volumes. Volume I is in a hard-copy format, and Volumes II-V are on a compact disk (CD). By June 13, 2001, seven copies of the complete document are to be transmitted to the following at the state regulatory agencies: Ms. Gaye Brewer, Mr. Steve Hampson, Mr. Tuss Taylor (three), Mr. John Volpe, and Mr. Mike Welch, and three copies are to be transmitted to Mr. Carl Froede at the U.S. Environmental Protection Agency. The remaining three copies are for your use. Also enclosed is suggested text for your use in transmitting the documents. This document is under a 14-day review period. Please request that the regulatory comments be provided both in hard copy, and, electronically, to DOE by Friday, July 6, 2001.

It is a pleasure assisting you on this project. If you have any questions or need additional information, please contact Mark Gage of my staff at 5125.

Sincerely,

Gordon L. Dover
Paducah Manager of Projects

GLD:ll
LTR-PAD/EP-LL-01-0058

Enclosures: 1. Subject document (13 copies, including CDs)
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PREFACE

This Feasibility Study for the Groundwater Operable Unit at Paducah Gaseous Diffusion Plant, Paducah, Kentucky, DOE/OR/07-1857&D (Internal Draft) was prepared to evaluate remedial alternatives for potential application to the Groundwater Operable Unit groundwater contamination located at the United States Department of Energy's Paducah Gaseous Diffusion Plant (PGDP). This work was performed under Bechtel Jacobs Company LLC subcontract 23900-BA-RM086F. Publication of this document will meet a primary document deliverable for the DOE pursuant to the PGDP's Federal Facility Agreement. This feasibility study was prepared in accordance with the U.S. Environmental Protection Agency's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA/540/G-89/004).

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ACRONYMS AND ABBREVIATIONS

1-D	one-dimensional
ACO	Administrative Order by Consent
AFIT	Air Force Institute of Technology
ALARA	as low as reasonably achievable
amsl	above mean sea level
AOC	Area of Concern
ARAR	applicable or relevant and appropriate requirement
AT123D	Analytical Transient 1-, 2-, 3-Dimensional Model
BGOU	Burial Grounds Operable Unit
bgs	below ground surface
BHHRA	baseline human health risk assessment
BMP	Best Management Practice
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
CM	contaminant migration
COC	contaminant of concern
COE	U.S. Army Corps of Engineers
COPC	contaminant of potential concern
CWA	Clean Water Act
DAT	Deployment Assistance Team
DCG	derived concentration guideline
DNAPL	dense nonaqueous phase liquid
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DUS	Dynamic Underground Stripping
EDE	effective dose equivalent
ELCR	excess lifetime cancer risk
EPA	U.S. Environmental Protection Agency
FFA	Federal Facility Agreement
FR	*Federal Register*
FS	feasibility study
FY	fiscal year
GWOU	Groundwater Operable Unit
HEC	Hydrologic Engineering Center Computer Program
HI	hazard index
HPO	hydrous pyrolysis oxidation
HSWA	Hazardous and Solid Waste Amendments
HU	hydrologic unit
IP	integrator points
ITRD	Innovative Treatment Remediation Demonstration
KAR	Kentucky Administrative Regulations
KDEP	Kentucky Department for Environmental Protection
KPDES	Kentucky Pollutant Discharge Elimination System
LUCAP	Land Use Control Assurance Plan
LUCIP	Land Use Control Implementation Plan
M&I	management and integration

MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MEPAS	Multimedia Environmental Pollutant Assessment System (software)
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NSDD	North-South Diversion Ditch
NWP	Nationwide Permit
O&M	operation and maintenance
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PGDP	Paducah Gaseous Diffusion Plant
PPE	personal protective equipment
PRAP	proposed remedial action plan
PRG	preliminary remediation goal
PRP	potentially responsible party
PTZ	permeable treatment zone
RAO	remedial action objective
RAGS	*Risk Assessment Guidance for Superfund*
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RGA	Regional Gravel Aquifer
RGO	remedial goal option
RI	remedial investigation
ROD	record of decision
SDWA	Safe Drinking Water Act
SESOIL	Seasonal Soil Compartment Model
SMP	Site Management Plan
SOU	Soils Operable Unit
SVE	soil vapor extraction
SWMU	solid waste management unit
SWOU	Surface Water Operable Unit
T&E	threatened and endangered
TBC	to be considered
TCE	trichloroethene
TSCA	Toxic Substances Control Act
TVA	Tennessee Valley Authority
UCRS	Upper Continental Recharge System
USEC	United States Enrichment Corporation
UST	underground storage tank
VOC	volatile organic compound
WAG	waste area group
WKWMA	Western Kentucky Wildlife Management Area

EXECUTIVE SUMMARY

The U.S. Department of Energy (DOE) is conducting environmental restoration activities at the Paducah Gaseous Diffusion Plant (PGDP) under the DOE Environmental Management and Enrichment Facilities Program. Remedial efforts are required to address groundwater contamination that has resulted from previous waste-handling and disposal practices. The DOE is conducting these remedial activities in compliance with the requirements of the Commonwealth of Kentucky and the U.S. Environmental Protection Agency (EPA) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). This act requires the usable groundwater to be remediated and brought back to beneficial use within a time frame that is reasonable given the particular circumstances of the site.

SCOPE

Source units and areas of contamination at the PGDP have been combined into operable units. One such operable unit is the Groundwater Operable Unit (GWOU). The GWOU has been identified in the PGDP Site Management Plan as a priority for remedial action because it includes suspected sources of off-site contamination (DOE 1999). Representatives of DOE, EPA, and the Commonwealth of Kentucky have evaluated the solid waste management units (SWMUs) applicable to the GWOU. As a result of these meetings, the GWOU contains SWMUs and areas of concern (AOCs) that previously were grouped in Waste Area Groupings (WAGs) 6, 26, 27, and 28. Table ES.1 contains the listing of SWMUs that are included in the GWOU. The potential remedial technologies for the groundwater contamination associated with these SWMUs are being addressed in this feasibility study (FS). Also, as a result of the decisions made by the representative agencies, the SWMUs C-749 Burial Ground (SWMU 2), C-404 Burial Ground (SWMU 3), and C-747 Burial Grounds (SWMUs 4, 7, and 30), although having been identified as suspected sources of groundwater contamination, were deferred to the Burial Grounds Operable Unit (BGOU). The decision was predicated on the fact that all burial grounds contain waste materials that would be a continuing source of contaminants to groundwater until remediated. These waste cells may contain materials that could be an ongoing source of groundwater contamination, and it may be technically difficult to gain access to the underlying groundwater contamination while the waste cell material still is intact. Furthermore, since the remedial alternatives under consideration for the BGOU may include excavation of the burial grounds, the technical circumstances suggest it would be more effective and efficient to coordinate implementation of the groundwater actions with the waste cell actions that ultimately will be selected under the BGOU. Therefore, groundwater actions for these specific burial grounds are being deferred from the GWOU to the BGOU. Table ES.1 footnotes contain the listing of burial ground SWMUs to which groundwater remedial measures are being deferred (i.e., the BGOU).

As a result of decisions reached by the representatives of DOE, EPA, and the Commonwealth of Kentucky, it was determined that the scope of this FS will include the target contaminants of trichloroethene (TCE), TCE dense nonaqueous-phase liquid (DNAPL), TCE degradation products, and technetium-99 (^{99}Tc). The detailed analysis will be performed on alternatives containing a single applicable technology. The technologies receiving complete detailed analyses were those contained in the eight alternatives (previously combined into treatment trains) as described in the D1 GWOU FS. These technologies were categorized by the zone in which the contaminants of concern (COCs) are contained. These zones include Primary Source Areas, Secondary Source Areas, and Dissolved Phase Plume Areas. The definitions of these groups as applied in this D2 documents are as follows.

- Primary Source Areas are those areas with the target contaminants present and have DNAPL concentrations in the surficial soils and soils of the Upper Continental Recharge System (UCRS) located above the Regional Gravel Aquifer (RGA).

Table ES.1. GWOU SWMUs[b]

Location	SWMU No.	Description	Active Remediation Operable Unit
WAG 6	11	C-400 Trichloroethene Leak Site (GW)	GWOU
	26	C-400 to C-404 Underground Transfer Line (GW)	GWOU
	40	C-403 Neutralization Tank (GW)	GWOU
	47	C-400 Technetium Storage Tank Area (GW)	GWOU
	203	C-400 Sump (GW)	GWOU
WAG 27	1	C-747-C Oil Land Farm	GWOU
	196	C-746-A Septic System (GW)	GWOU
	209	C-720 Compressor Shop Pit Sump (GW)	GWOU
	211	C-720 TCE Spill Site Northeast	GWOU
WAG 28*	99	C-745 Kellogg Building Site (previously AOC #C) (GW)	GWOU
	183	McGraw Underground Storage Tank (UST) (GW)	GWOU
	193	McGraw Const Facilities (Southside Cylinder Yards) (GW)	GWOU
	194	McGraw Construction Facilities (Southside) (GW)	GWOU
	204	Dykes Road Historical Staging Area (GW)	GWOU
WAG 26	201	Northwest Groundwater Plume	GWOU
	202	Northeast Groundwater Plume	GWOU
	210	Southwest Groundwater Plume	GWOU
Lasagna	91	UF_6 Cylinder Drop Test Area	Lasagna[b]

[a] Potential GWOU source areas including WAG 22 (SWMUs 2, 3, 7, and 30) and WAG 3 (SWMU 4) have been deferred to the BGOU.
[b] Lasagna is the name of a developing remediation technology that is being implemented at SWMU 91 to address the source of soil and groundwater contamination.

- Secondary Source Areas are those areas with the target contaminants present and have DNAPL concentrations in the RGA.

- Dissolved Phase Plume Areas are those areas within the RGA that contain the target compounds, but have no DNAPL concentrations present.

The technologies that received detailed analysis are as follows:

• Primary Source Area	Vapor Extraction Technology
	Direct Heating Technology
	Excavation Technology
• Secondary Source Areas	Steam Extraction Technology
	Pump-and-Treat Technology
	Oxidation Technology
• Dissolved Phase Plume Area	Pump-and-Treat Technology
	Ozonation Technology
	Permeable Treatment Zone Technology
	Oxidation Technology
	Bioremediation Technology

Previous remedial investigations (RIs) of the WAGs that compose the GWOU, along with data gathered through routine monitoring, have provided the necessary information to develop the following conclusions concerning groundwater in the RGA and the UCRS.

- Three groundwater plumes (Southwest Plume, Northwest Plume, and Northeast Plume) exist in the RGA. Two of the plumes, the Northwest Plume and the Northeast Plume, have migrated offsite (outside of the DOE property). The Southwest Plume has migrated to the unsecured area outside the PGDP security fence but remains within the DOE property boundary.

- The three groundwater plumes are the result of the release of contaminants at multiple source areas around PGDP, with the largest being the C-400 Decontamination Building area in WAG 6.

- The concentration of TCE contamination in soil and water samples from the C-400 Building area indicates that free-product TCE exists in the UCRS and the RGA.

- The levels of TCE contamination at the C-720 Building and SWMU 1 (WAG 27) suggest the presence of free-product TCE in the UCRS soils only.

- ^{99}Tc contaminant concentrations exist throughout the Northwest and Southwest Plumes and in limited portions of the Northeast Plume located inside the PGDP Security Fence, but do not result in excessive risk to the off-site groundwater user. ^{99}Tc concentrations have been measured onsite (inside security fence) in excess of 16,000 and 5,000 pCi/L in the Northwest and Southwest Plumes, respectively, which correlates to 6×10^{-4} and 2×10^{-4} excess lifetime cancer risk (ELCR), respectively, to a residential groundwater user. These considerations also equate to doses to a residential groundwater user of 16 and 5 mrem/yr for water drawn from the respective plumes.

- A summary of these previous investigations is contained in the Data Summary Report (DSR), which is included as Appendix A of this report. Also, these investigations, through a baseline risk assessment, have identified a limited number of COCs that would impact an off-site groundwater user or the Little Bayou Creek. Little Bayou Creek receives groundwater discharges from the RGA, downgradient of the PGDP. However, the primary COCs that drive the need for action, as demonstrated in the baseline risk assessment and by fate and transport modeling, are TCE, its degradation products (1,1-dichloroethene, 1,2-dichloroethene, and vinyl chloride), and ^{99}Tc.

The organic compounds are considered primary COCs for the GWOU for several reasons. First, their contribution to total ELCR and noncancer hazards in most areas at and around the plant is much greater than that of other contaminants (see Fig. ES.1). Second, the uncertainty associated with the estimates of risk and hazard for TCE and its degradation products is much smaller than that of other contaminants. Third, fate and transport modeling indicates that TCE and its degradation products are likely to persist in the environment and be the dominant contributors to unacceptable risk and hazard for the foreseeable future.

Several reasons also exist for considering ^{99}Tc as a primary COC. First, this radionuclide's migration in the environment is very rapid and movement to off-site locations is known to occur. Second, significant risk to humans may occur if ^{99}Tc in groundwater enters the human foodchain (i.e., in farm produce and fish). Third, ^{99}Tc has a long half-life and will persist in the environment for the foreseeable future.

Transuranics, beryllium, and various inorganic chemicals (i.e., metals) also were detected in samples during the groundwater field investigations, but are not considered primary COCs for this FS. The primary reason for this decision is that the frequency of detection for those compounds was not consistent, and detections at elevated concentrations were not widespread. Also, the levels did not substantially increase risk as compared to the primary COCs.

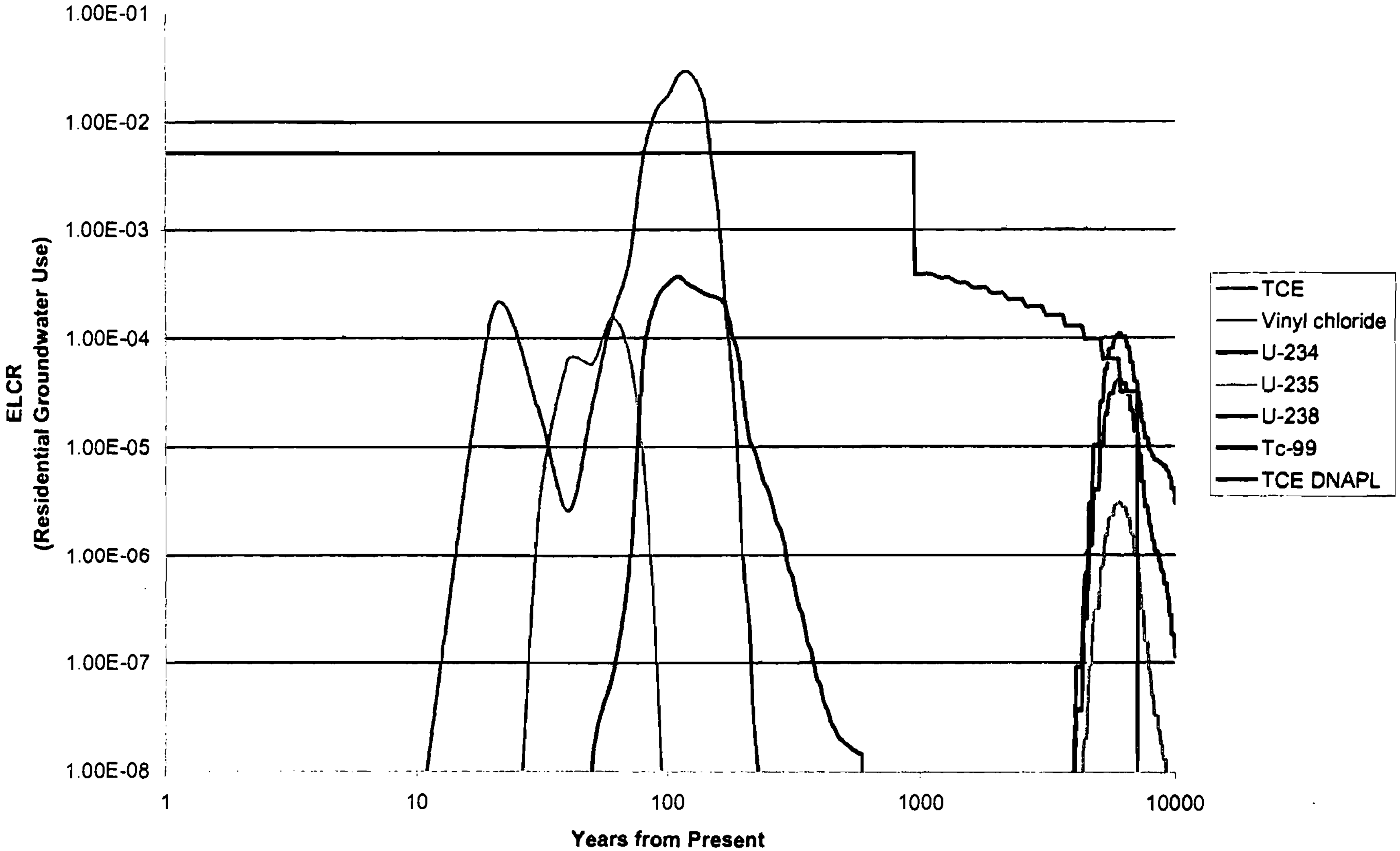


Fig. ES.1. Summary of excess lifetime cancer risk from all sources at the DOE property boundary.

U. S. DEPARTMENT OF ENERGY
DOE OAK RIDGE OPERATIONS
PADUCAH GASEOUS DIFFUSION PLANT

BECHTEL JACOBS COMPANY, LLC
MANAGED FOR THE US DEPARTMENT OF ENERGY UNDER US GOVERNMENT CONTRACT DE-AC-05-98OR22700
Oak Ridge, Tennessee • Paducah, Kentucky • Portsmouth, Ohio

Science Applications International Corporation
P.O. Box 2502
Oak Ridge, Tennessee 37831

FIGURE ES1
DATE 05-14-01

The DSR develops a conceptual site model of the PGDP. This conceptual site model is a representation of known site conditions and is intended to provide a framework for the assessment of the FS. The PGDP is one of two active uranium enrichment facilities in the United States. It is a large industrial plant that has been in operation since 1951. The security-fenced perimeter surrounds a total of 748 acres, which includes four main process buildings, a maintenance and stores building, a cleaning building, electrical switchyards, cooling towers, and other support facilities, as well as burial grounds and large storage yards housing cylinders of depleted uranium by-product.

TCE, a common industrial solvent, and ^{99}Tc, a man-made radioisotope, are the two primary groundwater contaminants previously known to be associated with the PGDP. Both TCE and ^{99}Tc have migrated offsite as dissolved contamination: the Northeast Plume (TCE); the Northwest Plume (TCE and ^{99}Tc); and the Southwest Plume (TCE and ^{99}Tc). Recent RIs of suspected source areas to groundwater contamination have revealed that additional COCs are present onsite: mainly several metals, carbon tetrachloride, and TCE degradation compounds. However, these contaminants do not appear to be widespread offsite.

Both geology and the continuing operation of the plant control the contaminant migration directions. The PGDP overlies the buried south bank of the ancestral (Pleistocene-age) Tennessee River. The sand and gravel deposit of the ancestral Tennessee River, at a depth of 20 to 30 m (60 to 90 ft) onsite, forms the shallow aquifer beneath the PGDP and the contiguous land extending north to the Ohio River. This aquifer, known as the RGA, is the primary pathway for contaminant migration to off-site areas. Groundwater flows north in the RGA to discharge into the Ohio River.

The dominant east-to-west orientation of the sand and gravel units (direction of flow in the ancestral Tennessee River), in combination with leakage from the plant water utilities, causes groundwater flow to diverge in the immediate vicinity of the PGDP. Thus, the Northeast and Southwest Plumes leave the security-fenced area on the east and west sides, respectively, and the Northwest Plume migrates offsite from near the northwest corner of the security-fenced area. The Northeast Plume (principally TCE) and the Northwest Plume (both TCE and ^{99}Tc) extend northward from the PGDP for several kilometers (km). The Southwest Plume (both TCE and ^{99}Tc) appears to have developed relatively recently and reaches approximately 0.5 km beyond the security fence.

Most of the groundwater contamination present at the PGDP is due to spillage and leaks from historic processes. TCE was the primary organic solvent used in degreasing operations at the PGDP from the 1950s through the 1980s. The on-site use of TCE was discontinued in July 1993. The remaining sources of TCE to groundwater are secondary TCE accumulations in the subsurface as free product and leaking burial grounds (Table ES.2).

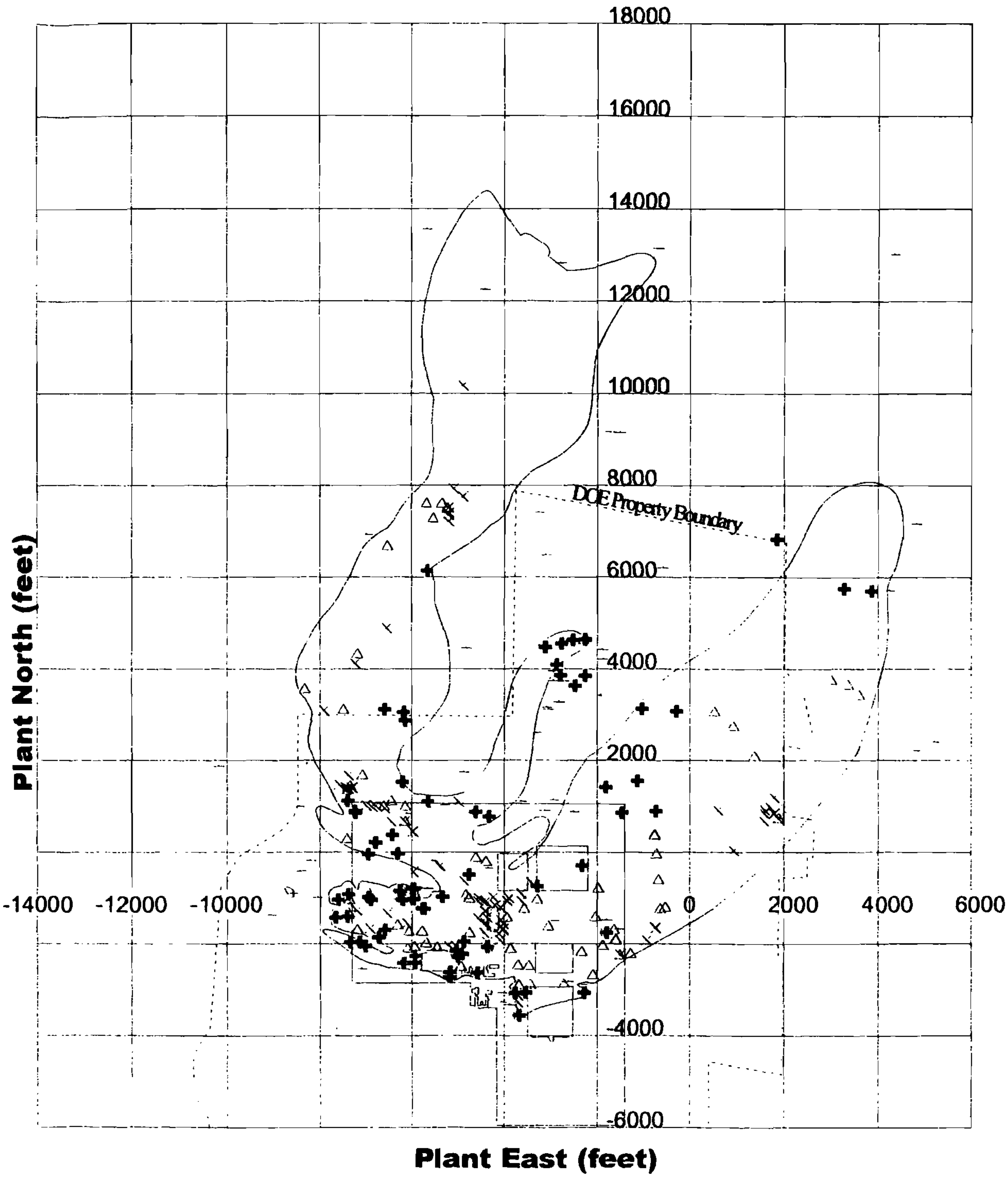
This FS used the extensive groundwater database of the PGDP to assess the nature and extent of groundwater contamination. The risk assessments of previous RIs at the PGDP had identified three major contaminant groups associated with the PGDP: volatile organic compounds (VOCs), metals, and radionuclides.

Carbon tetrachloride, TCE, and several TCE degradation products make up the VOCs found onsite. Other than TCE (Fig. ES.2), *cis*-1,2-dichloroethene (Fig. ES.3) is the only other VOC to be found frequently offsite (in the Northeast Plume). The primary COCs from previous risk assessments include 16 metals. Of these metals, aluminum, iron, and manganese appear ubiquitous at concentrations significantly exceeding background levels. All three of these metals are easily biased high in groundwater samples by typical collection methods and may not necessarily be related to releases from the PGDP. Of the remaining primary metal COCs, chromium (Fig. ES.4) is the only one to be found frequently in off-site groundwater at

Table ES.2. Representative known and suspected TCE source zones at the PGDP

	Free Product Zone	Source Zone Volume (meters^3)	Free Product Volume (liters)	Setting	Operable Unit Assignment for Source Zone
	Northwest Plume				
UCRS	C-400 (Southeast) TCE Transfer Pump	5,228	107,259	Heavy industrial setting	GWOU
	C-400 (Southeast) Leak Site (SWMU 11)				
	C-400 South End Storm Sewer	4,164	85,427	Heavy industrial setting	GWOU
	C-747-A Burial Ground (SWMU 7)	28,037	Unknown, may be small	Zone below mixed-waste burial cell	BGOU
	C-745-B Cylinder Drop Test Area (SWMU 91)	5,947	1,635	Remediation technology selected (Lasagna™)	GWOU
RGA	C-400 (Southeast) TCE Transfer Pump	16,911	547,822	Heavy industrial setting	GWOU
	C-400 (Southeast) Leak Site (SWMU 11)	623	20,189	Heavy industrial setting	GWOU
	C-400 South End Storm Sewer	139	4,500	Heavy industrial setting	GWOU
	Southwest Plume				
UCRS	Southeast C-720 Building Storm Sewer	368	6,624	Heavy industrial setting	GWOU
	Northeast Corner of C-720 Building	9	189	Moderate industrial setting	GWOU
	C-747-C Former Oil Landfarm (SWMU 1)	9	189	Grassed field	GWOU
	C-749 Uranium Burial Ground (SWMU 2)	27,187	<1,703	Zone below pyrophoric uranium burial ground	BGOU
	C-404 Low-Level Waste Burial Ground (SWMU 3)	73,825	Unknown, may be small	Zone below RCRA-closed, mixed-waste burial ground	BGOU
	C-747-C Contaminated Burial Yard (SWMU 4)	Small	>4,000	Grassed field	BGOU
	TCE Spill Site (SWMU 136)	46	<189	Roofed drum storage pad	No Assignment
	Northeast Plume				
UCRS	C-403 Neutralization Pit (SWMU 40)	146	3,002	Heavy industrial setting	GWOU
RGA	Undefined Source	Small	> 4,000	Near northeast corner of C-333 Building	GWOU
	Terrace Deposits				
	Dykes Road Historical Staging Area (AOC 204)	4	<189	Level field bisected by deep drainage ditch	SSOU

AOC = area of concern
DNAPL = dense nonaqueous-phase liquid
RCRA = Resource Conservation and Recovery Act
RGA = Regional Gravel Aquifer
SSOU = Surface Soils Operable Unit
SWMU = solid waste management unit
TCE = trichloroethene
UCRS = Upper Continental Recharge System



LEGEND:
<5 ppb
>=5 ppb
>=100 ppb
>=1000 ppb

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DOE OAK RIDGE OPERATIONS
PADUCAH GASEOUS DIFFUSION PLANT

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Oak Ridge, Tennessee • Paducah, Kentucky • Portsmouth, Ohio

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Oak Ridge, Tennessee 37831

Fig. ES.2. Trichloroethene levels in the RGA at PGDP.

Figure No. FSES-2
DATE 05-21-01

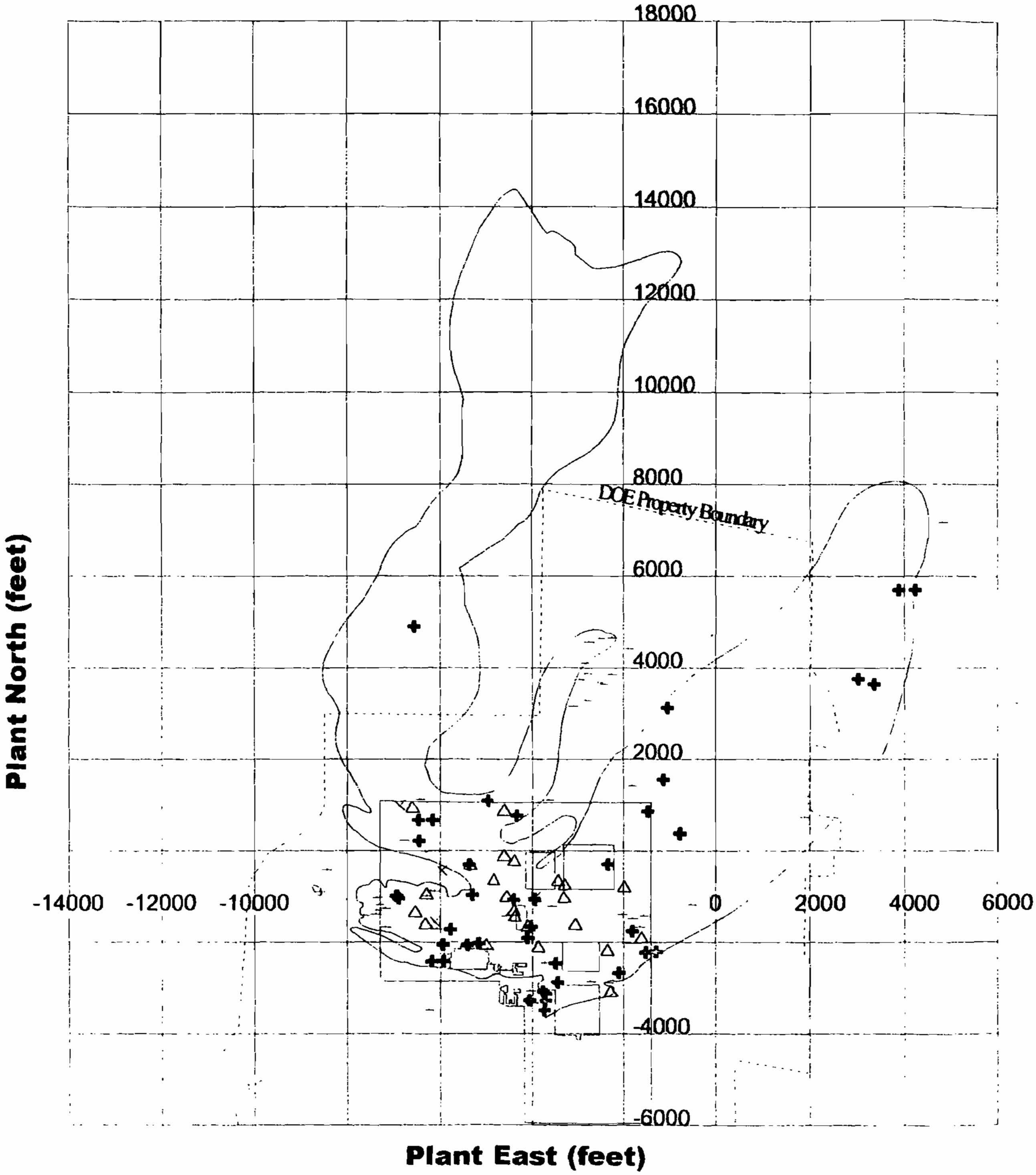

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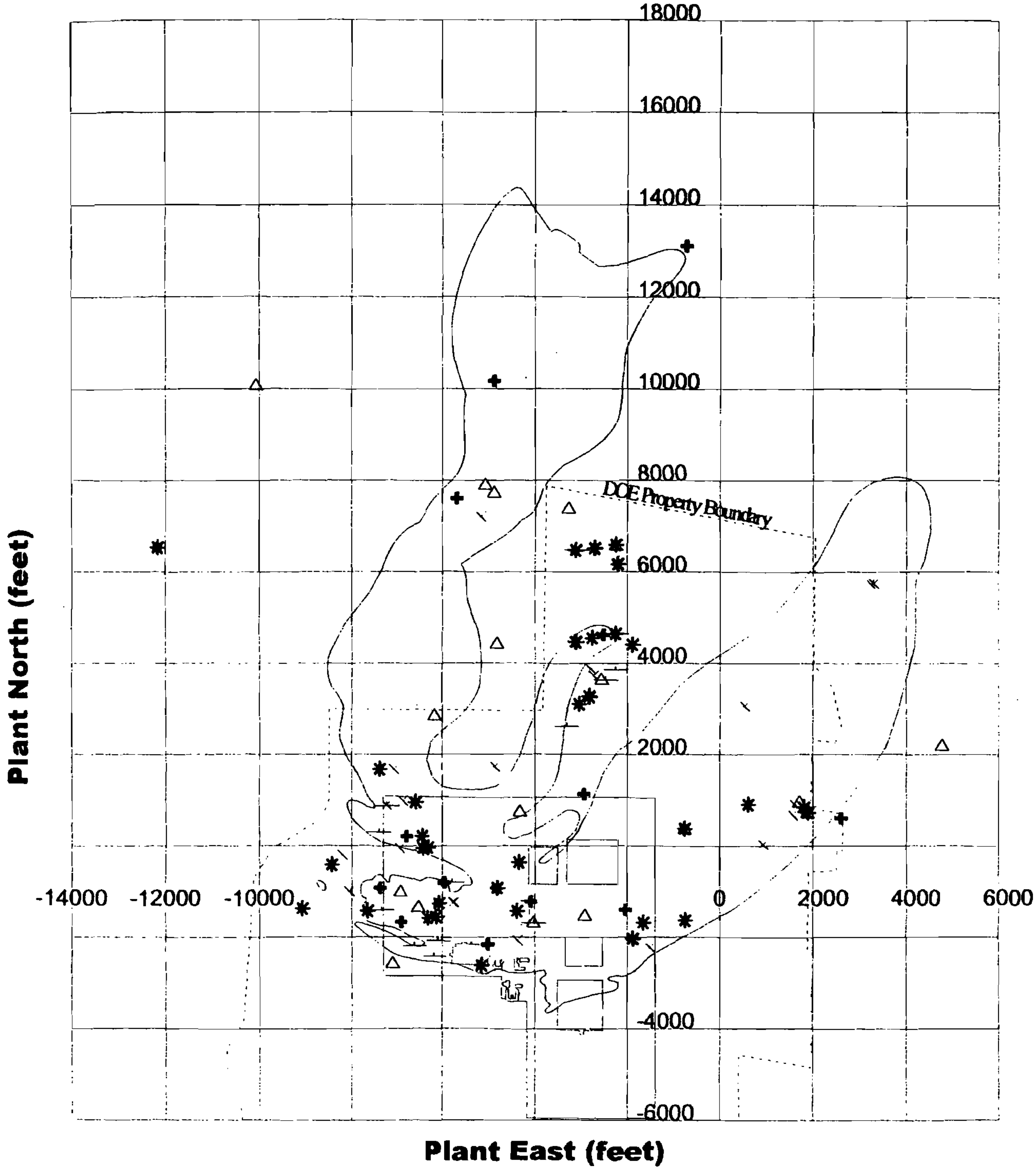
Fig. ES.3. Cis-1,2-dichloroethene levels in the RGA at the PGDP.

Figure No. FSES-3
DATE 05-21-01



LEGEND:

- <BKGD
- >=1X BKGD
- >=2X BKGD
- >=5X BKGD
- >=10X BKGD

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Fig. ES.4. Chromium levels in the RGA at PGDP.

Figure No. FSES-4
DATE 05-21-01

concentrations that significantly exceed background levels (in the Northeast Plume). ^{99}Tc (Fig. ES.5) is the primary radionuclide to be found frequently in off-site groundwater in activities in excess of background levels.

The groundwater contaminants associated with the PGDP are dissolved in groundwater and migrate offsite with groundwater flow. TCE is slightly soluble in water. Under the current setting, approximately 7,000 years will be required to deplete the shallow TCE free product at the C-400 Building by dissolution in infiltrating groundwater. This groundwater flow system is known as the UCRS. Thus, TCE dissolved phase contamination is expected to persist for a very long period of time in the absence of a remedial action.

The leading edge of the Northwest Plume appears to have stabilized at its present location. In part, the Northwest Plume discharges into Little Bayou Creek near the Tennessee Valley Authority's Shawnee Steam Plant. Thus, Little Bayou Creek becomes a point of exposure for the area ecosystem. DOE operates two well fields to reduce and contain the Northwest Plume core of contamination.

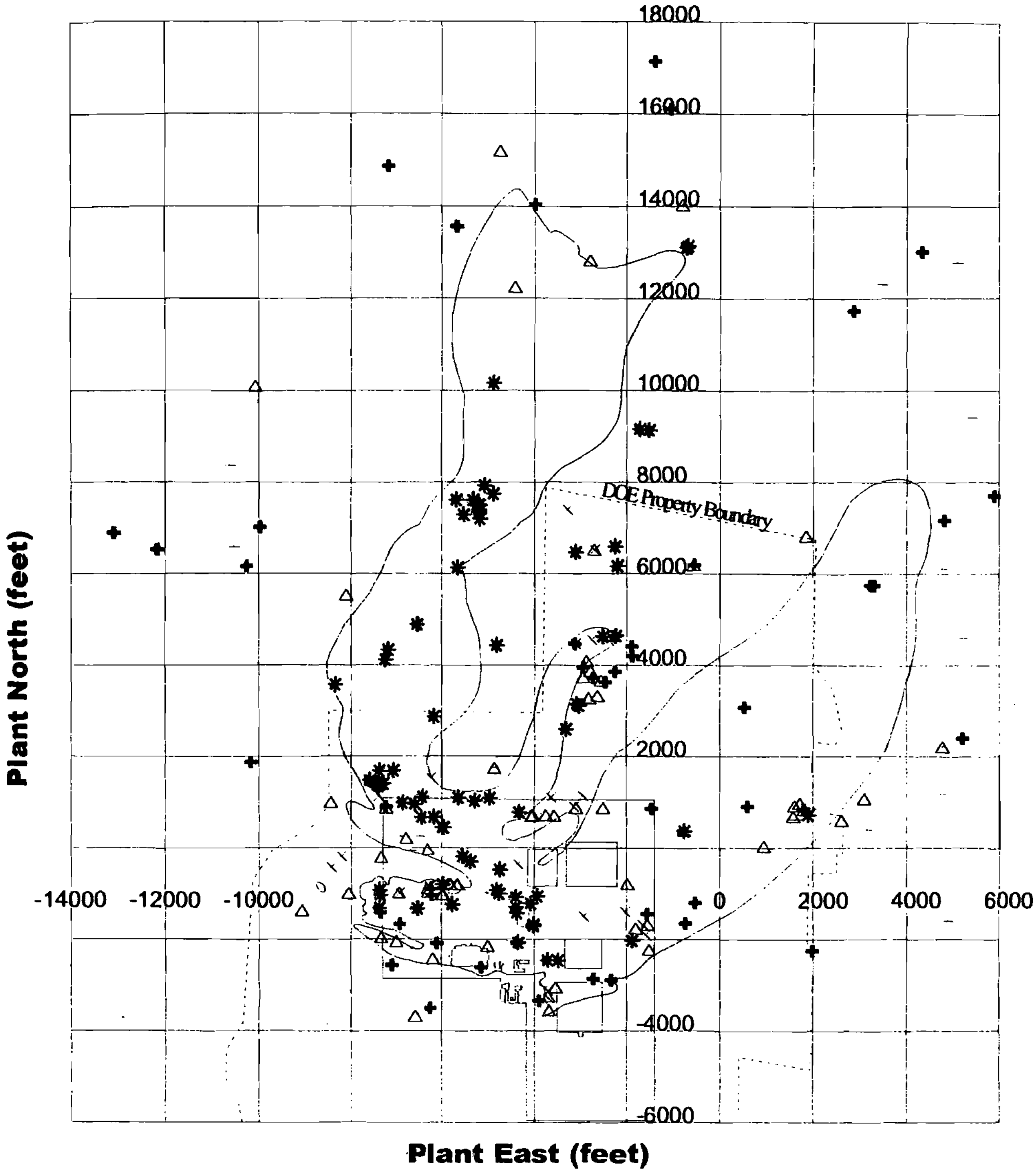
The Northeast Plume reaches northeast of the PGDP to near a residential area along Metropolis Lake Road. This plume does not discharge to a surface water body and appears to be slowly advancing northward. At the same time, contaminant concentrations near the source area are declining (as evidenced by TCE levels in MW255 and MW258), and a pump-and-treat facility is containing the north edge of the high-concentration core of the plume.

The PGDP's Southwest Plume is a relatively recent development that extends approximately 0.5 km beyond the on-site secured perimeter. Because it was first recognized in 1999, no interim containment system is in place yet for this plume.

REMEDIAL ACTION OBJECTIVES

As a result of the RIs and baseline risk assessment that have been performed at Paducah concerning groundwater and the conclusions that are listed above, the following groundwater problem statements have been developed.

- TCE exists as free product in three highly characterized areas (C-400 Building, C-720 Building, and SWMU 1). This organic compound is found in both the UCRS and RGA at the C-400 Building and in the UCRS at the C-720 Building and SWMU 1. The mass of TCE in these locations must be reduced, removed, or contained before it is possible to return the groundwater at and around the PGDP back to beneficial use.
- Other areas appear to exist where TCE occurs in the subsurface as free product. These areas include the source zones of the Northeast Plume. Potential remains for additional unknown source zones of free product TCE to be present at the PGDP. The remedial strategy to be selected must deal with this uncertainty.
- TCE and its degradation products exist at high concentrations at five burial grounds that cannot be addressed directly as part of the GWOU. Due to their complexity, SWMUs 2, 3, 4, 7, and 30 will be remediated as part of the BGOU. Because the mass of TCE and degradation products cannot be reduced or removed as part of the GWOU, the migration of the TCE from these burial grounds needs to be contained before it is possible to return the groundwater at and around PGDP to beneficial use.
- TCE and its degradation products exist at lower concentrations throughout three major plumes both on and off DOE property. These dissolved concentrations need to be reduced before the groundwater at or around the PGDP can be brought back to beneficial use.



LEGEND:

- <BKGD
- >=1X BKGD
- >=2X BKGD
- >=5X BKGD
- >=10X BKGD

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Fig. ES.5. Technetium-99 levels in the RGA at the PGDP.

Figure No. FSES-5
DATE 05-21-01

- Dissolved phase TCE is discharging at low concentrations to surface water in Little Bayou Creek in the off-site area. These releases need to be contained or eliminated to remove direct contact risks to human health and the environment.

In order to develop a remedial alternative that provides for the protection of human health and the environment, remedial action objectives (RAOs) were developed based on the risks identified in the baseline risk assessment and the above groundwater problem statements. The RAOs that were used in screening technologies and developing remedial alternatives are as follows.

- Until such time that groundwater is returned to beneficial use, protect a potential groundwater user north of the Porters Creek Terrace from contamination in excess of maximum contaminant levels (MCLs), and ensure that exposure to groundwater does not present an unacceptable risk to human health and the environment. Note: The Porters Creek Terrace is a buried geologic feature, a groundwater barrier, that extends east and west of the south end of the PGDP.

- Until such time that groundwater is returned to beneficial use, protect potential human and ecological receptors from exposure to contaminated groundwater discharged to surface water. Contaminant concentrations must be low enough to ensure that exposure to discharged groundwater does not present an unacceptable risk to human health and the environment.

- Return usable groundwater to beneficial use wherever practicable, within a timeframe that is reasonable, given the particular circumstances of the site. If restoration of groundwater to beneficial use is not practicable, then prevent further migration of the plume and evaluate further risk reduction.

Specifically, to protect human health, target contaminant concentrations will be reduced, at minimum, to their MCLs or natural state. Because the primary groundwater COCs over the long term at the PGDP (i.e., over 4,000 years, see Fig. ES.1) are TCE, which has an MCL of 5 μg/L, and its breakdown products, meeting the MCL for TCE will result in meeting the MCLs for other COCs, assuming appropriate source remediation. Similarly, ecological receptors will be protected by ensuring that there are no adverse impacts where groundwater discharges to surface water.

ALTERNATIVES

Following the development of the above RAOs, a series of general response actions were developed to meet the RAO requirements for the problem statements previously listed. These general response actions included treatment, containment, excavation, extraction, and disposal. Detailed discussion of the results of the general response action development is contained in Chapter 2, "Development of Remedial Alternatives." The general response actions then were used to screen remedial technologies and develop "representative process options" for applicability to the contaminants driving the risk for the GWOU. This screening process included the assistance of the DOE's Innovative Treatment Remediation Demonstration (ITRD) organization's Technical Assistance Group. The ITRD's Technical Assistance Group was composed of scientists and engineers from the DOE National Laboratories, the EPA, the Commonwealth of Kentucky, and environmental industry companies. The results of the ITRD activities are contained in the Paducah Project Innovative Technology Review located in Appendix C, Volume 4.

Using the general response actions analysis, alternatives were developed using selected technologies that are applicable to the COCs for this FS and the Primary Source Areas, Secondary Source Areas, and Dissolved Phase Plume Areas at PGDP. Table ES.3 identifies the alternatives in terms of the remediation strategies and process options. A brief description of each GWOU alternative is presented in the following subsections.

Table ES.3. Summary of GWOU remedial alternatives with representative process options

Contaminant Area	Target Contaminants	Media	Technology Type
Primary Source Area	TCE, TCE DNAPL, TCE Degradation Products, and ^{99}Tc	Surficial Soils, UCRS Soils, and UCRS Groundwater	Vapor Extraction Direct Heating Excavation
Secondary Source Area	TCE, TCE DNAPL, TCE Degradation Products, and ^{99}Tc	RGA Soils and Groundwater	Steam Extraction Pump-and-Treat Oxidation
Dissolved Phase Plume Area	TCE, TCE Degradation Products, and ^{99}Tc	RGA Groundwater	Pump-and-Treat Ozonation Permeable Treatment Zone Oxidation Bioremediation

After alternatives were assembled, each alternative was evaluated, in accordance with CERCLA, against seven of the nine criteria. Two of the nine criteria are threshold criteria that include Overall Protection of Human Health and the Environment and Compliance with Applicable or Relevant and Appropriate Requirements. Five of the remaining criteria are primary balancing criteria upon which the analysis is based. They include Long-term Effectiveness and Permanence; Reduction of Toxicity, Mobility, or Volume through Treatment; Short-term Effectiveness; Implementability; and Cost. The final two criteria are Commonwealth Acceptance and Community Acceptance, which will be evaluated and included in the record of decision documentation for the GWOU.

The following 12 remedial alternatives were evaluated.

No Action Alternative

This is a no-action alternative that provides a basis for evaluation and comparison of other remedial alternatives. This action does not include costs for the termination of any of the currently in-place remedial actions.

Primary Source Area – Vapor Extraction Technology Alternative

The Vapor Extraction Technology would remove primary contaminant source areas in the UCRS. For this technology, extraction wells in the zone of interest would be placed under vacuum to withdraw soil gas and limited water volumes, containing the contamination. An *ex situ* system would treat the contaminants in the off-gas and liquid waste streams. Section 4.2.2.1 describes the types of vapor extraction systems that could be implemented for the GWOU. Vapor Extraction Technology is effective for the remediation of VOCs. Although Vapor Extraction is not intended for ^{99}Tc, it also may remove ^{99}Tc contamination if groundwater contaminated with ^{99}Tc is produced from the area being treated. Vapor and liquids recovered would be treated before being released to the atmosphere and to an outfall, respectively. The present value unit cost of implementing this alternative would be $554,393 per acre-foot.

Primary Source Area – Direct Heating Technology Alternative

The Direct Heating Technology would remove primary contaminant source areas in the UCRS. This technology heats the soil within the targeted area. Once the area is heated, the contaminants more readily partition to a gaseous state that can be recovered, through either soil vapor extraction or a surface plenum, or released to the atmosphere. Section 4.2.2.2 of this FS, describes the types of direct heating that could be implemented for the GWOU. Direct Heating Technology is effective for the remediation of VOCs. Although some ^{99}Tc may be removed during treatment, Direct Heating Technology is not intended as a ^{99}Tc remediation technology. Vapor and liquids recovered would be treated before being released to the atmosphere and to an outfall, respectively. The present value unit cost of implementing this alternative would be $434,759 per acre-foot.

Primary Source Area – Excavation Technology Alternative

The Excavation Alternative would remove primary contaminant source areas in the UCRS. Excavation would remove soil and all contaminants from the source area, including DNAPL, thereby preventing additional COCs from entering the RGA. This alternative is effective for all the COCs. It is expected that soils would be treated by appropriate technologies to remove contamination before landfilling. The Excavation Technology has practical depth limitations of encountering groundwater. The present value unit cost of implementing this alternative would be $5,930,929 per acre-foot.

Secondary Source Area – Steam Extraction Technology Alternative

The Steam Extraction Technology would be implemented in a DNAPL source zone area of the RGA (i.e., Secondary Source Area). Injection wells would be used to inject steam into the zone of interest. The steam would volatilize the contaminants and allow them to partition more readily to the gaseous phase for recovery. Contaminants would be extracted via vapor and liquid phases via centrally located extraction well. The Steam Extraction Technology is effective for the removal of VOC contamination. The Steam Extraction Technology also will remove ^{99}Tc in the local area of implementation, since ^{99}Tc will be "carried" along with the produced water from the extraction well. Vapor and liquids recovered would be treated before being released to the atmosphere and to an outfall, respectively. The present value unit cost of implementing this alternative would be $1,042,276 per acre-foot.

Secondary Source Area – Pump-and-Treat Technology Alternative

The Pump-and-Treat Technology would be implemented in a DNAPL source zone area of the RGA (i.e., Secondary Source Area). Extraction wells would be placed in the zone of interest, and contaminated groundwater would be pumped from the wells and treated. The Pump-and-Treat Technology is effective for VOC and ^{99}Tc contamination; however, treatment time frames may be long. The treated water would result in a vapor phase and liquid phase that would undergo treatment before being released to the atmosphere and to an outfall, respectively. The present value unit cost of implementing this alternative would be $1,076,353 per acre-foot.

Secondary Source Area – Oxidation Technology Alternative

The Oxidation Technology alternative would be implemented in a DNAPL source zone area of the RGA (i.e., Secondary Source Area). Injection wells would be used to inject the zone of interest (i.e., secondary sources within the RGA) with an oxidizing compound such as potassium permanganate or sodium permanganate. The VOCs, including TCE DNAPL, would react with the oxidizing compound and would be destroyed *in situ* from the reaction with the oxidant. Although this technology is effective on VOCs, it would not remediate any ^{99}Tc contamination. The present value unit cost of implementing this alternative would be $12,218,892 per acre-foot.

Dissolved Phase Plume Area – Pump-and-Treat Technology Alternative

The Pump-and-Treat Technology would be implemented in the Dissolved Phase Area of the plumes. Extraction wells would be placed in the zone of interest and contaminated groundwater would be pumped from the wells and treated. The Pump-and-Treat Technology is effective for VOC and ^{99}Tc contamination; however, treatment time frames may be long. The surface treatment of the produced water would result in a liquid and vapor phase that would undergo treatment before being released to the atmosphere and to an outfall, respectively. The present value unit cost of implementing this alternative would be $361,039 per acre-foot.

Dissolved Phase Plume Area – Ozonation Technology Alternative

The Ozonation Technology alternative would destroy TCE dissolved phase concentrations and other VOCs from areas of the RGA. In addition, ^{99}Tc would be removed from groundwater as it passed across an ion exchange media incorporated into the Ozonation system. Injection wells would be used to inject the zone of interest (i.e., the RGA) with ozone. The VOCs would react with the ozone and, thus, would be destroyed *in situ*. Pumps located in the injection wells will force groundwater across an ion exchange media also located in the injection wells. The ion exchange media will remove ^{99}Tc *in situ* from the groundwater before being placed back into the wells. The present value unit cost of implementing this alternative would be $75,065 per acre-foot.

Dissolved Phase Plume Area – Permeable Treatment Technology Alternative

The Permeable Treatment Zone Technology would destroy TCE dissolved phase contamination and other VOCs within the RGA. In addition, the PTZ Technology would capture ^{99}Tc within the treatment zone. The treatment zones, constructed with iron or other reactive media, would be strategically placed in the RGA. The present value unit cost of implementing this alternative would be $124,285 per acre-foot.

Dissolved Phase Plume Area – Oxidation Technology Alternative

The Oxidation Technology alternative would remove TCE dissolved phase concentrations and other VOCs from areas of the RGA. Unlike the Secondary Source Area technologies described above, the Oxidation Technology in this alternative would be designed to remove only dissolved phase contaminant concentrations. Injection wells would be used to inject the zone of interest (i.e., the RGA) with an oxidizing compound such as potassium permanganate or sodium permanganate. The VOCs, including TCE DNAPL, would react with the oxidizing compound and, thus, would be destroyed *in situ* from the reaction with the oxidant. Although this technology is effective for the remediation of VOCs, it would not remediate any ^{99}Tc contamination. The present value unit cost of implementing this alternative would be $157,636 per acre-foot.

Dissolved Phase Plume Area – Bioremediation Technology Alternative

The Bioremediation Technology alternative would remove dissolved phase VOCs from areas of the RGA. Injection wells would be used to inject nutrients for native bacteria within the zone of interest (i.e., the RGA). Depending on the design of the bioremediation alternative, either aerobic or anaerobic bioremediation could be implemented. Although this technology is effective for the remediation of VOCs, it would not remediate any ^{99}Tc contamination. The present value unit cost of implementing this alternative would be $205,154 per acre-foot.

The Comparative Analysis Table, Table ES.4, provides a summary analysis of the alternatives including risk reduction, timeframe for remediation, and costs.

Based on the result of the detailed analysis, all of the alternatives, except the No Action alternative, meet the minimum requirements of overall protection of human health and the environment only when combined with additional remedial measures to provide overall groundwater restoration or restrictions of groundwater use. DOE will address the selection of institutional controls necessary to effect future groundwater restrictions under a separate CERCLA action. That action will consider a range of alternative actions to achieve the goals of protecting human health and the environment.

In accordance with CERCLA and outlines prescribed by the PGDP Federal Facility Agreement, this FS report does not identify a preferred alternative. This FS, consistent with requirements of the Secretarial Policy (DOE 1994), incorporates National Environmental Policy Act values to the extent practicable. This FS report was developed consistent with EPA guidance for conducting FSs (EPA 1988).

Table ES.4. Comparative analysis table

Criteria	No Action	Primary Source Areas			Secondary Source Areas		
Description	**No Action**	**Vapor Extraction Technology**	**Direct Heating Technology**	**Excavation**	**Steam Extraction Technology**	**Pump-and-Treat Technology**	**Oxidation Technology**
			Overall Protection of Human Health and the Environment				
Human health protection	Does not protect human health	Not protective unless combined with additional measures	Not protective unless combined with additional measures	Not protective unless combined with additional measures	Not protective unless combined with additional measures	Not protective unless combined with additional measures	Not protective unless combined with additional measures
Environmental protection	Discharges from the Northwest Plume into Little Bayou Creek will continue.	Discharges from the Northwest Plume into Little Bayou Creek will continue.	Discharges from the Northwest Plume into Little Bayou Creek will continue.	Discharges from the Northwest Plume into Little Bayou Creek will continue.	Discharges from the Northwest Plume into Little Bayou Creek will continue.	Discharges from the Northwest Plume into Little Bayou Creek will continue.	Discharges from the Northwest Plume into Little Bayou Creek will continue.
			Compliance with ARARs				
Chemical-specific	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater or surface water.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater or surface water.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater or surface water.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater or surface water.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater or surface water.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater or surface water.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater or surface water.
Location-specific	No location-specific ARARs were identified for this alternative.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.
Action-specific	No action-specific ARARs were identified for this alternative.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.
Other criteria and guidance	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.
			Long-Term Effectiveness and Permanence				
Magnitude of residual risk	Residual risks remain high during the first 30 years; residual risks will be reduced in 7,000 years.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the POC.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the POC.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the POC.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the POC.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the POC.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the POC.

Table ES.4 (continued)

Criteria	No Action	Primary Source Areas			Secondary Source Areas		
Description	No Action	Vapor Extraction Technology	Direct Heating Technology	Excavation	Steam Extraction Technology	Pump-and-Treat Technology	Oxidation Technology
Adequacy and reliability of controls	No implementation of controls preventing exposure to potential receptors	Adequate and reliable	Adequate and reliable	Adequate and very reliable where applicable. Reliability decreases where infrastructure impedes implementation	Adequate and reliable.	Adequate and reliable.	Adequate and moderately reliable.
Need for 5-year review	Required	Required	Required	Required	Required	Required	Required
Environmental impacts and mitigative measures	No action would allow current rates of contamination to continue.	Minimal environmental impacts and mitigative measures	Minimal environmental impacts and mitigative measures	Minimal overall environmental impacts and mitigative measures. However, local impacts will be significant.	Minimal environmental impacts and mitigative measures	Minimal environmental impacts and mitigative measures	Minimal environmental impacts and mitigative measures
Reduction of Toxicity, Mobility, or Volume through Treatment							
Treatment processes used	None	Vapor extraction; ion exchange and air stripper with cat/ox system	Direct heating with ion exchange and air stripper with cat/ox system	Excavation with *ex situ* thermal treatment of soil	Steam extraction; ion exchange and air stripper with cat/ox system	Pump and treat, ion exchange and air stripper with cat/ox system.	*In situ* oxidation
Amount destroyed or treated	None	TCE and VOCs will be treated. Moderately effective on DNAPL. Minimal ^{99}Tc will be captured.	TCE and VOCs will be treated. Highly effective on DNAPL. Minimal ^{99}Tc will be captured.	All contaminated soils will be removed. TCE and other VOCs will be treated. Highly effective on DNAPL if within excavation zone.	TCE and VOCs will be treated. Highly effective on DNAPL. ^{99}Tc will be captured.	TCE and VOCs will be treated. Minimally effective on DNAPL. Minimal ^{99}Tc will be captured.	TCE and VOCs will be treated. Moderately to highly effective on DNAPL. Not effective on ^{99}Tc.
Degree of reduction of toxicity, mobility, or volume	No reduction in toxicity, mobility, and volume.	High reduction in VOC toxicity and volume of sources. Minimal reduction in ^{99}Tc volume.	High reduction in VOC toxicity and volume of sources. Minimal reduction in ^{99}Tc volume.	High reduction in VOC toxicity and volume of VOC and ^{99}Tc sources within the zone of excavation.	High reduction in VOC toxicity and volume of sources. Moderate reductions in ^{99}Tc volume.	Low volume of VOC contaminants recovered. High reduction in toxicity of VOCs recovered. Large reductions in ^{99}Tc volume.	High reduction in VOC toxicity. No impact on ^{99}Tc.
Irreversibility of treatment	Not applicable	Reversible	Irreversible	Irreversible.	Reversible	Reversible	Irreversible
Type/quantity of residuals remaining after treatment	Not applicable	Treatment residuals include ^{99}Tc contaminated ion-exchange resin and salt from off-gas treatment.	Treatment residuals include ^{99}Tc contaminated ion-exchange resin and salt from off-gas treatment.	Treatment residuals include ^{99}Tc contaminated ion-exchange resin and salt from off-gas treatment.	Treatment residuals include ^{99}Tc contaminated ion-exchange resin and salt from off-gas treatment.	Treatment residuals include ^{99}Tc contaminated ion-exchange resin and salt from off-gas treatment.	None
Statutory preference for treatment	Not applicable	Satisfied for VOCs	Satisfied for VOCs	Satisfied for VOCs	Satisfied for VOCs	Satisfied for VOCs	Satisfied for VOCs
Short-term Effectiveness							
Community protection	No increase in risk to community as no action is taken.	No negative impacts to the community are anticipated.	No negative impacts to the community are anticipated.	No negative impacts to the community are anticipated.	No negative impacts to the community are anticipated.	No negative impacts to the community are anticipated.	No negative impacts to the community are anticipated.

Table ES.4 (continued)

Criteria	No Action	Primary Source Areas			Secondary Source Areas		
Description	No Action	Vapor Extraction Technology	Direct Heating Technology	Excavation	Steam Extraction Technology	Pump-and-Treat Technology	Oxidation Technology
Worker protection	No risks to workers as no action is taken.	Minimal risks to workers from handling contaminated groundwater. Risks can be minimized through adherence to health/safety protocols.	Minimal risks to workers from handling contaminated groundwater. Large volumes of electricity are used. Risks can be minimized through adherence to health/safety protocols.	Risks to workers from handling contaminated soils. Risks can be minimized through adherence to health/safety protocols.	Minimal risks to workers from handling contaminated groundwater. Potential exposure to steam under pressure. Risks can be minimized through adherence to health/safety protocols.	Risks to workers from handling contaminated groundwater. Risks can be minimized through adherence to health/safety protocols.	Risks to workers from handling oxidant. Risks can be minimized through adherence to health/ safety protocols.
Environmental impacts and mitigative measures	No action would allow current rates of contamination to continue	Minimal environmental impacts and mitigative measures	Minimal environmental impacts and mitigative measures	Minimal environmental impacts and mitigative measures	Minimal environmental impacts and mitigative measures	Increase in discharge to creeks will result.	Minimal environmental impacts and mitigative measures
Time until action is complete	Time until the groundwater is attenuated is 7,000 years.	Approximately 1,000 years	Approximately 1,000 years	Approximately 1,000 years	Approximately 7,000 years	Approximately 7,000 years	Approximately 7,000 years
Implementability							
Technical feasibility	Feasible to implement	Feasible to implement	Feasible to implement	Feasible to implement above water table and where infrastructure allows.	Feasible to implement	Feasible to implement	Feasible to implement
Administrative feasibility	Feasible to implement. ARARs waiver required.	Feasible to implement. ARARs waiver required.	Feasible to implement. ARARs waiver required.	Feasible to implement. ARARs waiver required.	Feasible to implement. ARARs waiver required.	Feasible to implement. Long-term presence required. ARARs waiver required.	Feasible to implement. ARARs waiver required.
Availability of services and materials	Feasible to implement	Services and materials are readily available.	Availability of vendors and equipment is limited	Services and materials are readily available.	Availability of vendors is limited	Services and materials are readily available.	Availability of vendors is limited.
Unit Cost (Per acre-foot and in dollars)							
Total cost: escalated	$0	$687,648	$694,837	$8,131,025	$2,083,677	$2,318,211	$12,304,300
Total costs: present worth	$0	$554,393	$434,759	$5,930,929	$1,042,276	$1,076,353	$12,218,892
Commonwealth Acceptance							
General	Comments from the Commonwealth of Kentucky will be incorporated into this feasibility study report as appropriate following review of the draft report.						
Community Acceptance							
General	Following a formal public comment period on the proposed plan, comments from the community will be addressed in a responsiveness summary, which will be presented in the GWOU Record of Decision documents.						

ARAR = applicable or relevant and appropriate requirement
RAO = remedial action objective
RGA = Regional Gravel Aquifer
TCE = trichloroethene
UCRS = Upper Continental Recharge System
VOC = volatile organic compound
^{99}Tc = technetium-99

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Table ES.4a. Comparative analysis table

Criteria	Dissolved Phase Areas				
Description	Pump-and-Treat Technology	Ozonation Technology	Permeable Treatment Zone Technology	Oxidation Technology	Bioremediation Technology
Overall Protection of Human Health and the Environment					
Human health protection	Not protective unless combined with additional measures	Not protective unless combined with additional measures	Not protective unless combined with additional measures	Not protective unless combined with additional measures	Not protective unless combined with additional measures
Environmental protection	May remediate discharges from the Northwest Plume into Little Bayou Creek. Long-term presence will be required.	May remediate discharges from the Northwest Plume into Little Bayou Creek. Long-term presence will be required.	May remediate discharges from the Northwest Plume into Little Bayou Creek. Long-term presence will be required.	May remediate discharges from the Northwest Plume into Little Bayou Creek. Long-term presence will be required.	May remediate discharges from the Northwest Plume into Little Bayou Creek. Long-term presence will be required.
Compliance with ARARs					
Chemical-specific	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater.
Location-specific	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.
Action-specific	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.
Other criteria and guidance	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.
Long-Term Effectiveness and Permanence					
Magnitude of residual risk	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the source zones.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the source zones.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the source zones.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the source zones.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the source zones.
Adequacy and reliability of controls	Adequate and reliable	Adequate and reliable	Adequate and reliable	Adequate and reliable.	Adequate and reliable
Need for 5-year review	Required	Required	Required	Required	Required
Environmental impacts and mitigative measures	Moderate environmental impacts and mitigative measures	Low environmental impacts and mitigative measures	Low environmental impacts and mitigative measures	Low environmental impacts and mitigative measures	Low environmental impacts and mitigative measures
Reduction of Toxicity, Mobility, or Volume through Treatment					
Treatment processes used	Pump and treat, ion exchange and air stripper with cat/ox system.	*In situ* ozonation with ion exchange	*In situ* permeable treatment zone	*In situ* oxidation	*In situ* bioremediation
Amount destroyed or treated	TCE and VOCs will be treated. ^{99}Tc will be captured.	TCE and VOCs will be treated. ^{99}Tc will be captured.	TCE and VOCs will be treated. ^{99}Tc will be captured and held within the aquifer.	TCE and VOCs will be treated. ^{99}Tc will not be captured.	TCE and VOCs will be treated to a level of approximately 100 µg/L. ^{99}Tc will not be captured.

Table ES.4a. Comparative analysis table (continued)

Criteria	Dissolved Phase Areas				
Description	Pump-and-Treat Technology	Ozonation Technology	Permeable Treatment Zone Technology	Oxidation Technology	Bioremediation Technology
Degree of reduction of toxicity, mobility, or volume	High reduction in dissolved phase VOC toxicity and volume. High reduction in dissolved phase ^{99}Tc volume.	High reduction in dissolved phase VOC toxicity and volume. High reduction in dissolved phase ^{99}Tc volume.	High reduction in dissolved phase VOC toxicity and volume. High reduction in dissolved phase ^{99}Tc volume.	High reduction in dissolved phase VOC toxicity and volume.	High reduction in dissolved phase VOC toxicity and volume.
Irreversibility of treatment	Reversible	Irreversible	Irreversible.	Irreversible.	Reversible
Type/quantity of residuals remaining after treatment	Treatment residuals include ^{99}Tc contaminated ion-exchange resin and salt from off-gas treatment.	Treatment residuals are ^{99}Tc contaminated ion-exchange resin.	Treatment residuals are ^{99}Tc contaminated iron filings.	None	100 µg/L VOCs. Note: residual VOCs may lead to higher risk than original VOCs due to degradation.
Statutory preference for treatment	Satisfied for VOCs	Satisfied for VOCs	Satisfied for VOCs and ^{99}Tc.	Satisfied for VOCs	Satisfied for VOCs
Short-term Effectiveness					
Community protection	Minimal negative impacts to the community are anticipated.	No negative impacts to the community are anticipated.	No negative impacts to the community are anticipated.	Potential negative impacts to the community are anticipated.	No negative impacts to the community are anticipated.
Worker protection	Minimal risks to workers from handling contaminated groundwater. Risks can be minimized through adherence to health/safety protocols.	Minimal risks to workers from handling contaminated groundwater. Risks can be minimized through adherence to health/safety protocols.	Risks to workers from handling contaminated soils. Risks can be minimized through adherence to health/safety protocols.	Minimal risks to workers from handling contaminated groundwater. Potential exposure to oxidant. Risks can be minimized through adherence to health/safety protocols.	Risks to workers from handling contaminated groundwater. Risks can be minimized through adherence to health/safety protocols.
Environmental impacts and mitigative measures	Moderate environmental impact. May eliminate contaminant discharge to Little Bayou Creek. Increase in water discharge to creeks will result.	Moderate environmental impact. May eliminate VOC discharge to Little Bayou Creek.	Moderate environmental impact. May eliminate contaminant discharge to Little Bayou Creek.	Moderate environmental impact. May eliminate VOC discharge to Little Bayou Creek.	Moderate environmental impact. May decrease VOC discharge to Little Bayou Creek.
Time until action is complete	Approximately 7,000 years in source areas. Approximately 100 yrs or less in downgradient areas.	Approximately 7,000 years in source areas. Approximately 100 yrs or less in downgradient areas.	Approximately 7,000 years in source areas. Approximately 100 yrs or less in downgradient areas.	Approximately 7,000 years in source areas. ^{99}Tc levels will not be affected.	Approximately 7,000 years in source areas. ^{99}Tc levels will not be affected.
Implementability					
Technical feasibility	Feasible to implement	Feasible to implement	Feasible to implement	Feasible to implement	Feasible to implement
Administrative feasibility	Feasible to implement. Long-term presence required. ARARs waiver required.	Feasible to implement. Long-term presence required. ARARs waiver required.	Feasible to implement. Long-term presence required. ARARs waiver required.	Feasible to implement. Long-term presence required. ARARs waiver required.	Feasible to implement. Long-term presence required. ARARs waiver required.
Availability of services and materials	Services and materials are readily available.	Services and materials are readily available.	Availability of vendors is limited	Availability of vendors is limited	Services and materials are readily available.
Unit Cost (per acre-foot and in dollars)					
Total cost: escalated	$692,703	$134,477	$180,269	$209,601	$248,424
Total costs: present worth	$361,039	$75,065	$124,285	$157,636	$205,154
Commonwealth Acceptance					
General	Comments from the Commonwealth of Kentucky will be incorporated into this feasibility study report as appropriate following review of the draft report.				
Community Acceptance					

Table ES.4a. Comparative analysis table (continued)

Criteria	Dissolved Phase Areas				
Description	Pump-and-Treat Technology	Ozonation Technology	Permeable Treatment Zone Technology	Oxidation Technology	Bioremediation Technology
General	Following a formal public comment period on the proposed plan, comments from the community will be addressed in a responsiveness summary, which will be presented in the GWOU Record of Decision documents.				

ARAR = applicable or relevant and appropriate requirement
RAO = remedial action objective
RGA = Regional Gravel Aquifer
TCE = trichloroethene
UCRS = Upper Continental Recharge System
VOC = volatile organic compound
^{99}Tc = technetium-99

REFERENCES

DOE 1994. *Secretarial Policy on the National Environmental Policy Act*, U.S. Department of Energy, Washington, D.C.

DOE 1999. *Site Management Plan, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1780&D2, U.S. Department of Energy, Paducah, Ky.

EPA 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, Office of Solid Waste and Emergency Response (OSWER) Directive No. 9355.3-01, U.S. Environmental Protection Agency, Washington, DC, October.

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1. INTRODUCTION

This chapter provides a brief introduction to the Paducah Gaseous Diffusion Plant (PGDP) and an explanation of the purpose and organization of the report. Detailed solid waste management unit (SWMU)-specific background information, including the site description, site history, and nature and extent of contamination, is referenced. The fate and transport of selected contaminants of concern (COCs) is described, and baseline risk assessment information is summarized.

1.1 PURPOSE AND ORGANIZATION OF THE FEASIBILITY STUDY REPORT

This Groundwater Operable Unit Feasibility Study (FS) report was developed consistent with the PGDP Site Management Plan (SMP) (DOE 1999a) and is intended to satisfy requirements for an FS under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) 40 *Code of Federal Regulations* (*CFR*) 300.430 and for a corrective measures study under the Resource Conservation and Recovery Act (RCRA). Further, the intent of the report is to evaluate the cost and benefit characteristics of viable alternatives to allow the selection of an appropriate remedy for incorporation into a Groundwater Operable Unit (GWOU) Proposed Remedial Action Plan (PRAP). The SMP (DOE 1999a) specifies that the Federal Facility Agreement (FFA) must effectively coordinate RCRA corrective actions and CERCLA remedial actions because the PGDP operates under a RCRA Part B Permit with Hazardous and Solid Waste Amendments (HSWA) corrective action requirements for the SWMUs. Therefore, this FS report has been prepared in accordance with CERCLA, but it also fulfills the RCRA requirements for a corrective measures study.

Section 1.1.1 presents the purpose and scope of this FS report. The organization utilized to prepare the report is contained in Sect. 1.1.2.

1.1.1 Purpose and Scope

In August 1998, the U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), and Commonwealth of Kentucky agreed to restructure the remedial strategy for the PGDP. This restructuring would reflect the accomplishment of sitewide remedial objectives as opposed to the original strategy, which emphasized a SWMU-by-SWMU approach. The basis for the revised strategy is the protection of human health and the environment through implementation of actions focused on accomplishing the following remedial objectives:

- protection of off-site residents from consumption of contaminated groundwater and a return of groundwater to beneficial use,
- protection of recreational users associated with Bayou/Little Bayou Creeks and the West Kentucky Wildlife Management Area (WKWMA),
- protection of industrial workers, and
- protection of ecosystems.

To accomplish these objectives, four remedial action operable units (OUs) have been defined with each having a specific emphasis corresponding to the above remedial objectives: GWOU, Surface Water OU (SWOU), Soils OU (SOU), and the Burial Grounds OU (BGOU). Each OU is scoped to remediate an area and contaminated media(s) associated with PGDP. The SWOU is directed at remediating the surface water bodies including the outfall ditches, impoundment ponds, and Little Bayou and Bayou Creeks. The SOU is designed to remediate the contaminated soils associated with the plant and not located in a waterway, outfall, ditch, or burial ground. The BGOU scope includes all of the contamination that is associated with the landfills and burial grounds that are associated with the plant. The GWOU is to develop and implement a remedial alternative for COCs associated with the groundwater beneath and near PGDP. Once the BGOU, SWOU, GWOU, and SOU are completed, a Comprehensive Sitewide OU will be conducted (Massey 1998a and 1998b).

Each SWMU or Area of Concern (AOC) at PGDP was assigned to one or more of the OUs. The GWOU received 18 SWMUs or AOCs that were previously included in the following seven Waste Areas Groups (WAGs):

- WAG 6,
- WAG 26,
- WAG 27, and
- WAG 28.

Representatives of the DOE, State of Kentucky and USEPA reevaluated the placement of several SWMUs. As a result of this reevaluation, several SWMUs that were contained in the GWOU have been now been placed in the BGOU for remedial action selection. These SWMUs are as follows:

- SMWU 2 – C-749 Uranium Burial Ground
- SWMU 3 – C-404 Low-Level Radioactive/Hazardous Waste Burial Ground
- SWMU 4 – C-747 and C-748-B Burial Grounds
- SWMU 7 – C-747-A Burial Ground
- SWMU 30 – C-747-A Burn Area

The relocation of these SWMUs was predicated on the fact that these SWMUs include waste cells may contain materials that could be an ongoing source of groundwater contamination, and it may be technically difficult to gain access to the underlying groundwater contamination while the waste cell material is still intact. Furthermore, since the remedial alternatives under consideration for the BGOU may include excavation of the burial grounds, the technical circumstances suggest it would be more effective and efficient to coordinate implementation of the groundwater actions with the waste cell actions that ultimately will be selected under the BGOU.

Table 1.1 and Fig. 1.1 identify the WAGs and SWMUs currently within the scope of the GWOU FS. Each of the SWMUs listed in Table 1.1 was added to the GWOU because of the presence of contaminated groundwater from that SWMU or the potential to contaminate groundwater based on modeling. A complete crosswalk of Paducah SWMUs to OUs is contained in Appendix C6. Figure 1.2 identifies the groundwater plumes that are contained in WAG 26.

Also as a result of decisions reached by the representatives of the DOE, Commonwealth of Kentucky and EPA, it was determined that the scope of this FS will have the following target contaminants.

- trichloroethene (TCE)
- TCE dense nonaqueous-phase liquid (DNAPL)
- TCE degradation products
- technetium-99 (^{99}Tc)

The detailed analysis for this FS has been performed on alternatives containing a single applicable technology. The technologies receiving complete detailed analyses were those contained in the eight

Table 1.1. WAG and SWMU listing for the GWOU at the PGDP

WAG	SWMU	Description
WAG 6	SWMU 11	C-400 TCE Leak Site
	SWMU 26	C-400 to C-404 Underground Transfer Line
	SWMU 40	C-403 Neutralization Pit
	SWMU 47	C-400 Technetium Storage Tank Area
	SWMU 203	C-400 Waste Discard Sump
WAG 26	AOC 201	Northwest Plume
	AOC 202	Northeast Plume
	AOC 210	Southwest Plume
WAG 27	SWMU 1	C-747-C Oil Landfarm
	SWMU 91	C-745-B Cylinder Drop Test Area (Lasagna)
	SWMU 196	C-746-A Septic Systems
	SWMU 209	C-720 Compressor Shop Pit
	AOC 211	C-720 TCE Spill Site – Northeast
WAG 28	SWMU 99	C-745 Kellogg Building Site
	SWMU 183	McGraw Underground Storage Tank
	SWMU 193	McGraw Construction Facilities
	SWMU 194	McGraw Construction Facilities
	AOC 204	Dykes Road Historical Staging Area

AOC = Area of Concern
GWOU = Groundwater Operable Unit
PGDP = Paducah Gaseous Diffusion Plant
SWMU = solid waste management unit
TCE = trichloroethene
WAG = waste area group

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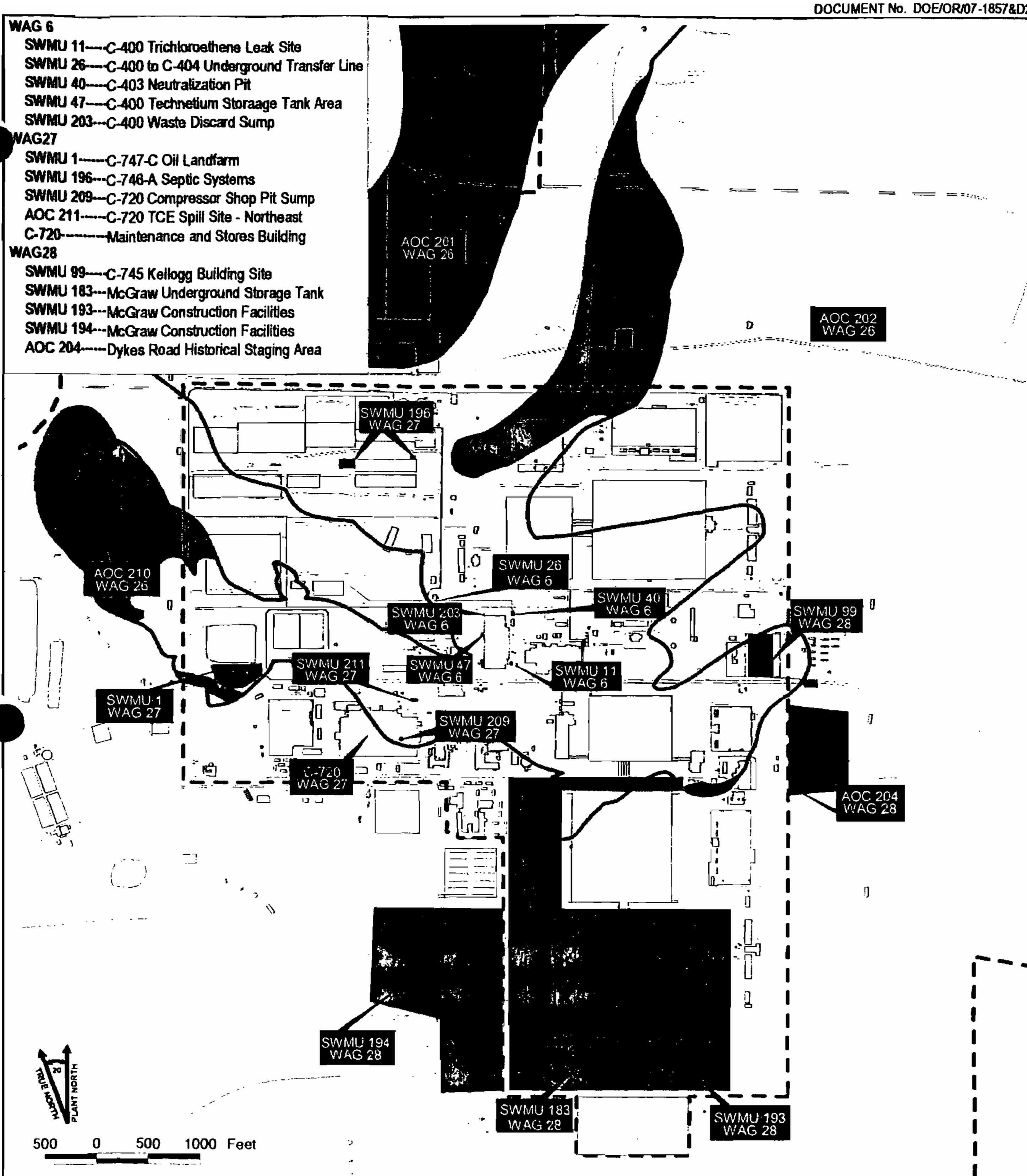


LEGEND:
STREAM
ROAD
DOE BOUNDARY
PGDP BOUNDARY
SOLID WASTE MANAGEMENT UNIT
EXTENT OF TECHNETIUM-99 CONTAMINATION
EXTENT OF TRICHLOROETHENE CONTAMINATION

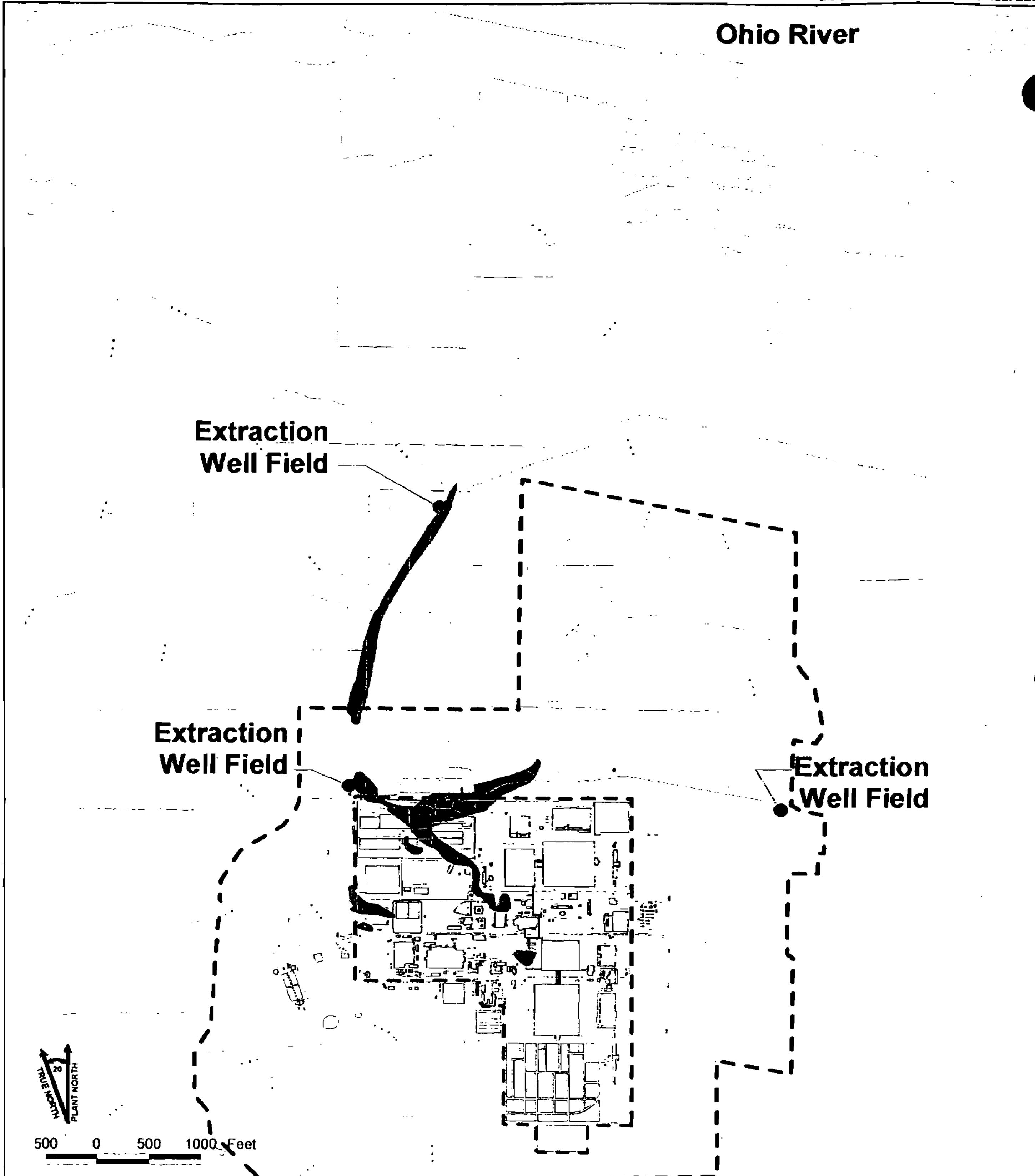
U.S. DEPARTMENT OF ENERGY
DOE OAK RIDGE OPERATIONS
PADUCAH GASEOUS DIFFUSION PLANT

BECHTEL JACOBS COMPANY, LLC
MANAGED FOR THE US DEPARTMENT OF ENERGY UNDER US GOVERNMENT CONTRACT DE-AC-05-98OR22700
Oak Ridge, Tennessee • Paducah, Kentucky • Portsmouth, Ohio

Science Applications International Corporation
P.O. Box 2502
Oak Ridge, Tennessee 37831

Fig. 1.1. Solid waste management unit locations at the Paducah Gaseous Diffusion Plant.

Figure No. FS1-1
DATE 05-25-01



LEGEND:
STREAM
ROAD
DOE BOUNDARY
PGDP BOUNDARY
TECHNETIUM-99 CONTAMINATION >900 pCi/L
TRICHLOROETHENE CONTAMINATION

U.S. DEPARTMENT OF ENERGY
DOE OAK RIDGE OPERATIONS
PADUCAH GASEOUS DIFFUSION PLANT

BECHTEL JACOBS COMPANY, LLC
MANAGED FOR THE US DEPARTMENT OF ENERGY UNDER US GOVERNMENT CONTRACT DE-AC-05-98OR22700
Oak Ridge, Tennessee • Paducah, Kentucky • Portsmouth, Ohio

Science Applications International Corporation
P.O. Box 2502
Oak Ridge, Tennessee 37831

Fig. 1.2. Northeast and Northwest Plume locations.

Figure No. FS1-2
DATE 05-25-01

alternatives that were combined into treatment trains in the D1 GWOU. These technologies have been further broken down to applicable areas that included Primary Source Areas, Secondary Source Areas, and Dissolved Phase Plume Areas. The definitions of these groups as applied in this D2 document are as follows:

- Primary Source Areas are those areas with the target contaminants present and have DNAPL concentrations in the surficial soils and soils of the Upper Continental Recharge System (UCRS) located above the Regional Gravel Aquifer (RGA).

- Secondary Source Areas are those areas with the target contaminants present and have DNAPL concentrations in the RGA.

- Dissolved Phase Plume Areas are those areas within the RGA that contain the target compounds but have no DNAPL concentrations present.

The technologies that received detailed analysis are as follows:

- Primary Source Areas — Vapor Extraction Technology; Direct Heating Technology; Excavation Technology

- Secondary Source Areas — Steam Extraction Technology; Pump-and-Treat Technology; Oxidation Technology

- Dissolved Phase Plume Areas — Pump-and-Treat Technology; Ozonation Technology; Permeable Treatment Technology; Oxidation Technology; Bioremediation Technology

1.1.2 Report Organization

This FS report has been prepared in accordance with the "Integrated FS/Corrective Measures Study" outline prescribed in Appendix D of the FFA for the PGDP (EPA 1998). As such, this FS report is considered to be a primary document. Primary documents may be described generally as those documents that the DOE is required to issue to the EPA and the Kentucky Department for Environmental Protection (KDEP) to fulfill the obligations of the FFA (EPA 1998). All subsections contained in the referenced outline have been included for completeness. Where specific sections of this outline do not apply, the text of the document provides clarification. Subsections have been added to the outline, as appropriate, and have been included to provide clarity and enhance the organization of the document.

1.2 BACKGROUND INFORMATION

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

1.2.1 Regulatory Setting

This section summarizes the framework for environmental restoration at the PGDP, including the major acts and accompanying regulations driving response actions, such as the CERCLA and the RCRA. It also describes the documents controlling response actions, such as the Administrative Order by Consent (ACO), the FFA, and the SMP.

In August 1988, TCE and ^{99}Tc were detected in private wells north of the PGDP. The contaminants originated as waste generated from materials commonly used during the operational history of the PGDP. As a result, the DOE and the EPA, with the participation of the Commonwealth of Kentucky, entered into an ACO, effective November 23, 1988. The ACO is a site-specific, legally binding agreement between the DOE and the EPA that triggered investigations to determine the nature and extent of contamination in the vicinity of the PGDP. The ACO defines the following mutual objectives for the DOE and the EPA:

- determine the nature and extent of threats to human health and welfare and the environment caused by off-site groundwater contamination originating from the PGDP;
- ensure that the environmental impacts associated with known and potential releases are thoroughly investigated and that appropriate action is taken to protect human health and welfare and the environment;
- establish a workplan and schedule(s) for developing, implementing, and monitoring response actions; and
- facilitate cooperation among, exchange of information between, and participation of the parties in the action.

The ACO was drafted under Sections 104 and 106 of the CERCLA. For the purposes of the ACO, the EPA determined that hazardous substances had been released into the environment from the PGDP and that the potential pathways of migration constitute both an actual release and a threatened release under CERCLA definitions [42 U.S.C.A. § 9601(22)].

Section 105(a)(8)(B) of CERCLA [42 U.S.C.A. § 9605(a)(8)(B)], as amended by the Superfund Amendments and Reauthorization Act, requires the 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, the EPA placed the PGDP on the National Priorities List (NPL) [59 *Federal Register* (*FR*) 27989 (May 31, 1994)]. Sites on the NPL are required to evaluate releases and conduct remedial actions/removal actions in accordance with CERCLA's National Oil and Hazardous Substances Pollution Contingency Plan (NCP). As the lead agency under CERCLA, the DOE is responsible for conducting cleanup activities at the PGDP in compliance with applicable or relevant and appropriate requirements (ARARs).

The CERCLA is not the only driver for cleanup at the PGDP. The RCRA, in addition to regulating the generation, transportation, treatment, storage, and disposal of hazardous waste, requires corrective action for releases of hazardous constituents from SWMUs.

The DOE was issued a Kentucky Hazardous Waste Management Permit and an EPA HSWA permit on July 16, 1991. The KDEP portion of the RCRA permit was issued pursuant to Chapter 224 of the K.R.S. by authority granted from the EPA to the KDEP. The EPA issued its portion of the RCRA permit pursuant to the HSWA. The RCRA permits require the proper treatment, storage, and disposal of waste; corrective action (i.e., cleanup); closure of regulated units; and investigation of off-site contamination.

To ensure that duplication of investigative/analytical work and documentation under both the RCRA and the CERCLA is minimized, the EPA, the KDEP, and the DOE signed the FFA for the PGDP on February 13, 1998, pursuant to Section 120 of the CERCLA. At that time, the FFA superseded the ACO. The FFA coordinates the CERCLA remedial action and the RCRA corrective action processes into a single, comprehensive procedure for site remediation. The FFA ensures that response actions be in compliance with ARARs under CERCLA, and that such actions be taken in a timely manner.

The FFA requires that the DOE prepare and submit to the EPA an annual SMP. The SMP is designed to coordinate and document the selected OUs, removal actions and proposed removal actions, work priorities, projected activities, and timetables and deliverables for the current and two successive fiscal years. The SMP also includes a basis for prioritizing response actions as well as the prioritization criteria. Additionally, the SMP contains a list of commitments and long-term projections.

Paragraph II E.2 of the *Secretarial Policy Statement on the National Environmental Policy Act* (NEPA) (DOE 1994d) states, "To facilitate meeting the environmental objectives of CERCLA and to respond to concerns of regulators, consistent with the procedures of most other Federal agencies, the DOE hereafter will rely on the CERCLA process for review of actions to be taken under CERCLA and will address NEPA values and public involvement procedures as provided below...Department of Energy CERCLA documents will incorporate NEPA values, such as analysis of cumulative, off-site, ecological, and socioeconomic impacts, to the extent practicable." To meet this goal, NEPA values have been incorporated into this document to the extent practicable.

1.2.2 Site Description of the PGDP Area

In this site description section, information is provided concerning environmental setting, land use, demographics, topography, climate, air quality, noise, ecological resources, and cultural resources of the PGDP. The section concludes with an overview of the surface water hydrology, geology, and hydrogeology of the region.

1.2.2.1 Setting, land use, and demographics

Setting and Land Use

The PGDP is located in western McCracken County, Kentucky, about 6.5 km (4 miles) south of the Ohio River and approximately 16 km (10 miles) west of the city of Paducah (Fig. 1.3). Approximately 90% of the area within an 8-km (5-mile) radius of the plant is agricultural or forested land. Urban and industrial lands comprise less than 4% of the surrounding area, and surface water bodies cover approximately 5% (MMES 1993).

The land at the PGDP and the area that surrounds it have been designated as the following:

- On-Site Secure — DOE Property Inside Security Fence
- On-Site Unsecure — DOE Property Outside Security Fence
- Off-Site — Outside of DOE Property

The total amount of land held by the DOE at the Paducah Reservation is 1,439 hectares (3,556 acres). The industrial portion of the PGDP is situated within a fenced security area consisting of approximately 303 hectares (748 acres). Within this area, designated as On-Site Secure (i.e., fenced and patrolled) land use is exclusively industrial and numerous buildings and offices, support facilities, equipment storage areas, and active and inactive waste management units are present. Outside the fenced security area is approximately 804 hectares (1,986 acres) of land designated as On-Site Unsecure that the DOE leases to

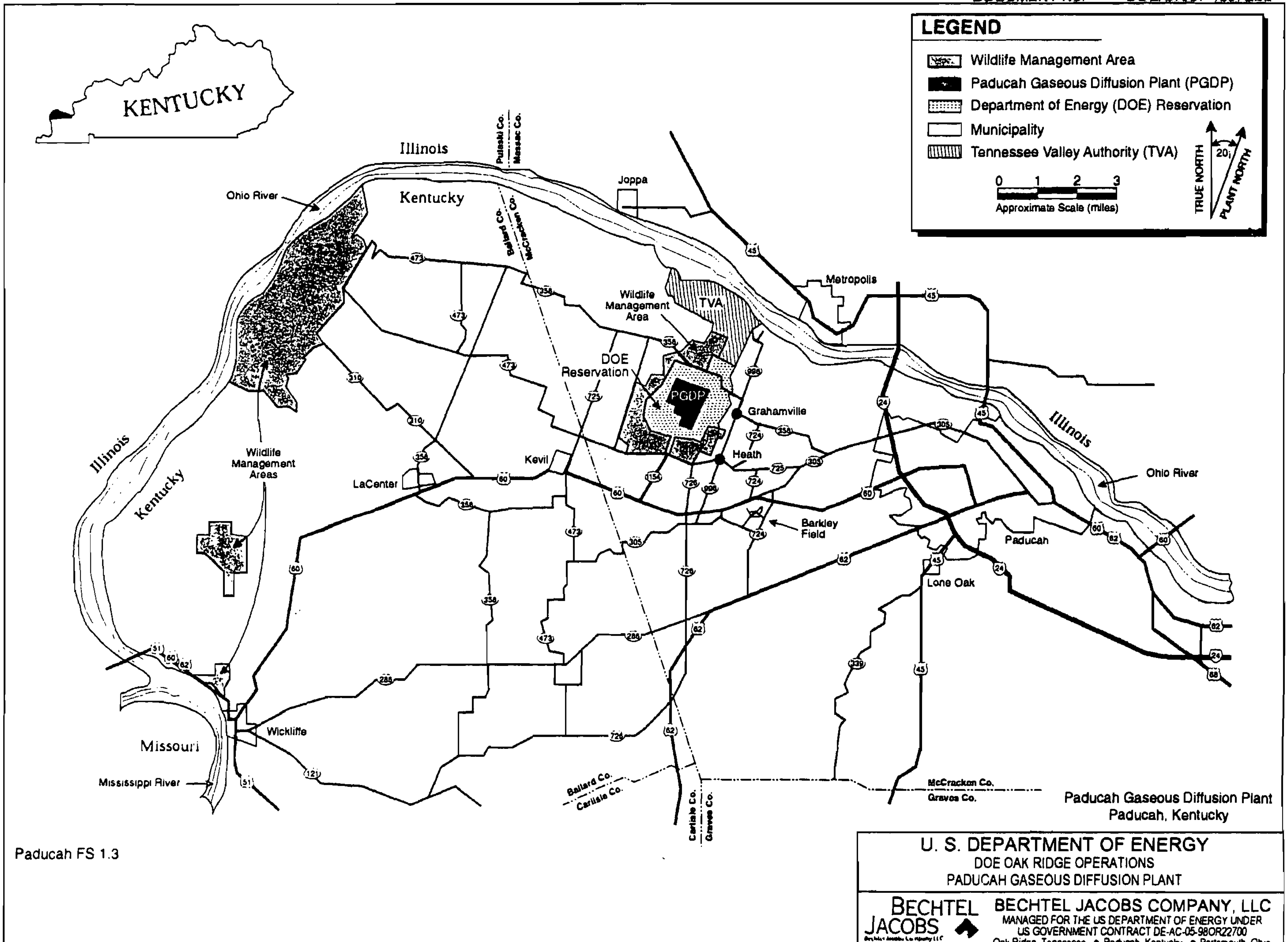


Fig. 1.3. PGDP vicinity map.

FIGURE FS1-3
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the Commonwealth of Kentucky as part of the WKWMA. The land leased to the WKWMA is designated as recreational and is used extensively for outdoor recreation such as hunting, horseback riding, and fishing. The remaining portions of the DOE property, all of which also are designated as On-Site Unsecure, consist of approximately 279 hectares (689 acres) of land maintained by the DOE and 54 hectares (133 acres) of easements acquired by the DOE (DOE 1998a). All other acreage located outside that which DOE owns is designated as Off-Site. Figure 1.4 details the current land use surrounding the PGDP. No changes to land use are expected in the foreseeable future.

Four federal highways (U.S. 45, 60, 62, and 68) and one interstate highway (I-24) are in the vicinity of the PGDP (Fig. 1.3). Highway 60 is used most frequently by plant personnel for access to the PGDP. The closest commercial airport is Barkley Regional Airport, which is located approximately 8 km (5 miles) southeast of the plant.

Demographics

The population of McCracken County, as of July 1995, was reported as 64,577 persons. Counties adjacent to McCracken, in closest proximity to the plant, reported the following populations: Ballard County, Kentucky, 8,232 and Massac County, Illinois, 15,370 (DOC 1995). The total population within an 80-km (50-mile) radius of the plant was estimated at 500,000 with approximately 66,000 residing within a 16-km (10-mile) radius of the PGDP (DOE 1994a). Between 300 and 500 individuals reside within the boundaries of the former Kentucky Ordnance Works (TCT-St. Louis 1992). The small communities of Grahamville, Heath, and Kevil are within a 5-km (3-mile) radius of the DOE property boundary. Larger municipalities such as Paducah and LaCenter, Kentucky, and Joppa and Metropolis, Illinois, are within a 16- to 32-km (10- to 20-mile) radius of the site.

1.2.2.2 Surface features and topography

The PGDP is situated in an area characterized by low relief. Elevations vary from about 107 to 119 m (350 to 390 ft) above mean sea level (amsl) on the plant property, with the ground surface sloping at a rate of approximately 5 m/km (27 ft/mile) toward the Ohio River. Two main topographic features dominate the landscape in the surrounding area: the loess-covered plains, at an average elevation of 119 m (390 ft) amsl; and the Ohio River floodplain zone, dominated by alluvial sediments, at an average elevation of 96 m (315 ft) amsl (USDA 1976). The terrain of the PGDP area is slightly modified by the dendritic drainage systems associated with the two principal streams in the area, Bayou Creek and Little Bayou Creek. These northerly flowing streams have eroded small valleys that are approximately 6.1 m (20 ft) lower in elevation than the adjacent plain.

1.2.2.3 Climate, air quality, and noise

Climate

The climate of the PGDP area can be described as humid-continental. It is characterized by warm and humid summers and moderately cold and humid winters. Temperatures for the summer months average 29.4°C (85°F), while winter temperatures average 2.2°C (36°F). During the winter months, temperatures drop below freezing an average of 60 nights and 10 days.

Precipitation is distributed relatively evenly throughout the year and averaged 128 cm (50 in.) per year from 1969 to 1989 (CH2M HILL 1992). The 5-year average annual precipitation for the region from 1990 to 1994 was 113.13 cm (44.54 in.) per year (MCC 1995). Most groundwater recharge and stream flooding occur between November and May, when evapotranspiration is normally less than the remainder of the year.

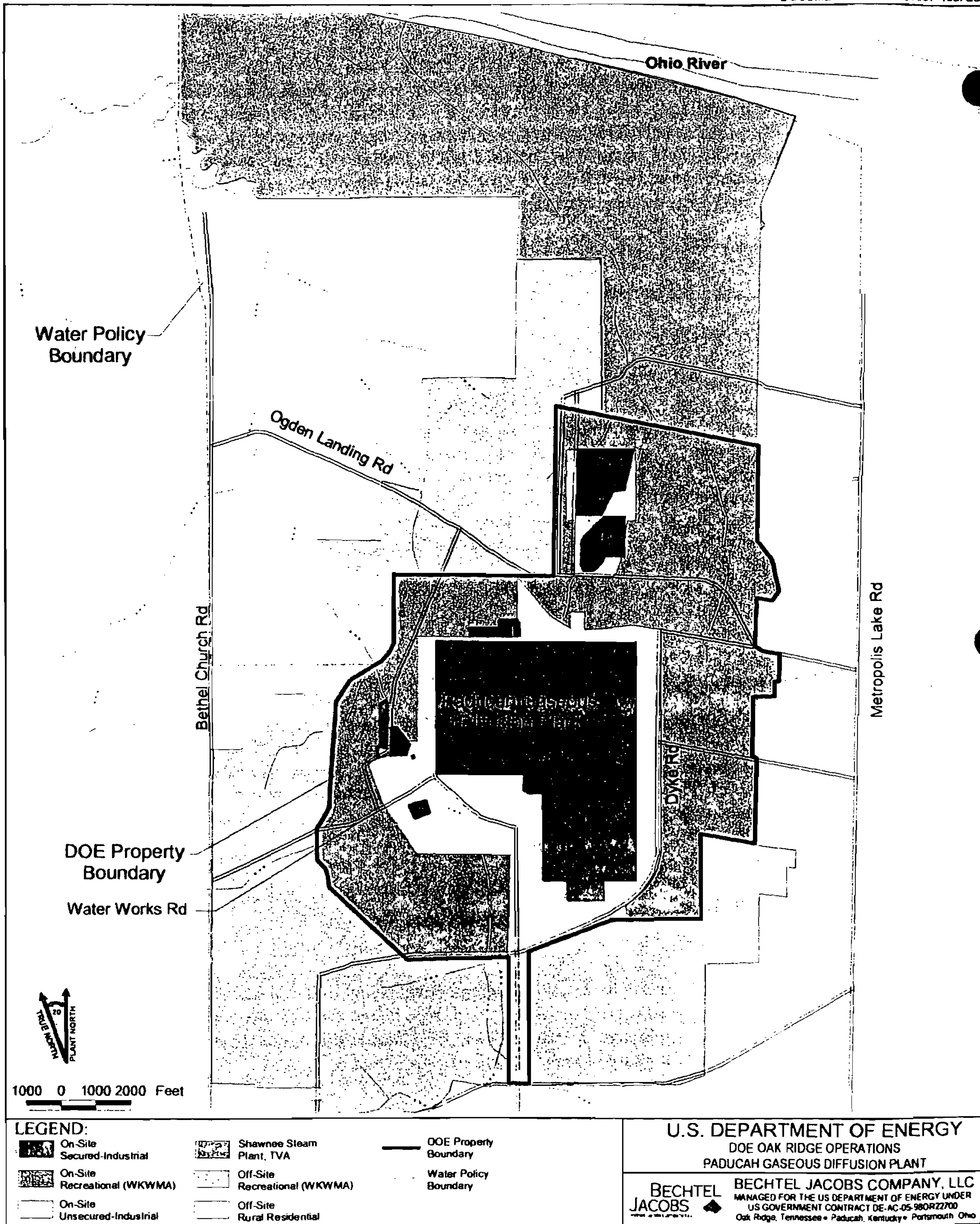

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Fig. 1.4. Current land use surrounding PGDP.

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Figure No. FS1-4
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The average prevailing wind in the area is from the south to southwest at approximately 16 km per hour (9.8 mph). Generally, stronger winds are observed when the winds are from the southwest or northwest.

Air Quality

The 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 (KEQC 1992). In addition, the U.S. Enrichment Corporation (USEC), which operates the PGDP, operates an ambient air monitoring system to assess the impact of various air contaminants emitted by the PGDP on the surrounding environment. Ambient air monitoring of radioactive particulates (gross alpha and gross beta) is accomplished by six continuous samplers. Eight additional ambient air sampling stations are operated by the Commonwealth of Kentucky Agreement in Principal organization to monitor air impacts from the PGDP.

Noise

Noises associated with plant activities generally are restricted to areas inside buildings located onsite. 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.

1.2.2.4 Ecological and cultural resources

Soils and Prime Farmland

Six soil types are associated with the 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. 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 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 66 cm (26 in.) below ground surface (bgs) to a depth of 127 cm (50 in.) or more. The fragipan reduces the vertical movement of water and causes a seasonally perched water table in some areas at the 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. Except for a single alternative, which has considerable drilling in the area north of the plant, only temporary impacts are expected to occur for the prime farmland through monitoring well installations (USDA 1976).

Vegetation

Vegetation at the PGDP primarily consists of agricultural, grassland, scrub-shrub, and mixed forest communities. The WKWMA employs an aggressive management program designed to promote native prairie vegetation using burning, mowing, and various other techniques. These managed areas have the greatest potential for restoration and establishment of a sizable prairie preserve in the Jackson Purchase area (KSNPC 1991).

Wildlife

Small mammal surveys conducted on the WKWMA documented the presence of southern short-tailed shrew (*Blarina carolinensis*), prairie vole (*Microtus ochrogaster*), house mouse (*Mus musculus*), rice rat (*Oryzomys palustris*), and deer mouse (*Peromyscus* sp.) (KSNPC 1991). Large mammals commonly present in the area include coyote (*Canis latrans*), opossum (*Didelphis marsupialis*), groundhog (*Marmota monax*), whitetail deer (*Odocoileus virginianus*), raccoon (*Procyon lotor*), and gray squirrel (*Sciurus carolinensis*).

Typical birds of the area include European starling (*Sturnus vulgaris*), cardinal (*Cardinalis cardinalis*), red-wing blackbird (*Agelaius phoeniceus*), mourning dove (*Zenaida macroura*), bobwhite quail (*Colinus virginianus*), turkey (*Meleagris gallopavo*), killdeer (*Charadrius vociferus*), American robin (*Turdus migratorius*), eastern meadowlark (*Sturnella magna*), eastern bluebird (*Sialia sialis*), bluejay (*Cyanocitta cristata*), red-tail hawk (*Buteo jamaicensis*), and great horned owl (*Bubo virginianus*), ducks, and geese.

Amphibians and reptiles present include cricket frog (*Acris crepitans*), Fowler's toad (*Bufo woodhousii fowleri*), common snapping turtle (*Chelydra serpentina*), green treefrog (*Hyla cinerea*), chorus frog (*Pseudacris triseriata*), southern leopard frog (*Rana utricularia*), eastern fence lizard (*Sceloporus undulatus*), and red-eared slider (*Trachemys scripta elegans*) (KSNPC 1991).

Mist netting activities in the area have captured red bat (*Lasiurus borealis*), little brown bat (*Myotis lucifugus*), Indiana bat (*Myotis sodalis*), northern long-eared bat (*Myotis septentrionalis*), evening bat (*Nycticeius humeralis*), and eastern pipistrelle (*Pipistrellus subflavus*) (KSNPC 1991).

Threatened and Endangered Species

Potential habitat for federally listed threatened and endangered (T&E) species was evaluated for the area surrounding the 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 Federal 1994). No T&E species or potential habitats for any T&E species were observed during the inside-the-fence investigation. The Indiana bat (listed endangered) has been observed in the PGDP area.

Cultural, Archaeological, and Historic Resources

Cultural resources were evaluated for the PGDP during the 1994 COE environmental investigation of the PGDP (COE 1994). No PGDP properties are currently listed or proposed for listing on the National Register of Historic Places (NRHP). However, determinations of NRHP eligibility have not been completed for PGDP production facilities. Below ground areas inside the plant security fence are considered to be disturbed significantly such that undisturbed sites of archaeological significance are very unlikely. Potential impacts to cultural resources are considered on a project-by-project basis in accordance with the National Historic Preservation Act.

1.2.2.5 Surface water hydrology and wetlands

Surface Water Hydrology

The PGDP is located in the western portion of the Ohio River basin. The plant's surface water drains to tributaries of the Ohio River; surface flow is to the east and northeast toward Little Bayou Creek, and to the west and northwest toward Bayou Creek (Fig. 1.5). Both Bayou and Little Bayou Creeks are perennial streams that ultimately discharge into the Ohio River. Little Bayou Creek is an intermittent stream upgradient of PGDP but becomes perennial near PGDP due to the plant's effluents. Bayou Creek is the larger and primary of the two creeks. The surface water and surface soils within the drainage areas of both creeks generally are acidic.

Bayou Creek flows generally northward along the western boundary of the plant from approximately 4 km (2.5 miles) south of the plant to the Ohio River. Little Bayou Creek originates within the WKWMA and flows northward along the eastern boundary of the plant. Little Bayou Creek joins Bayou Creek in a marsh located approximately 4.8 km (3 miles) north of the PGDP. Other surface water bodies located in the area surrounding the PGDP include the Ohio River, Metropolis Lake, Crawford Lake, numerous small ponds, gravel pits, and settling basins.

At the PGDP, man-made drainage ditches receive stormwater and effluent from the plant. These waters are routed through outfalls and eventually discharge into Bayou and Little Bayou Creeks. The Kentucky Pollutant Discharge Elimination System (KPDES) permitted outfalls have a combined average daily flow of 18.5 million liters per day (4.88 mgd) and are monitored by the PGDP.

Wetlands

Wetlands were identified during the 1994 COE environmental investigation for the area surrounding the PGDP. This investigation identified 1083 separate wetland areas of varying types (COE 1994). Five acres of potential wetlands were identified inside the fence at the PGDP (COE 1994). 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, flood water 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 the PGDP (COE 1994). This evaluation used the Hydrologic Engineering Center Computer Program (HEC)-2 model to estimate 100- and 500-year flood elevations. Flood boundaries from the HEC-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 the PGDP is associated with stormwater runoff and flooding from Bayou and Little Bayou Creeks. Drainage ditches inside the PGDP security fence can contain nearly all of the expected 100- and 500-year flood discharges (COE 1994).

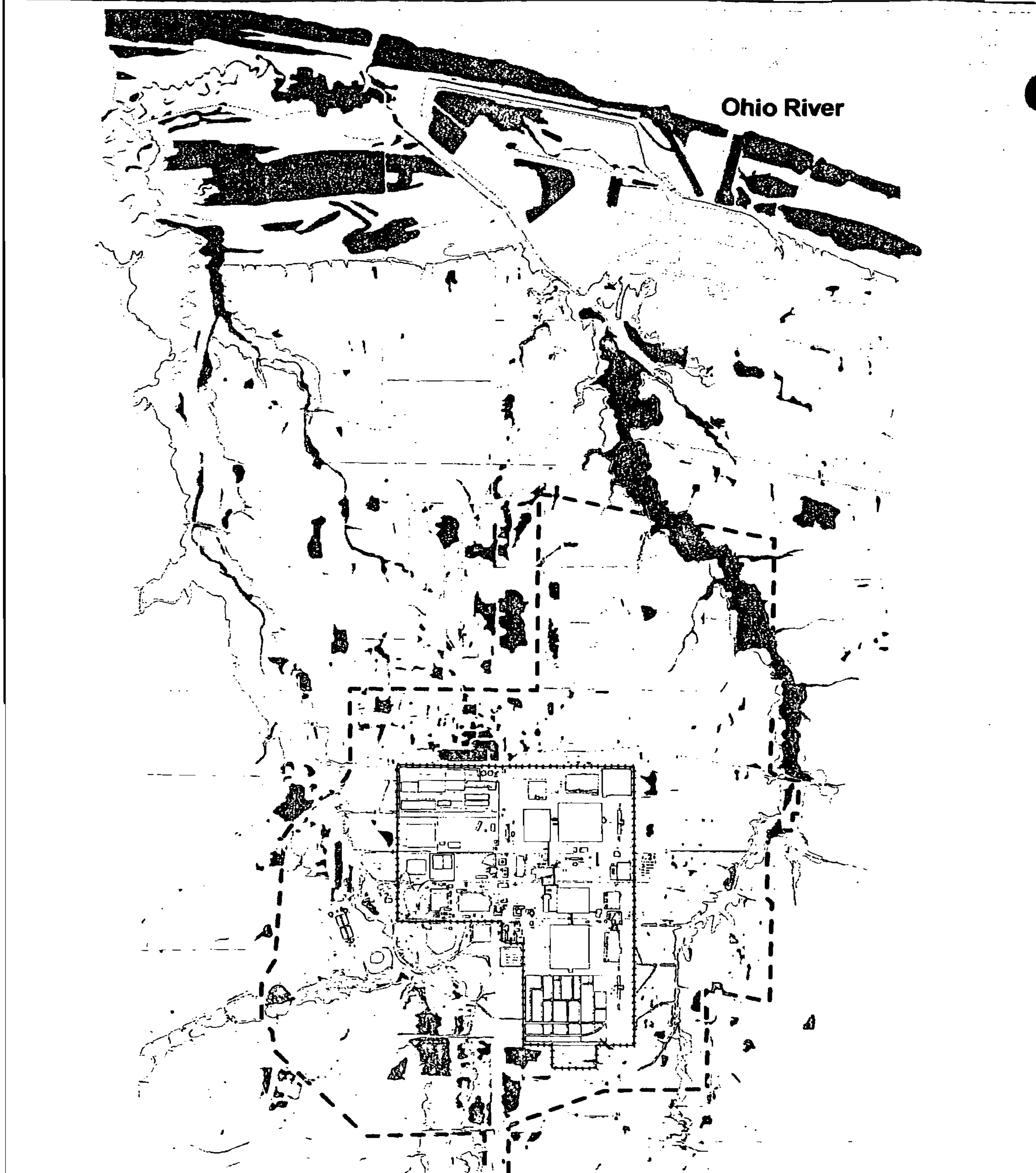

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Fig. 1.5. Surface water features in the vicinity of the PGDP.

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1.2.2.6 Regional geology/hydrogeology

This section summarizes the stratigraphy and hydrogeology of the PGDP area. The information presented in this section is derived primarily from the *Report of the Paducah Gaseous Diffusion Plant Groundwater Investigation Phase III* (MMES 1992a), unless otherwise indicated.

Regional Geology

The PGDP is located in the Jackson Purchase region of western Kentucky, at the northern tip of the Mississippi Embayment portion of the Gulf Coastal Plain Province. Cretaceous, Tertiary, and Quaternary sediments, with an approximate thickness of 104 m (340 ft), unconformably overlying Paleozoic bedrock, make up the stratigraphic sequence in the region. The pre-Cretaceous erosional surface is irregular, generally sloping south–southwest approximately 7 to 8 m/km (35 to 40 ft/mile). The strike of the Cretaceous and Tertiary strata is parallel to the margin of the Mississippi Embayment with the dip uniformly toward the embayment axis (USGS 1980). The deposits overlying the bedrock consist of the following strata, in order of decreasing depth: the rubble zone, the McNairy Formation, the Porters Creek Clay, the Eocene Sands, the continental deposits, and surficial loess and/or alluvium. Figure 1.6 presents a schematic diagram illustrating the relationships among the geologic horizons present at the PGDP.

Paleozoic bedrock regionally dips moderately (approximately 1 degree) to the northeast toward the Illinois Basin. Faulting has created local variations in orientation of bedrock strata. In 1981, Kolata, Treworgy, and Masters mapped northeast–southwest trending faults of the Fluorspar Area Fault Complex in Paleozoic rock north of the Ohio River in Illinois (ISGS 1981). Later research has shown that some faults of the area offset Tertiary and Quaternary sediments (Nelson et al. 1997). Continuity of these faults into Kentucky is not known. W.W. Olive mapped a few faults in Tertiary and Quaternary material in the Jackson Purchase region. However, he reported that most faults offsetting post-Paleozoic strata shown on his map were based on indirect evidence and were possibly attributable to causes other than tectonic faulting (USGS 1980).

The principal geologic feature in the PGDP area is the Porters Creek Clay Terrace, a large, low-angle, subsurface terrace trending approximately east–west across the southern portion of the plant. This terrace is believed to be the result of the erosion of the Porters Creek Clay by the ancestral Tennessee River. Due to the erosion, the Porters Creek Clay is essentially absent from the PGDP area north of the terrace slope.

North of the terrace slope, continental deposits directly overlay the McNairy Formation, a sequence of marine clays, silts, unconsolidated sands, and occasional fine gravel. The continental deposits are subdivided informally into the Lower Continental Deposits, consisting of chert gravel in a matrix of sand and silt, and the Upper Continental Deposits, which consist of thin interbedded layers of clayey silt, sand, and occasional gravel. Fine-grained aeolian deposits called loess commonly overlay the continental deposits. However, along rivers or creeks, the surficial deposits are typically alluvium.

In the PGDP area south of the terrace slope, the Porters Creek Clay directly overlies the McNairy Formation. The Porters Creek Clay is unconformably overlain by either the Eocene Sands or the continental deposits. The principal gravel facies within the continental deposits south of the Porters Creek Clay Terrace slope are Miocene-Pliocene gravels, commonly referred to as Terrace Gravel deposits.

Regional Hydrogeology

Several water-bearing zones are present in the PGDP area. North of the Porters Creek Clay Terrace, the primary water-bearing units, in order of increasing depth, are the UCRS, the RGA, and the McNairy Formation (Fig. 1.7). The RGA has been identified as the uppermost aquifer at the PGDP (MMES 1992b). South of the buried terrace slope, the principal water-bearing units are the Terrace Gravel, the

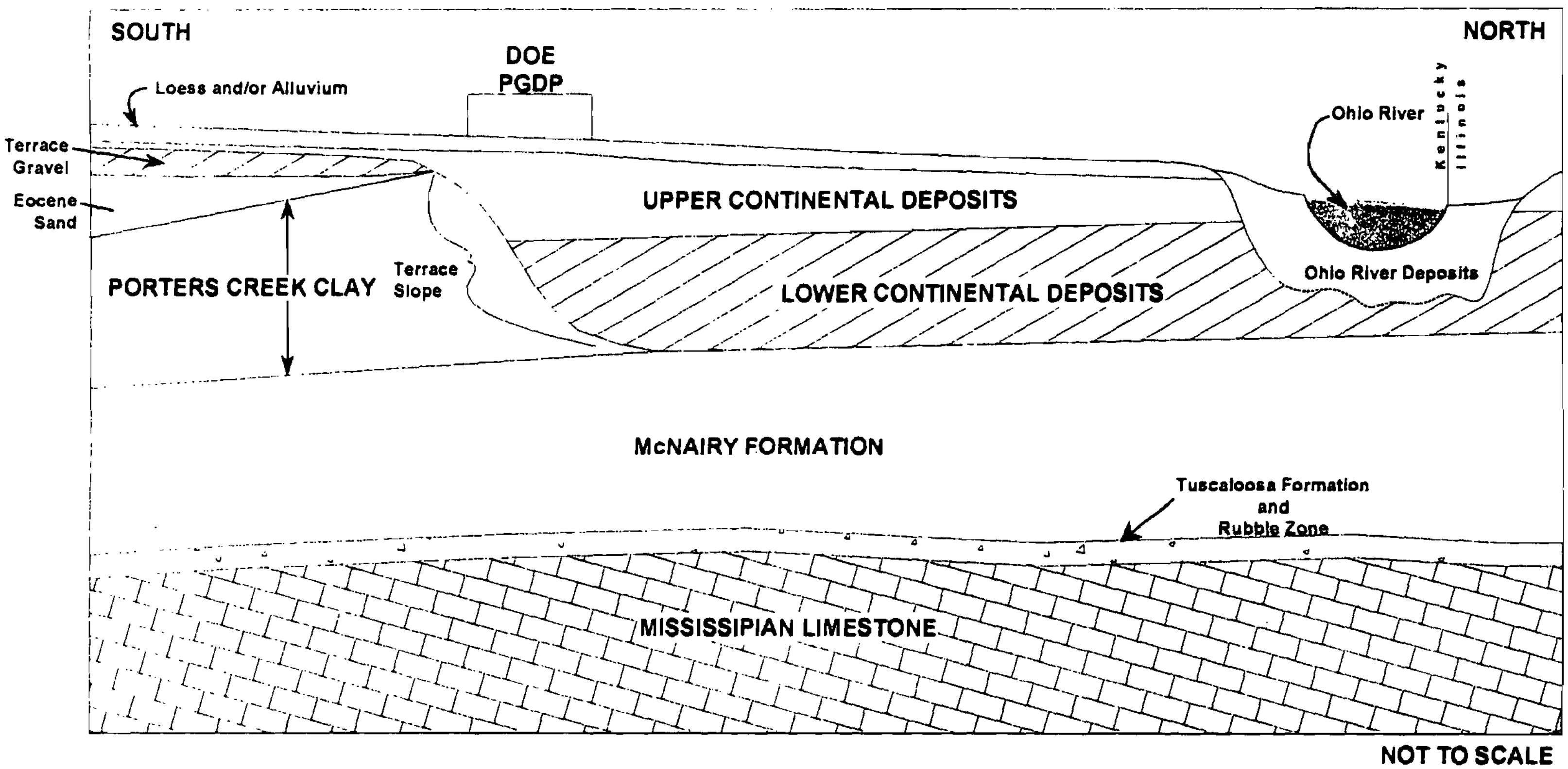

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Fig. 1.6. Schematic of stratigraphic and structural relationships near the PGDP.

FIGURE No. FS1-6
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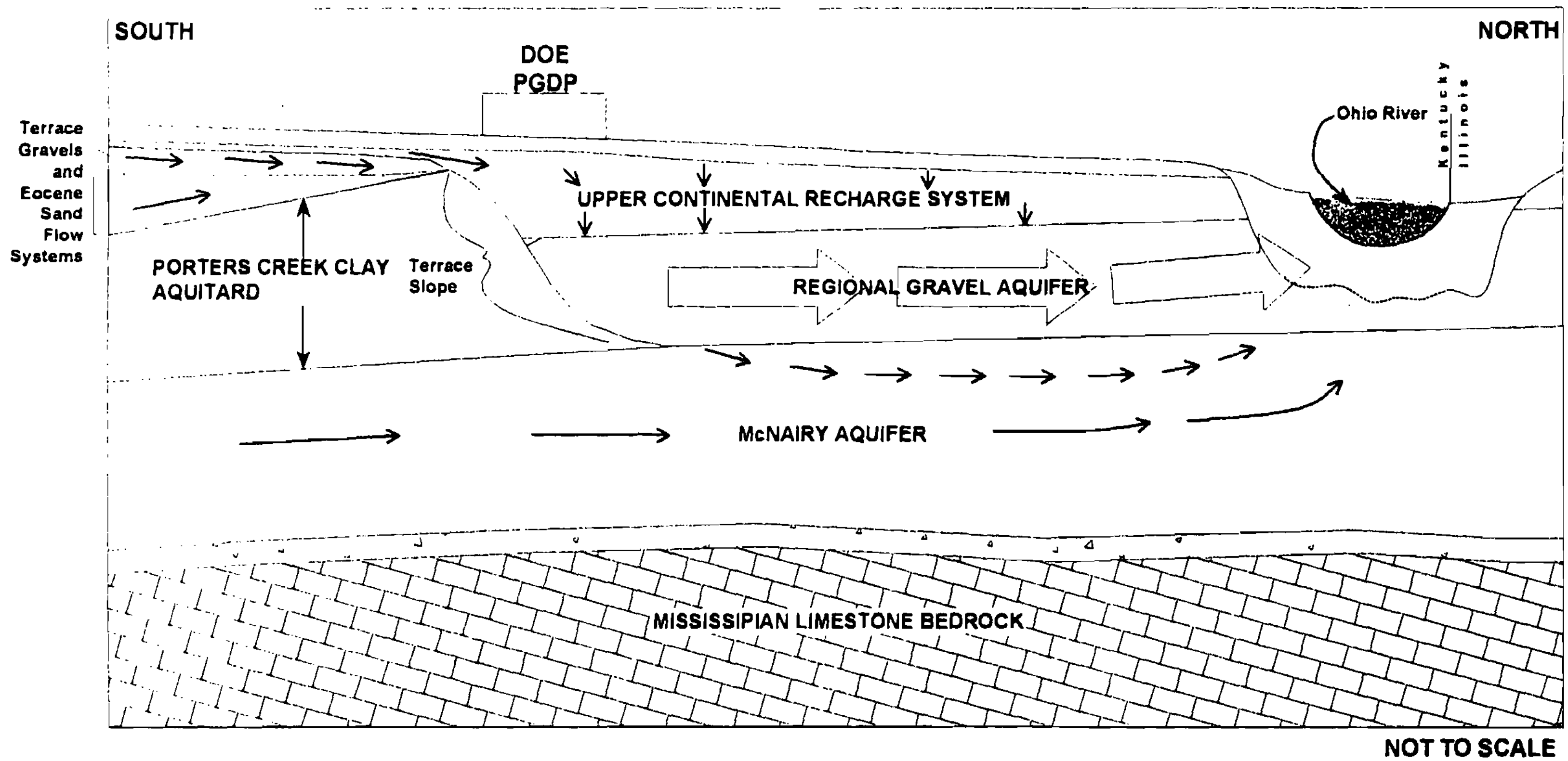

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Fig. 1.7. Water-bearing zones near the PGDP.

FIGURE No. FS1-7
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Eocene Sands, and the McNairy Formation. The RGA is the dominant groundwater flow system at the PGDP and contains the major on-site and off-site contaminant plumes.

For this FS report, the subsurface stratigraphy at the PGDP has been divided into the following six correlatable hydrogeologic units (HUs), based primarily on the physical properties that describe the HU's general ability to hold and/or conduct water:

- HU 1 — Loess,
- HU 2 — the sands and gravels of the UCRS,
- HU 3 — the aquitard between the overlying shallow sands and gravels and the underlying RGA,
- HU 4 — the generally thin sand horizon at the top of the RGA,
- HU 5 — the main sand and gravel deposit of the RGA, and
- HU 6 — the McNairy Flow System.

HU 1 is the uppermost member of the UCRS and consists of surficial deposits of clayey silt of wind-blown origin (loess). The loess deposits are typically 1.5 to 7.6 m (5 to 25 ft) thick in the PGDP area.

HU 2 consists of numerous sand and gravel units within a less-permeable clayey silt matrix of the Upper Continental Deposits. HU 2 has been further divided into two units, HU 2A and HU 2B. The uppermost unit, HU 2A, is a gravel or sand layer found approximately 4.8 m (16 ft) bgs across most of the site. Below HU 2A, and typically separated from it by clay or silt lenses of varying thickness, is a thin horizon of sand or gravel lenses designated HU 2B. The HU 2B units occur at various elevations beneath the reservation, and their degree of interconnection is not known.

At the base of the UCRS, a clay, silt, or clayey-silt layer (HU 3) separates the HU 2 sands and gravels from the underlying RGA. This layer is relatively continuous across the PGDP, but its thickness varies.

HU 4 is a discontinuous sand, typically found at the top of the RGA beneath the PGDP. HU 4 is hydraulically connected to HU 5 as they exhibit almost identical hydraulic heads in locations where nested wells are completed in both units.

Most of the flow in the RGA occurs in HU 5, which consists of the gravel and sand facies of the Lower Continental Deposits. The unit ranges in thickness from 3 to 21.3 m (10 to 70 ft) beneath the PGDP and to the north but pinches out against the base of the Porters Creek Clay terrace slope under the south end of the PGDP.

HU 6, the McNairy Flow System, includes most of the McNairy Formation. The McNairy Formation averages 70 m (230 ft) thick and lies at depths ranging from 18 to 37 m (60 to 120 ft) bgs. Where the sands of the upper part of the McNairy Formation are present directly beneath the RGA, they are grouped within the RGA.

Figure 1.8 identifies the HUs on a representative soil boring log from a monitoring well in the area. Table 1.2 summarizes the available hydraulic conductivity data from tests of the primary HUs in the PGDP area.

Groundwater Flow

Groundwater flow is predominately vertically downward in the UCRS, providing recharge to the RGA. In general, the depth to the UCRS water table is less than 20 ft in the western half of the PGDP and as much as 40 ft in the northeastern corner. The main features of the local water table are (1) a broad trough in the northeast and central areas of the PGDP, (2) a linear discharge area associated with a drainage

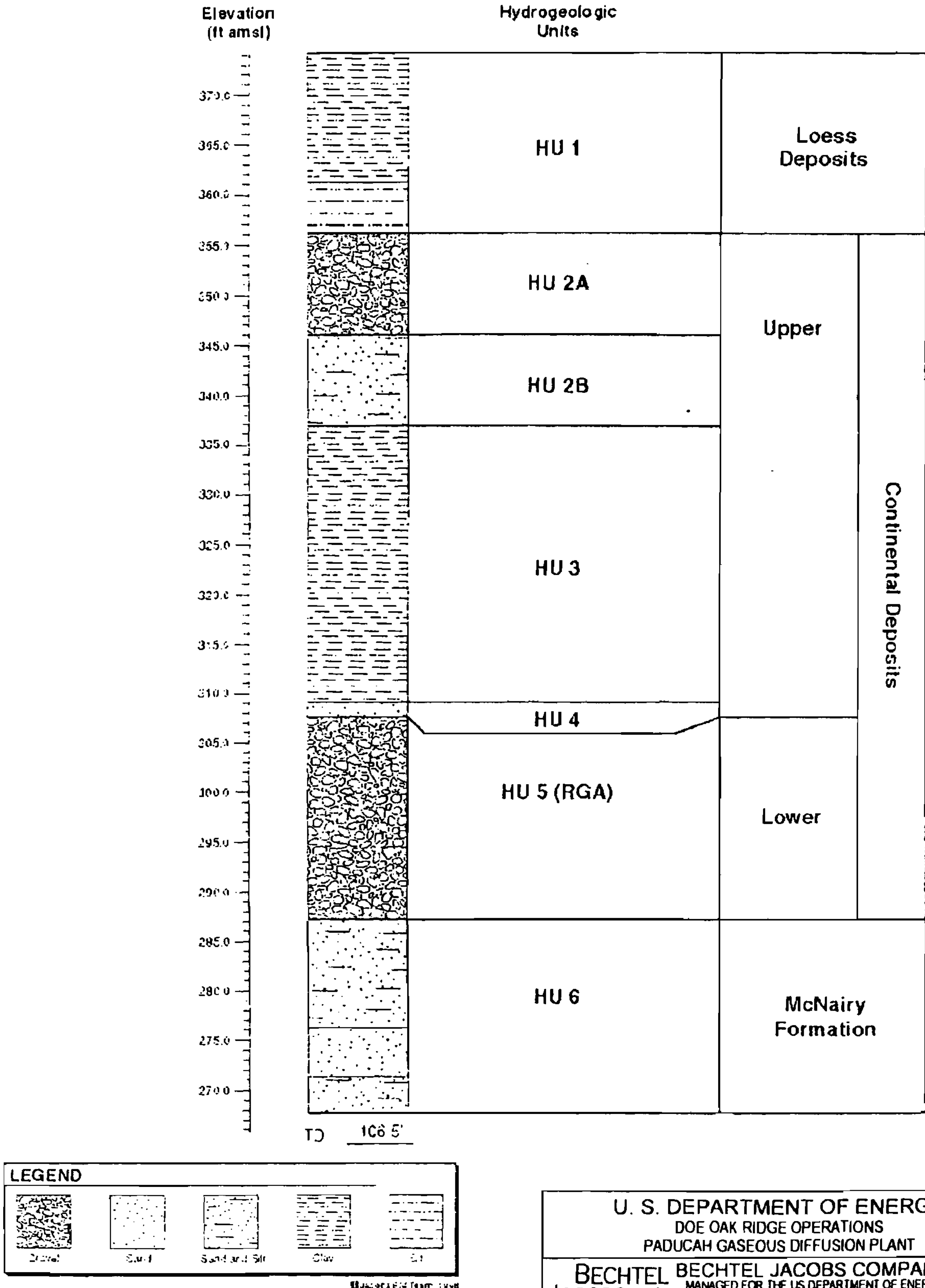

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Fig. 1.8. Hydrogeologic units.

FIGURE No. FS1-8
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Table 1.2. Hydraulic conductivity data for the PGDP

HU	Low	Mean	High	Type of test and reference
UCRS (K_h)	**UCRS (K_h)**	**UCRS (K_h)**	**UCRS (K_h)**	**UCRS (K_h)**
(cm/sec)	1.0×10^{-8}		6.9×10^{-4}	Slug tests
(ft/day)	2.9×10^{-5}		1.96	(CH2M HILL 1992)
HU3 (K_v)	**HU3 (K_v)**	**HU3 (K_v)**	**HU3 (K_v)**	**HU3 (K_v)**
(cm/sec)		2.0×10^{-4}		Pumping test at C-404
(ft/day)		5.7×10^{-1}		(Terran 1990)
(cm/sec)	1.1×10^{-5}		1.1×10^{-4}	Pumping test at C-333
(ft/day)	3.0×10^{-2}		3.0×10^{-1}	(Terran 1992)
RGA (K_h)	**RGA (K_h)**	**RGA (K_h)**	**RGA (K_h)**	**RGA (K_h)**
(cm/sec)	1.9×10^{-2}		3.8×10^{-2}	Pumping test at C-404 (Terran 1990)
(ft/day)	53		107	
(cm/sec)	3.2×10^{-5}		5.2×10^{-2}	Slug tests (CH2M HILL 1992)
(ft/day)	9.1×10^{-2}		146	
(cm/sec)	3.5×10^{-2}		5.3×10^{-2}	Pumping test at C-537 (CH2M HILL
(ft/day)	100		150	1992)
(cm/sec)	3.5×10^{-1}		4.2×10^{-1}	Pumping test at C-333 (Terran 1992)
(ft/day)	1,000		1,200	
(cm/sec)	1.9×10^{-1}		4.3×10^{-1}	Pumping test at Northeast Plume
(ft/day)	529		1,213	containment well field (DOE 1997a)
(cm/sec)	9.5×10^{-1}		2	Pumping test at Northwest Plume north
(ft/day)	2,686		5,700	containment well field (LMES 1996a)
McNairy (K_h)	**McNairy (K_h)**	**McNairy (K_h)**	**McNairy (K_h)**	**McNairy (K_h)**
(cm/sec)		6.2×10^{-6}		Analysis of cyclic water level trends in
(ft/day)		1.7×10^{-2}		McNairy wells (LMES 1996b)
(cm/sec)	2.9×10^{-5}		1.8×10^{-4}	Slug tests (CH2M HILL 1992)
(ft/day)	8.2×10^{-2}		5.2×10^{-1}	
McNairy (K_v)	**McNairy (K_v)**	**McNairy (K_v)**	**McNairy (K_v)**	**McNairy (K_v)**
(cm/sec)	1.8×10^{-8}		5.0×10^{-4}	Permeameter tests of C-746-U landfill and
(ft/day)	5.1×10^{-5}		1	Northwest Plume containment well field samples (LMES 1996b)
(cm/sec)		1.6×10^{-7}		Analysis of cyclic water level trends in
(ft/day)		4.5×10^{-4}		McNairy wells (LMES 1996b)

HU = hydrogeologic unit
PGDP = Paducah Gaseous Diffusion Plant
RGA = Regional Gravel Aquifer
UCRS = Upper Continental Recharge System

channel (the East-West Ditch) in the northwest quadrant of the PGDP, and (3) a lateral hydraulic gradient toward Bayou Creek on the west side of the PGDP. Strong downward vertical gradients of 0.5 m/m and greater prevail across the site in the UCRS.

The RGA typically has a relatively high hydraulic conductivity and so serves as the dominant flow system in the area. Hydraulic gradients direct groundwater flow in the RGA laterally to the north where the regional groundwater systems discharge into the Ohio River. Figure 1.9 presents the average RGA hydraulic potential surface map (relative to mean sea level) for the PGDP area. Over most of the plant area, the lateral gradient within the RGA is very low and on the order of 7×10^{-4}m/m. Groundwater velocity within the RGA is estimated to range from 61 to 122 m/year (200 to 400 ft/year) to the north–northeast, toward the Ohio River (DOE 1994a).

Silts and fine sands of the McNairy Formation, found beneath the RGA sediments, form the lower confining unit to the shallow aquifer system. The regional groundwater flow direction in the McNairy Formation is toward the Ohio River. Vertical hydraulic gradients in the McNairy Formation are downward beneath the PGDP but upward near the Ohio River.

Water Balance

Recharge to the RGA primarily is via infiltration from the UCRS. The Terrace Gravel flow system contributes some underflow to the RGA to the east and west of the PGDP. Groundwater flow models have provided the best analysis of the groundwater recharge budget at the PGDP. The annual rainfall for the PGDP averages 127 cm (50 in.) per year. Of this rainfall total, approximately 22 cm (8.5 in.) of water infiltrates through the UCRS to the RGA. The remainder of the rainfall total is returned to the atmosphere through evapotranspiration or routed to creeks as surface runoff.

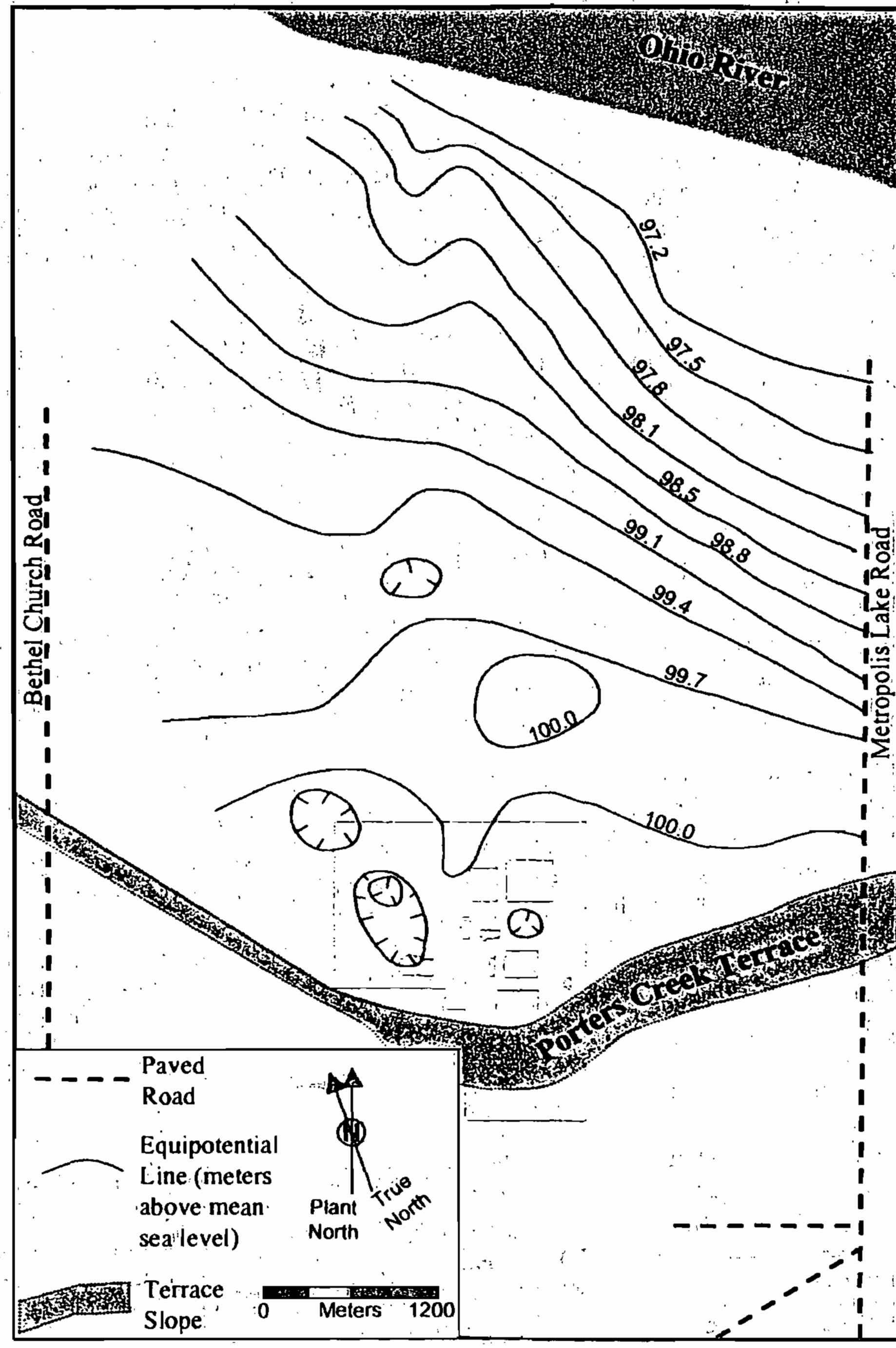
The PGDP is a water-intensive facility, on average using between 37.9 and 75.7 million liters (10 to 20 million gal) of water per day withdrawn from the Ohio River. Although it is known that leakage from the plant water utility system must be a significant contribution to RGA recharge, water use surveys have proven inadequate to quantify the amount. Groundwater flow modeling provides the best estimate of the impact of plant water utilities. The area recharge in the vicinity of the four PGDP cooling tower complexes and two main lagoons north of the PGDP must be approximately 86 cm (34 in.) per year (166,000 L — 44,000 gal — of water per day) for the model to duplicate groundwater flow directions evidenced by the main PGDP groundwater plumes. It is likely that other large lagoons at the PGDP (e.g., The C-611 Water Treatment Plant Lagoons) may also be sites of enhanced recharge.

1.2.3 Description and History of SWMUs in the GWOU

Because of the broad scope of current and historical operations at the PGDP, numerous SWMUs impact the GWOU. The history and investigation of these SWMUs is documented in many remedial investigation (RI) and site evaluation reports that have been written since the beginning of the DOE Environmental Restoration Program at the PGDP. Appendix A of this FS, the Data Summary Report (DSR), provides a review of the primary SWMUs associated with the GWOU and groundwater investigations at the PGDP.

1.2.4 Nature and Extent of Contamination in the GWOU

The DSR (Appendix A) includes an abstract of the assessment of the nature and extent of soil and groundwater contamination taken from each previous RI report. In addition, the DSR provides a sitewide perspective of the nature and extent of groundwater contamination related to the PGDP through a series of maps based upon the collective GWOU database. Viewed together, these sections provide an empirical basis for evaluating the impact of each SWMU, and the PGDP in general, upon the RGA.



(Modified from *Analysis and Interpretation of Water Levels in Observation Wells at the Paducah Gaseous Diffusion Plant, 1990-1997*, KY/EM-210, 1997)

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Fig. 1.9. Average potentiometric surface of the RGA for the years 1990 through 1997.

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FIGURE No. FS1-9
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1.2.5 Contaminant Fate and Transport

Sampling and analysis of groundwater provides a direct measure for the evaluation of risk to current human and ecological receptors. However, due to the complexities of contaminant fate and transport, current dissolved contaminant levels are not a good indication of past or future exposures. Contaminant fate and transport modeling is an established and conservative approach for estimating future contaminant levels that can be used in risk assessment.

1.2.5.1 Conceptual site model

The conceptual site model is a statement of known site conditions that serves as the framework for fate and transport modeling. These site conditions include hydrogeologic and transport parameters, as summarized in preceding text, as well as contaminant source characteristics. Because the PGDP is a large industrial facility with over 40 years of continuous operation, several types of contaminant sources have been discovered that impact the GWOU. Previous investigations for the PGDP have characterized many of these contaminant sources and the dominant groundwater pathways. In addition, groundwater flow model development for the PGDP has added crucial insight into aquifer properties and transport parameters.

The PGDP overlies the south bank of the ancestral Tennessee River. A 30-ft-thick sand and gravel deposit of the ancestral Tennessee River extends north from beneath the PGDP to the Ohio River. These course sediments form the shallow aquifer beneath the PGDP, known as the RGA. Approximately 60 ft of silt and clay with horizons of sand and gravel lenses overlie the RGA. The groundwater flow system developed in these shallow sediments is called the UCRS. Groundwater flow in the UCRS is predominantly downward, to recharge the RGA. Hydraulic gradients direct groundwater flow in the RGA laterally to the north where groundwater discharges into the Ohio River. Figure 1.9 presents the average potentiometric surface for the RGA.

Contaminant Sources, Release Mechanisms, and Migration Pathways

TCE and ^{99}Tc are the primary contaminants in off-site groundwater that have been previously associated with the PGDP. Some metals and other organic compounds (notably carbon tetrachloride and degradation products of TCE) have been identified in RGA groundwater at the PGDP, but these appear to be less persistent. Section 4 of the DSR (Appendix A) evaluates the nature and extent of the main PGDP COCs. Both historical waste management facilities and spills and leaks associated with production operations are responsible for most of the known contaminant sources to the GWOU. The setting of the primary SWMUs contributing to groundwater contamination and the main contaminants attributed to each are as follows.

Source areas	Setting	Groundwater contaminant(s)	
		UCRS	RGA
C-400 South	Leaks from TCE transfer pump and storm sewer	TCE	TCE
C-400 North	Leaks from waste treatment pit and waste storage tank	TCE and ^{99}Tc	^{99}Tc
AOC 211 (C-720 Northeast)	Spill from degreasing operation	TCE	—
C-720 Southeast	Leaks from storm sewer	TCE	—
C-333 Northeast	Process building operations	TCE	TCE
North-South Diversion Ditch	Infiltration from effluent ditch	^{99}Tc	—
SWMU 1	Infiltration from landfarm	TCE	—
SWMU 4	Infiltration from waste burial pits	TCE and ^{99}Tc	TCE and ^{99}Tc
SWMUs 7 and 30	Infiltration from waste burial pits	TCE and ^{99}Tc	TCE and ^{99}Tc
SWMU 99	Infiltration from scrap yard	^{99}Tc	—

UCRS = Upper Continental Recharge System; RGA = Regional Gravel Aquifer
AOC = Area of Concern; SWMU = solid waste management unit
TCE = trichloroethene; ^{99}Tc = technetium-99

The detection of contaminants in soil and groundwater during the pervious RIs at the PGDP confirms the potential for media-specific chemical transport. Both TCE and ^{99}Tc can move as dissolved contaminants leaching from the SWMUs through the underlying soil to the groundwater. Moreover, TCE has the ability to move as a DNAPL through soil and groundwater. Where DNAPL occurs in the subsurface, TCE will be dispersed through the soils along its migration pathway and may pool on top of low-permeability layers. In either case, the DNAPL forms a secondary source of TCE in the subsurface that will leach dissolved contamination to groundwater. Figure 1.10 illustrates the conceptual site model for the PGDP.

Once a dissolved contaminant reaches the RGA, the contaminant can be transported through the groundwater to downgradient receptors. The fate and transport modeling of the GWOU FS evaluates four potential points of exposure to contaminated groundwater defined as integrator points (IPs):

- the PGDP security fence, where a well might be drilled into the RGA by a future homesteader;
- the DOE property boundary, where a well might be drilled into the RGA by a future homesteader;
- a reach of Little Bayou Creek near the Tennessee Valley Authority's (TVA's) Shawnee Steam Plant, where recreational users and ecological receptors may be impacted by discharge of the RGA to the creek; and
- the Ohio River, where recreational users and ecological receptors may be impacted by discharge of the RGA to the river, which forms the discharge zone for all of the regional groundwater systems.

Four groundwater contaminant plumes define the major groundwater flow paths in the RGA beneath the PGDP, as follows:

- The Northeast Plume exits the east side of the PGDP and flows approximately 2 miles off-site in a northeastward arc.
- PGDP's Northwest Plume migrates off-site from the northwest corner of the facility and extends approximately 2.5 miles north to Little Bayou Creek.
- The Technetium-99 Plume leaves the PGDP from the north side and tracks east of the Northwest Plume to a canal off the Ohio River.
- A Southwest Plume reaches a short distance (less than 2,000 ft) to the west of the PGDP.

These plumes provide empirical evidence of the potential for exposure to PGDP contaminants through the groundwater pathway and facilitate a measure of the transport distance of PGDP-derived contaminants to exposure points. The DOE has enacted an interim Water Policy action that provides municipal water service to residents of the affected area to prevent direct exposure through the ingestion route.

DNAPL Evidence

As at most DNAPL sites, field sampling has been unable to yield a sample of the DNAPL or persuasively define the limits of a DNAPL zone. The primary lines of evidence to support the presence of a TCE DNAPL at the PGDP are as follows:

- the occurrence of TCE in soil samples at a concentration greater than that which can be provided by contaminated water in the soil porosity,

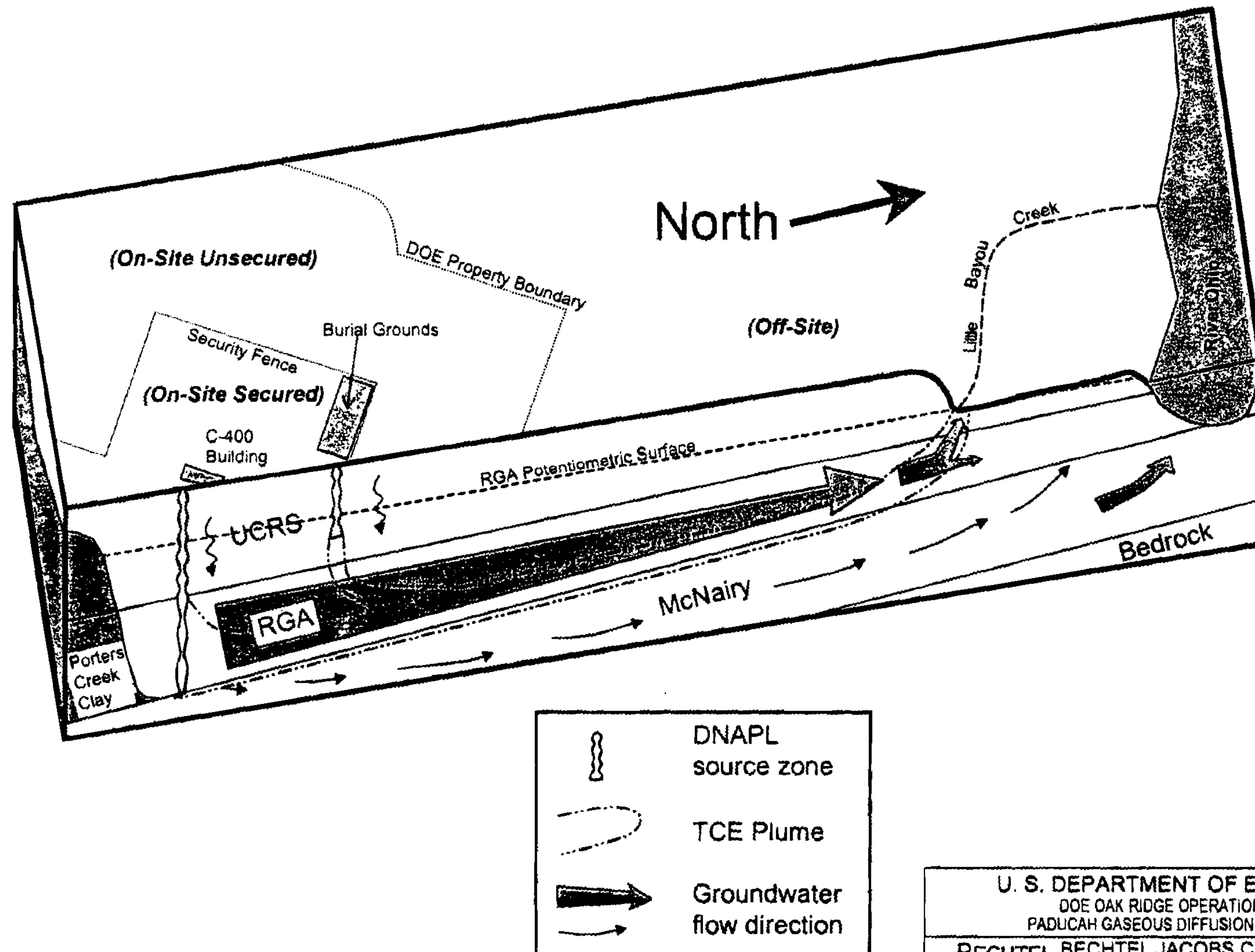

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Fig. 1.10. Conceptual site model for the PGDP.

- dissolved phase concentrations of TCE near the solubility limit in groundwater from suspected source zones, and
- high dissolved phase concentrations of TCE throughout the depth of the RGA in source zones and downgradient plumes.

Table 1.3 summarizes dimension and volume estimates for the representative known and suspected TCE DNAPL zones at the PGDP. Figure 1.11 shows the location of these DNAPL zones. Documentation for the estimates for the TCE DNAPL source zones at the C-400 and C-720 Buildings, as well as the C-747-C Former Oil Landfarm, is provided in Appendix C-5.

The relatively close spacing between source areas and the presence of preferred groundwater flow pathways has led to a commingling of dissolved-phase plumes at the PGDP, such that the impact of downgradient sources is difficult to determine. Thus, the assessment and remediation of groundwater contamination at the PGDP is best achieved from a sitewide perspective.

Hydrologic Properties

The UCRS consists of clayey silt with horizons where sand and gravel lenses are common. PGDP hydrogeologists have differentiated the UCRS into three general horizons:

- HU 1 — an upper silt and clay interval,
- HU 2 — an intervening interval where sand and gravel lenses are common, and
- HU 3 — a lower silt and clay interval.

In general, the water table is less than 20 ft deep in the western half of the PGDP and as much as 40 ft deep in the northeastern corner. The main features of the local water table are (1) a broad trough in the northeast and central areas of the PGDP, (2) a linear discharge area associated with a drainage way (East-West Ditch) in the northwest quadrant of the PGDP, and (3) a lateral hydraulic gradient toward Bayou Creek on the west side of the PGDP. Strong downward vertical gradients of 0.5 ft/ft and greater prevail across the site in the UCRS.

The RGA typically is comprised of a relatively thin HU 4 upper sand horizon and a thick HU 5 sand and gravel interval. A subcrop of the Porters Creek Clay, extending beneath the south end of the PGDP, marks the south limit of the RGA. Silts and fine sands of the McNairy Formation, found beneath the RGA sediments, form the lower confining unit to the shallow aquifer system. Although lateral hydraulic gradients within the RGA at the PGDP are on the order of 1×10^{-4} to 1×10^{-3} ft/ft, the high hydraulic conductivity of the RGA sediments supports average groundwater flow velocities of 0.5 to 2 ft/day. Table 1.2 summarizes the hydraulic conductivity measurements of HUs at the PGDP.

Water Balance

Groundwater flow models have provided the best analysis of the groundwater recharge budget for the PGDP. The annual rainfall for the PGDP averages 50 in./year. Of this rainfall total, approximately 8.5 in. of water infiltrates through the UCRS to the RGA. The remainder of the rainfall total is returned to the atmosphere through evapotranspiration or routed to creeks as surface runoff. Groundwater flow modeling also has emphasized the impact of plant water utilities. The area recharge in the vicinity of the four PGDP cooling tower complexes and two main lagoons north of the PGDP must be approximately 34 in./year for the model to duplicate groundwater flow directions evidenced by the main PGDP groundwater plumes.

Table 1.3. Representative known and suspected DNAPL source zones at the PGDP

	DNAPL Zone	Estimate Basis*	DNAPL Zone Thickness (meters)	DNAPL Zone Surface Area ($meters^2$)	DNAPL Zone Volume ($meters^3$)	DNAPL Volume (liters)	Setting	Operable Unit Assignment for Source Zone
	Northwest Plume							
UCRS	C-400 (Southeast) TCE Transfer Pump	A	17	301	5,228	107,259	Heavy industrial setting	Groundwater Operable Unit
	C-400 (Southeast) Leak Site (SWMU 11)							
	C-400 South End Storm Sewer	B	16	263	4,164	85,427	Heavy industrial setting	Groundwater Operable Unit
	C-747-A Burial Ground (SWMU 7)	C	15	1,839	28,037	Unknown, may be small	Zone below mixed-waste burial cell	Burial Ground Operable Unit
	C-745-B Cylinder Drop Test Area (SWMU 91)	A	11	557	5,947	1,635	Remediation technology selected (Lasagna™)	Groundwater Operable Unit
RGA	C-400 (Southeast) TCE Transfer Pump	D	12	1,353	16,911	547,822	Heavy industrial setting	Groundwater Operable Unit
	C-400 (Southeast) Leak Site (SWMU 11)	D	7	93	623	20,189	Heavy industrial setting	Groundwater Operable Unit
	C-400 South End Storm Sewer	D	1	182	139	4,500	Heavy industrial setting	Groundwater Operable Unit

* Estimate Basis Codes:
A 3-dimensional characterization of source zone soil contaminant levels
B 2-dimensional characterization of source zone soil contaminant levels
C Maximum possible DNAPL zone volume based on thickness of UCRS below waste unit and areal dimensions of waste unit
D 3-dimensional characterization of dissolved phase plume in source area

DNAPL = dense nonaqueous-phase liquid
PGDP = Paducah Gaseous Diffusion Plant
RCRA = Resource Conservation and Recovery Act
RGA = Regional Gravel Aquifer
SWMU = solid waste management unit
TCE = trichloroethene
UCRS = Upper Continental Recharge System

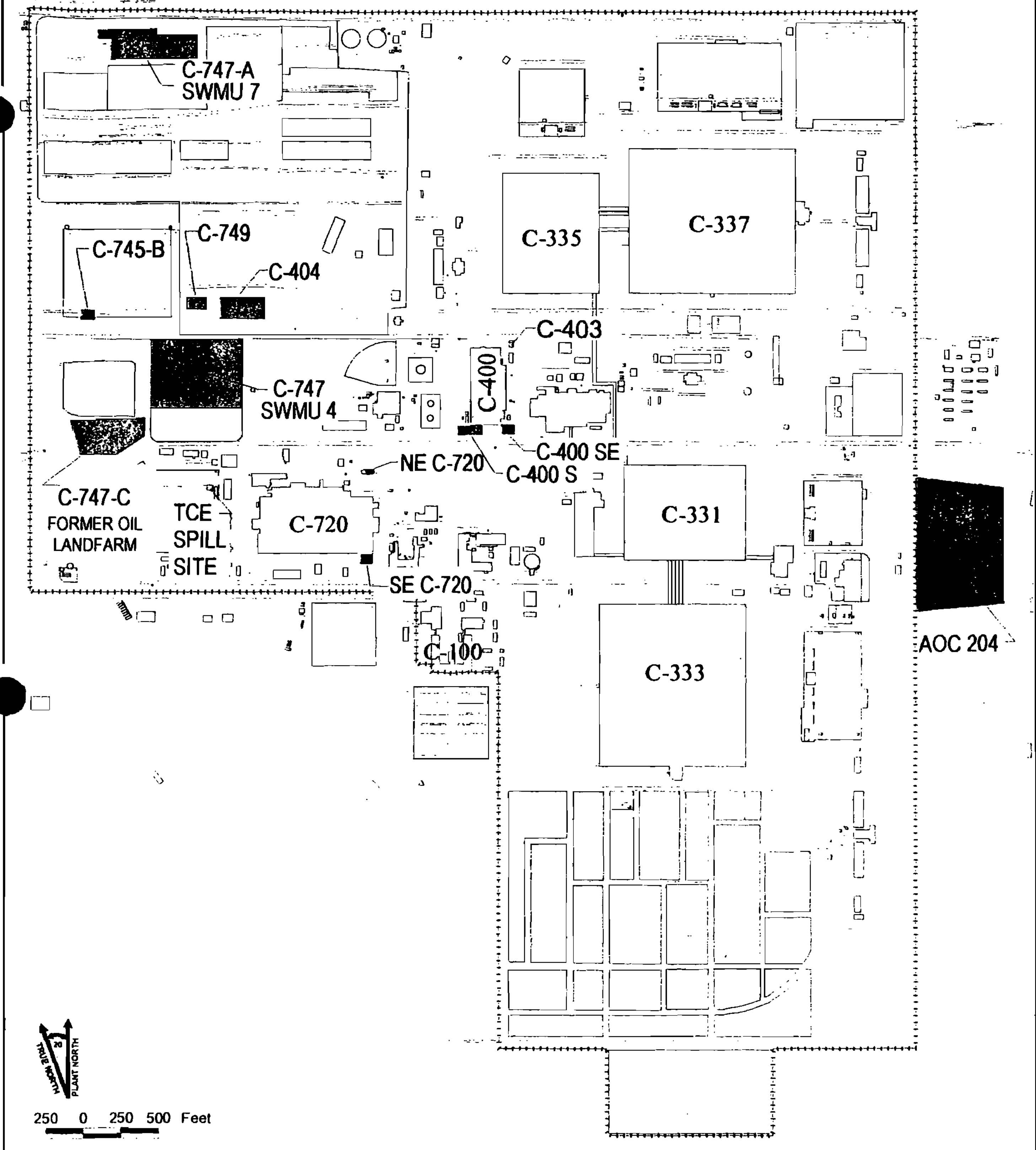
Table 1.3. (continued)

	DNAPL Zone	Estimate Basis	DNAPL Zone Thickness (meters)	DNAPL Zone Surface Area ($meters^2$)	DNAPL Zone Volume ($meters^3$)	DNAPL Volume (liters)	Setting	Operable Unit Assignment for Source Zone
Southwest Plume								
UCRS	Southeast C-720 Building Storm Sewer	B	7	49	368	6.624	Heavy industrial setting	Groundwater Operable Unit
	Northeast Corner of C-720 Building	E	11	1	9	189	Moderate industrial setting	Groundwater Operable Unit
	C-747-C Former Oil Landfarm (SWMU 1)	B	6	1	9	189	Grassed field	Groundwater Operable Unit
	C-749 Uranium Burial Ground (SWMU 2)	C	9	2,973	27,187	<1,703	Zone below pyrophoric uranium burial ground	Burial Ground Operable Unit
	C-404 Low-Level Waste Burial Ground (SWMU 3)	C	15	4,942	73,825	Unknown, may be small	Zone below RCRA-closed mixed-waste burial ground	Burial Ground Operable Unit
	C-747-C Contaminated Burial Yard (SWMU 4)	F	18	No Basis for Estimate	Small	>4,000	Grassed field	Burial Ground Operable Unit
	TCE Spill Site (SWMU 136)	A	20	2	46	<189	Roofed drum storage pad	No Assignment
Northeast Plume								
UCRS	C-403 Neutralization Pit (SWMU 40)	E	13	11	146	3,002	Heavy industrial setting	Groundwater Operable Unit
RGA	Undefined Source	G	No Basis for Estimate	No Basis for Estimate	Small	> 4,000	Near northeast corner of C-333 Building	Groundwater Operable Unit
Terrace Deposits								
	Dykes Road Historical Staging Area (AOC 204)	E	2	2	4	<189	Level field bisected by deep drainage ditch	Surface Soil Operable Unit

* Estimate Basis Codes:

A 3-dimensional characterization of source zone soil contaminant levels
B 2-dimensional characterization of source zone soil contaminant levels
C Maximum possible DNAPL zone volume based on thickness of UCRS below waste unit and areal dimensions of waste unit
E Conceptual model and characterization of dissolved phase plume near source area
F Professional judgement and site experience – based on extent of Southwest Plume and dissolved phase levels near the source area
G Professional judgement and site experience – based on extent of Northeast Plume and recent trends of declining dissolved phase levels near the source area

AOC = Area of Concern
DNAPL = dense nonaqueous-phase liquid
PGDP = Paducah Gaseous Diffusion Plant
RCRA = Resource Conservation and Recovery Act
RGA = Regional Gravel Aquifer
SWMU = solid waste management unit
TCE = trichloroethene
UCRS = Upper Continental Recharge System



LEGEND:
STREAM
ROAD
PGDP SECURITY FENCE
FACILITY
KNOWN OR SUSPECTED DNAPL SOURCE ZONE

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Fig. 1.11. Representative known or suspected DNAPL source zones at the PGDP.

Figure No. FS1-11
DATE 05-25-01

1.2.5.2 Contaminant fate-and-transport analyses

As a part of previous RIs conducted at the PGDP, screening-level fate and transport modeling of contaminants was performed specific to each WAG's conceptual model. The purpose of this modeling was to help discern which contaminants may pose a significant problem in the future to off-site receptors. Screening level modeling utilizes conservative assumptions (worst-case scenario) with regard to source delineation as well as transport parameters in a simple, one-dimensional (1-D) analytical fate and transport model. In the past, a number of different 1-D modeling codes were used, including Seasonal Soil Compartment Model (SESOIL), Analytical Transient 1-, 2-, 3-Dimensional Model (AT123D), and Multimedia Environmental Pollutant Assessment System (MEPAS). Since 1997, the MEPAS code has been used exclusively. It was selected as the best model to use (1) to simulate both partially saturated and saturated conditions; (2) to simulate degrading source terms; (3) to simulate several exposure pathways other than groundwater; (4) to perform risk calculations; and (5) for its ease of use. However, since some of the WAGs included in this GWOU FS had RIs performed prior to 1997, not all of the fate and transport modeling presented here was conducted using MEPAS.

The information in the RIs that focused on fate and transport modeling of the groundwater pathway are utilized in the GWOU FS. Fate and transport modeling conducted as a part of the RIs for WAG 22 (SWMUs 7 and 30), WAG 6 (C-400 building area), WAG 27, and WAG 28 were reviewed for use in evaluating the cumulative impacts of various contaminants at receptor points for this GWOU FS at the PGDP.

Modeling results for each of the previous RIs only reported simulated maximum concentrations that would be contributed from various sources to receptor points of interest. In order to evaluate the cumulative effects of all of these WAGs, however, it is necessary to evaluate the simulated concentrations over time from all the source areas that impact a particular receptor point. Thus, output data were regenerated at each of three receptor points: the PGDP security fence, the DOE property boundary, and the Ohio River. An additional receptor point was evaluated at a reach of Little Bayou Creek near the TVA's Shawnee Steam Plant for any SWMUs which contribute to that location, including WAG 6 and WAG 22 (SWMUs 7 and 30). Table 1.4 presents the approximate distances from the source to the applicable receptor points used in the fate and transport analysis.

Table 1.4. Distances to the receptor locations/integrator points from the source areas

Area	Distance to PGDP Fenceline [ft]	Distance to DOE Property Boundary [ft]	Distance to Bayou Creek [ft]	Distance to the Ohio River [ft]
WAG 3 (SWMU 4)	2,220	4,130	N/A	N/A
WAG 3 (SWMU 5)	890	2,780	N/A	N/A
WAG 3 (SWMU 6)	920	2,820	N/A	N/A
WAG 6 (Sectors 1 through 8)	3,300	5,500	16,500	21,000
WAG 22 (SWMUs 7 and 30)	400	2,400	13,500	18,000
WAG 27 (SWMU 91)	350	2,500	N/A	22,000
WAG 27 (SWMU 001)	500	3,300	N/A	22,800
WAG 27 (C-720)	1,800	4,600	N/A	24,100
WAG 27 (SWMU 196)	800	2,800	N/A	19,800
WAG 28 (SWMU 99)	10	4,500	N/A	19,500
WAG 28 (SWMU 99 west of Kellogg Building)	700	4,800	N/A	19,800
WAG 28 (SWMU 193)	3,000	7,400	N/A	22,400
WAG 28 (SWMU 194)	10	4,500	N/A	19,500

DOE = U.S. Department of Energy
PGDP = Paducah Gaseous Diffusion Plant
SWMU = Solid Waste Management Unit
WAG = Waste Area Group

Using these data, output was generated at the four receptor points in the form of time versus concentration plots for the preliminary contaminant migration (CM) COCs. The constituents whose predicted maximum concentrations exceed the groundwater criterion are designated as preliminary CM COCs. Constituents that are not expected to arrive at the water table within the 1,000-year modeling period are eliminated from consideration as preliminary CM COCs. The preliminary CM COCs include: antimony, chromium, manganese, cobalt, TCE, vinyl chloride, ^{99}Tc, uranium-234 (^{234}U), uranium-235 (^{235}U), and uranium-238 (^{238}U). These constituents were selected as a result of the fate and transport modeling conducted in the RIs, which determined that these contaminants posed the most significant contribution to off-site contamination. Because many of the WAGs had numerous sources, the results were first combined by each contributing source and then by each WAG's contribution.

The complex nature of the hydrogeology and contaminants in the numerous SWMUs at the PGDP precluded development of a single computer model to describe fate and transport of contaminants at this site. Rather, a combination of small-scale analytical groundwater transport models and simple estimates of contaminant attenuation/dilution along specific pathways were combined in the framework of the conceptual model for fate and transport analysis. The combination of methods is site specific and was discussed in detail in the PGDP RI reports. The summary of fate and transport analysis performed under different WAGs is presented in the following paragraphs.

WAG 22

Fate and transport modeling for this WAG was conducted using SESOIL and AT123D models. Based on historical process knowledge and the findings of sampling and analysis at SWMUs 7 and 30, the following contaminant sources were identified.

- Waste burial pits, including Pit A, Pit B/C, and the F Pits. As-built drawings indicated the presence of additional pits, including Pit D and Pit G. Because Pit G is located beneath Drum Mountain, it was assumed, based on process knowledge, that the nature and extent of contamination in Pit G is the same as in Pits B and C. (Note: Additional contamination may be present in Pit G that is related to Drum Mountain. Future remedial assessments or actions must address this uncertainty.)

- Surrounding surface soils, which appear to act as a source of surface runoff.

- Surrounding subsurface soils, specifically in the area of the old incinerator, directly south of SWMU 30.

The following conclusions were made about the distribution of contaminants in the SWMUs 7 and 30 source areas and surrounding environmental media:

- Contaminants disposed of in the three primary source areas of SWMUs 7 and 30, Pit A, Pit B/C Pits, and the F Pits include metals, radionuclides (primarily ^{99}Tc and uranium), organic solvents (primarily TCE), and fuel-related volatile and semivolatile organic compounds (SVOCs). Of the contaminants disposed of in the source areas, only ^{99}Tc and several VOCs were detected in the UCRS and RGA. Metals, other radionuclides, and SVOCs were not detected in either unit.

- DNAPL from an historic release appears to be trapped in HU 3 or HU 4, near the top of the RGA, in the vicinity of, and underlying, Pit B near MW 66.

- Contaminants have also been detected in surface soils. These contaminants, thought to be unrelated to contaminants buried in the waste burial pits, are found in the upper 1 ft of soils and include uranium and other radionuclides, polychlorinated biphenyls (PCBs), and polynuclear aromatic hydrocarbons (PAHs). These contaminants are associated with activities at the old incinerator, spills of radioactive wastes, and airborne radioactivity from Drum Mountain. Based on sampling of the surface drainage sediments and waters, the contaminants in the SWMUs 7 and 30 surface soils appear to be migrating to the drainage ditches.

A complete description of the site geology and hydrology is provided in the RI report. A north drainage ditch and a south drainage ditch capture stormwater runoff. Flow in these ditches is in a westerly direction, and the ditches converge beyond the western boundary of SWMU 30 and flow toward Bayou Creek. The screening processes to select the contaminants from the individual source areas for fate and transport modeling are presented in the RI report.

The summary of results of the quantitative modeling for WAG 22 represented the expected maximum concentrations at the receptor locations that included the DOE property boundary and the PGDP security fence. These results were the predicted future maximum concentrations resulting from the integration of the contributions from multiple sources and different pathways. Vertical transport modeling to the RGA for all the source areas, including UCRS, was performed using SESOIL to predict the maximum leachate concentrations at the RGA interface. The leachate concentrations were compared against their respective risk-based concentrations (RBCs). All of the constituents that exceeded the groundwater RBCs were selected for horizontal transport modeling using AT123D. The model derived peak contributing concentrations at 30 years and in 100 years at the PGDP security fence in the direction of flow, and the peak contributing concentrations in 30 and 100 years at the DOE property boundary in the direction of flow. Based on these analyses it was determined that ^{99}Tc was the only constituent that would continue to be a major problem at the receptor locations. Therefore, ^{99}Tc was chosen for further fate and transport evaluations in order to facilitate preparation of the future risk scenario for GWOU risk assessment.

The revised transport analysis for ^{99}Tc included developing predicted concentrations versus time plots at the four probable receptor locations/IPs. The IPs used in this modeling are the Ohio River, PGDP security fence, DOE property boundary, and a reach of Little Bayou Creek near the TVA's Shawnee Steam Plant. Figure 1.12 represents plots of predicted groundwater concentrations for ^{99}Tc (i.e., the preliminary CM COCs from WAG 22) versus time at the four receptor locations due to combined contaminant loading from the WAG 22 source areas. The curves in this figure represent an estimate of total concentration versus time at the IPs. These curves were developed by combining multiple curves of concentration versus time based on model results predictions from the individual sources of the WAG.

WAG 6

The MEPAS modeling for this WAG was conducted using source terms for eight of the nine sectors delineated for this area. The ninth area (Sector 9) had no source delineated. This sector was delineated only for purposes of assessing the presence and location of a dissolved contaminant plume originating from Sector 2.

For those soil sample analytes with established preliminary remediation goals (PRGs) or background levels, modelers compared all detections in a sector against the larger of the PRG or twice the background level. If no detection of the analyte was above the reference level, then that analyte was screened out as a sector-related contaminant. Note: screening against twice background was applied only to reduce the number of contaminants for fate and transport modeling to a manageable level. This was not the screening process used in the RI risk assessment.

Next, laboratory-related contaminants, decontamination solvents, and essential human nutrients were excluded from the list of potential sector-related contaminants. Laboratory-related contaminants in the WAG 6 RI database included acetone, carbon disulfide, methylene chloride, and all phthalate esters. Detections of the solvents 2-propanol and 2-hexanone appeared to be geographically unrelated, other than

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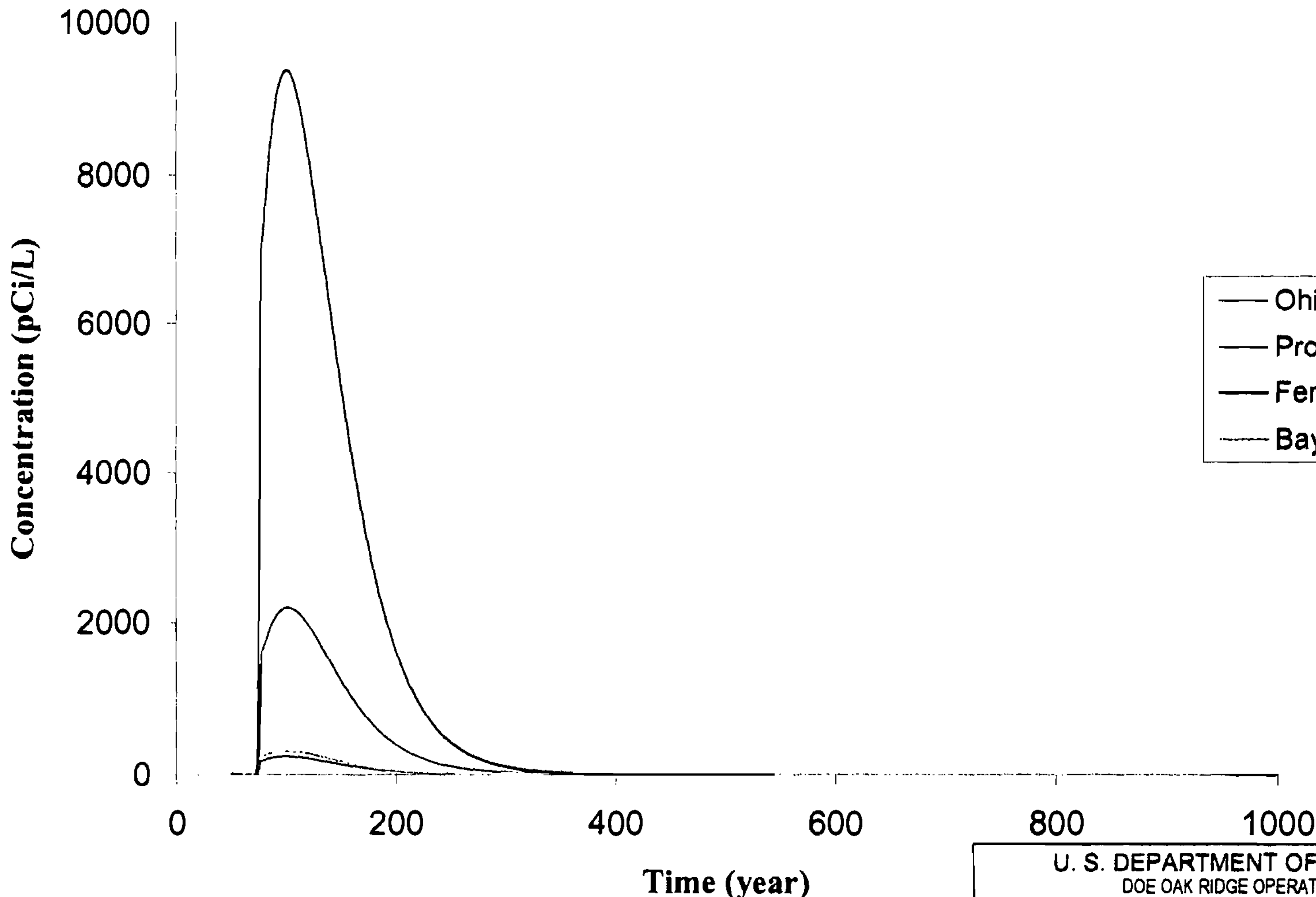

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Fig. 1.12. Predicted Tc-99 activity concentrations at the PGDP receptor locations due to loading from WAG 22, PGDP.

FIGURE No. FS1-12
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common to discrete borings. These chemicals, typically used as decontamination solvents, are not thought to be sector-related contaminants. The essential human nutrients screened from consideration as sector-related contaminants are calcium, chloride, iodine, magnesium, potassium, sodium, and phosphorus. Additional analytes were screened out of the list of sector-related contaminants where very few detections (typically one) of the analyte were present in the database for the sector and analyte concentrations did not greatly exceed a screening level. These analyte concentrations that did not greatly exceed a screening level were determined by site experts based on the range of observed contaminant levels and the closeness of the screening level to the sample quantification level. Analyte concentrations that did not greatly exceed a screening level were determined by site experts based on the range of observed contaminant levels and the closeness of the screening level to the sample quantification level.

In general, the full distance to adjacent boreholes where a contaminant could be documented to be below detection level and the full depth to where a contaminant could be assessed to be below detection level defined the extent of the modeled source terms. As a consequence, many source terms incorporate the entire volume of the unsaturated soil in a sector. However, in a few instances where source delineation was not so clearly derived, some professional judgment was necessary to assess source zones. In all instances, modelers applied conservatism (worst case) in the definition of the extent of the source zones.

For each defined sector within WAG 6, constituents were modeled for both surface and subsurface sources. The source terms for "Surface" and "Subsurface," respectively, apply to topsoil and the UCD (host formation of the UCRS). Modelers identified sources of undissolved contaminants within the lower Continental Deposits (host formation of the RGA) for Sectors 5 and 7. These source terms are identified as "RGA."

MEPAS will handle a number of partially saturated zones, but restricts the user to one saturated zone. At the PGDP, the primary saturated zone is the RGA. The RGA is considered the primary groundwater pathway through which contaminants can leave the site. To represent each SWMU within WAG 6 as accurately as possible, available geophysical logs and borings were reviewed and a hydrogeologic conceptual model was developed for the MEPAS simulations. For each of the sectors modeled in WAG 6, two model layers were used. The first layer was the partially saturated zone (UCRS), and the second was the saturated zone (RGA). A complete description of the hydrogeology of this area may be found in Appendix C of the WAG 6 RI report.

Based on these analyses it was determined that TCE, vinyl chloride, antimony, ^{99}Tc, ^{234}U, ^{235}U, and ^{238}U are the constituents that may continue to be major problems at the receptor locations. Therefore, these constituents are defined as the preliminary CM COCs from WAG 6, and they are selected for further fate and transport evaluations in order to facilitate preparation of the future risk scenario for GWOU risk assessment. The revised transport analysis for CM COCs included developing predicted concentrations versus time plots at the four probable receptor locations or IPs. The IPs used in this modeling are the Ohio River, PGDP security fence, DOE property boundary, and a reach of Little Bayou Creek near the TVA's Shawnee Steam Plant. The source term information for each sector is provided in the GWOU DSR. Figure 1.13 represents the plots of MEPAS predicted groundwater concentrations for ^{99}Tc versus time at the four IPs due to combined contaminant loading from the WAG 6 source areas. The curves in this figure represent estimates of total concentration versus time at the IPs. These curves were developed by combining multiple curves of concentration versus time for preliminary CM COCs based on model results predictions from the individual sources of the WAG. Figures for the remaining CM COCs are presented in Appendix C3.

WAG 27

Within the WAG 27 grouping, contaminant fate and transport modeling was conducted using MEPAS for the groundwater pathway for SWMU 1, SWMU 91, SWMU 196 and the C-720 complex.

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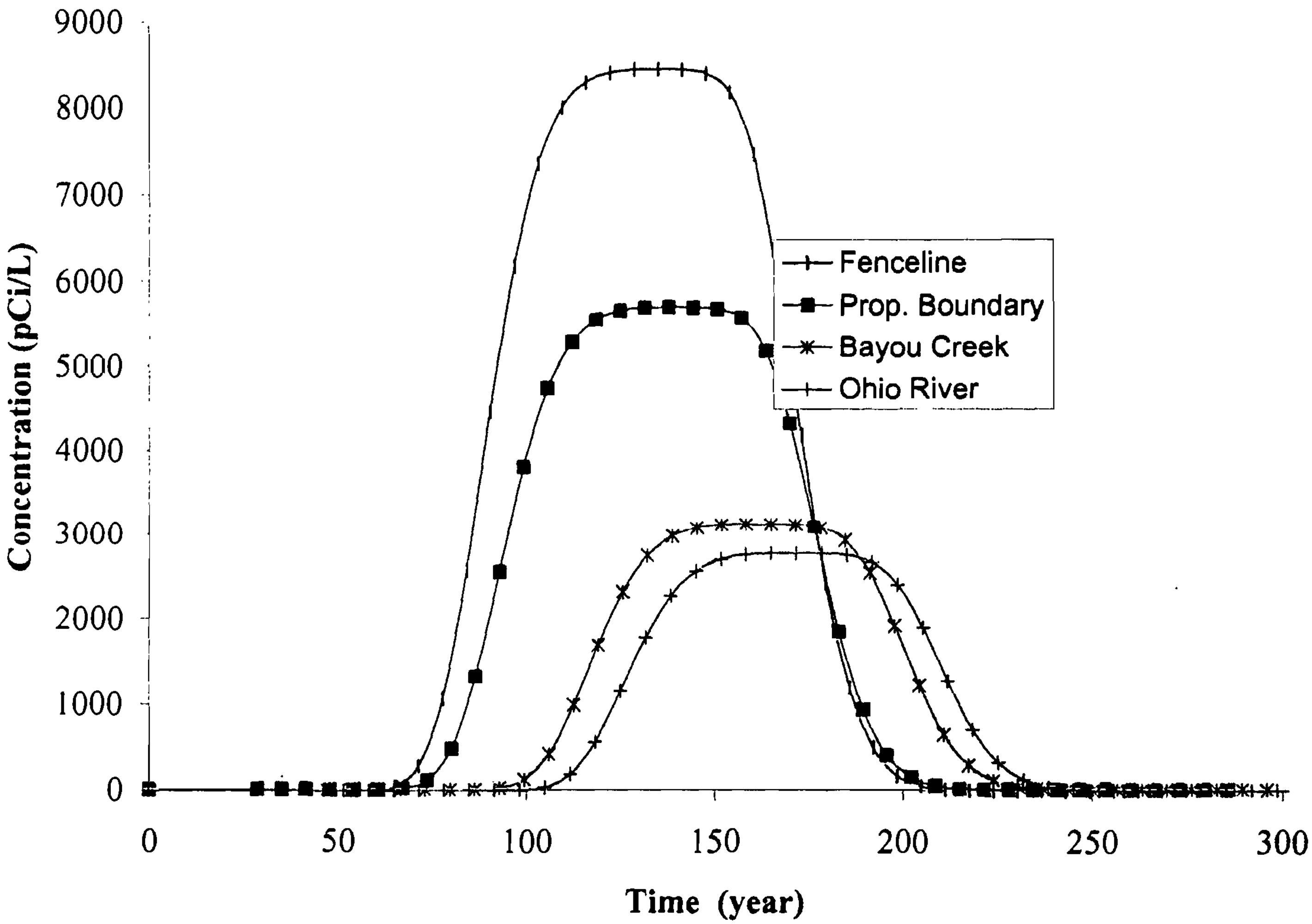

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Fig. 1.13. Predicted Tc-99 activity concentrations at the PGDP receptor locations due to loading from WAG 6.

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Contaminant transport from WAG 27 to exposure points located at the PGDP security fence, the DOE property boundary, and the Ohio River were modeled over a maximum 10,000-year period. The following paragraphs summarize the source term information for the modeling and the results of the MEPAS simulations. A summary of the contaminant screening process and conceptual model is also included here. For a complete description of the WAG 27 source identification, screening process, and complete MEPAS simulation results for all of the contaminants identified, the reader is directed to Appendix C of *Remedial Investigation Report for Waste Area Grouping 27 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1777&D2 (DOE 1999c).

Groundwater contaminant migration at WAG 27 occurs principally by dissolution of contaminant sources present in the UCRS soils and subsequent transport by advective and dispersive mechanisms to the RGA. This occurs as rainwater infiltrates from the surface and percolates through the contamination zone in the saturated zone. The contaminated leachate then mixes with the ambient groundwater while migrating laterally in the direction of groundwater flow to exposure locations.

An additional source release mechanism at the WAG 27 is DNAPL dissolution. WAG 27 contains several distinct areas of TCE DNAPL releases. Due to its greater density than water and low solubility, DNAPL movement is gravity driven, largely independent of groundwater flow, and often is directed by subtle textural changes in the soils. Where spill volumes are sufficiently large, DNAPLs will penetrate to significant depths. As dissolution removes residual DNAPL ganglia left along the DNAPL flow path, discrete sources of contamination result where DNAPL is pooled above zones of lower permeability.

Values of various parameters describing the site soils, geology, and hydrogeology are inputs to the MEPAS program. The majority of transport parameters were derived independently for each WAG 27 site based upon site-specific data. When relevant on-site data were not available, data collected at nearby SWMUs having similar hydrogeologic conditions were utilized to define parameters. Where no site-specific data were available, MEPAS default values were used. The soil and aquifer transport parameters used are presented in the GWOU DSR.

The contaminant source concentrations were determined from soil-sampling results. Where soil-sampling data were not available, groundwater data were used to back-calculate the soil concentrations used in the model. Simulated sources were defined separately for the UCRS and the RGA to accommodate the remedial action decision process.

To represent each SWMU within WAG 27 as accurately as possible, available geophysical logs and borings were reviewed and a hydrogeologic conceptual model was developed for the MEPAS simulations. Table 1.5 presents a summary of the breakdown of MEPAS model layers for each SWMU simulated. A more detailed description is available in Appendix C of the RI report.

Table 1.5. Hydrogeologic conceptual model for WAG 27 MEPAS modeling

Location	Number of Partially Saturated Zone Layers	Number of Saturated Zone Layers	Total Number of Model Layers Used in MEPAS Simulation
SWMU 1	2 (UCRS, HU3)	1 (RGA)	3
SWMU 91	3 (HU1, UCRS, HU3)	1 (RGA)	4
SWMU 196	3 (HU1, UCRS, HU3)	1 (RGA)	4
C-720	3 (HU1, UCRS, HU3)	1 (RGA)	4

HU = hydrogeologic unit
MEPAS = Multimedia Environmental Pollutant Assessment System
RGA = Regional Gravel Aquifer
SWMU = solid waste management unit
UCRS = Upper Continental Recharge System
WAG = Waste Area Group

The source term information for the contaminants selected for groundwater fate and transport modeling from this WAG is presented in the GWOU DSR.

Based on these analyses it was determined that TCE, vinyl chloride, and antimony are constituents that may continue to be major problems at the receptor locations. Therefore, these constituents were defined as the preliminary CM COCs from WAG 27, and they were selected for further fate and transport evaluations in order to facilitate preparation of the future risk scenario for GWOU risk assessment. The revised transport analysis for the preliminary CM COCs included developing predicted concentrations versus time plots at the three probable receptor locations or IPs. The IPs used in this modeling are the Ohio River, PGDP security fence, and DOE property boundary. The GWOU Data Summary Report presents the source term information for the preliminary CM COCs listed above. Figure 1.14 represents a plot of MEPAS-predicted groundwater concentrations for antimony [a CM contaminant of potential concern (COPC)] versus time at the three IPs due to combined contaminant loading from the WAG 27 source areas. The curves in these figures represent estimates of total concentration versus time at the IPs. These curves were developed by combining multiple curves of concentration versus time for preliminary CM COCs based on model results predictions from the individual sources of the WAG. Figures for the remaining CM COCs are presented in Appendix C3.

WAG 28

For the WAG 28 MEPAS simulations, contaminant source concentrations and source inventories were derived from soil sampling results. The sampling data used included the 1999 WAG 28 RI data as well as historical sampling conducted at the site in support of the CERCLA Site Investigation (CH2M Hill 1992). The following investigations provided additional data used at specific sites:

- the 1995 Northeast Plume Investigation, consisting of the site evaluation at SWMUs 193 and 194 and the Groundwater Phase IV Investigation; and
- the 1995 sampling conducted at AOC 204 for the site evaluation for the Outfall 010, 011, and 012 areas.

MEPAS requires values for various parameters describing the site soils, geology, and hydrogeology. The majority of transport parameters were derived independently for each WAG 28 site, based upon site-specific data. When relevant on-site data were not available, data collected at nearby SWMUs having similar hydrogeologic conditions were utilized to define a given parameter. Where no site-specific data were available (i.e., K_d values), MEPAS default values were used. The soil and aquifer transport parameters that were input into the MEPAS model for SWMU 99, SWMU 193, SWMU 194, and AOC 204 are presented in the GWOU DSR. The screening process by which contaminants to be modeled were identified can be found in the RI report. The source terms for the constituents modeled are presented in the GWOU DSR. To represent each SWMU within WAG 28 as accurately as possible, available geophysical logs and borings were reviewed and a hydrogeologic conceptual model was developed for the MEPAS simulations. Table 1.6 presents a summary of the breakdown of MEPAS model layers for each SWMU simulated. A more detailed description is available in Appendix B of the RI report.

Table 1.6. Hydrogeologic conceptual model for WAG 28 MEPAS modeling

Location	Number of Partially Saturated Zones	Number of Saturated Zones	Total Number of Model Layers
SWMU 99	2 (UCRS, HU3)	1 (RGA)	3
SWMU 193	2 (UCRS, HU3)	1 (RGA)	3
SWMU 194	2 (UCRS, HU3)	1 (RGA)	3
AOC 204	2 (HU2, HU3)	1 (RGA)	3

AOC = Area of Concern
HU = hydrogeologic unit
MEPAS = Multimedia Environmental Pollutant Assessment System
RGA = Regional Gravel Aquifer
SWMU = solid waste management unit
UCRS = Upper Continental Recharge System

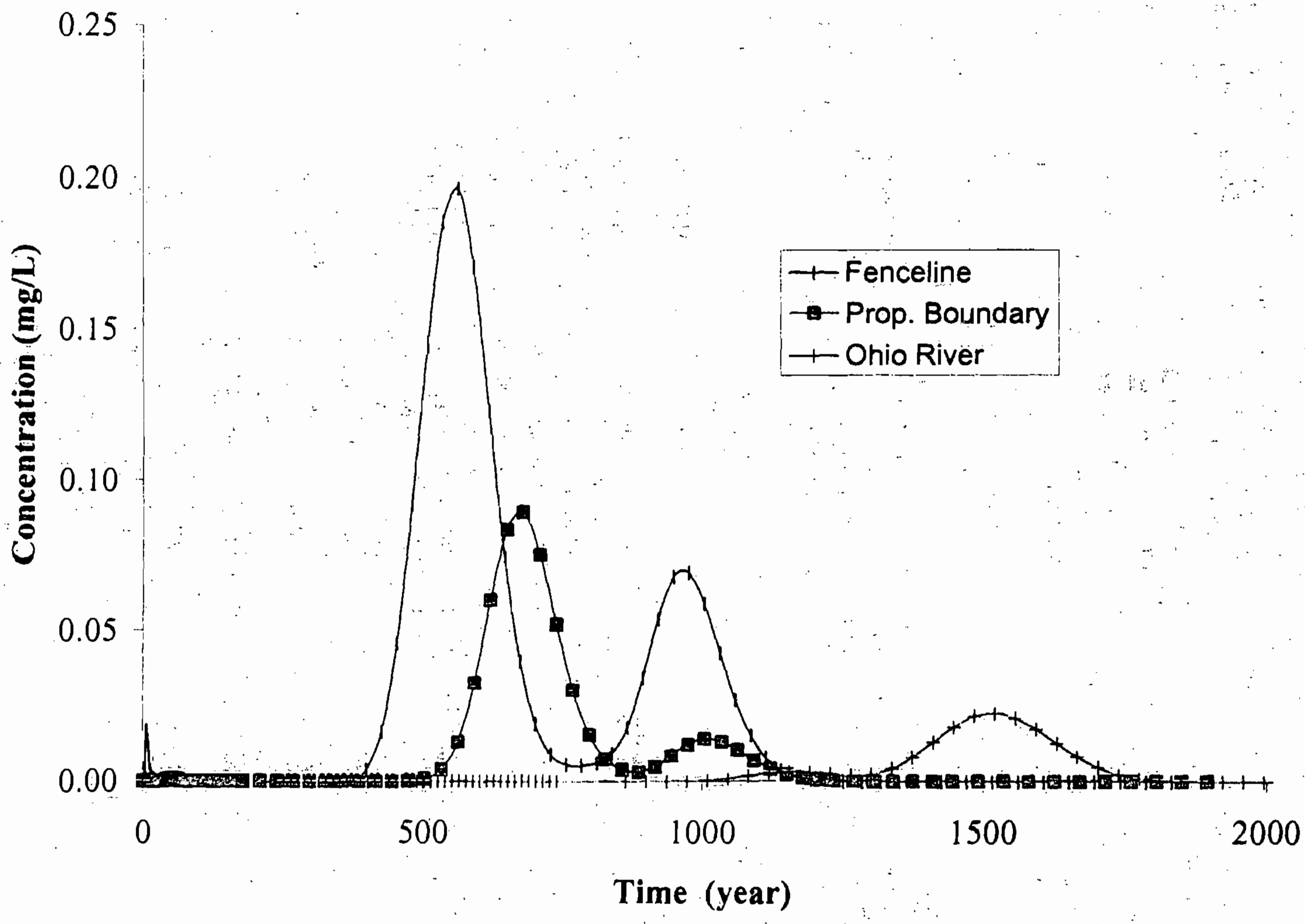

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Fig. 1.14. Predicted antimony concentrations in the RGA groundwater at the PGDP receptor locations due to loading from WAG 27.

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FIGURE No. FS1-14
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Based on these analyses it was determined that ^{99}Tc, TCE, manganese, lithium, strontium, cobalt, and chromium are constituents that may continue to be major problems at the receptor locations. Therefore, these constituents were defined as the preliminary CM COCs from WAG 28, and they were selected for further fate and transport evaluations in order to facilitate preparation of the future risk scenario for GWOU risk assessment. The revised transport analysis for the preliminary CM COCs included developing predicted concentrations versus time plots at the three probable receptor locations or IPs. The IPs used in this modeling are the Ohio River, PGDP security fence, and DOE property boundary. The source term information for each area for the preliminary CM COCs listed above is presented in the GWOU Data Summary Report. Figure 1.15 represents a plot of MEPAS-predicted groundwater concentrations for ^{99}Tc (a CM COC) versus time at the IPs due to combined contaminant loading from the WAG 28 source areas. The curves in these figures represent estimates of total concentration versus time at the IPs. These curves were developed by combining multiple curves of concentration versus time for preliminary CM COCs based on model results predictions from the individual sources of the WAG. Figures for the remaining CM COCs are presented in Appendix C3.

WAG 3

For the WAG 3 MEPAS simulations, contaminant source concentrations and source inventories were derived from soil sampling results. The WAG 3 RI, the SI (CH2M HILL 1991, 1992), and the Data Gaps Investigation Report (DOE 2000a) provided surface and subsurface soil data used to develop the source terms. Source terms for surface soils were delineated for the most part along drainage pathways. Discrete subsurface source areas were defined for each contaminant present in the partially saturated layer.

MEPAS requires values for various parameters describing the site soils, geology, and hydrogeology. The majority of transport parameters were derived independently for each WAG 3 site, based upon site-specific data. When relevant on-site data were not available, data collected at nearby SWMUs having similar hydrogeologic conditions were utilized to define a given parameter. Where no site-specific data were available (i.e., K_d values), MEPAS default values were used. The DSR presents soil and aquifer transport parameters that were input into the MEPAS model for SWMU 4, SWMU 5, and SWMU 6, as well as the source terms for the constituents modeled. The screening process by which contaminants to be modeled were identified can be found in the RI Report. To represent each SWMU within WAG 3 as accurately as possible, available geophysical logs and borings were reviewed and a hydrogeologic conceptual model was developed for the MEPAS simulations.

Table 1.7 presents a summary of the breakdown of MEPAS model layers for each SWMU simulated. A more detailed description is available in Volume 4, Appendix B of the WAG 3 RI Report (DOE 2000b).

Table 1.7. Hydrogeologic conceptual model for WAG 3 MEPAS modeling

Location	Number of Partially Saturated Zones	Number of Saturated Zones	Total Number of Model Layers
SWMU 4	1 (UCRS)	1 (RGA)	2
SWMU 5	2 (UCRS, HU3)	1 (RGA)	3
SWMU 6	2 (UCRS, HU3)	1 (RGA)	3

RGA = Regional Gravel Aquifer
HU = hydrogeologic unit
MEPAS = Multimedia Environmental Pollutant Assessment System
SWMU = solid waste management unit
UCRS = Upper Continental Recharge System

Based on these analyses it was determined that ^{234}U, ^{238}U, ^{99}Tc, ^{237}Np, TCE, DCE, vinyl chloride, manganese, copper, cobalt, and iron are constituents that will continue to be major problems at the receptor locations. Therefore, these constituents are defined as the preliminary CM COCs from WAG 3, and they are

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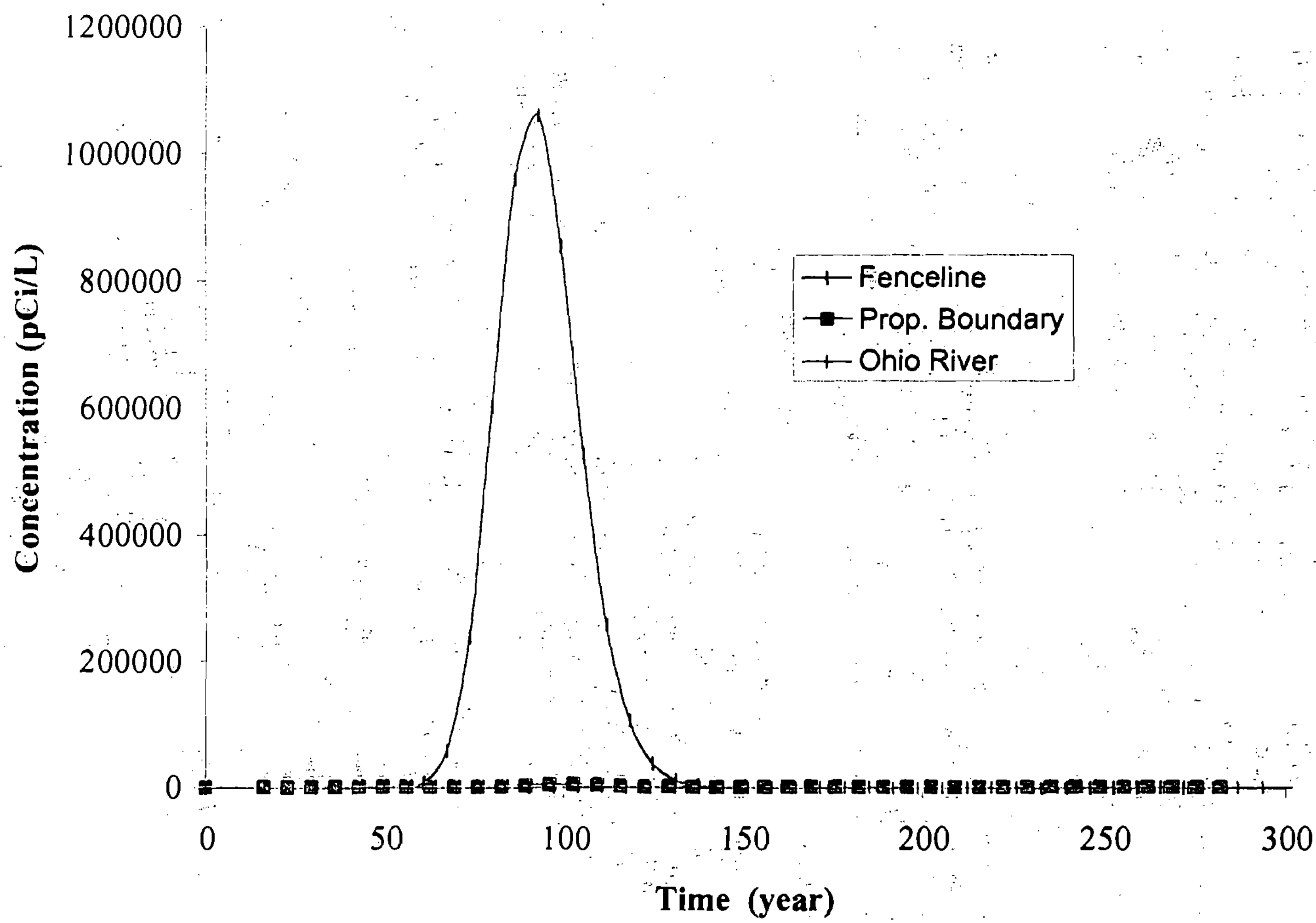

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Fig. 1.15. Predicted Tc-99 activity concentrations at the PGDP receptor locations due to loading from WAG 28.

FIGURE No. FS1-15
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selected for further fate and transport evaluations in order to facilitate preparation of the future risk scenario for GWOU risk assessment. The revised transport analysis for the preliminary CM COCs included developing predicted concentrations versus time plots at the two probable receptor locations or IPs. The IPs used in this modeling are the PGDP Security Fence, and DOE Property Boundary. Source term information for each area for the preliminary CM COCs listed above is presented in the GWOU Data Summary Report. Figure 1.16 represents a plot of MEPAS-predicted groundwater concentrations for ^{99}Tc (a CM COC) versus time at the IPs due to combined contaminant loading from the WAG 3 source areas. The curves in these figures represent estimates of total concentration versus time at the IPs.

These curves were developed by combining multiple curves of concentration versus time for preliminary CM COCs based on model results predictions from the individual sources of the WAG. Figures for the remaining CM COCs are presented in Appendix C3.

Summary of Modeling Results for the GWOU FS

The plots of predicted concentrations versus time at the four IPs, generated for the preliminary CM COCs from the individual WAGs, were combined to estimate the maximum concentration of a constituent at any particular time. For example, the concentration versus time curves for ^{99}Tc at the PGDP Fence from WAG 22, WAG 6, and WAG 28 were combined to produce a new curve representing the total concentration versus time at the PGDP Fence shown in Figure 1.16. Figures representing the plots of total concentrations versus time at the four IPs for all the preliminary CM COCs at this site are presented in Appendix C3.

Limitations and Assumptions

Predictions of future conditions at the receptor locations based on contaminant loading from the source area (waste unit) require that a set of assumptions be made regarding the physical and chemical conditions present at the site. Use of these assumptions introduces some uncertainties in the predictions. In addition, some mechanisms that affect contaminant mobility are ignored in order to limit the complexity and cost of site characterization required to support the contaminant migration analysis. The main assumptions that introduce uncertainty are as follows.

- Infiltration of water through vadose zone soils consists of 1-D, steady flow through soils with uniform average soil properties. This represents average flow over the period of interest. Dispersion is not incorporated into the vadose zone estimate that may affect the maximum predicted groundwater concentration or the arrival time of the constituent. More complex flow may either increase or decrease contaminant mobility and transport to the water table.

- Soil sample analytical results accurately reflect the chemical, physical, and hydrologic characteristics of the transport media (vadose zone soils) and the contaminants that are present. The analysis of sample results is configured to present a conservative interpretation of site conditions.

- Soil-water partitioning of constituents is linear, reversible, and at equilibrium. This allows the use of the partitioning coefficient (K_d). Kinetic-based partitioning would likely decrease the concentration of contaminants in pore water, decreasing groundwater concentrations of preliminary CM COCs at the receptor locations.

- Natural attenuation due to biodegradation is completely ignored. This is a highly conservative assumption. Biodegradation would significantly decrease the concentration of CM COCs.

- The use of K_d and R_d to describe the reaction term of the transport equation assumes that an equilibrium relationship exists between the solid- and solution-phase concentrations and that the

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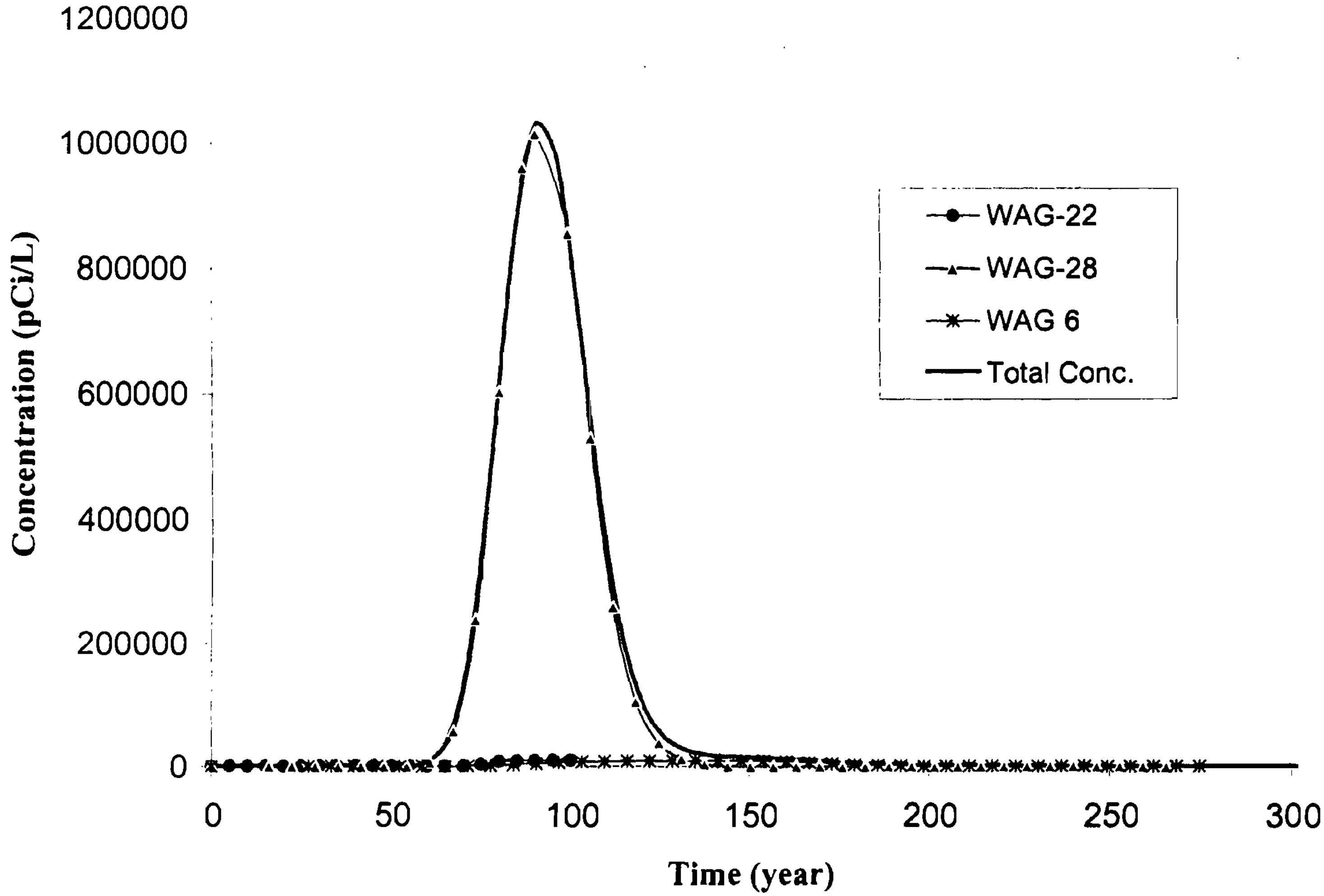

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Fig. 1.16. Predicted Tc-99 activity concentrations at the DOE fenceline due to loading from PGDP source areas.

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FIGURE No. FS1-16
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relationship is linear and reversible. The K_d values in this analysis represent literature values and may not always represent the site conditions. The values selected for this analysis were intended to produce conservative results. A summary of model parameters used at the PGDP is presented as Appendix C-8 of this FS.

- The total concentration at the IP (representing contributions from all the sources) is obtained by summing the predicted concentrations at the IP based on contaminant loading from the individual source areas. This is a highly conservative approach and may overestimate the concentrations at the IP by an order of magnitude.

In every case, conservative assumptions were used in order to bias the analysis toward a false positive rather than a false negative result. The input parameters used in the analysis were developed from site-specific data for the SWMUs. When site-specific data were not available, they were either taken from data for the PGDP, MEPAS default, or from EPA-suggested conservative default values.

There are also uncertainties with DNAPL movement at this site. The MEPAS modeling does not account for the DNAPL, instead it assumes that all the TCE (including DNAPL) is either in the dissolved phase or adsorbed to soil particles. It assumes equilibrium partitioning between the solid-phase and dissolved-phase concentrations, thereby overestimating the leaching rate. Therefore, the estimate of approximately **250 years** for TCE (a DNAPL at this site) to be removed from the site without any active treatment, based on MEPAS modeling, is highly conservative.

The DNAPL-water mass transfer rate is estimated as the sum of two mechanisms. First, water infiltrating vertically through the separate phase plume in the unsaturated zone is assumed to leach soluble components from the DNAPL according to equilibrium phase partitioning. Second, groundwater passing by the DNAPL in direct contact with the aquifer moves soluble components according to the nonequilibrium mass transfer function. Based on these assumptions it is estimated that it will take more than **a thousand years** to remove the DNAPL from the PGDP sites. It should be noted here that this estimation did not account for the immobile residual DNAPL. Residual DNAPL in the saturated zone occurs as hydraulically discontinuous blobs trapped within the continuous water phase, and residual DNAPL in the unsaturated zone occurs as thin films and as pendular rings of DNAPL at particle contacts, and held against gravitational drainage in the unsaturated zone.

Volatilization of Sorbed Contaminants on Soil

Because of very high concentrations of TCE and vinyl chloride in the vadose zone soils of PGDP source areas, a study was undertaken to evaluate the potential for vinyl chloride and TCE vapor exposures. SESOIL modeling was used to estimate the volatilization release of TCE and vinyl chloride from the contaminated soils in the vadose zone. As an example, Sector 4 of WAG 6, which has the most contaminated soils with TCE and vinyl chloride, was selected for this analysis. The volatilization/diffusion model in SESOIL is based on the model of Farmer et al. (1980) and Millington and Quirk (1961) and is a discretized version of Fick's first law over space, assuming vapor phase diffusion as the rate-controlling process. SESOIL-predicted vapor flux from the site was used to estimate on-site, ground-level atmospheric concentration based on the following equation (EPA 1988):

$$C(x) = Q/(3.142*dy*dz*\mu),$$

where,

$C(x)$ = ground-level atmospheric concentration of the pollutant at a distance x from the site (mass/vol),

Q = mass release rate, mass/time,

dy = lateral dispersion (crosswind direction), (distance),
dz = vertical dispersion (crosswind direction), (distance), and
μ = mean wind speed, (distance/time).

Figure 1.17 presents plots of atmospheric concentrations of vinyl chloride within a distance of 100 m on a centerline of a plume directly downwind from the source. These results indicate that there may be a potential threat to human health as the predicted maximum concentrations exceed the human health standard for both TCE and vinyl chloride. However, at a downwind distance of 200 m the ground-level atmospheric concentration reduces to less than the atmospheric standards. Also, by reducing the volatilization index by 50%, a parameter in SESOIL that allows 0 to 100% volatilization reduces the concentration to below the standard. Because these results indicated that risks could be present, sampling activities were performed in spring 2000. The results of these studies indicated that exposure to TCE, or vinyl chloride volatilizing from source areas or from the contaminant plumes at the PGDP, does not present significant risk. (See the uncertainty section of the risk assessment presented in the FS for additional information regarding this study.)

1.2.6 Risk Assessment Summary

1.2.6.1 Previous assessments

Several baseline risk assessments have been performed for the GWOU and the sources contributing contaminants to it. The assessments for the source units appear in the following reports.

- *Results of the Public Health and Ecological Assessment, Phase II* (CH2M Hill 1991a) [This report is Vol. 6 of *Results of the Site Investigation, Phase II, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (CH2M Hill 1992)]

- *Baseline Risk Assessment for the Underground Storage Tanks at the C-200, C-710, and C-750 Buildings, Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 1992)

- *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 1994a)

- *Remedial Investigation Addendum for Waste Area Grouping 23, PCB Sites, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 1994b)

- *Resource Conservation and Recovery Act Facility Investigation/Remedial Investigation Report for Waste Area Groupings 1 and 7 at Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 1996a)

- *Baseline Risk Assessment for Exposure to Polycyclic Aromatic Hydrocarbons at Underground Storage Tanks C-750 A&B, Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 1996b)

- *Baseline Risk Assessment for Underground Storage Tanks 130, 131, 132, 133, and 134 as presented in the WAGs 1&7 RFI/RI, Paducah Gaseous Diffusion Plant, Paducah, Kentucky, UST Facility/Site Identification Number 6319073* (DOE 1996c)

- *Data Summary and Interpretation Report for Interim Remedial Design at Solid Waste Management Unit 2 of Waste Area Grouping 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 1997b)

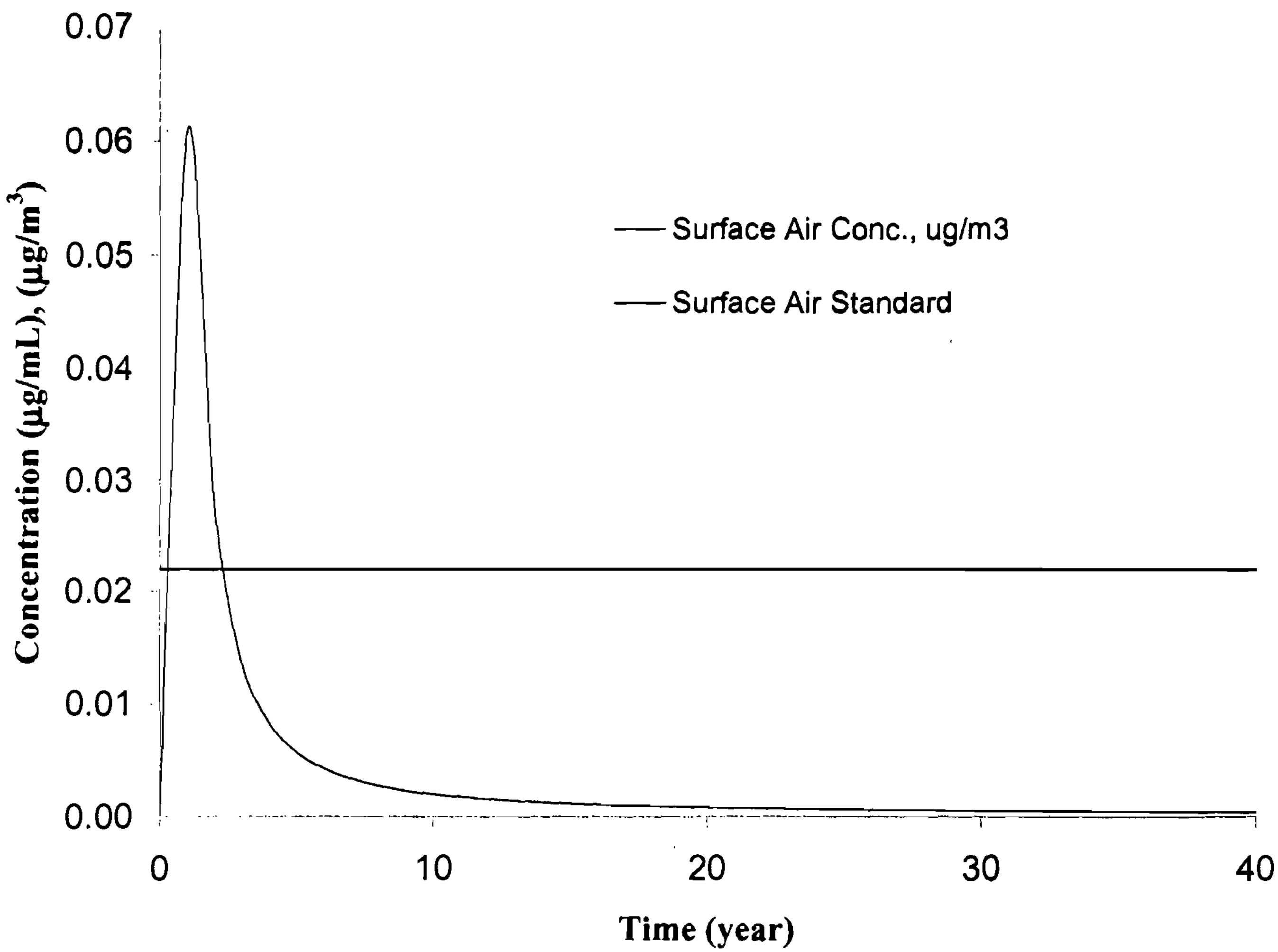

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Fig. 1.17. Predicted vinyl chloride concentrations in the atmosphere due to contaminated soil in the WAG 6 (Sector 4).

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- *Remedial Investigation for Solid Waste Management Units 7 and 30 of Waste Area Grouping 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 1998b)

- *Remedial Investigation Report for Waste Area Grouping 6 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 1999b)

- *Remedial Investigation Report for Waste Area Grouping 27 at the Paducah Gaseous Diffusion Plant Paducah, Kentucky* (DOE 1999c)

- *Residual Risk Evaluation for Waste Area Grouping 23 and Solid Waste Management Unit 1 of Waste Area Grouping 27 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 1999d)

- *Remedial Investigation Report for Waste Area Grouping 28 at the Paducah Gaseous Diffusion Plant Paducah, Kentucky* (DOE 2000a)

- *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2000b)

The assessments for the GWOU (i.e., groundwater integrator unit investigations) appear in the following reports:

- *Results of the Site Investigation, Phase I at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (CH2M Hill 1991b);

- *Results of the Public Health and Ecological Assessment, Phase II* (CH2M Hill 1991a) [This report is Volume 6 of *Results of the Site Investigation, Phase II at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (CH2M Hill 1992)];

- *Human Health Baseline Risk Assessment for the Northwest Plume, Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 1993); and

- *Baseline Risk Assessment and Technical Investigation Report for the Northwest Dissolved Phase Plume, Paducah Gaseous Diffusion Plant* (DOE 1994c).

Please see Appendix B of this FS report for detailed reviews of the results from the baseline human health risk assessments (BHHRAs) contained in these reports and for a summary of the ecological risk assessment contained in DOE 1994c.

Overall, the source control unit investigations previously listed indicate that direct exposure (i.e., ingestion, inhalation, and dermal contact) to contaminated media (i.e., soil, sediment, and groundwater) may lead to unacceptable risks at all source control units except the underground storage tanks (USTs) under one or more of the scenarios assessed. However, these investigations also indicate that not all of the units are sources of off-site groundwater contamination. The following list summarizes the units that were found to be sources of off-site groundwater contamination and the contaminants associated with that source.

- WAG 6 – Source of antimony, copper, iron, manganese, carbon tetrachloride, tetrachloroethene, TCE, TCE breakdown products, and ^{99}Tc.

- WAG 27 – Source of antimony, manganese, silver, thallium, vanadium, phenanthrene, xylenes, TCE, and TCE breakdown products.

- WAG 28 – Source of chromium, lithium, manganese, strontium, TCE, and ^{99}Tc.

- WAG 3 – Source of arsenic, cobalt, copper, iron, manganese, nickel, vanadium, 1,1-dichloroethene, carbon tetrachloride, TCE, TCE breakdown products, ^{237}Np, ^{239}Pu, ^{226}Ra, ^{99}Tc, and uranium isotopes.

- WAG 22/SWMUs 7 and 30 – Source of the TCE breakdown product vinyl chloride and ^{99}Tc.

- WAG 22/SWMU 2 – Source of arsenic, PCBs, TCE, and TCE breakdown products.

- WAGs 1 and 7 – Not a source. (See exception for SWMU 8. Fate and transport modeling for SWMU 8 has not been completed; however, this unit is a known source of metals contamination to the creeks surrounding it.)

- WAG 23 – Not a source.

- USTs – Not a source.

Therefore, fate and transport models for source units indicate that several metals, TCE and its breakdown products, and several radionuclides may be migrating through groundwater to off-site areas from source control units at the PGDP. Specifically, the contaminants include antimony, arsenic, chromium, cobalt, copper, iron, lithium, manganese, nickel, silver, strontium, thallium, vanadium, 1,1 dichloroethene, carbon tetrachloride, tetrachloroethene, PCBs, phenanthrene, xylenes, TCE, *trans*-1,2-dichloroethene, *cis*-1,2-dichloroethene, vinyl chloride, ^{237}Np, ^{239}Pu, ^{226}Ra, ^{99}Tc, and uranium isotopes. Overall, the groundwater integrator unit investigations listed above indicate that the dominant contaminants in groundwater at the PGDP are TCE, the TCE breakdown products, ^{99}Tc and, possibly, carbon tetrachloride. However, several other organic compounds are infrequently detected and pose considerable risk. Additionally, these investigations indicate that although various inorganic chemicals pose considerable risk, these chemicals may not be related to releases from the PGDP but are at naturally occurring concentrations.

1.2.6.2 Baseline human health risk assessment for the GWOU

In addition to the aforementioned reports, a BHHRA was prepared to reexamine the risks to human health from exposure to groundwater at and around the PGDP using the most recent sampling information available. This BHHRA appears in Appendix B of this FS report. A summary of the methods used to complete this assessment and the information in this BHHRA appears below. (Note that the BHHRA also includes a dose assessment for residential use of groundwater. Please see Attachment 10 to the BHHRA for an explanation of the methods used to derive the dose assessment results presented here.)

The BHHRA in Appendix B utilizes information collected during a number of previous investigations and during routine monitoring to characterize the baseline risks posed to human health from contact with contaminants in groundwater at the PGDP. The assessment also uses information from fate and transport modeling to estimate the baseline risks posed to human health through contact with groundwater and other media impacted by contaminants migrating from the various sources at the PGDP to four points of exposure. Generally, baseline risks are defined as those that may be present now or in the future in the absence of corrective or remedial actions.

The assessment in Appendix B follows the methods and presentations in *Methods for Conducting Human Health Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant*, DOE/OR/07-1506&D1, as modified by regulatory comments (DOE 1996d). The Methods Document, which integrates the human health risk assessment guidance from the EPA with that from the KDEP and incorporates the various instructions contained in regulatory agency comments on earlier risk assessments performed for the PGDP, received final approval from the Commonwealth of Kentucky for use in environmental investigations and restoration activities at the PGDP in February 1998. As noted in the Methods Document, the methods used here are consistent with those in *Risk Assessment Guidance for Superfund* (RAGS) (EPA 1989) and additional guidance developed and distributed by EPA and KDEP subsequent to the release of RAGS.

The BHHRA, utilizing sampling data, derives risk estimates for several area and depth data aggregates and individual sampling stations. The areas are as follows:

- Area a – inside TCE-contaminated area at C-400 Building – inside industrialized area;
- Area b – inside the Northwest TCE Plume – inside industrialized area (i.e., west main plant);
- Area c – inside the Northeast TCE Plume – inside industrialized area (i.e., east main plant);
- Area d – outside the TCE Plumes – south of C-400 in industrialized area;
- Area e – inside the Northwest TCE Plume – outside industrialized area;
- Area f – inside the Northeast TCE Plume – outside industrialized area;
- Area g – outside the TCE Plumes – west of industrialized area (i.e., west of plume);
- Area h – outside the TCE Plumes – east of industrialized area (i.e., east of plume);
- Area i – outside the TCE Plumes – north of industrialized area (i.e., between the plumes);
- Area j – outside the TCE Plumes – TVA area;
- Area k – outside the TCE Plumes – south of industrialized area above terrace;
- Area l – inside plant area – composed of Areas a, b, c, and d;
- Area m – outside plant area – composed of Areas e, f, g, h, i, j, and k; and
- Area n – all groundwater – composed of Areas m and n.

These areas were chosen to remain consistent with previous integrator unit assessments and to ensure that the exposure concentrations were appropriately calculated using information representative of contamination found within the TCE contaminant plumes at and around the PGDP. Figure 1.18 depicts these areas. Plates 1 and 2 in Appendix B also depict the areas and present the sampling points associated with each area.

The depth classifications used in the BHHRA, utilizing sampling data, were based upon a combination of the depth at which the sample was collected and the characteristics of the subsurface in the area of the sampling station. These groups and their definitions are as follows:

- HU1 – data from a sample collected in Hydrogeological Unit 1;
- HU2 – data from a sample collected in Hydrogeological Unit 2;
- HU3 – data from a sample collected in Hydrogeological Unit 3;
- HU4 – data collected from a sample collected in Hydrogeological Unit 4;
- HU5 – data collected from a sample collected in Hydrogeological Unit 5;
- HU6 – data collected from a sample collected in Hydrogeological Unit 6;
- Other – data from a sample collected from a hydrogeological unit not included above (i.e.. Terrace Gravel, Porters Creek Clay, and Eocene Sands);
- UCRS – data from samples assigned to HU1, HU2, or HU3;

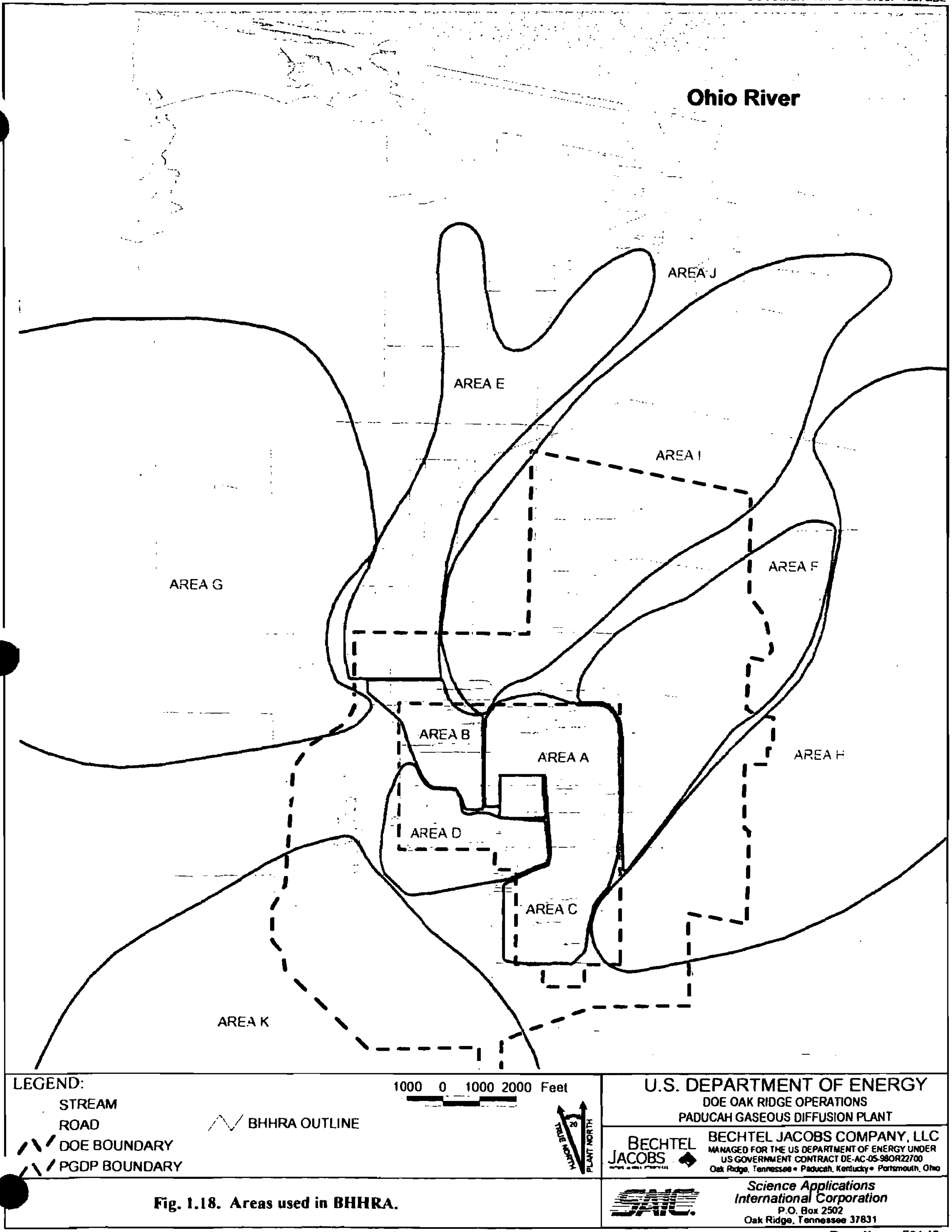

Fig. 1.18. Areas used in BHHRA.

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- RGA – data from samples assigned to HU4 or HU5; and

- McNairy Formation – data from samples assigned to HU6.

Except for the data aggregation described above, all data screening matched that used in the baseline risk assessments for source units described earlier.

Consistent with regulatory guidance and previous agreements, the BHHRA, utilizing sampling data, evaluated scenarios that encompass both current use and several hypothetical future uses of groundwater at the PGDP. These scenarios and the exposure routes considered under each are as follows:

Industrial worker

- Ingestion of groundwater
- Dermal contact with groundwater while showering
- Inhalation of vapors emitted by groundwater while showering

Recreational user

- Incidental ingestion of water while swimming in ponds filled with groundwater
- Dermal contact with water while swimming in ponds filled with groundwater
- Dermal contact with water while wading in ponds filled with groundwater
- Consumption of fish raised in ponds filled with groundwater
- Consumption of venison from deer drinking groundwater
- Consumption of meat from rabbits drinking groundwater
- Consumption of meat from quail drinking groundwater

Rural resident

- Ingestion of groundwater
- Dermal contact with groundwater while showering
- Inhalation of vapors emitted by groundwater during household use
- Inhalation of vapors emitted by groundwater while showering
- Consumption of vegetables
- Consumption of beef from cows drinking groundwater
- Consumption of milk from cows drinking groundwater
- Consumption of meat from chickens and turkeys drinking groundwater
- Consumption of eggs from chickens drinking groundwater
- Consumption of pork from swine drinking groundwater

A summary of the risk characterization results over all areas (i.e., Area n) is presented in Table 1.7. Summary tables for other areas are presented as Tables 5.10 through 5.22 in Appendix B. (Dose assessment results over all areas are summarized in the footnote to Table 1.7)

The BHHRA for modeling data followed the same methods as those used to perform the assessment of sampling data. However, for the assessment of modeling data, the exposure concentrations were the modeled values discussed in Sect. 1.2.5.3, only four points of exposure were modeled, and only risk from residential use (i.e., the first four exposure routes listed under the "Rural resident" above) was estimated for those points. The four points of exposure were at the PGDP security fence, at the PGDP property boundary, at Little Bayou Creek, and at the Ohio River.

Table 1.7. Summary of risk characterization for Area n

Receptor	Total ELCR[a,b]	ELCR COCs	% Total ELCR	ELCR POCs	% Total ELCR	Total HI[a,b]	Systemic Toxicity COCs	% Total HI	Systemic Toxicity POCs	% Total HI
Future Worker (McNairy Formation)	2.3×10^{-4}	Arsenic	10.6	Direct ingestion	58.0	4.5	Antimony	52.2	Direct ingestion	81.0
		Beryllium	60.3	Dermal contact	17.0		Arsenic	3.4	Dermal contact	15.8
		Trichloroethene	4.6	Inhalation of vapors	25.0		Cadmium	11.2	Inhalation of vapors	3.3
		^{226}Ra	0.5				Chromium	2.7		
		^{222}Rn	23.7				Iron	6.6		
							Vanadium	5.0		
							Trichloroethene	11.6		
Future Worker (RGA)	1.4×10^{-2}	Arsenic	0.1	Direct ingestion	87.0	33	Antimony	6.8	Direct ingestion	56.5
		Beryllium	1.0	Dermal contact	3.8		Cadmium	<0.1	Dermal contact	17.8
		1,1-Dichloroethene	2.0	Inhalation of vapors	9.7		Chromium	1.5	Inhalation of vapors	25.7
		Acrylonitrile	0.2				Iron	<0.1		
		Carbon tetrachloride	0.7				Vanadium	<0.1		
		Chloroform	<0.1				1,1-Dichloroethene	<0.1		
		Methylene chloride	<0.1				Acrylonitrile	<0.1		
		Aroclor-1254	<0.1				Carbon tetrachloride	12.3		
		Tetrachloroethene	1.0				Aroclor-1254	1.6		
		Trichloroethene	3.1				Tetrachloroethene	2.3		
		Vinyl chloride	90.6				Trichloroethene	65.0		
		^{137}Cs	<0.1				*cis*-1,2-Dichloroethene	4.4		
		^{226}Ra	0.4				*trans*-1,2-Dichloroethene	2.1		
		^{222}Rn	0.9							
		^{99}Tc	<0.1							
		^{238}U	<0.1							
Future Worker (UCRS)	3.9×10^{-2}	Arsenic	0.2	Direct ingestion	87.0	89	Antimony	1.6	Direct ingestion	51.6
		Beryllium	<0.1	Dermal contact	3.2		Arsenic	<0.1	Dermal contact	18.4
		1,1-Dichloroethene	2.2	Inhalation of vapors	9.7		Cadmium	<0.1	Inhalation of vapors	30.0
		Benzene	<0.1				Chromium	<0.1		
		Bromodichloromethane	<0.1				Iron	<0.1		
		Chloroform	<0.1				Manganese	<0.1		
		Trichloroethene	4.1				Vanadium	<0.1		
		Vinyl chloride	92.8				1,1-Dichloroethene	<0.1		
		^{222}Rn	0.6				Trichloroethene	89.2		
		^{99}Tc	<0.1				*cis*-1,2-Dichloroethene	6.7		
		^{234}U	<0.1				*trans*-1,2-Dichloroethene	<0.1		
		^{238}U	<0.1							
Future Worker (other)	5.6×10^{-4}	Arsenic	2.5	Direct ingestion	38.0	4.9	Antimony	21.0	Direct ingestion	85.8
		Beryllium	10.0	Dermal contact	3.5		Cadmium	8.7	Dermal contact	9.7
		1,1-Dichloroethene	20.7	Inhalation of vapors	58.0		Chromium	2.1	Inhalation of vapors	4.5
		Trichloroethene	0.3				Fluoride	2.1		
		Vinyl chloride	19.8				Iron	31.6		
		^{222}Rn	46.1				Manganese	18.9		
		^{228}Th	0.2				Vanadium	4.2		
							1,2-Dichloroethene	2.8		
							cis-1,2-Dichloroethene	2.9		

Table 1.7. (continued)

Receptor	Total ELCR[a,b]	ELCR COCs	% Total ELCR	ELCR POCs	% Total ELCR	Total HI[a,b]	Systemic Toxicity COCs	% Total HI	Systemic Toxicity POCs	% Total HI
Recreator (McNairy Formation)	4.0×10^{-4}	Arsenic	0.9	Direct ingestion	2.2	8.8	Antimony	51.0	Direct ingestion	4.7
		Beryllium	92.9	Dermal contact[c]	97.8		Beryllium	1.7	Dermal contact[c]	95.3
		Trichloroethene	6.2				Cadmium	18.6		
							Chromium	2.7		
							Iron	1.3		
							Vanadium	8.2		
							Trichloroethene	14.4		
Recreator (RGA)	6.1×10^{-3}	Arsenic	<0.1	Direct ingestion	13.0	70	Antimony	6.0	Direct ingestion	2.6
		Beryllium	6.0	Dermal contact[c]	87.0		Beryllium	0.2	Dermal contact[c]	97.4
		1,1-Dichloroethene	0.9				Cadmium	1.2		
		Acrylonitrile	<0.1				Chromium	1.3		
		Bis(2-ethylhexyl)phthalate	<0.1				Vanadium	0.5		
		Carbazole	<0.1				Carbon tetrachloride	5.0		
		Carbon tetrachloride	1.5				Aroclor-1254	5.2		
		Chrysene	<0.1				Tetrachloroethene	7.1		
		Aroclor-1254	0.1				Trichloroethene	72.9		
		PCBs	<0.1				*cis*-1,2-Dichloroethene	0.7		
		Tetrachloroethene	12.6							
		Trichloroethene	16.4							
		Vinyl chloride	62.2							
		^{226}Ra	<0.1							
Recreator (UCRS)	1.5×10^{-2}	Arsenic	<0.1	Direct ingestion	15.0	200	Antimony	1.4	Direct ingestion	2.6
		Beryllium	0.6	Dermal contact[c]	85.0		Cadmium	0.3	Dermal contact[c]	97.4
		1,1-Dichloroethene	1.1				Chromium	0.1		
		Trichloroethene	25.2				Manganese	0.1		
		Vinyl chloride	73.0				Vanadium	0.2		
							1,1-Dichloroethene	<0.1		
							Ethylbenzene	<0.1		
							Trichloroethene	96.7		
							cis-1,2-Dichloroethene	1.0		
Recreator (other)	2.1×10^{-4}	Arsenic	1.0	Direct ingestion	6.8	6.2	Antimony	31.7	Direct ingestion	6.9
		Beryllium	71.5	Dermal contact[c]	93.2		Cadmium	22.1	Dermal contact[c]	93.1
		1,1-Dichloroethene	10.1				Chromium	3.1		
		Trichloroethene	1.7				Iron	9.7		
		Vinyl chloride	15.6				Manganese	16.1		
							Vanadium	10.7		
							Trichloroethene	2.9		
Resident (McNairy Formation)	1.1×10^{-3}	Arsenic	12.7	Direct ingestion	70.0	39	Aluminum	0.3	Direct ingestion	64.2
		Beryllium	62.2	Dermal contact	9.7		Antimony	37.5	Dermal contact	5.0
		Trichloroethene	11.5	Inhalation of vapors[d]	20.2		Arsenic	2.7	Inhalation of vapors[d]	30.8
		^{226}Ra	0.4				Barium	0.5		
		^{222}Rn	13.0				Beryllium	0.7		
		^{99}Tc	0.1				Cadmium	7.5		
							Chromium	2.0		
							Fluoride	0.7		
							Iron	5.2		

Table 1.7. (continued)

Receptor	Total ELCR[a,b]	ELCR COCs	% Total ELCR	ELCR POCs	% Total ELCR	Total HI[a,b]	Systemic Toxicity COCs	% Total HI	Systemic Toxicity POCs	% Total HI
Resident							Manganese	1.5		
(McNairy Formation)							Molybdenum	1.2		
(continued)							Nickel	0.4		
							Vanadium	3.3		
							Trichloroethene	36.3		
Resident	1.1×10^{-1}	Arsenic	<0.1	Direct ingestion	55.0	800	Antimony	1.7	Direct ingestion	14.7
(RGA)		Beryllium	0.5	Dermal contact	1.1		Arsenic	<0.1	Dermal contact	1.6
		1,1,2-Trichloroethane	<0.1	Inhalation of vapors[d]	43.9		Beryllium	<0.1	Inhalation of vapors[d]	83.7
		1,1-Dichloroethene	5.8				Boron	<0.1		
		1,2-Dichloroethane	<0.1				Cadmium	0.2		
		Acrylonitrile	0.2				Chromium[c]	0.4		
		Benzene	<0.1				Fluoride	<0.1		
		Bis(2-ethylhexyl)phthalate	<0.1				Iron	<0.1		
		Carbazole	<0.1				Lithium	<0.1		
		Carbon tetrachloride	0.9				Manganese	<0.1		
		Chloroform	<0.1				Molybdenum	<0.1		
		Chloromethane	<0.1				Nickel	<0.1		
		Methylene chloride	<0.1				Silver	<0.1		
		Aroclor-1254	<0.1				Vanadium	<0.1		
		PCBs	<0.1				1,1,1-Trichloroethane	<0.1		
		Tetrachloroethene	0.5				1,1-Dichloroethene	0.4		
		Trichloroethene	4.0				1,2-Dichloroethane	<0.1		
		Vinyl chloride	87.4				2-Butanone	<0.1		
		^{241}Am	<0.1				4-Methyl-2-pentanone	<0.1		
		^{137}Cs	<0.1				Acetone	<0.1		
		^{237}Np	<0.1				Acrylonitrile	1.0		
		^{226}Ra	0.2				Benzene	<0.1		
		^{222}Rn	0.3				Bromomethane	<0.1		
		^{99}Tc	<0.1				Carbon tetrachloride	16.9		
		^{234}U	<0.1				Chlorobenzene	<0.1		
		^{235}U	<0.1				Chloroform	<0.1		
		^{238}U	<0.1				Ethylbenzene	<0.1		
							Aroclor-1254	0.3		
							Tetrachloroethene	0.5		
							Trichloroethene	70.1		
							cis-1,2-Dichloroethene	5.7		
							trans-1,2-Dichloroethene	2.7		
Resident	2.9×10^{-1}	Arsenic	0.1	Direct ingestion	55.0	2,400	Aluminum	<0.1	Direct ingestion	13.4
(UCRS)		Beryllium	<0.1	Dermal contact	1.0		Antimony	0.4	Dermal contact	1.8
		1,1-Dichloroethene	6.3	Inhalation of vapors[d]	43.9		Arsenic	0.1	Inhalation of vapors[d]	84.8
		1,2-Dichloroethane	<0.1				Barium	<0.1		
		Benzene	<0.1				Cadmium	<0.1		
		Bromodichloromethane	<0.1				Chromium	<0.1		
		Chloroform	<0.1				Fluoride	<0.1		
		Dibromochloromethane	<0.1				Iron	<0.1		
		Methylene chloride	<0.1				Manganese	<0.1		
		Trichloroethene	5.3				Mercury	<0.1		

Table 1.7. (continued)

Receptor	Total ELCR[a,b]	ELCR COCs	% Total ELCR	ELCR POCs	% Total ELCR	Total HI[a,b]	Systemic Toxicity COCs	% Total HI	Systemic Toxicity POCs	% Total HI
Resident (UCRS) (continued)		Vinyl chloride	88.0				Molybdenum	<0.1		
		^{237}Np	<0.1				Nickel	<0.1		
		^{239}Pu	<0.1				Silver	<0.1		
		^{226}Ra	<0.1				Strontium	<0.1		
		^{222}Rn	0.2				Uranium	<0.1		
		^{99}Tc	<0.1				Vanadium	<0.1		
		^{228}Th	<0.1				1,1-Dichloroethene	0.5		
		^{234}U	<0.1				1,2-Dichloroethane	<0.1		
		^{235}U	<0.1				1,2-Dichloroethene	<0.1		
		^{238}U	<0.1				2,4-Dimethylphenol	<0.1		
							Benzene	<0.1		
							Bromodichloromethane	<0.1		
							Chloroform	<0.1		
							Dimethylbenzene	<0.1		
							Ethylbenzene	<0.1		
							Naphthalene	0.3		
							Trichloroethene	89.9		
							cis-1,2-Dichloroethene	8.1		
							trans-1,2-Dichloroethene	0.5		
Resident (other)	4.7×10^{-3}	Arsenic	1.6	Direct ingestion	25.0	50	Aluminum	0.5	Direct ingestion	58.5
		Beryllium	5.5	Dermal contact	1.1		Antimony	12.6	Dermal contact	6.3
		1,1-Dichloroethene	59.3	Inhalation of vapors[d]	74.0		Arsenic	1.1	Inhalation of vapors[d]	35.2
		Methylene chloride	<0.1				Beryllium	0.2		
		Trichloroethene	0.4				Cadmium	4.8		
		Vinyl chloride	19.2				Chromium	1.3		
		^{226}Ra	<0.1				Fluoride	1.4		
		^{222}Rn	13.6				Iron	20.5		
		^{228}Th	0.1				Manganese	11.8		
		^{234}U	<0.1				Nickel	0.4		
		^{238}U	<0.1				Vanadium	2.4		
							1,1-Dichloroethene	2.8		
							1,2-Dichloroethene	8.8		
							Acetone	0.5		
							Naphthalene	13.5		
							Trichloroethene	4.0		
							cis-1,2-Dichloroethene	8.9		

Note: COCs = contaminant of concern; POCs = pathway of concern
ELCR = excess lifetime cancer risk; RGA = Regional Gravel Aquifer
HI = hazard index; UCRS = Upper Continental Recharge System

Values for ELCR greater than 1×10^{-2} fall outside the calculation bounds in EPA 1989a and are approximate values only.

Risk results for other areas are presented in Tables 5.10 through 5.23 in Appendix B of this FS Report. Dose assessment results (summarized below for use of water drawn from the RGA in Area N) are in Attachment 10 to Appendix B of this FS Report.

[a]Total ELCR and total HI columns are values from direct contact pathways without lead included.
[b]The ELCR values are those for lifetime exposure. The HI values are those for a child.
[c]Sum of dermal contact while wading and while swimming.
[d]Sum of inhalation of emissions from groundwater while showering and during household use.

Table 1.7. (continued)

Summary of Dose Assessment for Use of Groundwater Drawn from the RGA by the Adult Resident

Radionuclide	Dose (mrem/yr)	% of Total Dose
Americium-241	2.1	31%
Cesium-137	0.1	1%
Cobalt-60	<0.1	<1%
Neptunium-237	1.3	20%
Plutonium-239	0.3	5%
Radium-226	1.8	26%
Technetium-99	0.2	3%
Thorium-230	0.2	3%
Uranium-234	0.3	5%
Uranium-235	<0.1	1%
Uranium-235/236	<0.1	<1%
Uranium-238	0.4	5%
Total	6.9	

Notes:

All doses were calculated using the representative concentrations for Area n.

Doses to child are one-half of those to the adult due to their lower ingestion rate (2 L/day versus 1 L/day).

The major conclusions and observations from these assessments are presented in the following material. Note that the procedure outlined in the Methods Document was utilized to select the land uses, pathways, and COCs for the assessment of sampling data. This procedure is as follows.

- To determine land-use scenarios of concern, risk characterization results for total systemic toxicity [total hazard index (HI)] and total risk [total excess lifetime cancer risk (ELCR)] for each land-use scenario at each area was compared to benchmarks of 1 and 1×10^{-6} for HI and ELCR, respectively. Land-use scenarios with total HIs exceeding the benchmark of 1 were deemed land-use scenarios of concern for systemic toxicity. Land-use scenarios with total ELCR exceeding the benchmark of 1×10^{-6} were deemed land-use scenarios of concern for ELCR.

- To determine POCs, the exposure route HI and ELCR over all COPCs within the land-use scenarios of concern were compared to benchmarks of 0.1 and 1×10^{-6} for exposure route HI and ELCR, respectively. Exposure routes with HIs and ELCRs that exceed these benchmarks were deemed POCs for that land-use scenario of concern.

- To determine COCs, the chemical-specific HI and ELCR contributed by each COPC over all pathways within a land-use scenario of concern were compared to benchmarks of 0.1 and 1×10^{-6} for chemical-specific HI and ELCR, respectively. COPCs with chemical-specific HIs or ELCRs that exceed these benchmarks were deemed COCs for that land-use scenario of concern.

Land Uses of Concern from the Assessment of Sampling Data

Not all area/depth classifications were found to have land-use scenarios of concern for both systemic toxicity and ELCR. However, the RGA was found to be of concern for all uses in all areas, and the UCRS was found to be of concern for residential and industrial use in all areas where data were available and for recreational use in all but Areas c, f, h, and j.

The McNairy Formation had more areas than the UCRS and RGA where the land uses assessed were not of concern. Under the industrial worker scenario, Areas a, c, d, f, and i, were not of concern; under the recreational user, Areas a, c, d, f, h, and i, were not of concern; and under the rural resident, Areas a, b, and f, were not of concern. (Note that data were not available for the McNairy Formation in Areas a and b. Also, the McNairy Formation did not apply to Area k.)

Area k (i.e., groundwater taken to the south of the PGDP on the terrace) was of concern for each land use for systemic toxicity and ELCR.

Pathways of Concern from the Assessment of Sampling Data

All direct contact exposure routes (i.e., those involving ingestion, dermal contact, and inhalation) and the sum of the biota consumption exposure routes were of concern for at least one area/depth classification combination. However, specific biota consumption routes were determined to not be of concern for some areas. Biota consumption routes for the recreational user that were not of concern in any area were consumption of venison, rabbit, and quail. Biota consumption routes for the resident that were not of concern in any area were consumption of eggs and consumption of pork. Biota consumption routes for the recreational user and resident that were of concern for virtually all area and depth classification combinations were consumption of fish and consumption of vegetables, respectively.

Contaminants of Concern from the Assessment of Sampling Data

Multiple COCs were found for each of the land uses. These COCs are summarized by scenario across all areas in Table 1.8 and summarized for the residential scenario across all areas in Table 1.9. As shown in Table 1.9, 22 of the COCs across groundwater sources are inorganic chemicals, 33 of the COCs across groundwater sources are organic compounds, and 10 of the COCs across groundwater sources are radionuclides.

Combining the results for systemic toxicity and ELCR and considering the magnitude of the chemical-specific HIs and ELCRs, the following COCs were identified in the BHHRA as "priority COCs" in UCRS groundwater across all use scenarios (excluding Area k).

- Inorganic chemicals – arsenic, antimony, beryllium, cadmium, chromium, iron, lead, manganese, nickel, and vanadium

- Organic compounds – 1,1-dichloroethene, benzene, chloroform, ethylbenzene, naphthalene, *trans*-1,2-dichloroethene, *cis*-1,2-dichloroethene, TCE, and vinyl chloride

- Radionuclides – ^{222}Rn

For Area k, the "priority COCs" in groundwater across all use scenarios were as follows:

- Inorganic chemicals – antimony, beryllium, cadmium, iron, lead, manganese, and vanadium

- Organic compounds – 1,1-dichloroethene, 1,2-dichloroethene, naphthalene, *cis*-1,2-dichloroethene, TCE, and vinyl chloride

- Radionuclides – ^{222}Rn

For the RGA, the following COCs were identified in the BHHRA as "priority COCs" in RGA groundwater across all use scenarios.

- Inorganic chemicals – antimony, arsenic, beryllium, cadmium, chromium, iron, lead, manganese, molybdenum, and vanadium

- Organic compounds – 1,1-dichloroethene, acrylonitrile, carbon tetrachloride, Aroclor-1254, tetrachloroethene, *cis*-1,2-dichloroethene, *trans*-1,2-dichloroethene, TCE, and vinyl chloride

- Radionuclides – ^{226}Ra and ^{222}Rn

For the McNairy Formation, the following COCs were identified in the BHHRA as "priority COCs" in McNairy Formation groundwater across all use scenarios.

- Inorganic chemicals – antimony, arsenic, beryllium, cadmium, chromium, iron, manganese, molybdenum, and vanadium

- Organic compounds – TCE

- Radionuclides – ^{222}Rn

Table 1.8. Summary of COCs for residential use of groundwater over all areas (unfiltered)

Analyte	McNairy Formation	RGA	UCRS	Migration from Source Areas
		Inorganic chemical COCs		
Aluminum	X		X	
Antimony	X	X	X	X
Arsenic	X	X	X	X
Barium	X		X	
Beryllium	X	X	X	
Boron		X		
Cadmium	X	X	X	
Chromium	X	X	X	X
Copper				X
Fluoride	X	X	X	
Iron	X	X	X	X
Lead		X	X	
Lithium		X		X
Manganese	X	X	X	X
Mercury			X	
Molybdenum	X	X	X	
Nickel	X	X	X	
Silver		X	X	X
Strontium			X	X
Thallium				X
Uranium			X	
Vanadium	X	X	X	X
		Organic compound COCs		
1,1,1-Trichloroethane		X		
1,1,2-Trichloroethane		X		
1,1-Dichloroethene		X	X	
1,2-Dichloroethane		X	X	
1,2-Dichloroethene			X	
cis-1,2-Dichloroethene		X	X	X
trans-1,2-Dichloroethene		X	X	X
2-Butanone		X		
2,4-Dimethylphenol			X	
4-Methyl-2-pentanone		X		
Acetone		X		
Acrylonitrile		X		
Benzene		X	X	
Bis(2-ethylhexyl)phthalate		X		
Bromodichloromethane			X	
Bromomethane		X		
Carbazole		X		
Carbon tetrachloride		X		X
Chlorobenzene		X		
Chloroform		X	X	
Chloromethane		X		
Dibromochloromethane			X	
Dimethylbenzene			X	
Ethylbenzene		X	X	

Table 1.8. (continued)

Analyte	McNairy Formation	RGA	UCRS	Migration from Source Areas
Methylene chloride		X	X	
Naphthalene			X	
Phenanthrene				X
Aroclor-1254		X		
Polychlorinated biphenyls		X		X
Tetrachloroethene		X		X
Trichloroethene	X	X	X	X
Vinyl chloride		X	X	X
Xylenes				X
		Radionuclide COCs		
^{241}Am		X		
^{137}Cs		X		
^{237}Np		X	X	
^{239}Pu			X	
^{226}Ra	X	X	X	
^{222}Rn	X	X	X	
^{99}Tc	X	X	X	X
^{234}U		X	X	
^{235}U		X	X	
^{238}U		X	X	

Notes: A solid cell indicates that the analyte was identified as a priority COC because its chemical-specific HI exceeded 1, or its chemical-specific ELCR exceeded 1×10^{-4} for one or more areas. An "X" indicates that the analyte was identified as a COC with a chemical-specific HI between 0.1 and 1 or a chemical-specific ELCR between 1×10^{-6} and 1×10^{-4}. A blank cell indicates that the analyte was not a COC for the specified group.

COC = contaminant of concern
RGA = Regional Gravel Aquifer
UCRS = Upper Continental Recharge System

Table 1.9. Frequency of detection of COCs for residential use of groundwater over all areas (unfiltered)

Analyte	McNairy Formation	RGA	UCRS	Migration from Source Areas
		Inorganic chemical COCs		
Aluminum	30/110		166/201	
Antimony	1/76	6/1096	7/177	X
Arsenic	4/59	57/1364	81/326	X
Barium	51/59		185/197	
Beryllium	1/59	43/974	5/170	
Boron		34/48		
Cadmium	1/59	19/1389	8/336	
Chromium	2/49	345/1368	53/329	X
Copper				X
Fluoride	71/71	718/841	138/194	
Iron	116/119	1139/1511	239/259	X
Lead		34/1078	15/243	
Lithium		24/48		X
Manganese	118/119	719/1162	180/229	X
Mercury			5/226	
Molybdenum	1/50	32/509	1/133	
Nickel	2/59	324/1060	60/203	
Silver		18/693	4/65	X
Strontium			9/10	X
Thallium				X
Uranium			77/308	
Vanadium	21/32	371/717	121/143	X
		Organic compound COCs		
1,1,1-Trichloroethane		1/1667		
1,1,2-Trichloroethane		1/1805		
1,1-Dichloroethene		7/1641	10/205	
1,2-Dichloroethane		1/1824	1/233	
1,2-Dichloroethene			2/15	
cis-1,2-Dichloroethene		45/1738	58/218	X
trans-1,2-Dichloroethene		8/1800	3/237	X
2-Butanone		45/404		
2,4-Dimethylphenol			1/10	
4-Methyl-2-pentanone		3/433		
Acetone		58/406		
Acrylonitrile		1/384		
Benzene		2/1646	4/269	
Bis(2-ethylhexyl)phthalate		7/35		
Bromodichloromethane			1/233	
Bromomethane		3/436		
Carbazole		1/15		
Carbon tetrachloride		6/1823		X
Chlorobenzene		3/435		
Chloroform		16/1757	10/236	
Chloromethane		14/434		
Dibromochloromethane			1/43	
Dimethylbenzene			13/269	
Ethylbenzene		2/1649	15/270	

Table 1.9. (continued)

Analyte	McNairy Formation	RGA	UCRS	Migration from Source Areas
Methylene chloride		47/435	16/42	
Naphthalene			1/17	
Phenanthrene				X
Aroclor-1254		1/26		
Polychlorinated biphenyls		1/135		X
Tetrachloroethene		11/1780		X
Trichloroethene	10/154	1782/2578	327/623	X
Vinyl chloride		3/1842	34/249	X
Xylenes				X
		Radionuclide COCs		
^{241}Am		16/29		
^{137}Cs		14/44		
^{237}Np		64/106	12/23	
^{239}Pu			6/20	
^{226}Ra	19/22	60/72	9/15	
^{222}Rn	98/98	809/810	79/79	
^{99}Tc	113/158	2652/3857	583/651	X
^{234}U		24/33	14/16	
^{235}U		10/22	6/9	
^{238}U		21/30	13/14	

Notes: Solid cells indicates that the analyte was identified as a priority COC because its chemical-specific HI exceeded 1 or its chemical-specific ELCR exceeded 1×10^{-4} for one or more areas.

Frequency of detection is over all areas.

Frequency of detection cannot be derived for migration from source areas.

COC = contaminant of concern
RGA = Regional Gravel Aquifer
UCRS = Upper Continental Recharge System

(Note that "priority COCs" are those that present either a chemical-specific HI or ELCR at one or more areas, across all land uses, that exceeds 1 or 1×10^{-4}, respectively.)

Results from the Assessment of Modeling Data

Results for the assessment of modeling data for the property boundary point of exposure are presented in Figs. 1.19 through 1.22. (Results for other areas are similar and are in Sect. 5 of the BHHRA in Appendix B.) These results show that the total HI and ELCR is dominated through years 2600 and 4700, respectively, by releases of TCE from the DNAPL source except for a period from about years 80 to 140 (Figs. 1.19 and 1.20). During this period, the risk from exposure to contributions from source areas (i.e., SWMUs in WAGs 6, 22, 27, and 28) is greater. However, the results also show that the majority of ELCR and HI from contributions from source areas during this during this period also are from TCE (Figs. 1.21 and 1.22). After year 2600 for HI and year 4700 for ELCR, driving source area contaminants are antimony for HI and uranium isotopes for ELCR.

Although TCE migrating from DNAPL and source areas dominate HI and ELCR until far into the future, exposure to other contaminants migrating from source areas also have unacceptable levels of chemical-specific HI and ELCR. As shown in Figs. 1.21 and 1.22, respectively, chemical-specific HIs from lithium, antimony, manganese and chromium migrating each exceed 1, and chemical-specific ELCR from vinyl chloride, ^{99}Tc, and ^{238}U each exceed 1×10^{-4}.

1.2.6.3 Risk management considerations

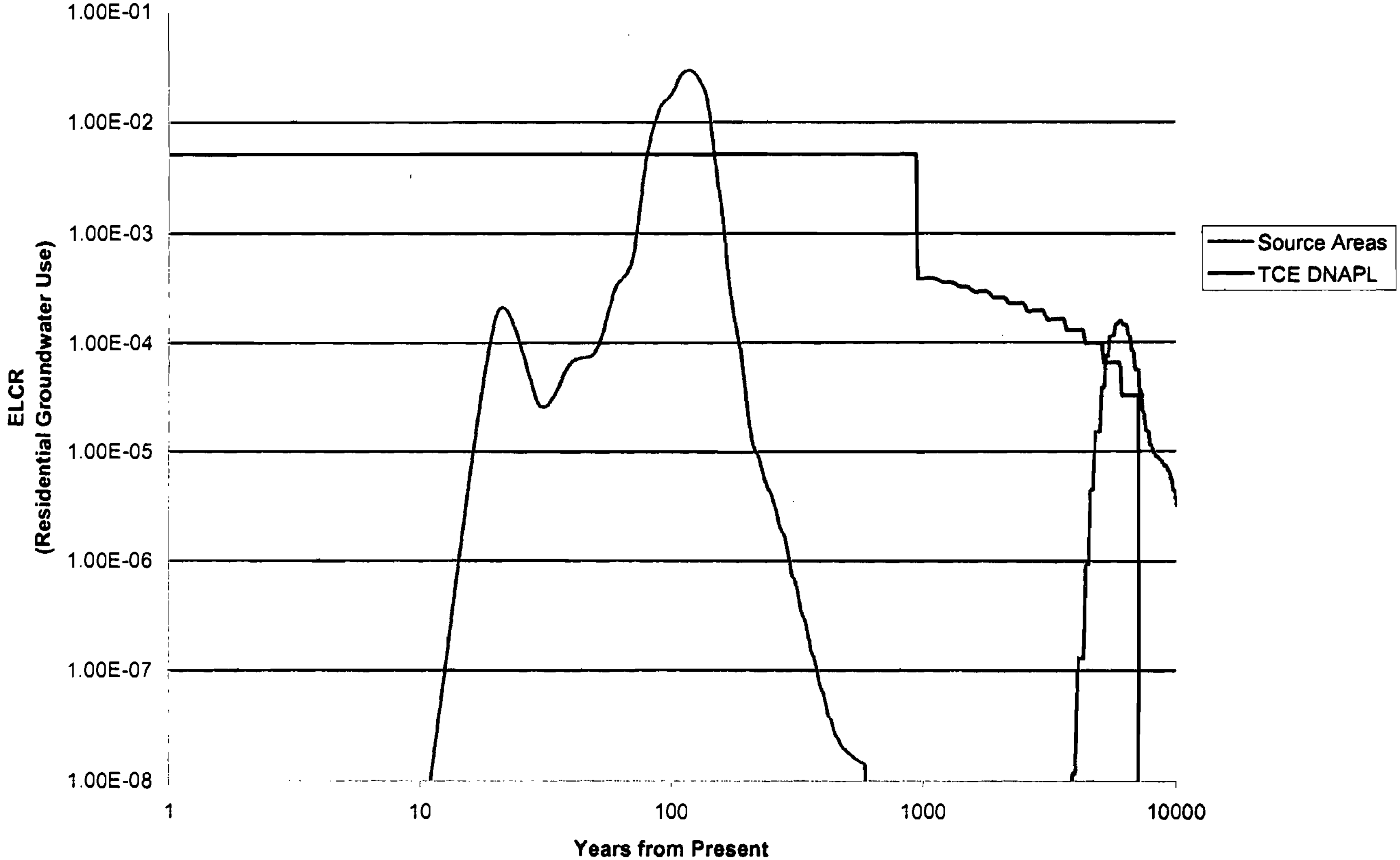
In order to evaluate the remedial actions appropriate for the GWOU, the COCs need to be evaluated to identify those contaminants that can best be used to support the development of remedial action objectives (RAOs) and select among remedial alternatives. This section summarizes pertinent information about each of the 65 COCs identified previously in order to develop a smaller list of representative COCs that can be used to screen remedies in later portions of this FS. This information is drawn in large part from Tables 1.7 through 1.10 and Figures 1.19 and 1.22. As noted above, 22 of the COCs identified in the GWOU BHHRA are inorganic chemicals, 33 of the COCs are organic compounds, and 10 of the COCs are radionuclides. (Note that these COCs were selected under residential use.)

Aluminum

Aluminum is a COC for systemic toxicity for the McNairy Formation and UCRS but not the RGA. The contribution of aluminum to total HI for use of water drawn from these two sources (39 and 2400, respectively) is minimal (0.3% and <0.1%, respectively). Additionally, the calculation of the HI for aluminum utilizes a provisional toxicity value [i.e., a provisional reference dose (RfD)], which makes the HI less certain than that for some other COCs. The frequencies of detection in unfiltered samples are 27% for McNairy Formation and 83% for UCRS. The frequencies of detection in filtered samples are similar at 23% and 51%, respectively. Based upon the small contribution and uncertain toxicity value, aluminum is not considered a COC further in this FS.

Antimony

Antimony is a priority COC for systemic toxicity for the McNairy Formation, RGA, and UCRS. The contribution of antimony to total HI for use of water drawn from these three sources (39, 800, and 2400, respectively) is moderate for the McNairy Formation (37.5%) but minimal for the other two water sources (1.7% and 0.4%, respectively). Antimony was identified as posing a significant migration risk from source areas in both previous reports and in modeling completed for this FS. The noncancer toxicity value (i.e., RfD) for antimony is an approved value. However, the frequencies of detection in both unfiltered



U. S. DEPARTMENT OF ENERGY
DOE OAK RIDGE OPERATIONS
PADUCAH GASEOUS DIFFUSION PLANT

BECHTEL JACOBS COMPANY, LLC
MANAGED FOR THE US DEPARTMENT OF ENERGY UNDER US GOVERNMENT CONTRACT DE-AC-05-98OR22700
Oak Ridge, Tennessee • Paducah, Kentucky • Portsmouth, Ohio

Science Applications International Corporation
P.O. Box 2502
Oak Ridge, Tennessee 37831

Fig. 1.19. Total ELCR from source areas at property boundary versus that from TCE DNAPL sources.

FIGURE No. FS1-19
DATE 05-25-01

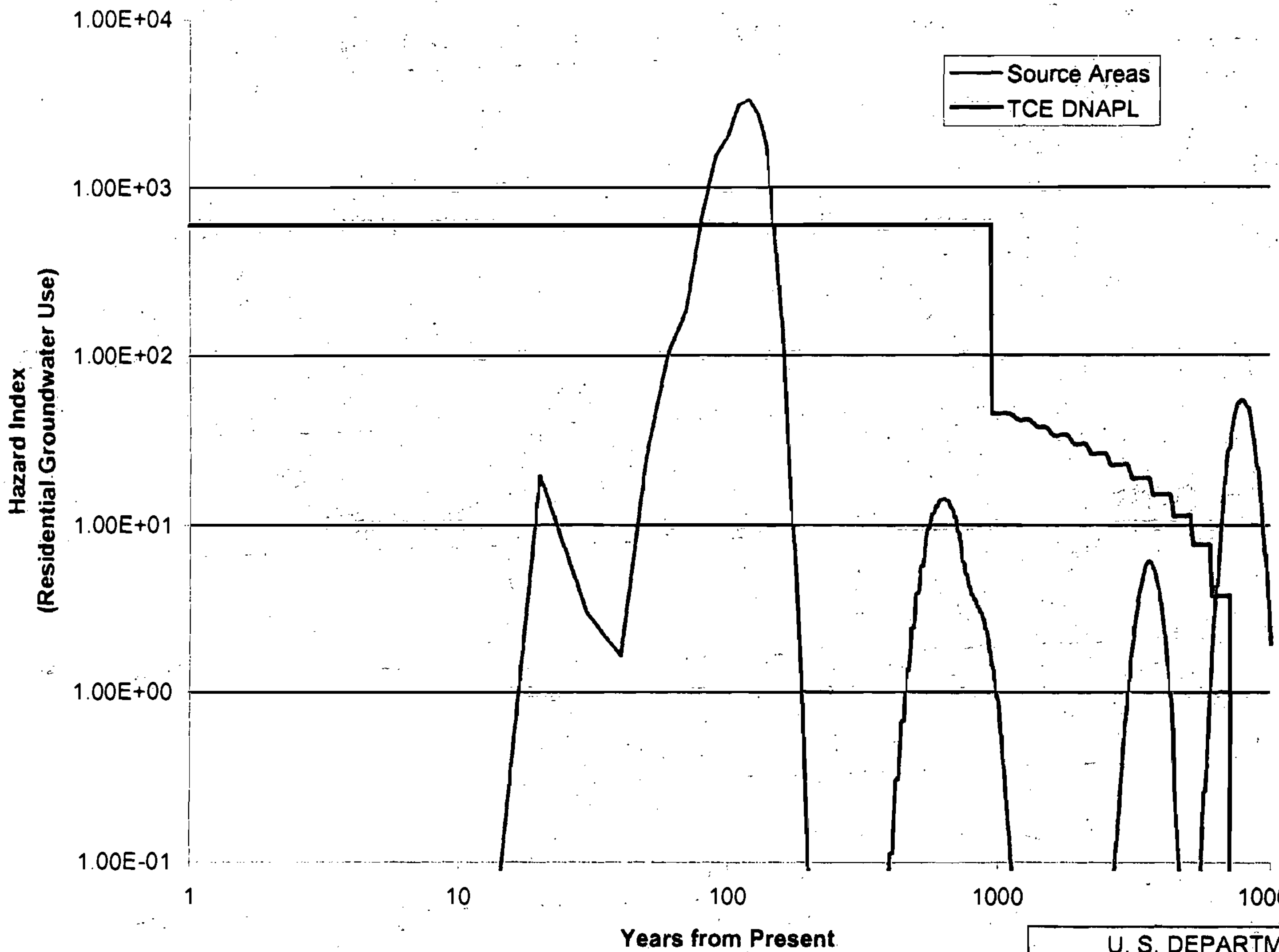


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Fig. 1.20. Total hazard index from source areas at property boundary versus that from TCE DNAPL sources.

FIGURE No. FS1-20
DATE 05-25-01

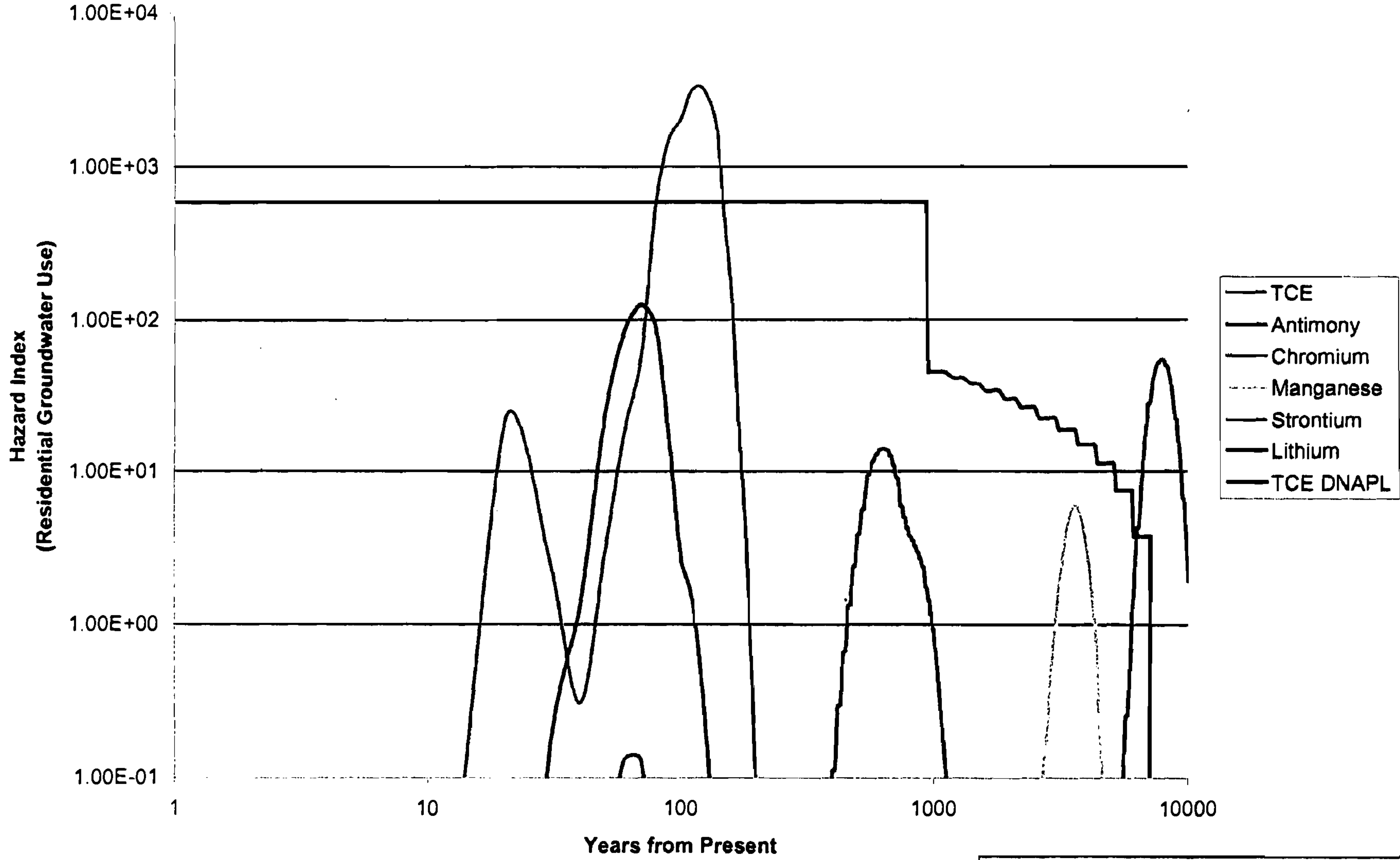

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Fig. 1.21. Summary of hazard indices for contaminants at property boundary from all sources.

FIGURE No. FS1-21
DATE 05-25-01

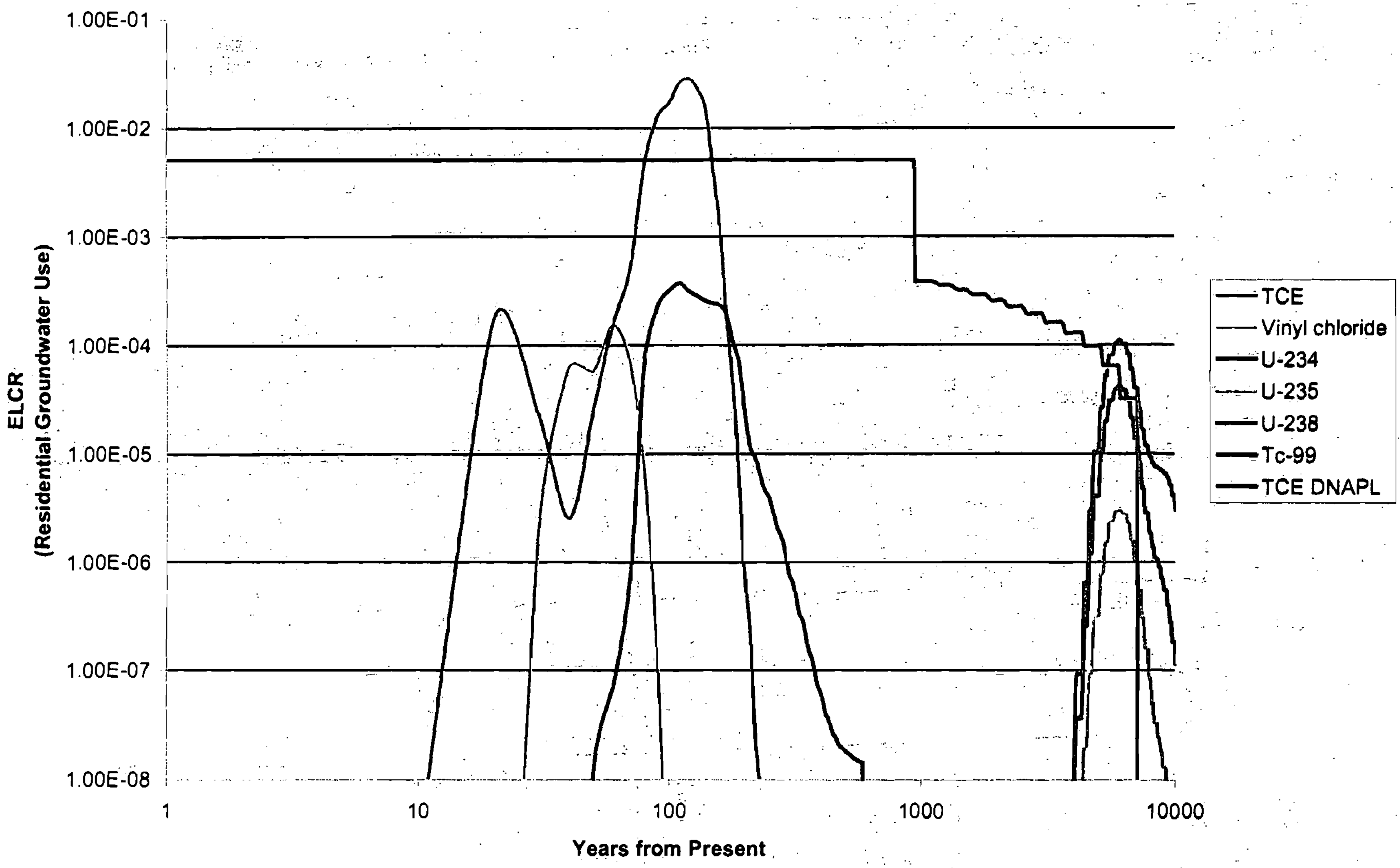

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Fig. 1.22. Summary of ELCR from all sources at property boundary.

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FIGURE No. FS1-22
DATE 05-25-01

Table 1.10. Frequency of detection of COCs for residential use of groundwater over all areas (filtered)

Analyte	McNairy Formation	RGA	UCRS	Migration from Source Areas
Inorganic chemical COCs				
Aluminum	24/103		93/181	
Antimony	0/68	22/745	2/160	X
Arsenic	1/54	21/1130	42/301	X
Barium	51/58		166/183	
Beryllium	0/52	17/625	0/153	
Boron		22/36		
Cadmium	0/57	8/1176	3/304	
Chromium	0/47	21/1247	1/298	X
Copper				X
Fluoride	0/0	0/0	0/0	
Iron	108/114	308/1177	104/226	X
Lead		3/868	2/212	
Lithium		12/36		X
Manganese	112/114	545/1043	132/198	X
Mercury			3/203	
Molybdenum	1/43	15/446	0/126	
Nickel	0/52	166/722	44/173	
Silver		14/574	0/52	X
Strontium			0/1	X
Thallium				X
Uranium			31/129	
Vanadium	19/32	325/444	106/129	X
Radionuclide COCs				
^{241}Am		0/0		
^{137}Cs		0/0		
^{237}Np		0/0	0/0	
^{239}Pu			0/0	
^{226}Ra	0/0	0/0	0/0	
^{222}Rn	0/0	0/0	0/0	
^{99}Tc	0/0	0/0	0/0	X
^{234}U		0/1	0/0	
^{235}U		0/1	0/0	
^{238}U		0/1	0/0	

Notes: Solid cells indicates that the analyte was identified as a priority COC for unfiltered water because its chemical-specific hazard index exceeded 1 or its chemical-specific ELCR exceeded 1×10^{-4} for one or more areas.

Only inorganic chemicals and radionuclide COCs were identified from filtered samples.

COC = contaminant of concern
RGA = Regional Gravel Aquifer
UCRS = Upper Continental Recharge System

(1%, 0.5%, and 4%) and filtered samples (0%, 3%, and 1%) are very low for all three water sources. Based upon the very low frequency of detection, antimony is not considered further in this FS as a COC; however, consideration of antimony in future source actions may be appropriate because of migration risk.

Arsenic

Arsenic is a priority COC for systemic toxicity and ELCR for the McNairy Formation, RGA, and UCRS. The contribution of arsenic to total HI for use of water drawn from these three sources (39, 800, and 2400, respectively) is minimal for all three water sources (2.7%, <0.1%, and 0.1%, respectively). The contribution of arsenic to total ELCR for use of water drawn from these three sources (1.1×10^{-3}, 1.1×10^{-1}, and 2.9×10^{-1}, respectively) is moderate for the McNairy Formation (12.7%) but minimal for the other two water sources (<0.1%, and 0.1%, respectively). Arsenic was identified as posing a significant migration risk from source areas in previous reports but not in the fate and transport modeling completed in the FS. The toxicity values for arsenic (RfD and cancer slope factor) are approved values, and arsenic is a known human carcinogen (Class A). The frequencies of detection in both unfiltered (7%, 4%, and 25%) and filtered samples (2%, 2%, and 14%) are low for the McNairy and RGA but moderate for UCRS. Based upon the minimal contribution to total HI, arsenic is not considered further in this FS as a COC.

Barium

Barium is a COC for systemic toxicity for the McNairy Formation and UCRS. The contribution of barium to total HI for use of water drawn from these two sources (39 and 2400, respectively) is minimal for both water sources (0.5% and <0.1%, respectively). The noncancer toxicity value for barium is an approved value. Frequencies of detection in both unfiltered (86% and 94%) and filtered samples (88% and 91%) are high for both water sources. Based upon the minimal contribution to total HI, barium is not considered further as a COC in this FS.

Beryllium

Beryllium is a priority COC for systemic toxicity for the McNairy Formation and RGA and for ELCR for the McNairy Formation, RGA, and UCRS. The contribution of beryllium to total HI for use of water drawn from the McNairy Formation and RGA (39 and 800, respectively) is minimal (0.7% and <0.1%, respectively). The contribution of beryllium to total ELCR for use of water drawn from all three sources (1.1×10^{-3}, 1.1×10^{-1}, and 2.9×10^{-1}, respectively) is high for the McNairy Formation (62.2%) but minimal for the other two water sources (0.5%, and <0.1%, respectively). The noncancer toxicity value for beryllium is an approved value, but the cancer value (oral only) was recently withdrawn. The frequencies of detection in both unfiltered (2%, 4%, and 3%) and filtered samples (0%, 3%, and 0%) are very low for all three water sources. Based upon the low frequency of detection, beryllium is not considered further as a COC in this FS.

Boron

Boron is a COC for systemic toxicity for the RGA. The contribution of boron to total HI for water drawn from the RGA (800) is minimal (<0.1%). The noncancer toxicity value for boron is an approved value. The frequencies of detection in both unfiltered (71%) and filtered samples (61%) are moderate. Based upon the minimal contribution to total HI, boron is not considered further as a COC in this FS.

Cadmium

Cadmium is a priority COC for systemic toxicity for the McNairy Formation, RGA, and UCRS. The contribution of cadmium to total HI for use of water drawn from these three water sources (39, 800, and

2400, respectively) is small for the McNairy (7.5%) Formation and minimal for the other two water sources (0.2% and <0.1%, respectively). The noncancer toxicity value for cadmium is an approved value. The frequencies of detection in both unfiltered (2%, 1%, and 2%) and filtered samples (0%, 0.7%, and 1%) are very low for all three water sources. Based upon the minimal contribution to total HI and the low frequency of detection, cadmium is not considered further as a COC in this FS.

Chromium

Chromium is a priority COC for systemic toxicity for the McNairy Formation, RGA, and UCRS. The contribution of chromium to total HI for use of water drawn from these three water sources (39, 800, and 2400, respectively) is small for the McNairy Formation (2.0%) and minimal for the other two water sources (0.4% and <0.1%, respectively). Chromium was identified as posing a significant migration risk from source areas in previous reports and in the fate and transport modeling completed for the FS. The noncancer toxicity value for chromium is an approved value. The frequencies of detection in unfiltered samples are low for water drawn from the McNairy Formation (4%) and moderate for water drawn from the RGA and UCRS (25% and 16%, respectively). However, the frequencies of detection in filtered samples are very low for all three water sources (0%, 2%, and 0.3%). Based upon the minimal contribution to total HI and the low frequency of detection (especially when results from unfiltered and filtered samples are compared), chromium is not considered further in this FS as a COC; however, consideration of chromium in future source actions may be appropriate because of the migration risk.

Copper

Copper is not a COC for any water source. However, copper was identified as posing a significant migration risk from source areas in previous reports but not in the fate and transport modeling completed for the FS. Based upon the lack of any current risk, copper is not considered further as a COC in this FS.

Fluoride

Fluoride is a COC for systemic toxicity for the McNairy Formation, RGA, and UCRS. The contribution of fluoride to total HI for use of water drawn from these three sources (39, 800, and 2400, respectively) is minimal for all three water sources (0.7%, <0.1%, <0.1%, respectively). The noncancer toxicity value for fluoride is an approved value. The frequencies of detection in unfiltered samples are high in samples from all three water sources (100%, 85%, and 71%). Analyses for fluoride were not performed on filtered water samples. Based upon the minimal contribution to total HI, fluoride is not considered further as a COC in this FS.

Iron

Iron is a priority COC for systemic toxicity for the McNairy Formation, RGA, and UCRS. The contribution of iron to total HI for use of water drawn from these three sources (39, 800, and 2400, respectively) is low for the McNairy Formation (5.2%) and minimal from the other two water sources (<0.1% for both). The noncancer toxicity value for iron is a provisional value. The frequencies of detection in unfiltered samples are high for samples drawn from all three water sources (97%, 75%, and 92%). However, the frequency of detection in filtered samples is high for the McNairy Formation (95%) and moderate for RGA and UCRS (26% and 46%, respectively). Based upon the fact that the toxicity value for iron is a provisional value, iron is not considered further as a COC in this FS.

Lead

Lead is a priority COC for systemic toxicity for the RGA and UCRS based upon the results from the EPA's Integrated Exposure Uptake Bio-kinetic Lead Model and comparisons to regulatory values.

However, the frequency of detection in both unfiltered (3% and 6%) and filtered samples (0.3% and 0.9%) drawn from these two water sources are low. Based upon the frequency of detection information, lead is not considered further as a COC in this FS.

Lithium

Lithium is a COC for systemic toxicity for the RGA. The contribution of lithium to total HI for use of water drawn from this source (800) is minimal (<0.1%). The noncancer toxicity value for lithium is an approved value. Lithium was identified as posing a significant migration risk from source areas in previous reports and in the fate and transport modeling completed for the FS. The frequencies of detection in unfiltered (50%) and filtered samples (33%) are moderate. Based upon the minimal contribution to total HI, lithium is not considered further as a COC in this FS; however, due to the migration risk, consideration of lithium during future source actions may be appropriate.

Manganese

Manganese is a priority COC for systemic toxicity for the McNairy Formation, RGA, and UCRS. The contribution of manganese to total HI for use of water drawn from these three sources (39, 800, and 2400, respectively) is minimal (1.5%, <0.1%, <0.1%, respectively). The noncancer toxicity value for manganese is an approved value. Manganese was identified as posing a significant migration risk from source areas in previous reports and in the fate and transport modeling completed for the FS. The frequencies of detection in both filtered (99%, 62%, and 79%) and unfiltered samples (98%, 52%, and 67%) were high to moderate for all water sources. Based upon the minimal contribution to total HI, manganese is not considered further as a COC in this FS; however, due to the migration risk, consideration of manganese during future source actions may be appropriate.

Mercury

Mercury is a COC for systemic toxicity for the UCRS. The contribution of mercury to total HI for use of water drawn from the UCRS (2400) was minimal (<0.1%). The noncancer toxicity value for mercury is an approved value. The frequencies of detection of mercury in both unfiltered and filtered UCRS samples are low (2% and 1%, respectively). Based upon the minimal contribution to total HI and the low frequency of detection, mercury is not considered further as a COC in this FS.

Molybdenum

Molybdenum is a priority COC for systemic toxicity for the McNairy Formation and RGA and a COC for systemic toxicity for the UCRS. The contribution of mercury to total HI for use of water drawn from these three sources (39, 800, and 2400, respectively) is minimal (1.2%, <0.1%, and <0.1%, respectively). The noncancer toxicity value for molybdenum is an approved value. The frequencies of detection in both unfiltered (2%, 6%, and 0.8%) and filtered (2%, 3%, and 0%) are small to minimal. Based upon the minimal contribution to total HI and the small to minimal frequency of detection, molybdenum is not considered further as a COC in this FS.

Nickel

Nickel is a COC for systemic toxicity for the McNairy Formation, RGA, and UCRS. The contribution of nickel to total HI for use of water drawn from these three sources (39, 800, and 2400, respectively) is minimal (0.4%, <0.1%, and <0.1%, respectively). The noncancer toxicity value for nickel is an approved value. The frequencies of detection in unfiltered samples are small for water drawn from the McNairy Formation (3%,) but moderate for the other two water sources (31%, and 30%). The frequencies of detection in filtered samples are minimal for water drawn from the McNairy Formation (0%) and moderate for the other two water sources (23% and 25%). Based upon the minimal contribution to total HI, nickel is not considered further as a COC in this FS.

Silver

Silver is a COC for systemic toxicity for the RGA and UCRS. The contribution of silver to total HI for use of water drawn from these two sources (800 and 2400, respectively) is minimal (<0.1% for both). The noncancer toxicity value for silver is an approved value. Silver was identified as posing a significant migration risk from source areas in previous reports but not in the fate and transport modeling completed for the FS. The frequencies of detection in both unfiltered (3% and 6%) and filtered samples (2% and 0%) are small to minimal. Based upon the minimal contribution to total HI and the small to minimal frequency of detection, silver is not considered further as a COC in this FS.

Strontium

Strontium is a COC for systemic toxicity for the UCRS. The contribution of strontium to total HI for use of water drawn from the UCRS (2400) is minimal (<0.1%). The noncancer toxicity value for strontium is an approved value. Strontium was identified as posing a significant migration risk from source areas in previous reports and in the fate and transport modeling completed for the FS. The frequencies of detection in unfiltered (90%) water is high but in filtered water (0%) is minimal. However, the number of samples upon which analyses for strontium were performed is small compared to that for other COCs (ten and one for unfiltered and filtered, respectively). Hence, considerable uncertainty exists in the presence and extent of strontium contamination in the UCRS at the PGDP. Based upon the minimal contribution to total HI and the uncertainty in the presence and extent of contamination, strontium is not considered further as a COC in this FS; however, collection of additional information concerning the presence and extent of strontium contamination may be appropriate.

Thallium

Thallium is not a COC for any water source. However, thallium was identified as posing a significant migration risk from source areas in previous reports but not in the fate and transport modeling completed for the FS. Based upon the lack of any current risk, thallium is not considered further as a COC in this FS.

Uranium (as a metal)

Uranium is a COC for systemic toxicity for the UCRS. The contribution of uranium to total HI for use of water drawn from the UCRS (2400) is minimal (<0.1%). The noncancer toxicity value for uranium is an approved value. The frequencies of detection in unfiltered and filtered samples (25% and 24%, respectively) are moderate. Based upon the minimal contribution to total HI, uranium is not considered further as a COC in this FS.

Vanadium

Vanadium is a priority COC for systemic toxicity for the McNairy Formation, RGA, and UCRS. The contribution of vanadium to total HI for use of water drawn from these three sources (39, 800, and 2400) is small to minimal (3.3%, <0.1%, and <0.1%, respectively). The noncancer toxicity value for vanadium is an approved value. The frequencies of detection in unfiltered (66%, 52%, and 85%) and filtered samples (59%, 73%, and 82%) are moderate to high. Based upon the minimal contribution to total HI, vanadium is not considered further as a COC in this FS.

1,1,1-Trichloroethane

1,1,1-Trichloroethane is a COC for systemic toxicity for the RGA. The contribution of 1,1,1-trichloroethane to total HI for use of water drawn from the RGA (800) is minimal (<0.1%). The noncancer toxicity value for 1,1,1-trichloroethane is a provisional value. The frequency of detection in unfiltered samples (<0.01%) is minimal. Based upon the minimal contribution to total HI and the minimal frequency of detection, 1,1,1-trichloroethane is not considered further as a COC in this FS.

1,1,2-Trichloroethane

1,1,2-Trichloroethane is a COC for ELCR for the RGA. The contribution of 1,1,2-trichloroethane to total ELCR for use of water drawn from the RGA (1.1×10^{-1}) is minimal (<0.1%). The cancer toxicity value for 1,1,2-trichloroethane is an approved value. The frequency of detection in unfiltered samples (<0.01%) is minimal. Based upon the minimal contribution to total ELCR and the minimal frequency of detection, 1,1,2-trichloroethane is not considered further as a COC in this FS.

1,1-Dichloroethene

1,1-Dichloroethene is a priority COC for both systemic toxicity and ELCR for the RGA and UCRS. The contribution of 1,1-dichloroethene to total HI for use of water drawn from these two sources (800 and 2400, respectively) is minimal (0.4% and 0.5%, respectively). The contribution of 1,1-dichloroethene to total ELCR for use of water drawn from these two sources (1.1×10^{-1} and 2.9×10^{-1}, respectively) is small (5.8% and 6.3%, respectively). The toxicity values for 1,1-dichloroethene are approved values. This organic compound is a degradation product of TCE. The frequencies of detection in unfiltered samples are minimal (0.4% and 5%, respectively). Even though 1,1-dichloroethene's contribution to total HI, ELCR, and frequencies of detection are small to minimal, this organic compound will be considered further as a COC in this FS because it is a degradation product of TCE.

1,2-Dichloroethane

1,2-Dichloroethane is a COC for both systemic toxicity and ELCR for the RGA and UCRS. The contribution of 1,2-dichloroethane to total HI for use of water drawn from these two sources (800 and 2400, respectively) is minimal (<0.1% for both). The contribution of 1,2-dichloroethane to total ELCR for use of water drawn from these two sources (1.1×10^{-1} and 2.9×10^{-1}, respectively) is also minimal (<0.1% for both). The toxicity values for 1,2-dichloroethane are approved values. The frequencies of detection in unfiltered samples are minimal (<0.1% and 0.4%, respectively). Based upon the minimal contribution to total HI and ELCR and the minimal frequencies of detection, 1,2-dichloroethane is not considered further as a COC in this FS.

1,2-Dichloroethene, cis-1,2-Dichloroethene, and trans-1,2-Dichloroethene

Both isomers of 1,2-dichloroethene are priority COCs for systemic toxicity for the RGA and UCRS. The mixture of isomers (1,2-dichloroethene) was identified as a COC for systemic toxicity for the UCRS only. The contribution of *cis*-1,2-dichloroethene to total HI for use of water drawn from these two sources (800 and 2400, respectively) is small (5.7% and 8.1%, respectively), and the contribution of *trans*-1,2-dichloroethene is slightly smaller (2.7% and 0.5%, respectively). The contribution of 1,2-dichloroethene to total HI for use of water drawn from the UCRS is minimal (<0.1%). The noncancer toxicity values for these organic compounds are approved values. These organic compounds are also degradation products of TCE. These organic compounds were identified as posing a significant migration risk from source areas in previous reports but not in the fate and transport modeling completed for the FS. The frequencies of detection for *cis*-1,2-dichloroethene in unfiltered samples are small and moderate (3% and 27%, respectively), but those for *trans*-1,2-dichloroethene are minimal to small (0.4% and 1.2%, respectively). The frequency of detection for 1,2-dichloroethene in unfiltered samples drawn from the UCRS is 13%, but few sample results are available (15). Based upon this information, both isomers of 1,2-dichloroethene and their mixture will be considered further as COCs in this FS.

2-Butanone

2-Butanone is a COC for systemic toxicity for the RGA. The contribution of 2-butanone to total HI (800) for use of water drawn from the RGA is minimal (<0.1%). The noncancer toxicity value for 2-butanone is an approved value. The frequency of detection for 2-butanone in unfiltered samples is moderate (11%). Based upon the minimal contribution to total HI, 2-butanone is not considered further as a COC in this FS.

2,4-Dimethylphenol

2,4-Dimethlyphenol is a COC for systemic toxicity for the UCRS. The contribution of 2,4-dimethylphenol to total HI (2400) for use of water drawn from the UCRS is minimal (<0.1%). The noncancer toxicity value for 2,4-dimethylphenol is an approved value. The frequency of detection for 2,4-dimethylphenol in unfiltered samples is moderate (10%), but few sample results are available (10). Based upon the minimal contribution to total HI, 2,4-dimethylphenol is not considered further as a COC in this FS.

Acetone

Acetone is a COC for systemic toxicity for the RGA. The contribution of acetone to total HI (800) for use of water drawn from the RGA is minimal (<0.1%). The toxicity value for acetone is an approved value. The frequency of detection of acetone in unfiltered samples is moderate (14%). Based upon the minimal contribution to total HI, acetone is not considered further as a COC in this FS.

Acrylonitrile

Acrylonitrile is a COC for both systemic toxicity and ELCR for the RGA. The contribution of benzene to total HI (800) and total ELCR (1.1×10^{-1}) for use of water drawn from the RGA is small and minimal (1.0% and 0.2%, respectively). The toxicity values for acrylonitrile are approved values. The frequency of detection for acrylonitrile in unfiltered samples is minimal (0.2%). Based upon the minimal frequency of detection, acrylonitrile is not considered further as a COC in this FS.

Benzene

Benzene is a COC for both systemic toxicity and ELCR for the RGA and UCRS. The contribution of benzene to total HI (800 and 2400, respectively) and total ELCR (1.1×10^{-1} and 2.9×10^{-1}, respectively) for use of water drawn from these two sources is minimal (<0.1% in all cases). The toxicity values for benzene are approved values. The frequencies of detection for benzene in unfiltered samples are minimal to small (0.1% and 1%, respectively). Based upon the minimal contribution to total HI and ELCR and the minimal frequencies of detection, benzene is not considered further as a COC in this FS.

Bis(2-ethylhexyl)phthalate

Bis(2-ethylhexyl)phthalate is a COC for ELCR for the RGA. The contribution of bis(2-ethylhexyl)phthalate to total ELCR (1.1×10^{-1}) for use of water drawn from the RGA is minimal (<0.1%). The toxicity value for bis(2-ethylhexyl)phthalate is an approved value. The frequencies of detection for bis(2-ethylhexyl)phthalate in unfiltered samples are moderate (20%), but the number of sample results are lower than those for most other COCs (35). Based upon the minimal contribution to total ELCR, bis(2-ethylhexyl)phthalate is not considered further as a COC in this FS.

Bromodichloromethane

Bromodichloromethane is a COC for systemic toxicity and ELCR for the UCRS. The contribution of bromodichloromethane to total HI (2400) and total ELCR (2.9×10^{-1}) for use of water drawn from the UCRS is minimal (<0.1% for both). The toxicity value for bromodichloromethane is an approved value. The frequency of detection for bromodichloromethane in unfiltered samples is minimal (0.4%). Based upon the minimal contribution to total HI and total ELCR and the minimal frequency of detection, bromodichloromethane is not considered further as a COC in this FS.

Bromomethane

Bromomethane is a COC for systemic toxicity for the RGA. The contribution of bromomethane to total HI (800) for use of water drawn from the RGA is minimal (<0.1%). The toxicity value for bromomethane is an approved value. The frequency of detection for bromomethane in unfiltered samples is minimal (0.7%). Based upon the minimal contribution to total HI and the minimal frequency of detection, bromomethane is not considered further as a COC in this FS.

Carbazole

Carbazole is a COC for ELCR for the RGA. The contribution of carbazole to total ELCR (1.1×10^{-1}) for use of water drawn from the RGA is minimal (<0.1%). The toxicity value for carbazole is an approved value. The frequency of detection for carbazole in unfiltered samples is small (7%), but the number of sample results are lower than for most other COCs (15). Based upon the minimal contribution to total HI and the minimal frequency of detection, carbazole is not considered further as a COC in this FS.

Carbon tetrachloride

Carbon tetrachloride is a priority COC for systemic toxicity and ELCR for the RGA. The contribution of carbon tetrachloride to total HI (800) and total ELCR (1.1×10^{-1}) for use of water drawn from the RGA is moderate for systemic toxicity (16.9%) and minimal for ELCR (0.9% for both). The toxicity values for carbon tetrachloride are approved values. Carbon tetrachloride was identified as posing a significant migration risk from source areas in previous reports but not in the fate and transport modeling completed for the FS. The frequency of detection for carbon tetrachloride in unfiltered samples is minimal (0.3%). Based upon the moderate contribution to systemic toxicity and its potential for future migration, carbon tetrachloride is considered further as a COC in this FS.

Chlorobenzene

Chlorobenzene is a COC for systemic toxicity for the RGA. The contribution of chlorobenzene to total HI (800) for use of water drawn from the RGA is minimal (<0.1%). The toxicity value for chlorobenzene is an approved value. The frequency of detection for chlorobenzene in unfiltered samples is minimal (0.7%). Based upon the minimal contribution to total HI and the minimal frequency of detection, chlorobenzene is not considered further as a COC in this FS.

Chloroform

Chloroform is a COC for both systemic toxicity and ELCR for the RGA and UCRS. The contribution of chloroform to total HI (800 and 2400, respectively) and total ELCR (1.1×10^{-1} and 2.9×10^{-1}, respectively) for use of water drawn from these two sources is minimal (<0.1% in all cases). The toxicity values for chloroform are approved values. The frequencies of detection for chloroform in unfiltered samples are minimal to small (0.9% and 4%, respectively). Based upon the minimal contribution to total HI and ELCR and the low frequencies of detection, chloroform is not considered further as a COC in this FS.

Chloromethane

Chloromethane is a COC for ELCR for the RGA. The contribution of chloromethane to total ELCR (1.1×10^{-1}) for use of water drawn from the RGA is minimal (<0.1%). The toxicity value for chloromethane is an approved value. The frequency of detection for chloromethane in unfiltered samples is small (3%). Based upon the minimal contribution to total HI and the small frequency of detection, chloromethane is not considered further as a COC in this FS.

Dibromochloromethane

Dibromochloromethane is a COC for systemic toxicity for the UCRS. The contribution of dibromochloromethane to total HI (2400) for use of water drawn from the UCRS is minimal (<0.1%). The toxicity value for dibromochloromethane is an approved value. The frequency of detection for dibromochloromethane in unfiltered samples is small (2%), but the number of sample results are lower than for most other COCs (43). Based upon the minimal contribution to total HI and the small frequency of detection, dibromochloromethane is not considered further as a COC in this FS.

Dimethylbenzene

Dimethylbenzene is a COC for systemic toxicity for the UCRS. The contribution of dimethylbenzene to total HI (2400) for use of water drawn from the UCRS is minimal (<0.1%). The toxicity value for dimethylbenzene is an approved value. The frequency of detection for dimethylbenzene in unfiltered samples is small (5%). Based upon the minimal contribution to total HI and the small frequency of detection, dibromochloromethane is not considered further as a COC in this FS.

Ethylbenzene

Ethylbenzene is a COC for systemic toxicity for the RGA and UCRS. The contribution of ethylbenzene to total HI (800 and 2400, respectively) for use of water drawn from these sources is minimal (<0.1% for both). The toxicity value for ethylbenzene is an approved value. The frequencies of detection for ethylbenzene in unfiltered samples drawn from the RGA and UCRS are minimal and small (0.1% and 6%, respectively). Based upon the minimal contribution to total HI and the rather low frequency of detection, ethylbenzene is not considered further as a COC in this FS.

Methylene chloride

Methylene chloride is a COC for ELCR for the RGA and UCRS. The contribution of methylene chloride to total ELCR (1.1×10^{-1} and 2.9×10^{-1}, respectively) for use of water drawn from these sources is minimal (<0.1% for both). The toxicity value for methylene chloride is an approved value. The frequencies of detection for methylene chloride in unfiltered samples drawn from the RGA and UCRS are moderate (11% and 38%, respectively). Based upon the minimal contribution to total ELCR, methylene chloride is not considered further as a COC in this FS.

Naphthalene

Naphthalene is a COC for systemic toxicity for the UCRS. The contribution of naphthalene to total HI (2400) for use of water drawn from the UCRS is minimal (0.3%). The toxicity value for naphthalene is an approved value. The frequency of detection for naphthalene in unfiltered samples is small (6%), but the number of sample results are lower than for most other COCs (17). Based upon the minimal contribution to total HI and the small frequency of detection, naphthalene is not considered further as a COC in this FS.

Phenanthrene

Phenanthrene is not a COC for any water source. However, phenanthrene was identified as posing a significant migration risk from source areas in previous reports but not in the fate and transport modeling completed for the FS. Based upon the lack of any current risk, phenanthrene is not considered further as a COC in this FS.

Polychlorinated biphenyls and Aroclor-1254

PCBs and Aroclor-1254 are COCs for ELCR for the RGA. (Aroclor-1254 is a priority COC.) The contributions of each of these to total ELCR (1.1×10^{-1}) for use of water drawn from the RGA are minimal (<0.1%). The toxicity values for PCBs (and Aroclor-1254) are approved values. PCBs were identified as posing a significant migration risk from source areas in previous reports but not in the fate and transport modeling completed for the FS. The frequencies of detection for PCBs and Aroclor-1254 in unfiltered samples are small and minimal (0.7% and 4%, respectively). Based upon the minimal contribution to total HI and the small frequency of detection, PCBs and Aroclor-1254 are not considered further as COCs in this FS.

Tetrachloroethene

Tetrachloroethene is a priority COC for systemic toxicity and ELCR for the RGA. The contributions of tetrachloroethene to total HI (800) and total ELCR (1.1×10^{-1}) for use of water drawn from the RGA are small (0.5% for both). The toxicity values for tetrachloroethene are approved values. Trichloroethene is a degradation product of tetrachloroethene. Tetrachloroethene was identified as posing a significant migration risk from source areas in previous reports but not in the fate and transport modeling completed for the FS. The frequency of detection for tetrachloroethene in unfiltered samples is minimal (0.6%). Based upon its being a precursor of TCE and its potential for future migration, tetrachloroethene is considered further as a COC in this FS even though its level of contribution to total HI and ELCR and frequency of detection are low.

Trichloroethene

Trichloroethene is a priority COC for systemic toxicity and ELCR for the McNairy Formation, RGA, and UCRS. The contributions of TCE to total HI (39, 800, and 2400, respectively) for use of water drawn from these sources is moderate for the McNairy Formation (36.3%) but large for the RGA and UCRS (70.1 and 89.9%, respectively). The contributions of TCE to total ELCR (1.1×10^{-3}, 1.1×10^{-3}, and 2.9×10^{-1}, respectively) for use of water drawn from these sources is moderate for the McNairy Formation (11.5%) but small for the RGA and UCRS (4.0% and 5.3%). The toxicity values for TCE are provisional values. Trichloroethene was identified as posing a significant migration risk from source areas in previous reports and in the fate and transport modeling completed for the FS. The frequencies of detection for TCE in unfiltered samples drawn from the McNairy Formation, RGA, and UCRS are low for the McNairy Formation (6%) and moderate for the RGA and UCRS (69% and 52%, respectively). Based upon this information, TCE is considered further as a COC in this FS.

Vinyl chloride

Vinyl chloride is a priority COC for ELCR for the RGA and UCRS. The contributions of vinyl chloride to total ELCR (1.1×10^{-3} and 2.9×10^{-1}, respectively) for use of water drawn from these sources is large for both the RGA and UCRS (87.4% and 88.0%). The cancer toxicity value for vinyl chloride is an approved value, and vinyl chloride is a known human carcinogen (Class A). Vinyl chloride is a degradation product of TCE. Vinyl chloride was identified as posing a significant migration risk from source areas in previous reports and in the fate and transport modeling completed for the FS. The frequencies of detection for vinyl chloride in unfiltered samples drawn from the RGA and UCRS are small for the RGA (0.1%) and moderate for the UCRS (14%). Based upon this information, vinyl chloride is considered further as a COC in this FS.

Xylenes

Xylenes are not a COC for any water source. However, xylenes were identified as posing a significant migration risk from source areas in previous reports but not in the fate and transport modeling completed for the FS. Based upon the lack of any current risk, xylenes are not considered further as a COC in this FS.

Americium-241 (^{241}Am)

Americium-241 is a COC for ELCR for the RGA. The contribution of ^{241}Am to total ELCR (1.1×10^{-1}) for use of water drawn from the RGA is minimal (<0.1%). (Dose to adult for use of RGA water in Area n is 2.1 mrem/yr.). The toxicity value for ^{241}Am is an approved value. The frequency of detection for ^{241}Am in unfiltered samples is moderate (55%), but the number of sample results are lower than for most other COCs. Based upon the minimal contribution to total ELCR, ^{241}Am is not considered further as a COC in this FS.

Cesium-137 (^{137}Cs)

Cesium-137 is a COC for ELCR for the RGA. The contribution of ^{137}Cs to total ELCR (1.1×10^{-1}) for use of water drawn from the RGA is minimal (<0.1%). (Dose to adult for use of RGA water in Area n is 0.1 mrem/yr.). The toxicity value for ^{137}Cs is an approved value. The frequency of detection for ^{137}Cs in unfiltered samples is moderate (32%), but the number of sample results are lower for most other COCs. Based upon the minimal contribution to total ELCR, ^{137}Cs is not considered further as a COC in this FS.

Neptunium-237 (^{237}Np)

Neptunium-237 is a COC for ELCR for the RGA and UCRS. The contribution of ^{237}Np to total ELCR (1.1×10^{-1} and 2.9×10^{-1}, respectively) for use of water drawn from the RGA is minimal (<0.1%). (Dose to adult for use of RGA water in Area n is 1.3 mrem/yr.). The toxicity value for ^{237}Np is an approved value. The frequencies of detection for ^{237}Np in unfiltered samples from the RGA and UCRS are moderate (60% and 52%, respectively), but the number of sample results for the UCRS are lower for most other COCs. Based upon the minimal contribution to total ELCR, ^{237}Np is not considered further as a COC in this FS.

Plutonium-239 (^{239}Pu)

Plutonium-239 is a COC for ELCR for the UCRS. The contribution of ^{239}Pu to total ELCR (2.9×10^{-1}) for use of water drawn from the UCRS is minimal (<0.1%). (Dose to adult for use of RGA water in Area n is 0.3 mrem/yr.). The toxicity value for ^{239}Pu is an approved value. The frequencies of detection for ^{239}Pu in unfiltered samples from the UCRS are moderate (30%), but the number of sample results for the UCRS are lower than for most other COCs. Based upon the minimal contribution to total ELCR, ^{239}Pu is not considered further as a COC in this FS.

Radium-226 (^{226}Ra)

Radium-226 is a COC for ELCR for the McNairy Formation, RGA, and UCRS. (It is a priority COC for the RGA.) The contribution of ^{226}Ra to total ELCR (1.1×10^{-3}, 1.1×10^{-1}, and 2.9×10^{-1}, respectively) for use of water drawn from all three sources is small to minimal (0.4%, 0.2%, and <0.1%, respectively). (Dose to adult for use of RGA water in Area n is 1.8 mrem/yr.). The toxicity value for ^{226}Ra is an approved value. The frequencies of detection for ^{226}Ra in unfiltered samples from the three water sources are moderate to high (86%, 83%, and 60%, respectively), but the number of sample results for all water sources are lower than for most other COCs. Based upon the minimal contribution to total ELCR, ^{226}Ra is not considered further as a COC in this FS.

Radon-222 (^{222}Rn)

Radon-222 is a priority COC for ELCR for the McNairy Formation, RGA, and UCRS. The contribution of ^{222}Rn to total ELCR (1.1×10^{-3}, 1.1×10^{-1}, and 2.9×10^{-1}, respectively) for use of water drawn from all three sources is moderate for the McNairy Formation (13.0%) but minimal for the RGA and UCRS (0.3% and 0.2%, respectively). (Dose to adult for use of RGA water in Area n was not calculated: please see Attachment 10 to Appendix B.)The toxicity value for ^{222}Rn is an approved value. The frequencies of detection for ^{222}Rn in unfiltered samples from the three water sources are very high (100% for each). Based upon this information, especially the frequency of detection, it would appear that ^{222}Rn should be considered further as a COC in this FS. However, additional information in Section 6 of the BHHRA (Appendix B) and in a report entitled *Paducah Groundwater Contamination, Detailed History and Summary of Future Actions* (KY/H-41/Rev. 1; December 1988) indicates that the identification of ^{222}Rn as a priority COC is an artifact of the risk assessment data summarization process. Generally, as noted in the aforementioned report, it is unlikely that the PGDP is a significant source of ^{222}Rn.

> "Since Thorium-230 has a half-life of approximately 80,000 years, the production of Radon-222 is extremely slow. Uranium from plant operations cannot contribute to any significant formation of Radon-222 because all the Thorium was removed in the refining and feed preparation processes...Radon-222 in the plant aquifer is unrelated to plant operations."

Therefore, ^{222}Rn is not considered further as a COC in this FS.

Technetium-99 (^{99}Tc)

Technetium-99 is a COC for ELCR for the McNairy Formation, RGA, and UCRS. The contribution of ^{99}Tc to total ELCR (1.1×10^{-3}, 1.1×10^{-1}, and 2.9×10^{-1}, respectively) for use of water drawn from all three sources is minimal (0.1%, <0.1%, and <0.1%, respectively). (Dose to adult for use of RGA water in Area n is 0.2 mrem/yr.). The toxicity value for ^{99}Tc is an approved value. Technetium-99 was identified as posing a significant migration risk from source areas in previous reports and in the fate and transport modeling completed for the FS. The frequencies of detection for ^{99}Tc in unfiltered samples from the three water sources are moderate to high (72%, 69%, and 90%, respectively). Based upon this information ^{99}Tc is considered further as a COC in this FS.

Uranium-238 (^{238}U), Uranium-235 (^{235}U), and Uranium-234 (^{234}U)

The uranium isotopes are COCs of ELCR for the RGA and UCRS. The contribution of each to the total ELCR (1.1×10^{-1} and 2.9×10^{-1}, respectively) is minimal in all cases (<0.1%). (Doses to adult for use of RGA water in Area n are0.3, <0.1, and 0.4 mrem/yr., respectively, for the three uranium isotopes). The toxicity values for the uranium isotopes are approved values. The frequencies of detection for ^{238}U, ^{235}U, and ^{234}U in the RGA are moderate (70%, 45%, and 73%, respectively) as are those for the UCRS (93%, 67%, and 88%, respectively.) Based upon the minimal contribution to the total ELCR, the uranium isotopes are not considered further as COCs in this FS.

Summary of COCs to be Addressed in the FS

Based upon the information presented above, the following COCs are those that will be used in this FS to develop RAOs and screen remedial technologies.

- 1,1-Dichloroethene
- 1,2-Dichloroethene (mixed, *cis*, and *trans*)
- Carbon tetrachloride
- Tetrachloroethene
- Trichloroethene
- Vinyl chloride
- ^{99}Tc

It should be noted that these contaminants currently contribute the most to potential risk from use of groundwater at and around the PGDP both now and in the future. However, it also should be noted that under current conditions, only potential risks exist because groundwater is not used at the PGDP and because an alternate water supply has been provided.

1.3 REFERENCES

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2. DEVELOPMENT OF REMEDIAL ALTERNATIVES

This section describes the first phase of the FS, the development of remedial alternatives. The remedial alternatives were developed using the following six-step process.

1. RAOs were developed based on the COCs, calculated remedial goal options (RGOs), and ARARs. (This information is summarized in Sect. 2.1.)

2. General response actions were developed for each media. Actions necessary to achieve the RAOs were identified. (This information is summarized in Sect. 2.2.)

3. Volumes and/or areas of contaminated media, to which general response actions may be applied, were identified. (This information is summarized in Sect. 2.2.)

4. Technologies potentially applicable to each general response action were identified. They then were screened to eliminate those that are not technically implementable. (This information is summarized in Sect. 2.3.1.)

5. Within each technology type, specific process options were identified and screened with respect to effectiveness, implementability, and cost effectiveness. Representative process options were selected for use during the assembly and evaluation of remedial alternatives. Although specific process options were selected, the selected process options are intended to represent the broader range of process options that are available within each general technology type. (This information is summarized in Sects. 2.3.2 and 2.3.3.)

6. Finally, the selected technology types and representative process options were assembled into remedial alternatives representing a range of treatment and containment combinations as specified in the NCP. (This information is summarized in Sect. 2.4.)

Sections 2.1 through 2.4 summarize the results of these steps. Additional, extensive, supporting documentation, such as the identification and screening of technology types and process options, is presented in Appendix C of this report.

2.1 REMEDIAL ACTION OBJECTIVES

RAOs consist of medium-specific or OU-specific goals for protecting human health and the environment (EPA 1988). The RAOs are developed by taking into account use scenarios of concern, pathways of concern, COCs, RGOs, and ARARs.

Based upon previous investigations and the GWOU risk assessment, industrial workers, rural residents, recreational users, and ecological receptors are most likely to be affected by groundwater contaminated by PGDP operations. Accordingly, the following RAOs have been established.

- Return usable groundwater to beneficial use wherever practicable, within a time frame that is reasonable given the particular circumstances of the site. If restoration of groundwater to beneficial use is not practicable, then prevent further migration of the plume and evaluate further risk reduction.

- Until such time that groundwater is returned to beneficial use, protect potential groundwater users north of the Porter's Creek Terrace from contamination in excess of MCLs and ensure that exposure to groundwater does not present an unacceptable risk to human health and the environment. (Note: The Porters Creek Terrace is a buried geologic feature, groundwater barrier, that extends east and west of the south end of the PGDP.)

- Until such time that groundwater is returned to beneficial use, protect potential human and ecological receptors from exposure to contaminated groundwater discharged to surface water. Contaminant concentrations must be low enough to ensure that exposure to discharged groundwater does not present an unacceptable risk to human health and the environment.

To protect human health, COC concentrations must be reduced, at a minimum, to MCLs. The primary groundwater COCs over the long term at the PGDP (i.e., over 4,000 years) are TCE, its breakdown products, and ^{99}Tc. Since TCE has an MCL of 5 µg/L meeting the MCL for TCE will result in meeting the MCLs for the other VOC COCs, assuming appropriate source remediation. The MCL for ^{99}Tc is 4 mrem/yr. It may be necessary to achieve concentrations more stringent than MCLs if multiple COCs are present in the groundwater that lead to greater risks due to cumulative impacts. Risk-based concentrations may be used to protect humans that are exposed to groundwater discharged to surface water based on the receptor available for contact. Ecological receptors will be protected by ensuring that no adverse impacts occur where groundwater discharges to surface water.

2.2 GENERAL RESPONSE ACTIONS AND ASSOCIATED AREAS/VOLUMES

The following subsections present media-specific, general response actions. Since the GWOU is large in scope and multiple remedial actions will be required, for the purposes of this FS, a representative site for each media was chosen. Areas and volumes for specific SWMUs will be developed at a later date as part of the individual GWOU Records of Decision (RODs).

Volumes associated with personal protective equipment (PPE), decontamination water, cuttings from drilling activities, and other similar wastes are not presented in this section. These volumes are dependent on the construction activities associated with each remedial alternative, so they are presented as appropriate in Chap. 4, "Detailed Analysis of Alternatives."

2.2.1 Air

Air is not a medium requiring remediation as part of the GWOU. However, best management practices (BMPs) will be employed as needed during any remedial activities to prevent/minimize air pollution.

2.2.2 Soil

Although groundwater is the primary medium requiring remediation within the scope of the GWOU, some SWMUs that are significant sources of groundwater contamination (such as the C-400 area) fall within the scope of the GWOU. In general, SWMUs that are sources of groundwater contamination contain COCs in the soil that may be located above or below the water table. General response actions applicable to soils include access restrictions, containment, *in situ* treatment, and excavation with *ex situ* treatment and/or disposal. A representative area and volume for a UCRS primary source is presented in Table 2.1. This representative area and volume was developed using a known contaminated area at the southeast corner of the C-400 Building. The representative area is 52,425 ft^2 with an estimated depth of 30 feet. This site represents a highly contaminated and highly industrial area. The volume of excavated soil always will be greater than the *in situ* volume of contaminated soil that is to be excavated as a result of overexcavation, potential sloping requirements, and the increased volume associated with disturbing the soil.

Table 2.1. General response actions and areas/volumes of principal sources and groundwater plumes

General Response Action	Representative Primary Source – UCRS VOC Contamination	Representative Secondary Source – RGA Contamination	Representative Dissolved Phase Plume
Treatment	Recovered vapors and liquids would require *ex situ* treatment	Recovered vapors and liquids would require *ex situ* treatment	Recovered vapors and liquids would require *ex situ* treatment
Containment	NA	NA	600 ft width; 1,000 ppb TCE contours; 200 gpm pump rate
Excavation	Representative Volume[a]: 1,512,750 ft^3 (bulk volume)	NA	NA
Extraction	Representative Volume[a]: 1,512,750 ft^3 (bulk volume)	Representative Volume[b]: 6,283,150 ft^3 (bulk volume)	NA
Disposal	Treatment residuals may require disposal; excavated soils/solids would require disposal at an approved facility	Treatment residuals may require disposal	Treatment residuals may require disposal

[a] Assumes a representative area of 52,425 ft^2 at a 30 ft depth.
[b] Assumes a representative area of 125,663 ft^2 (approx. a 400 ft treatment diameter) at 50 to 100 feet in depth.

2.2.3 Surface Water

Remediation of contaminated surface water will be addressed separately on a plant-wide basis as part of the SWOU. Remediation of contaminated surface water is not within the scope of this FS. Although contamination associated with the North-South Diversion Ditch (NSDD), which is part of the SWOU, is believed to have contributed to groundwater contamination, general response actions for surface water are not applicable. BMPs will be employed as needed during any remedial activities to prevent pollution of surface waters.

Contaminated groundwater from the Northwest Plume appears to be discharging into Little Bayou Creek. Although remediation of contaminated surface water is not within the scope of this FS, protection of potential surface water receptors does fall within the scope. General response actions may be appropriate for groundwater to protect surface water receptors, such as containment to eliminate discharge into the creek or treatment of the contaminated groundwater at the point of discharge or at an upgradient location.

2.2.4 Groundwater

Groundwater is the primary medium requiring remediation within the scope of the GWOU. General response actions include containment, *in situ* treatment, extraction with *ex situ* treatment and/or disposal. The primary COCs targeted for remediation are TCE, its associated degradation products, and ^{99}Tc. It is believed that remedial actions targeted at these COCs will satisfy the RAOs and coremediate other contaminants (such as metals) to varied degrees. Table 2.1 presents a representative plume width of 600 ft for a 1,000 ppb contour. This representative plume was developed using a known contaminated plume (i.e., the Northwest Plume). If treatment actions are employed, disposal actions will be applicable to waste streams produced following treatment. The volumes of materials requiring disposal may be less than or greater than the original volume of material to be treated, depending upon the treatment technology(ies) employed.

2.3 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

Consistent with EPA guidance (EPA 1988), potentially suitable technologies, including innovative technologies, have been identified and evaluated to satisfy 40 *CFR* 300.430 (e)(2)(ii). The following subsections briefly summarize the identification and screening of remedial technologies and process options for each media-specific general response action. Technically valid process options also are evaluated and screened. Technology identification and evaluation tables are presented in Appendix C4.

The identification and screening of remedial technologies and process options for this FS were directly supported by two studies previously conducted at PGDP by external experts. From September 1996 through July 1998, the Air Force Institute of Technology (AFIT) and Virginia Commonwealth University worked closely with DOE to conduct decision analysis evaluations of technology types and process options potentially capable of remediating TCE (DNAPL and dissolved phase) and ^{99}Tc at WAG 6 of the PGDP. During February 1999, the PGDP site began working with the Innovative Treatment Remediation Demonstration (ITRD) Program, which is funded by the DOE Office of Environmental Restoration to help accelerate the adoption and implementation of new and innovative remediation technologies. The ITRD technical advisory group for the GWOU evaluated innovative technologies, gathered cost and technical information, and provided a report with recommendations (presented in Appendix C2). The ITRD conducted a bench-scale treatability study to evaluate reactive media for potential use in a permeable reactive barrier. The AFIT and the ITRD studies contributed significantly to this FS.

In addition, during 1999, DOE assembled a Deployment Assistance Team (DAT) to review the status of actions associated with remedial actions at the PGDP and to recommend a path forward. The technologies evaluated in this report are consistent with the path forward recommended by the DAT (DOE 1999).

2.3.1 Initial Identification and Screening of Technologies and Process Options

The term "technology type" refers to general categories of remedial technologies. The term "process option" refers to specific processes within each technology type. Tables 1 through 6 in Appendix C2 identify a universe of remedial technology types potentially applicable for each general response action by media. These tables also present process options for each remedial technology type and a brief description of the process options. The initial screening step allows process options that are not technically implementable to be deleted from further consideration, as well as identifying technology types and process options that were initially considered (EPA 1988). Process options that are demonstrated to be effective or potentially effective for at least one type of COC and are potentially implementable may be retained for further consideration (either as a single treatment or as part of a treatment train). Process options that do not meet this criterion are deleted from further consideration. These tables also contain a brief summary of comments from the initial screening process. Vendor literature and several EPA, DOE, and U.S. Department of Defense (DOD) reports were consulted to perform the initial identification and screening phase. The results of the studies conducted at PGDP by AFIT and ITRD support and complement this screening step.

Since the inception of EPA's Superfund program in 1980, the remedial and removal programs have found that certain categories of sites have similar characteristics, such as types of contaminants present, types of disposal practices, or how environmental media are affected. Based on information acquired from evaluating and cleaning up these sites, the Superfund program has undertaken various initiatives to incorporate lessons learned, develop presumptive remedies for sites with similar characteristics, streamline the remedial planning process, and in general accelerate the pace of cleanups at NPL sites

(EPA 1993). These initiatives have resulted in the publication of numerous guidance documents, directives, and policy statements relevant to the GWOU; these include the following:

- *Guidance on Accelerating CERCLA Environmental Restoration at Federal Facilities*, PB97-143804 (EPA 1994a), encourages the use of presumptive remedies and innovative technologies;

- *Contaminants and Remedial Options at Solvent-Contaminated Sites*, EPA/600/R-94/203 (EPA 1994b), identifies response actions and remedial technologies commonly used—and demonstrated to be effective—for remediation of soils and groundwater with contaminants similar to PGDP GWOU;

- *Remediation Technologies Screening Matrix and Reference Guide*, EPA 542-B-93-005 (EPA 1994c), identifies a comprehensive listing of remedial technologies for VOC-contaminated soil and groundwater; effectively addresses the preliminary screening step to determine the technical implementability of a given technology for possible use at PGDP GWOU;

- *Presumptive Response Strategy and Ex-Situ Treatment Technology for Contaminated Groundwater at CERCLA Sites*, EPA 540/R-96/023 (EPA 1996), states that groundwater extraction and *ex situ* treatment constitute EPA's presumptive remedy for contaminated groundwater; however, this guidance is still under development and subject to change once issued as a final draft; and

- *Presumptive Remedies: Site Characterization and Technology Selection for CERCLA Sites with Volatile Organic Compounds in Soils*, EPA 540-F-93-048 (EPA 1993), identifies soil vapor extraction (SVE), thermal desorption, and incineration as presumptive remedies. Another commonly used technology for contaminated soils is bioventing.

2.3.2 Evaluation of Process Options

Tables 7 through 12 (in Appendix C2) present the remedial technology types and process options for each general response action that were retained for further consideration following the initial screening documented in Tables 1 through 6 (in Appendix C2). These tables summarize the evaluation based on the effectiveness of each process option relative to other process options within the same technology type, the implementability of the process option, and the cost, relative to other process options within the same technology type. The effectiveness evaluation is focused on the potential effectiveness of the process options to handle the estimated area/volume of contaminated soil and meet the RAOs, potential impacts to human health and the environment during construction and implementation, and the reliability of the process options with respect to COCs and conditions at the areas to be remediated. The implementability evaluation includes both technical and administrative feasibility of implementing the process options and places greater emphasis on institutional aspects, such as obtaining services and permits. The cost evaluation does not include detailed estimates, but is based on relative capital and operation and maintenance (O&M) costs. This evaluation, or screening step, allows additional process options to be deleted from further consideration so that a representative process option from each technology type can be selected for subsequent assembly of alternatives. Several references, including EPA, DOE, and DOD reports, were consulted to evaluate the effectiveness, implementability, and cost of the process options for this screening phase. The results of the studies conducted at PGDP by AFIT and ITRD support and complement this evaluation and screening step.

2.3.3 Retained Process Options

Based upon the results of the process option evaluations contained in Tables 7 through 12 (in Appendix C2), the list of process options retained for further consideration was significantly refined. In accordance with EPA guidance, an attempt has been made to select one "representative process option" from each technology type for use when assembling the remedial alternatives. This does not necessarily delete any particular process option from later consideration. EPA guidance (EPA 1988) contains the following explanation for selecting one process option to represent each technology type:

> One representative process is selected, if possible, for each technology type to simplify the subsequent development and evaluation of alternatives without limiting flexibility during remedial design. The representative process provides a basis for developing performance specifications during preliminary design; however, the specific process actually used to implement the remedial action at a site may not be selected until the remedial design phase. In some cases, more than one process option may be selected for a technology type. This may be done if two or more processes are sufficiently different in their performance that one would not adequately represent the other.

Table 2.2 summarizes the representative process options that were selected following the technology screening activities.

2.4 ASSEMBLY OF REMEDIAL ALTERNATIVES

For CERCLA actions, the range of alternatives should include a no-action alternative, one or more alternatives that involve containment with little or no treatment, and a range of alternatives in which treatment addresses the principal threat and eliminates or minimizes the need for long-term management (EPA 1988).

Section 121(b) of CERCLA identifies the following statutory preferences when developing and evaluating remedial alternatives:

- Remedial actions involving treatment that permanently and significantly reduce the toxicity, mobility, and volume of the contaminants or hazardous substances are preferred;
- Off-site transport and disposal of hazardous substances or contaminated materials without treatment is considered the least favorable remedial action when practical treatment technologies are available; and
- Remedial actions using permanent solutions, alternative treatment technologies, or resource recovery technologies are to be assessed.

2.4.1 Development of Preliminary Alternatives

As stated in Chap. 1 of this report, this FS addresses COCs presenting risks to off-site groundwater users regardless of the media contaminated. The contaminated media includes 1) soils (i.e., primary sources of groundwater contamination), 2) groundwater containing DNAPL or ^{99}Tc (i.e., secondary sources), and 3) groundwater containing dissolved-phase contamination. The following subsections describe the alternatives presented in this FS for each of these media.

2.4.1.1 No Action Alternative

This remedial alternative provides a basis for assessing the effects of taking no remedial action and provides a baseline against which the other alternatives are compared. No additional monitoring or site restrictions are included as part of this alternative. The five-year reviews mandated by CERCLA would be required since untreated wastes would remain onsite. A thorough description of this alternative is provided in Sect. 4.2.1.1 of this report.

Table 2.2. Summary of representative process options

Media	General Response Actions	Technology Types	Process Options	Contaminants Addressed	Comments
Soil	No Action	NA	NA	None	Provides a baseline for comparison.
	Institutional Actions	Access Restrictions	All	All	May be used singly or in combination with other technology types/process options.
		Monitoring	All	All	May be used singly or in combination with other technology types/process options.
	Containment Actions	All	All	All	Retained for secondary consideration; removal actions are preferred.
	Removal Actions	Excavation and Dewatering	All	All	Intended for use in combination with *ex situ* treatment and/or disposal actions.
	Treatment Actions	Physical/Chemical	Thermal Desorption (*ex situ*)	VOCs	Presumptive remedy; preferred option for *ex situ* treatment of VOC-contaminated soils. Radionuclides may prohibit use.
			Soil Vapor Extraction (*in situ*)	VOCs	Presumptive remedy; preferred option for *in situ* treatment of VOC-contaminated soils. Radionuclides may prohibit use.
			Solidification/Stabilization	All	May be favorable because it is effective for radionuclides and metals.
			Monitored Natural Attenuation	All	Considered as a low-cost, passive, *in situ* treatment option.
		Thermal	*Ex situ* Vitrification	All	Effective for all contaminants. An on-site, full-scale demonstration of an innovative oxidation and vitrification process (i.e., Vortec™) is planned. However, legal challenges have resulted in delaying the activity for an undetermined amount of time.
	Disposal Actions	On-Site Disposal	All	All	Retained for consideration in conjunction with excavation.
		Off-Site Disposal	All	All	Retained for secondary consideration; on-site disposal options are preferred. Retained for consideration in conjunction with excavation.
		Interim Storage	All	All	Retained for consideration in support of disposal options.
Groundwater	No Action	NA	NA	None	Provides a baseline for comparison.
	Institutional Actions	Access Restrictions	All	All	May be used singly or in combination with other technology types/process options.
		Monitoring	All	All	May be used singly or in combination with other technology types/process options.
	Containment Actions	Hydraulic Containment	All	All	Applicable in RGA.
	Removal Actions	Extraction	Vapor Extraction (Dual Phase Extraction)	VOCs	Applicable in saturated portions of UCRS.
			Pump-and-Treat	All	Applicable in RGA.
			Steam Extraction (Dynamic Underground Stripping)	VOCs	Retained for removal of TCE DNAPL in RGA and lower UCRS.
	In situ Treatment Actions	Physical/Chemical	Permeable Treatment Zones	VOCs and Radionuclides	Applicable in RGA. A 3-year, full-scale, treatability study will be conducted in the Southwest Plume beginning late 2000.
			Oxidation	VOCs	Applicable to dissolved-phase TCE; not applicable to DNAPLs.
			In situ Ozonation (Ozone Sparging)	VOCs	Applicable to dissolved-phase TCE; addition of ion-exchange media may allow treatment of radionuclides.
			Monitored Natural Attenuation	All	Considered as a low-cost, passive, *in situ* treatment option.
		Thermal	Direct Heating (Six-Phase Soil Heating)	VOCs	Applicable in UCRS and has potential applicability to volatiles contamination in the RGA.
		Biological Treatment	All	VOCs and Radionuclides	Applicable to dissolved-phase TCE and ^{99}Tc; recommended by DOE's DAT."

Table 2.2. (continued)

Media	General Response Actions	Technology Types	Process Options	Contaminants Addressed	Comments
Groundwater (continued)	*Ex situ* Treatment Actions	Miscellaneous	EPA Presumptive Remedies[b]	All	Retained for consideration in conjunction with groundwater removal actions.
	Disposal Actions	Permitted Discharge to Surface Water	KPDES-permitted Outfall(s)	All	Retained for consideration in conjunction with groundwater removal and *ex situ* treatment actions.

[a]DOE 1999. Draft "Recommendations for Accelerated Cleanup at Paducah," Deployment Assistance Team (DAT) Report for Cleaning Groundwater at the Paducah Gaseous Diffusion Plant, Paducah, Ky. November 30.
[b]EPA 1996. *Presumptive Response Strategy and Ex-Situ Treatment Technology for Contaminated Groundwater at CERCLA Sites*. EPA 540 R-96-023. U.S. Environmental Protection Agency, Washington, D.C.

DAT = Deployment Assistance Team
DNAPL = dense nonaqueous phase liquid
DOE = U.S. Department of Energy
EPA = U.S. Environmental Protection Agency
KPDES = Kentucky Pollutant Discharge Elimination System
NA = Not Applicable
PGDP = Paducah Gaseous Diffusion Plant
RGA = Regional Gravel Aquifer
TCE = trichloroethene
UCRS = Upper Continental Recharge System
VOC = volatile organic compound

2.4.1.2 Primary Source Area Alternatives

Primary Source Areas, as defined within this FS, are those areas with the target contaminants present and have DNAPL concentrations in the surficial soils and soils of the UCRS above the RGA. The use of technologies to reduce sources within the UCRS would prevent additional contamination from entering the RGA, which is the uppermost aquifer at the PGDP. Three alternatives for the remediation of primary sources were evaluated. These include Vapor Extraction Technology, Direct Heating Technology, and Excavation.

Vapor Extraction Technology

The Vapor Extraction Technology would remove primary contaminant source areas in the UCRS. For this technology, an extraction well in the zone of interest would be placed under vacuum to withdraw soil gas, containing the contamination. An *ex situ* system would treat the contaminants in the off-gas waste stream. Section 4.2.2.1 describes the types of vapor extraction systems that could be implemented for the GWOU. Vapor Extraction Technology is effective for the remediation of VOCs. It also may remove ^{99}Tc contamination, depending on the type of Vapor Extraction system implemented.

Direct Heating Technology

The Direct Heating Technology would remove primary contaminant source areas in the UCRS. This technology heats the soil within the targeted area. Once the area is heated, the contaminants more readily partition to a gaseous state that can be recovered, either through soil vapor extraction or through a surface plenum, or released to the atmosphere. Section 4.2.2.2 of this FS, describes the types of direct heating that could be implemented for the GWOU. Direct Heating Technology is effective for the remediation of VOCs. Although some ^{99}Tc may be removed during treatment, Direct Heating Technology is not intended as a ^{99}Tc remediation technology.

Excavation

The Excavation Alternative would remove primary contaminant source areas in the UCRS. Excavation would remove soil and all contaminants from the source area, including DNAPL, thereby preventing additional COCs from entering the RGA. This alternative is effective for all the COCs.

2.4.1.3 Secondary Source Area Alternatives

Secondary Source Area, as defined within this FS, are those area with the target contaminants of present and have DNAPL concentrations in the RGA. Source reduction activities conducted in the RGA would prevent additional contamination from dissolving or moving within the groundwater and would possibly prevent the enlargement of the contaminant plumes. Three alternatives for the remediation of secondary sources were evaluated. These include Steam Extraction Technology, Pump-and-Treat Technology, and Oxidation Technology.

Steam Extraction Technology

The Steam Extraction Technology would be implemented in a DNAPL source zone area of the RGA (i.e., secondary source area). Injection wells would be used to inject steam into the zone of interest (i.e., secondary source areas). Contaminants would be extracted via a centrally located extraction well. The Steam Extraction Technology is effective for the removal of VOC contamination. The Steam Extraction Technology also will remove ^{99}Tc in the local area of implementation since ^{99}Tc will be "carried" along with the produced water from the extraction well.

Pump-and-Treat Technology

The Pump-and-Treat Technology would be implemented in a DNAPL source zone area of the RGA (i.e., secondary source area). Extraction wells would be placed in the zone of interest and contaminated groundwater would be pumped from the wells and treated. The Pump-and-Treat Technology is effective for VOC and ^{99}Tc contamination; however, treatment time frames may be long.

Oxidation Technology

The Oxidation Technology alternative would be implemented in a DNAPL source zone area of the RGA (i.e., secondary source area). Injection wells would be used to inject the zone of interest (i.e., secondary sources within the RGA) with an oxidizing compound such as potassium permanganate or sodium permanganate. The VOCs, including TCE DNAPL, would react with the oxidizing compound and thus, would be destroyed from the reaction with the oxidant. Although this technology is effective on VOCs, it would not remediate any ^{99}Tc contamination.

2.4.1.4 Dissolved Phase Plume Area

The general scope and role of the GWOU is to address groundwater contamination. Remediation of the GWOU, therefore, may include remedial actions at source areas as well as dissolved phase contamination within the groundwater plumes. This FS evaluated five alternatives for the treatment of dissolved phase plumes. The alternatives evaluated include Pump-and-Treat Technology, Ozonation Technology, Permeable Treatment Zone Technology, Oxidation Technology, and Bioremediation Technology as described in the following sections.

Pump-and-Treat Technology

The Pump-and-Treat Technology would be implemented in the RGA contaminant plumes (i.e., dissolved phase area). Extraction wells would be placed in the zone of interest and contaminated groundwater would be pumped from the wells and treated. The Pump-and-Treat Technology is effective for VOC and ^{99}Tc contamination; however, treatment time frames may be long.

Ozonation Technology

The Ozonation Technology alternative would destroy TCE dissolved phase concentrations and other VOCs from areas of the RGA. In addition, ^{99}Tc would be removed from groundwater as it passed across an ion exchange media incorporated into the Ozonation system. Injection wells would be used to inject the zone of interest (i.e., the RGA) with ozone. The VOCs would react with the ozone and thus, would be destroyed. Pumps located in the injection wells will force groundwater across an ion exchange media also located in the injection wells. The ion exchange media will remove ^{99}Tc from the groundwater circulating through the wells.

Permeable Treatment Zone Technology

The Permeable Treatment Zone Technology would destroy TCE dissolved phase contamination and other VOCs within the RGA. In addition, the PTZ Technology would capture ^{99}Tc within the treatment zone. The treatment zones, constructed with iron or other reactive media, would be strategically placed in the RGA.

Oxidation Technology

The Oxidation Technology alternative would remove TCE dissolved phase concentrations and other VOCs from areas of the RGA. Unlike the Secondary Source Area technologies described above, the

Oxidation Technology in this alternative would be designed only to remove dissolved phase contaminant concentrations. Injection wells would be used to inject the zone of interest (i.e., the RGA) with an oxidizing compound such as potassium permanganate or sodium permanganate. The VOCs, including TCE DNAPL, would react with the oxidizing compound and thus, would be destroyed from the reaction with the oxidant. Although this technology is effective for the remediation of VOCs, it would not remediate any ^{99}Tc contamination.

Bioremediation Technology

The Bioremediation Technology alternative would remove VOCs from areas of the RGA. Injection wells would be used to inject nutrients for native bacteria within the zone of interest (i.e., the RGA). Depending on the design of the bioremediation alternative, either aerobic or anaerobic bioremediation could be implemented. Although this technology is effective for the remediation of VOCs, it would not remediate any ^{99}Tc contamination.

2.4.2 GWOU Remediation Strategies

Since the GWOU is extensive and contains a number of SWMUs, multiple remedial actions are planned. At a minimum, these multiple actions will focus on remediation of (a) on-site sources, (b) off-site dissolved-phase groundwater plumes, and (c) potential "fenceline" containment or treatment actions. These future remedial actions may address one or more SWMUs using the alternatives presented in this FS. The multiple actions also may use a combination of alternatives to address one or media types. For example, a primary source alternative and a secondary source alternative may be used together in a future remedial action.

2.5 REFERENCES

DOE 1999. Draft "Recommendations for Accelerated Cleanup at Paducah," Deployment Assistance Team (DAT) Report for Cleaning Groundwater at the Paducah Gaseous Diffusion Plant, Paducah, Ky, November 30.

EPA 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, Office of Solid Waste and Emergency Response (OSWER) Directive No. 9355.3-01, U.S. Environmental Protection Agency, Washington, D.C., October.

EPA 1993. *Presumptive Remedies: Site Characterization and Technology Selection for CERCLA Sites with Volatile Organic Compounds in Soils*, EPA-540-F-93-048, U.S. Environmental Protection Agency, Washington, D.C., September.

EPA 1994a. *Guidance on Accelerating CERCLA Environmental Restoration at Federal Facilities*, PB97-143804, U.S. Environmental Protection Agency, Washington, D.C., August.

EPA 1994b. *Contaminants and Remedial Options at Solvent-Contaminated Sites*, EPA/600/R-94-203, U.S. Environmental Protection Agency, Washington, D.C.

EPA 1994c. *Remediation Technologies Screening Matrix and Reference Guide*, EPA 542-B-93-005, U.S. Environmental Protection Agency, Washington, D.C.

EPA 1996. *Presumptive Response Strategy and Ex-Situ Treatment Technology for Contaminated Groundwater at CERCLA Sites*, EPA 540/R-96-023, U.S. Environmental Protection Agency, Washington, D.C.

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3. SCREENING OF REMEDIAL ALTERNATIVES

This section describes the second phase of the FS, the screening of remedial alternatives.

At this phase of the FS, the preliminary remedial alternatives that have been assembled can be evaluated and screened to reduce the number of alternatives that will undergo the more thorough detailed analysis outlined in Chap. 4. However, the screening of alternatives is an optional phase, and because a manageable (i.e., not excessive) number of remedial alternatives have been developed, it is not necessary to screen these alternatives before conducting the detailed analysis.

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4. DETAILED ANALYSIS OF ALTERNATIVES

This section describes the third and final phase of the FS, the detailed analysis of the remedial alternatives. Section 4.1 provides a brief introduction to the detailed analysis and the nine evaluation criteria prescribed by the CERCLA (42 U.S.C.A. §§ 9601 through 9675). Section 4.2 presents the individual analysis of each alternative against the nine criteria, and Sect. 4.3 contains a comparative analysis of the alternatives.

4.1 INTRODUCTION

This chapter describes and evaluates the alternatives developed in Chap. 2 for remediating the GWOU. Each alternative undergoes a detailed, comparative analysis in which its advantages and disadvantages are evaluated. The detailed analysis of each alternative includes the following components:

- a description of each remedial alternative,
- an evaluation that incorporates the first seven of nine CERCLA criteria, and
- an objective discussion of the projected environmental consequences of each alternative.

4.1.1 Comprehensive Environmental Response, Compensation, and Liability Act Requirements

Pursuant to the CERCLA and the NCP (40 *CFR* 300), remedial action alternatives must be evaluated in an FS. Pursuant to CERCLA § 121, the remedial action selected as the preferred alternative should do the following:

- protect human health and the environment;

- attain ARARs, or define criteria for invoking a waiver;

- be cost effective;

- use permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable; and

- satisfy the preference for treatment that reduces toxicity, mobility, or volume as a principal element (or explain why this is not attainable).

To assess whether CERCLA § 121 requirements would be met by the remedial action alternatives analyzed in an FS, EPA developed the following nine evaluation criteria: (1) overall protection of human health and the environment; (2) compliance with ARARs; (3) long-term effectiveness and permanence; (4) reduction of toxicity, mobility, or volume through treatment; (5) short-term effectiveness; (6) implementability; (7) cost; (8) state acceptance; and (9) community acceptance [40 *CFR* §300.430(e)(9)(iii)]. Pursuant to the NCP, these criteria have been grouped into threshold, balancing, and modifying criteria categories [40 *CFR* § 300.430(f)(1)(i)]. Consistent with Section 6.2.2 of *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, OSWER Directive 9355.3-01 (EPA 1988a), each remedial action alternative identified in this FS has undergone an evaluation based on the first seven CERCLA criteria. Consistent with the preamble to the NCP [55 *FR* 8723 (March 8, 1990)], comments from the Commonwealth of Kentucky will be incorporated into the final FS, and community acceptance will be evaluated during a public comment period that follows publication of a PRAP for the selected remedial action.

In the preamble to the original and revised NCP [55 *FR* 8666 through 8810 (March 8, 1990) and 53 *FR* 51394 through 51520 (December 21, 1988)] and in several guidance documents (EPA 1988a and 1988b), the EPA further categorizes the criteria into subcriteria. Based on the NCP and the referenced documents, a discussion of the nine CERCLA criteria and subcriteria is presented in the following subsections.

4.1.1.1 Threshold criteria

The selected remedial action alternative must meet these criteria. These criteria include overall protection of human health and the environment and compliance with ARARs.

Overall Protection of Human Health and the Environment

Under this criterion, alternatives are evaluated to determine the ability to reduce risk to human health and the environment. The evaluation also is used to determine whether alternatives pose unacceptable short-term or cross-media impacts. For each alternative, the evaluation includes a discussion of the following:

- how the source of contamination is to be reduced or controlled; and
- how the site-related risks to human health and the environment are to be reduced, and whether target levels are attained.

Compliance with ARARs

Congress specified in CERCLA § 121 (42 U.S.C.A. § 9621) that remedial actions for the cleanup of hazardous substances must comply with the requirements, criteria, standards, or limitations under federal or more stringent state environmental laws that are legally applicable or relevant and appropriate to the hazardous substances or circumstances at a site. EPA defines and explains ARARs using two categories. First, EPA categorizes ARARs as being either "applicable" or "relevant and appropriate" to a site. The terms and conditions pertinent to this category are as follows.

- "Applicable" requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental, state environmental, or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site (40 *CFR* § 300.5).
- "Relevant and appropriate" are requirements that address problems that are sufficiently similar to those encountered at the site that their use is well suited to the particular site.
- Facility siting laws that 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).
- Requirements under federal or state law may be either applicable or relevant and appropriate to CERCLA cleanup actions, but not both. If a requirement is not applicable, it must be both relevant and appropriate in order for it to be an ARAR. In cases when both a federal and a state ARAR are available, or when two potential ARARs address the same issue, the more stringent regulation must be selected. However, in cases where EPA has delegated implementation of a federal environmental program to a state, the analogous state program requirements are the ARARs.
- Other information not meeting the definition of an ARAR may be necessary to determine what is protective of human health, welfare, or the environment, or the information may be useful in developing CERCLA remedies. Additionally, ARARs do not exist for every chemical or circumstance found at a

CERCLA site. Therefore, EPA believes it may be necessary, when determining cleanup requirements or designing a remedy, to consult reliable information that otherwise would not be considered a potential ARAR. Criteria or guidance developed by EPA, other federal agencies, or states may assist in determining, for example, health-based levels for a particular contaminant or the appropriate method for conducting an action for which there are no ARARs. This other information is to be considered (TBC) information and may be used when developing CERCLA remedies. Such TBC information falls generally within three categories: (1) health effects information, (2) technical information on how to perform or evaluate investigations or response actions, and (3) policy. A possible fourth category for TBC information is proposed regulations, when they are noncontroversial and likely to be promulgated as drafted.

The second EPA categorization for ARARs is based on whether the ARARs are specific to the chemical(s) present at the site (i.e., chemical specific), the remedial action being evaluated (i.e., action specific), or the location of the site (i.e., location specific). The terms and conditions pertinent to this second category are as follows.

- "Chemical-specific" ARARs usually are health- or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of numerical values. These values establish the acceptable amount or concentration of a chemical that may remain in, or be discharged to, the ambient environment [53 *FR* 51437 (December 21, 1988)].

- "Action-specific" ARARs usually are technology- or activity-based requirements or limitations placed on the remedial action being evaluated. Selection of a particular remedial action at a site will trigger action-specific ARARs that specify appropriate technologies and performance standards [53 *FR* 51437 (December 21, 1988)].

- "Location-specific" ARARs generally are restrictions placed upon the concentrations of hazardous substances or the conduct of activities solely because they are in special locations. Some examples of special locations include floodplains, wetlands, historic places, and sensitive ecosystems or habitats [53 *FR* 51437 (December 21, 1988)].

Examples of chemical-, action-, and location-specific ARARs are as follows:

- Chemical-specific ARARs — MCLs, KPDES effluent limits;

- Action-specific ARARs — Performance and design standards; and

- Location-specific ARARs — Preservation of historic sites, regulations pertaining to activities near wetlands or floodplains.

As discussed in the preamble to the NCP at 53 *FR* 51443 (December 21, 1988), potentially responsible parties (PRPs) conducting remedial actions, or portions of remedial actions, entirely on-site as defined in 40 *CFR* § 300.5, must comply with the substantive portions of ARARs but not with the procedural or administrative requirements. Substantive requirements pertain directly to the actions or conditions at a site, while administrative requirements (e.g., permit applications and procedural requirements) facilitate remedial action implementation.

The CERCLA § 121(d)(4) [42 U.S.C.A. § 9621(d)(4)] provides several ARAR waiver options that may be invoked, provided that human health and the environment are protected. Finally, under § 121(e) [42 U.S.C.A. § 9621(e)], PRPs (such as DOE) are not required to obtain federal, state, or local permits in order to conduct on-site response actions; however, the substantive requirements of the permitting programs must be followed.

In the NCP at 40 *CFR* § 300.150, EPA has addressed the relationship of ARARs to worker protection standards. EPA states that CERCLA response actions must comply with the worker protection standards and requirements of the Occupational Safety and Health Act of 1970 (29 U.S.C. §§ 651 through 678) and analogous state laws; however, the standards and requirements are not ARARs [55 *FR* 8680 (March 8, 1990)].

The DOE, in Orders 440.1, *Worker Protection Management for DOE Federal and Contractor Employees*, and 5480.4, *Environmental Protection, Safety, and Health Protection Standards* (DOE 1991 and 1995), establishes general requirements for environmental protection, safety, and health standards for DOE and its contractor operations. The Orders are DOE internal standards for the protection of DOE employees and contractor workers, and, consistent with 40 *CFR* § 300.150, are not ARARs. Nonetheless, the Orders must be followed during the design, construction, operation, modification (if any), and decommissioning phases of the remedial action.

Finally, in 10 *CFR* § 835, the DOE sets forth occupational standards for radiation protection of workers at its facilities. The regulation, like DOE Orders 440.1 and 5480.4, is an internal DOE worker protection standard and is not an ARAR.

4.1.1.2 Balancing criteria

Balancing criteria are the primary criteria upon which analyses of remedial actions are based. The criteria provide decision makers with a means for determining which alternative best achieves the remedial objectives. The balancing criteria include long-term effectiveness and performance; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost. At this time, the DOE has not irretrievably or irreversibly committed any resources to bias the selection of any of the alternatives described in this document.

Long-Term Effectiveness and Permanence

Long-term effectiveness and permanence are evaluated based on the magnitude of residual risk and the adequacy and reliability of controls used to manage remaining waste (untreated waste and treatment residuals) over the long term (i.e., after remedial objectives are met). Alternatives that afford the highest degree of long-term effectiveness and permanence are those that leave little or no waste at the site, make long-term maintenance and monitoring unnecessary, and minimize the need for institutional controls. The assessment of long-term effectiveness is made considering the following factors:

- the magnitude of the residual risk to human and environmental receptors remaining from untreated waste or treatment residues at the completion of interim remedial activities;
- an assessment of the type, degree, and adequacy of long-term management (including engineering controls, monitoring, and O&M) required for untreated waste or treatment residues remaining at the site;
- an assessment of the long-term reliability of engineering and/or institutional actions to provide continued protection from untreated waste or treatment residues;
- the potential need for replacement of the action and the continuing need for repairs to maintain the performance of the remedy;
- long-term effects on floodplain, wetlands, T&E species, and ecological communities;

- long-term effects on historical and cultural resources;
- long-term effects on land use; and
- cumulative effects.

Reduction of Toxicity, Mobility, or Volume Through Treatment

The statutory preference is to select a remedial action that employs treatment to reduce the toxicity, mobility, or volume of hazardous substances. This criterion addresses the anticipated performance of the technologies that may be employed to achieve treatment goals. Alternatives that do not employ treatment technologies are not considered to reduce toxicity, mobility, or volume of contaminants. This criterion considers:

- the treatment processes;
- the amount of hazardous materials that will be treated or destroyed;
- the degree of expected reduction in toxicity, mobility, or volume through treatment, including how the principal threat is addressed through treatment;
- the degree to which the treatment will be irreversible; and
- the type and quantity of treatment residuals that will remain following treatment.

Short-Term Effectiveness

The short-term effectiveness of an alternative is evaluated relative to its effect on human health and the environment. Clearly insignificant impacts are not addressed in detail, but all relevant environmental attributes are considered, and enough information is provided to demonstrate why greater consideration is not needed.

The short-term effectiveness assessment is based on the following key factors:

- short-term risks that might be posed to the community during implementation of an alternative;
- potential for impact on workers during construction and the effectiveness and reliability of protective measures;
- potential for an adverse environmental impact that may result from the action and the effectiveness and reliability of mitigation measures in preventing or reducing the potential impact;
- socioeconomic effects;
- time until remedial objectives are achieved; and
- cumulative effects.

Implementability

Implementability deals with the technical and administrative feasibility of implementing an alternative and the availability of necessary materials and services required during its implementation. The following factors are considered during the implementability analysis:

- technical feasibility;
- administrative feasibility, including
  - — steps required to coordinate with other agencies to implement the remedy; and
  - — steps required to set up long-term or future coordination among agencies, and the ability to obtain permits for off-site activities;
- availability of services and materials, including
  - — available capacity and location of needed treatment, storage, and disposal services;
  - — availability of necessary equipment and specialists to implement an alternative;
  - — timing of the availability of prospective technologies under consideration; and
  - — the potential for obtaining bids that are competitive (which may be particularly important for innovative technologies).

Cost

Preliminary cost estimates are presented for each remedial alternative. The FS-level estimates are intended to aid in making project evaluations and comparisons between alternatives. Consistent with EPA guidance (EPA 1988b), the estimates have an expected accuracy of -30% to +50% for the scope of action described for each alternative. The management and integration (M&I) contract approach has been used as the basis for preparing the cost estimates. The M&I contractor will be responsible for contract administration of all remediation work for this project. Detailed breakdowns of the cost estimates, including major assumptions used to develop the cost estimates, are presented in Appendix C7.

The estimates are divided into capital cost and O&M cost. All estimates have been escalated using DOE-approved annual rates and a schedule for the various activities based on similar project experience. Also, present-worth values are included using a discount factor of 5% (EPA 1988b). Contingency costs have been included as 25% of the total cost.

- Capital costs are defined as those expenditures required to initiate and install an alternative. These are short-term costs and are exclusive of costs required to maintain the action throughout the project lifetime. Capital costs consist of direct (construction) and indirect (nonconstruction and overhead) costs. Direct costs include construction costs (material, labor, and equipment incurred to develop, construct, and implement an action); service equipment, process and new process buildings, utilities, and waste disposal costs. Indirect costs include services that are not actually a part of construction but are required to implement a remedial alternative, such as expenditures for engineering (Title I and II design engineering, Title III inspection), project integration, project administration and management, and financial services.

- O&M costs are long-term costs associated with ongoing remediation at a site. These costs, which are necessary to ensure the continued effectiveness of an action, occur after construction and installation are completed. The costs include labor, materials, utilities, and services required to monitor, operate, and maintain the facilities for a period of 30 years or more.

- Present-worth analysis is used to evaluate the capital and O&M costs of an alternative on a present worth, or present value, basis. Present-worth analysis is a method of comparing expenditures for various alternatives that occur over different time periods. By discounting all costs to a common base year, the cost for different alternatives can be computed on the basis of a single cost figure for each alternative. The total present worth for a given alternative is equal to the full amount of all costs incurred through the end of the first year of operation (capital costs), plus the series of expenditures in following years reduced by the appropriate future-value/present-worth discount factor. This analysis allows the comparison of alternatives on the basis of a single cost representing an amount that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the action over its planned life. The discount rate represents the cost of borrowed capital. Present-worth costs are given as present value. The estimated present worth of each remedial alternative was determined on a discount rate of 5% and a base maintenance/monitoring study period of 30 years per EPA guidance.

4.1.1.3 Modifying criteria

The preferred remedial alternative is implemented after state regulatory agencies and the public have had an opportunity to comment on the RI/FS and the PRAP document that follows the RI/FS. The modifying criteria, and the process by which DOE complies with them, are described in the following section.

State Acceptance

State acceptance provides for the consideration of any formal comments by the Commonwealth of Kentucky [40 *CFR* § 300.430(e)(9)(iii)(H)].

Community Acceptance

Many of these alternatives will impact the community or replace current facilities. In order to define that impact, it is necessary to consider community acceptance. Documented community concerns about alternatives will be solicited during the public comment period for the PRAP and will be addressed in making a final decision on the remedy to be selected. A ROD document will include a responsiveness summary in which documented community concerns will be addressed [40 *CFR* §300.430(e)(9)(iii)(I)].

4.2 INDIVIDUAL ANALYSIS OF ALTERNATIVES

This section contains an individual detailed analysis of each of the twelve alternatives utilizing the nine CERCLA criteria supplemented with appropriate NEPA values.

Also as a result of decisions reached by the representatives of the DOE, State of Kentucky and EPA, it was determined that the scope of the scope of alternatives for this FS will have the target contaminants of TCE, TCE DNAPL, TCE degradation products and ^{99}Tc. The detailed analysis also will be performed on alternatives containing a single applicable technology. These technologies were further broken down to applicable areas that included Primary Source Areas, Secondary Source Areas, and Dissolved Phase Plume Areas. The definitions of these groups as applied in this D2 document are:

- Primary Source Areas are those areas with the target contaminants present and have DNAPL concentrations in the surficial soils and soils of the UCRS located above the RGA.

- Secondary Source Areas are those areas with the target contaminants present and have DNAPL concentrations in the RGA.

- Dissolved Phase Plume Area are those areas within the RGA that contain the target compounds but have no DNAPL concentrations present.

The technologies that received detailed analysis below are as follows.

- Primary Source Area — Vapor Extraction Technology; Direct Heating Technology; Excavation Technology

- Secondary Source Areas — Steam Extraction Technology; Pump-and-Treat Technology; Oxidation Technology

- Dissolved Phase Plume Area — Pump-and-Treat Technology; Ozonation Technology; Permeable Treatment Technology; Oxidation Technology; Bioremediation Technology

4.2.1 No Action Alternative

The following subsections contain a description of the No Action Alternative, a detailed analysis/ assessment, and a summary.

4.2.1.1 Description of No Action Alternative

This alternative will consists of no action toward remediating the groundwater contamination. Five-year reviews will be conducted because waste is left in place.

Because alternative proposes no active mass removal or containment, the time until remedial objectives are attained is dependent upon natural attenuation. For the primary COC, TCE, the time for complete dissolution of the DNAPL mass under the C-400 Building is the limiting factor. Although much greater TCE volume is present in the RGA DNAPL zone at C-400 (estimated at approximately 550,000 L in the RGA and 105,000 L in the UCRS), the significantly lower groundwater flow rates in the UCRS extend the period of dissolution. Approximately 7,000 years will be required to remove the expected DNAPL volume under natural conditions. Once the DNAPL is removed, on-site TCE levels will drop to below the MCL of 5 µg/L in less than 10 years and off-site groundwater will flush clean within approximately 50 years.

4.2.1.2 Assessment of No Action Alternative

The detailed analysis of this alternative, using the CERCLA criteria, is presented in the following subsections.

Overall Protection of Human Health and the Environment

Implementation of this alternative would not provide overall protection of human health or the environment. Risks would remain uncontrolled, and the RAOs would not be achieved. If residents (within the Water Policy Box) begin to use groundwater for home use, they would be subject to an increased level of risk under current conditions.

Compliance with ARARs

Potential chemical-specific ARARs

Chemical contamination. The aquifers are known to contain chemical contaminants in the form of metals and organics. The federal and state water quality requirements include standards that would be applicable ARARs. The regulations that apply are found in 40 *CFR* 141 (National Primary Drinking Water Standards); 40 *CFR* 143 (Secondary Drinking Water Standards); 401 KAR 5:029 (General Provisions); and 401 KAR 5:031 (Surface Water Standards). These standards, summarized in Table 4.1, include general state standards, domestic water supply standards, and standards applicable to warm water aquatic habitat. These are applicable based upon the classification of the designation for surface water use associated with the area (Ohio River, River Mile 940.7 to River Mile 943.3) as specified in 401 KAR 5:026. All potentially applicable chemical ARARs for COCs have been included in the table for completeness. Those standards that must be achieved in order to meet the applicable requirements are the lowest of the applicable standards, which in most cases are the MCLs.

Radiological contamination. The OU is known to be contaminated with radionuclides such as ^{99}Tc. DOE's Order on Radiation Protection of the Public and Environment, DOE Order 5400.5 (codified at 10 *CFR* 834), is TBC information for cleanup of radionuclides at DOE sites. The order, as codified, requires that remediation activities must not result in radiation exposures to members of the general public greater than an effective dose equivalent (EDE) of 100 mrem/year from all exposure pathways. Exposure to the general public must also be as low as reasonably achievable (ALARA) (DOE 1990).

The DOE Order 5400.5 also contains reference values, known as derived concentration guidelines (DCGs), for operational DOE facilities. Based on the DCGs, radionuclide concentrations in air and drinking water must not exceed an EDE of 10 mrem/year and 4mrem/year, respectively to the total body or any organ.

The Nuclear Regulatory Commission (NRC) also has set criteria for decommissioning standards at nuclear facilities at 10 *CFR* 20 Subpart E. These rules require that residual radioactivity at nuclear sites meet a total EDE of 25 mrem/year for unrestricted release. In addition to the NRC standards, EPA has issued guidance for cleanup levels at CERCLA sites with radioactive contamination. EPA has disagreed with the protectiveness specified within the NRC standard and has specified that a 15 mrem/year EDE be used as the risk level that is protective of human health and the environment. EPA has also codified exposure limits for environmental radiation protection standards for nuclear power operations at 40 *CFR* 190. These requirements apply to operations involved in uranium fuel cycle and include enrichment operations. Subpart B of these requirements specifies that the annual dose equivalent to the public must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment from uranium fuel cycle operations and to radiation from these operations. These requirements would be considered relevant and appropriate because the release to the groundwater would not be planned.

The Commonwealth of Kentucky is an NRC Agreement State and has promulgated regulations for radiation protection of the public. The Kentucky radiation protection standard for individual members of the public is 0.1 rem (100 mrem) EDE per year or less (902 KAR 100:019 Section 10), which is equivalent to the DOE radiation protection standard found in DOE Order 5400.5.

Table 4.1. GWOU chemical ARAR table

COC	KAR General Standards 401 KAR 5:029	KAR Surface Water Standards (Domestic Water Supply) 401 KAR 5:031	KAR Warm Water Aquatic Habitat Criteria-acute 401 KAR 5:031	KAR Warm Water Aquatic Habitat Criteria-chronic 401 KAR 5:031	Outstanding State Resource Waters 401 KAR 5:031[a]	MCLs 40 *CFR* 141	MCLGs 40 *CFR* 141
			Metals (µg/L)				
aluminum							
antimony	4300	6				6	6
arsenic			340[b]	50/150[b]	50	50	
barium						2,000	2,000
beryllium		0.4				4	4
boron							
cadmium		5	$e^{(1.128(\ln Hard) -3.687)}$	$e^{(0.7852(\ln Hard) -2.715)}$	Same as warm water aquatic	5	5
chromium		100	$e^{(0.8190(\ln Hard) +3.726)/16c}$	$e^{(0.8190(\ln Hard) +0.685)/11c}$	16/11[d]	100	100
copper		1,000	$e^{(0.9422 (\ln Hard) -1.700)}$	$e^{(0.8545 (\ln Hard) -1.702)}$	same as warm water aquatic		1,300
iron			4	1			
manganese		50					
nickel	4600	100	$e^{(0.8460 \ln Hard) +2.255)}$	$e^{(0.8460 (\ln Hard) +0.0584)}$			
silver		50	$e^{(1.72 (\ln Hard -6.52)}$				
uranium							
vanadium							
			Other Inorganics (µg/L)				
fluoride		2,000			2,000	4,000	4,000
nitrate		10,000			10,000	10,000	10,000
			Organics (µg/L)				
acrylonitrile	0.65	0.058					
Aroclor-1254				0.0014		0.5	
benzene	71	1.2				5	
bromodichloromethane	46						
carbon tetrachloride	4.4	0.25				5	
chloroform	470	5.7					
1,1-dichloroethene		0.057				7	7
1,2-dichloroethene							
cis-1,2-dichloroethene						70	70
trans-1,2-dichloroethene	140,000					100	100
naphthalene							
trichloroethene	81	2.7				5	
vinyl chloride	525	2				2	
			Radionuclides				
Am-241							

Table 4.1. (continued)

COC	KAR General Standards 401 KAR 5:029	KAR Surface Water Standards (Domestic Water Supply) 401 KAR 5:031	KAR Warm Water Aquatic Habitat Criteria-acute 401 KAR 5:031	KAR Warm Water Aquatic Habitat Criteria-chronic 401 KAR 5:031	Outstanding State Resource Waters 401 KAR 5:031[a]	MCLs 40 *CFR* 141	MCLGs 40 *CFR* 141
Neptunium-237							
Technetium-99							
Thorium-228							
Uranium-234							
Uranium-238							
Gross Alpha (pCi/L)	15					4 mrem/year	
Gross Beta (mrem)	50					15	

[a]Metal standards are for total recoverable, except Chromium (VI) that is dissolved
[b]Standard is for Arsenic as Arsenic (III)
[c]Standard is for Chromium (III)/Chromium (VI)
[d]Standard is for dissolved Chromium (VI) - acute/chronic
[e]Maximum Contaminant Levels found in drinking water regulations for the Commonwealth of Kentucky at 401 KAR, Chapter 8 are equivalent to Federal MCLs.

CFR = *Code of Federal Regulations*
COC = Contaminant of Concern
KAR = Kentucky Administrative Regulations
MCLs = maximum contaminant level
MCLGs = maximum containment level goals

Due to the differing views and values among NRC, EPA and DOE total EDE for members of the general public, EPA and DOE have agreed not to finalize their respective standards until an agreement can be reached. In the interim, DOE Order 5400.5 is identified as TBC information and the NRC standard is identified as relevant and appropriate. Therefore, the radiation protection standard identified within the NRC regulations at 10 *CFR* 20 Subpart E requiring an EDE of 25 mrem/year or less shall be used as the exposure limit for the general public.

Chemical-specific ARARs summary. Implementation of this alternative would not meet the chemical-specific ARARs provided in Table 4.1 applicable to groundwater and surface water where groundwater discharge occurs. The current state of the associated groundwater and surface water do not meet criteria such as MCLs, KAR water quality standards, or maximum contaminant level goals (MCLGs). In addition, the potential discharge of groundwater to surface water bodies may not meet applicable KAR Warm Water Aquatic Habitat Criteria for chronic or acute exposures.

Potential location-specific ARARs. This alternative does not result in modification of the existing terrain or habitat. No location-specific ARARs are identified with this alternative.

Potential action-specific ARARs. This alternative does not require action to be taken; therefore, no action-specific ARARs are identified for this alternative.

The potential ARARs for the No-Action alternative are presented in Table 4.2. There are no location- or action-specific ARARs for this alternative.

The No Action Alternative would not comply with the MCLs for TCE at the point of compliance or points of exposure. In addition, the MCLs applicable to antimony, chromium (action level), and alpha-emitting radionuclides would be exceeded at the point of compliance (plant fenceline) and points of exposure (DOE property boundary, Ohio River) if contaminants were allowed to continue to migrate off-site according to the modeling used in the development of this FS. As stated in the risk assessment, the metals and radionuclides based upon historic observations are far less mobile than current modeling indicates. Based on the time frames illustrated in the model required for migration to the point of compliance and the historical observations associated with migration of metals and radionuclides at the PGDP, exceedance of the associated MCLs is considered unlikely. However, monitoring of the groundwater for these contaminants would be required to demonstrate no migration of these contaminants.

Because of the TCE contamination currently encountered in the groundwater at the point of compliance and point of exposure, this alternative does not comply with identified chemical-specific ARARs. In order to conduct this alternative, an ARAR waiver would be required.

Long-Term Effectiveness and Permanence

This alternative includes no controls for exposure and no long-term management measures. A discussion of the magnitude of residual risk at the site is presented in the following section.

Magnitude and residual risk. The residual risk within the GWOU may increase because vinyl chloride is part of the breakdown path of TCE. Five-year reviews, mandated by CERCLA [40 *CFR* §300.430(f)(4)(ii)], will be required to demonstrate the integrity and effectiveness of the controls and confirm that additional exposure pathways have not developed.

Adequacy and reliability of controls. No long-term O&M and controls are associated with this alternative.

Table 4.2. Summary of Potential ARARs for the No Action Alternative

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
Chemical-specific ARARs			
National Primary Drinking Water Standards	40 *CFR* 141	Provides chemical-specific numeric standards for toxic pollutants expressed as MCLs and MCLGs.	These requirements are relevant and appropriate due to the nature of the contaminants found within the groundwater.
National Secondary Drinking Water Standards	40 *CFR* 143	Provides secondary maximum contaminant levels for public water systems	These requirements are TBCs as they have been established as guidelines for the states and are not federally enforceable.
Kentucky Surface Standards including • Warm Water Aquatic Habitat Criteria • Kentucky Domestic Water Supply • Kentucky General Standards • Kentucky Outstanding State Resource Waters	401 KAR 5:031 and 5:026	Provides chemical-specific numeric standards for pollutants discharged or found in surface waters. Provides chemical-specific numeric standards for pollutants in domestic water supplies.	These standards are applicable to the segment of the Ohio River into which the Little Bayou Creek discharges. The requirements found in these standards are applicable due to the groundwater to surface water interface to Little Bayou Creek and subsequently to the Ohio River. Note: Clean Water Act Water Quality Criteria are not relevant and appropriate because Kentucky has promulgated these state standards that Kentucky has determined to be appropriate for waters of the State.
Radiation Exposure of the General Public at DOE Facilities	DOE Order 5400.5	Specifies that the general public must not receive an effective dose equivalent of >100 mrem/year from all exposure pathways. In addition, all releases of radioactive materials resulting in doses to the general public must meet the ALARA criteria.	This requirement is TBC information.
Decommissioning Standards at Nuclear Facilities	10 *CFR* 20, Subpart E	Specifies a residual activity at nuclear facilities for unrestricted release of 25 mrem/year.	These standards are considered to be applicable to the GWOU.
Environmental Radiation Protection Standards for Nuclear Power Operations	40 *CFR* 190, Subpart B	Requires that the annual dose equivalent to the public must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment from uranium fuel cycle operations and the radiation from these operations.	These standards are considered to be relevant and appropriate and are equivalent to the NRC standards.
Location-specific ARARs			
No location-specific standards are ARAR for this alternative.			
Action-specific ARARs			
No action-specific standards are ARAR for this alternative			

ALARA = as low as reasonably achievable
ARAR = applicable or relevant and appropriate requirement
CFR = *Code of Federal Regulations*
DOE = U.S. Department of Energy
GWOU = groundwater operable unit
KAR = Kentucky Administrative Regulations
MCLGs = maximum contaminant level goals
MCLs = maximum contaminant level
NRC = U.S. Nuclear Regulatory Commission
TBC = to be considered

Environmental impacts and mitigative measures. The following text describes potential long-term impacts to resources and mitigative measures to offset any potential impacts. The depth of impact analysis and mitigative measures is correlated to the degree to which a resource may be impacted.

Land use. No impacts to land use would result from implementing this alternative.

Socioeconomics. The no-action alternative would not have any direct effects on socioeconomics. However, the continued presence of contaminants in the groundwater will prevent its use and may limit economic development opportunities until the groundwater is brought back to beneficial use.

Air quality and noise. Air quality and noise would not be affected by implementing this alternative.

Vegetation. No impacts to vegetation would result from implementing this alternative.

Wildlife. No impacts to wildlife would result from implementation of this alternative.

Threatened and endangered species. No impacts would result from implementing this alternative.

Cultural resources. No long-term effects are anticipated for this alternative.

Groundwater. Implementation of No Action Alternative is not expected to have any adverse impact on groundwater hydrology and ambient flow conditions.

Surface water. Current discharges from the Northwest Plume into Little Bayou Creek will continue; however, COC levels will decrease as the plume dissipates. No adverse impacts to wetlands have been identified currently, and no additional impacts are expected as a result of surface water discharges.

Floodplains. No long-term effects are anticipated for this alternative.

Wetlands. No long-term effects are anticipated for this alternative.

Soils and prime farmland. No long-term impacts would be expected to occur to soils and farmland. No prime farmland is located at or adjacent to these units.

Transportation. No long-term direct or indirect effects will result from implementing this alternative.

Cumulative impacts. Cumulative impacts are defined as the incremental impact of an action when added to other past, present, and reasonable foreseeable future actions, regardless of what agency or person undertakes other such actions. No notable cumulative impacts resulting from this alternative have been identified.

Reduction of Toxicity, Mobility, or Volume Through Treatment

The No Action Alternative does not include any treatment technologies to address the source areas; therefore, a reduction in toxicity, mobility, or volume through treatment of the sources would not be achieved. Toxicity within the GWOU may increase since vinyl chloride is part of the breakdown path of TCE. Eventually, the volume and toxicity of COCs would decrease. Within the first 30 years of the alternative, the DNAPL volume at C-400 would be expected to be reduced by 20,000 L, 3% of the total volume present.

Short-Term Effectiveness

Community protection. This alternative would not pose additional risks to the community because no action would be taken.

Worker protection. This alternative would not pose additional risks to workers, because no action would be taken.

Environmental impacts and mitigative measures. Short-term environmental impacts and mitigative measures are qualitatively assessed and include an evaluation of the impacts on environmentally and potentially sensitive ecological resources, short-term impacts on socioeconomic and cultural resources, and cumulative impacts of remedial construction and other activities occurring in the area.

Land use. Land use at the PGDP would not change existing conditions if the no-action alternative is implemented; thus, no land use impacts would occur.

Socioeconomics. The socioeconomic conditions of the PGDP area would not change with implementation of the no-action alternative. However, as a result of shutting down the existing Groundwater Remedial Actions, a limited reduction in workforce could occur. These reductions would be limited and are not expected to significantly impact other operations at the plant or the surrounding community. However, the presence of contaminants in the groundwater will prevent its use and may limit economic development opportunities until the groundwater is brought back to beneficial use.

Air quality and noise. No air quality or noise impacts would occur as a result of implementation of this alternative.

Vegetation. No adverse impacts to vegetation have been identified as a result of implementing this alternative.

Wildlife. No impacts to wildlife are expected from implementation of this alternative.

Threatened and endangered species. No impacts are expected from implementation of this alternative.

Cultural resources. No cultural resources would be impacted if the no action alternative is implemented.

Groundwater. Implementation of the no action alternative is not expected to have any adverse impact on groundwater hydrology and ambient flow conditions.

Surface water. Current discharges from the Northwest Plume into Little Bayou Creek will continue; however, COC levels will decrease as the plume dissipates. No adverse impacts to wetlands have been identified currently, and no additional impacts are expected as a result of surface water discharges.

Floodplains. The no-action alternative would not have an adverse effect on floodplains as no construction would occur (COE 1994).

Wetlands. No short-term effects are anticipated for this alternative.

Soils and prime farmland. No impacts to soils would be experienced as a result of no action. No prime farmland is located at or adjacent to these units.

Transportation. No short-term direct or indirect effects are anticipated for this alternative.

Cumulative impacts. Cumulative impacts are defined as the incremental impact of an action when added to other past, present, and reasonable foreseeable future actions, regardless of what agency or person undertakes other such actions. No notable cumulative impacts resulting from this alternative have been identified.

Implementability

This alternative would not pose any implementability concerns since no action would be taken.

Cost

These cost estimates are based upon FS-level scoping and are intended to aid with selection of a preferred alternative. Consistent with EPA guidance, the estimates have an expected accuracy of -30% to +50% for the proposed scope of action (EPA 1988b).

Because this is a no-action alternative, no capital costs and no O&M costs are associated with this alternative. Costs associated with the termination of the currently in-place remedial actions including pump-and-treat systems, the monitoring network, and the Water Policy are not included.

4.2.1.3 Evaluation summary of the No Action Alternative

The No Action Alternative is a no-action alternative. Implementation of this alternative would not provide overall protection of human health or the environment. Risks would remain uncontrolled, and the RAOs would not be achieved. This alternative does not include any treatment technologies to address the source areas; therefore, a reduction in toxicity, mobility, or volume through treatment of the sources would not be achieved. Toxicity within the GWOU may increase because vinyl chloride is part of the breakdown path of TCE. Eventually, the volume of COCs would decrease. Five-year reviews would be required because waste is left in place.

4.2.2 Primary Source Area

The following subsections provide a detailed analysis of alternatives for the Primary Source Area. A Primary Source Area is defined for the purposes of this GWOU FS as those areas with the target contaminants of TCE, TCE degradation products, or ^{99}Tc present and having DNAPL concentrations in the surficial soils and soils of the UCRS located above the RGA.

4.2.2.1 Primary Source Area – Vapor Extraction Technology

The following subsections contain a description of Primary Source Area – Vapor Extraction Technology Alternative and the detailed analysis.

Description of Primary Source Area – Vapor Extraction Technology

Vapor extraction is a common technology used to abate areas of subsurface contamination by VOCs. These contaminants partition to soil gas. With vapor extraction, an extraction well is placed under vacuum to withdraw soil gas, containing the contamination. A number of *ex situ* processes are available to treat the contaminants in the off-gas waste stream.

There are three general categories of the vapor extraction technology: passive soil vapor extraction (SVE), standard SVE, and high vacuum SVE.

- Passive SVE, also known as barometric pumping, relies upon the atmospheric potential generated by passing low-pressure weather fronts to induce the movement of contaminated soil gas to the atmosphere.

- Standard SVE uses pumps that generate a vacuum of 13 to 25 cm (5 to 10 inches) of mercury.

- High vacuum SVE pumps typically generate vacuums of 38 to 74 cm (15 to 29 in.) of mercury. They are primarily used in areas of tight vadose zone soils with hydraulic conductivities ranging from 10^{-6} to 10^{-7} cm/sec, such as those common to the PGDP. Vapor extraction vendors frequently use soil fracturing in conjunction with high vacuum SVE in tight soils to enhance the permeability of the soil and the radius of influence of the remediation system. The high vacuum SVE's radius of influence typically is 3 to 6 m (10 to 20 ft) in tight soils and 9 to 15 m (30 to 50 ft) in more conductive soils.

Vapor extraction is only applicable in the vadose zone, where soil gas can migrate to the extraction well. Several extraction well systems have been developed that lower the water table and induce vapor extraction in formerly saturated soils. Dual Phase Extraction combines the benefits of a powerful vacuum system applied to the well to recover soil gas with a pump placed in the bottom of the well to recover groundwater and lower the water table. Dual Phase Extraction and similar systems are capable of remediating the vadose zone and typically saturated zone of the UCRS together. Technologies that remove water also are capable of remediating ^{99}Tc-contaminated sites. Dual Phase Extraction is the selected process option for the vapor extraction alternative that is evaluated in the following text.

The vapor extraction alternative provides no RGA source zone volume reduction or treatment of dissolved phase plumes. In the absence of a source-area action, the worst RGA source zones can be expected to contaminate on-site groundwater with VOC levels in excess of MCLs for approximately 1,000 years. Alone, vapor extraction of the worst UCRS source zones is expected to leave enough residual to contaminate groundwater with VOCs above MCLs for 2,000 years. Dissolved phase actions could reduce contaminant levels outside of the source zone areas to below MCLs in less than 100 years. However, the dissolved phase actions would be required to continue for the 2,000 years until the UCRS source zones are depleted.

The vapor extraction alternative consists of the following primary components:

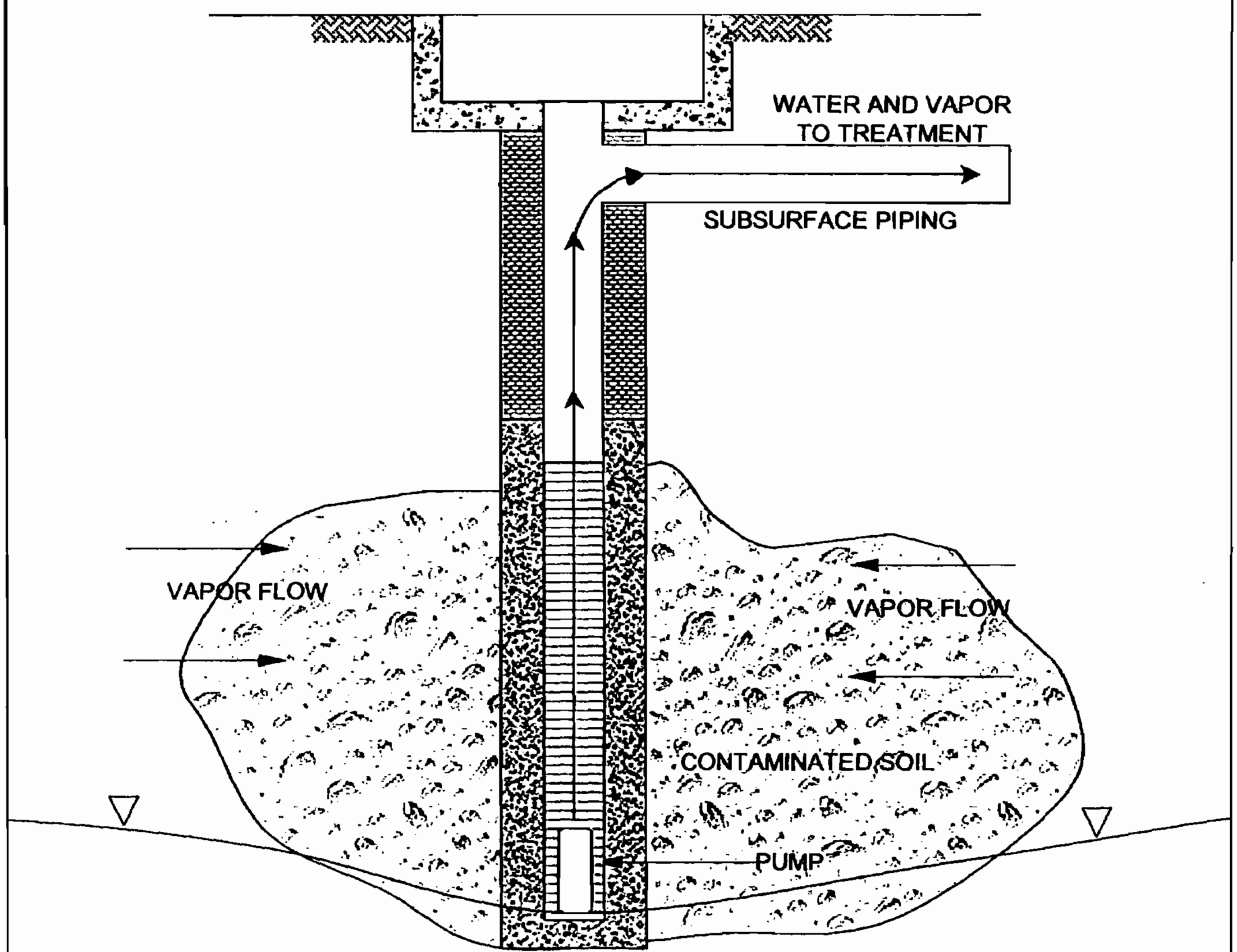
- implementing Dual Phase Extraction to reduce sources of contamination in the UCRS;

- implementing a groundwater monitoring system to monitor the post action effectiveness of the remedial measure and to provide protection; and

- performing five-year reviews of the alternative as required by CERCLA.

Descriptions of these components are provided in the following sections. Figure 4.1 illustrates the primary components of the vapor extraction alternative. The vapor extraction alternative features significant DNAPL mass reduction in the UCRS DNAPL source zones.

Access Restrictions. The primary source areas and highest concentration portions of the groundwater contamination addressed by the GWOU are located within portions of the PGDP that are within security fences. On-site workers are, and would continue to be, alerted to potential exposure hazards at these units through the use of work permits, administrative controls, and safety programs.



U. S. DEPARTMENT OF ENERGY
DOE OAK RIDGE OPERATIONS
PADUCAH GASEOUS DIFFUSION PLANT

BECHTEL JACOBS COMPANY, LLC
MANAGED FOR THE US DEPARTMENT OF ENERGY UNDER US GOVERNMENT CONTRACT DE-AC-05-98OR22700
Oak Ridge, Tennessee • Paducah, Kentucky • Portsmouth, Ohio

Science Applications International Corporation
P.O. Box 2502
Oak Ridge, Tennessee 37831

Fig. 4.1. Primary source area - dual phase vapor/liquid extraction technology.

FIGURE No. FS4-1
DATE 05-25-01

Source Reduction Activities in the UCRS. Source reduction activities would be conducted on-site in the UCRS to reduce the level of COCs that are entering the RGA, which is the uppermost aquifer.

Environmental Media Monitoring. The existing groundwater monitoring program would be continued to monitor the movement of COCs. The monitoring program would integrate existing PGDP monitoring wells, where possible, with additional monitoring wells to be installed as needed following a review of the existing program.

CERCLA Five-Year Review. It is anticipated that this remedial alternative would result in "contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure"; therefore, this remedial action would be reviewed "no less often than every five years" in accordance with 40 *CFR* 300.430 (f)(4)(ii).

Assessment of Vapor Extraction Alternative

A detailed analysis of the performance of the vapor extraction alternative against the nine CERCLA criteria is provided.

Overall Protection of Human Health and the Environment. Implementation of this alternative provides for COC volume reduction in soils and groundwater in UCRS source zone areas. This technology is primarily targeted for DNAPL areas but also has limited effectiveness for the removal of dissolved-phase ^{99}Tc.

The water and off-gas waste streams would require subsequent surface treatment. An air stripper would be used to separate VOCs from the produced wastewater. It is not expected that ^{99}Tc would be entrained in vapor phase emissions due to the radionuclide's high solubility in water. The water treatment system would trap ^{99}Tc on ion exchange resin and the resin would be disposed of or regenerated by an approved mechanism. Processing through a catalytic oxidizer would destroy VOCs produced from air stripping or vapor extraction.

The continuation of a groundwater monitoring program would provide indirect protection for human health and the environment by minimizing the potential exposure to contaminated groundwater through early identification and avoidance.

Although the vapor extraction alternative, alone, would not satisfy the RAOs for the GWOU with regards to projection of human health and the environment, this alternative would support the achievement of RAOs when implemented in concert with other source reduction and dissolved phase GWOU technologies.

Compliance with ARARs. An alternative must meet this threshold criterion to be eligible for selection. The following discussion summarizes the potential ARARs and TBC Guidance for Primary Source Area – Vapor Extraction Technology.

Potential chemical-specific ARARs. The potential chemical-specific ARARs for Vapor Extraction Technology are summarized in the following paragraphs.

Chemical contamination. The aquifers are known to contain chemical contaminants in the form of metals and organics. The federal and state water quality requirements include standards that would be applicable ARARs. The regulations that apply are found in 40 *CFR* 141 (National Primary Drinking Water Standards); 40 *CFR* 143 (Secondary Drinking Water Standards); 401 KAR 5:029 (General Provisions); and 401 KAR 5:031 (Surface Water Standards). These standards, summarized in Table 4.3, include general state standards, domestic water supply standards, and standards applicable to warm water aquatic habitat.

Table 4.3. Summary of potential ARARs for Primary Source Area – Vapor Extraction Technology

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Chemical-Specific ARARs	
National Primary Drinking Water Standards	40 *CFR* 141	Provides chemical-specific numeric standards for toxic pollutants expressed as MCLs and MCLGs.	These requirements are relevant and appropriate due to the nature of the contaminants found within the groundwater.
National Secondary Drinking Water Standards	40 *CFR* 143	Provides secondary MCLs for public water systems.	These requirements are TBCs, as they have been established as guidelines for the states and are not federally enforceable.
Kentucky Surface Standards including • Warm Water Aquatic Habitat Criteria • Kentucky Domestic Water Supply • Kentucky General Standards • Kentucky Outstanding State Resource Waters	401 KAR 5:031 and 5:026	Provides chemical-specific numeric standards for pollutants discharged or found in surface waters. Provides chemical-specific numeric standards for pollutants in domestic water supplies.	These standards are applicable to the segment of the Ohio River into which the Little Bayou Creek discharges. The requirements found in these standards are applicable due to the groundwater to surface water interface to Little Bayou Creek and subsequently to the Ohio River. Note: CWA Water Quality Criteria are not relevant and appropriate because Kentucky has promulgated these state standards that Kentucky has determined to be appropriate for waters of the State.
Radiation Exposure of the General Public at DOE Facilities	DOE Order 5400.5	Specifies that the general public must not receive an effective dose equivalent of >100 mrem/year from all exposure pathways. In addition, all release of radioactive materials resulting in doses to the general public must meet the ALARA criteria.	This requirement is TBC information.
Decommissioning Standards at Nuclear Facilities	10 *CFR* 20, Subpart E	Specifies a residual activity at nuclear facilities for unrestricted release of 25 mrem/year.	These standards are considered to be applicable to the GWOU.
Environmental Radiation Protection Standards for Nuclear Power Operations	40 *CFR* 190, Subpart B	Requires that the annual dose equivalent to the public must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughter products excepted, to the general environment from uranium fuel cycle operations and the radiation from these operations.	These standards are considered to be relevant and appropriate and are equivalent to the NRC standards.

Table 4.3. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Location-Specific ARARs	
Protection of Wetlands	10 *CFR* Section 1022, Executive Order 11990 40 *CFR* 230.10 33 *CFR* 330.5	Activities must avoid or minimize impacts to wetlands to preserve and enhance their natural and beneficial value. If wetland resources are not avoided, measures must be taken to address ecologically sensitive areas and mitigate adverse effects. Such measures may include, minimum grading requirements, runoff controls, design and construction considerations. Allows minor discharges of dredge and fill material, or other minor activities for which there are no practicable alternatives, provided that the pertinent requirements of the NWP system are met.	These requirements are applicable due to the presence of wetlands, but will be met though avoidance of wetlands during construction and implementation of alternatives.
Endangered Species Act	16 U.S.C. 1531 et seq. Section 7(a)(2)	Actions that jeopardize the existence of listed species or result in the destruction of adverse modification of critical habitat must be avoided or reasonable and prudent mitigation measures taken.	Action that is likely to jeopardize fish, wildlife, or plant species or destroy or adversely modify critical habitat-applicable.
Migratory Bird Treaty Act	16 U.S.C. 703-711 Executive Order 13186	Federal Agencies are encouraged (until requirements are established under a formal MOU) to do the following: • avoid or minimize, to the extent practicable, adverse impacts on migratory bird resources when conducting agency actions; • restore and enhance the habitats of migratory birds, as practicable; • prevent or abate the pollution or detrimental alteration of the environment for the benefit of migratory birds, as practicable; • ensure that environmental analysis of federal actions required by the NEPA or other established environmental review processes evaluate the effects of actions and agency plans of migratory birds, with emphasis on species of concern; and • identify where unintentional take will likely result from agency actions and develop standards and/or practices to minimize such unintentional take.	Action that is likely to impact migratory birds, habitats, and resources-applicable.

Table 4.3. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Action-Specific ARARs	
Fugitive Dust Emissions during site preparation and construction activities.	401 KAR 63:010	Precautions must be taken to prevent particulate matter from becoming airborne. Such precautions must be incorporated into the planning and design of activities and include actions such as • wetting or adding chemicals to control dust from construction activities; • using materials such as asphalt or concrete (or other suitable chemicals/fixing agents) on roads or material stockpiles to prevent fugitive emissions; • using covers on trucks when transporting materials to and from the construction site(s). The requirement specifies that for on-site construction activities, no visible emissions may occur at the PGDP fenceline. Similar points of compliance shall be identified for construction activities that occur outside the fence.	These requirements are applicable and will be met through the use of appropriate dust control practices identified during alternative design phase.
Toxic Emissions	401 KAR 63:022	The regulations require that a determination of toxic emissions be made in order to assess the applicability of required controls. Calculations of the significant emission levels are compared to the allowable emission limits specified in Appendix A of 63:022. If emission levels are exceeded, best available control technologies must be incorporated into equipment/process design.	These requirements are considered to be applicable and shall be complied with through calculation of significant emission levels for toxic materials and application of best available control technology as necessary during the design of the alternative.
Monitoring Well Installation	401 KAR 6:310	Monitoring wells (including extraction wells) must be constructed in a manner to maintain existing protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole. In addition, wells with no further use must be plugged and abandoned in accordance with the requirements specified.	These requirements are considered to be applicable. Compliance with well design and protection standards shall be achieved through the use of approved well design and materials of construction. While in service, wells shall be secured as required. Wells with no further use shall be plugged and abandoned as required.
Discharge of Stormwater	40 *CFR* 122, 401 KAR 5:055	Stormwater discharges from construction activities on-site are subject to the requirements of the KPDES permit. This requires that BMPs to control stormwater runoff and sedimentation be employed. Although off-plant construction activities within the contaminated area are not subject to the permit, these requirements should be considered relevant and appropriate and be incorporated into any off-site construction activities.	These requirements are considered applicable for all on-site construction or treatment activities where a discharge of stormwater or treated groundwater occurs. For off-site construction activities, these requirements are considered relevant and appropriate and will be adhered to. Compliance with these ARARs shall be achieved by application of required controls during the design phase of the alternative.

Table 4.3. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
Hazardous Waste Management	40 *CFR* 260 through 268; 401 KAR 32 through 37	All wastes or environmental media containing wastes must be characterized to determine whether the waste also is a hazardous waste in accordance with 40 *CFR* 262.11 and 401 KAR 32:010. If it is determined that a waste is a hazardous waste or that environmental media contain a hazardous waste subject to the RCRA regulation, the substantive requirements of 40 *CFR* 262 through 268 are applicable. These standards include design and operation of storage and accumulation areas, waste handling and shipment, and treatment technologies or numeric standards applicable to wastes before disposal.	These requirements are applicable and will be complied with through characterization of wastes and environmental media generated as a result of implementation of the alternative. Waste management will be predicated upon the characterization and comply with all substantive requirements associated with hazardous waste management, if identified as such.
PCB Waste Management	40 *CFR* 761	TSCA requirements for the management of PCB wastes or items containing >50 ppm PCBs or from a source of 50 ppm or greater. Requirements include the following: • waste and material management; • characterization of PCB-containing materials; • labeling and storage for disposal; • manifest completion for shipment offsite; • decontamination of affected equipment or items; • disposal of PCB wastes. These requirements will be complied with if PCBs are found at concentrations requiring compliance.	These requirements are applicable if PCBs are found or result from items or equipment regulated under 40 *CFR* 761. Activities necessary to comply with these ARARs shall be incorporated into the planning phase of the alternative implementation.

ALARA = as low as reasonably achievable
ARAR = applicable or relevant and appropriate requirement
BMP = best management practice
CFR = *Code of Federal Regulations*
CWA = Clean Water Act
DOE = U.S. Department of Energy
GWOU = groundwater operable unit
KAR = Kentucky Administrative Regulation
KPDES = Kentucky Pollutant Discharge Elimination System
MCLGs = maximum containment level goals
MCLs = maximum contaminant level
NRC = Nuclear Regulatory Commission
NWP = Nationwide Permit
PCB = polychlorinated biphenyl
PGDP = Paducah Gaseous Diffusion Plant
TBC = to be considered
TSCA = Toxic Substances Control Act

These are applicable based upon the classification of the designation for surface water use associated with the area (Ohio River, River Mile 940.7 to River Mile 943.3) as specified in 401 KAR 5:026. All potentially applicable chemical ARARs for COCs have been included in the table for completeness. Those standards that must be achieved in order to meet the applicable requirements are the lowest of the applicable standards, which in most cases are the MCLs.

Radiological contamination. The OU is known to be contaminated with radionuclides such as ^{99}Tc, radon, uranium, and uranium daughter products. DOE's Order on Radiation Protection of the Public and Environment, DOE Order 5400.5, is TBC information for cleanup of radionuclides at DOE sites. The order requires that remediation activities must not result in radiation exposures to members of the general public greater than an EDE of 100 mrem/year from all exposure pathways. Exposure to the general public also must be ALARA (DOE 1990).

The DOE Order 5400.5 also contains reference values, known as DCGs, for operational DOE facilities. Based on the DCGs, radionuclide concentrations in air and drinking water must not exceed an EDE of 10 mrem/year and 4 mrem/year, respectively, to the total body or any organ.

The Nuclear Regulatory Commission (NRC) also has set criteria for decommissioning standards at nuclear facilities at 10 *CFR* 20 Subpart E. These rules require that residual radioactivity at nuclear sites meet a total EDE of 25 mrem/year for unrestricted release. In addition to the NRC standards, EPA has issued guidance for cleanup levels at CERCLA sites with radioactive contamination. EPA has disagreed with the protectiveness specified within the NRC standard and has specified that a 15 mrem/year EDE be used as the risk level that is protective of human health and the environment. EPA also has codified exposure limits for environmental radiation protection standards for nuclear power operations at 40 *CFR* 190. These requirements apply to operations involved in uranium fuel cycle and include enrichment operations. Subpart B of these requirements specifies that the annual dose equivalent to the public must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughter products excepted, to the general environment from uranium fuel cycle operations and to radiation from these operations. These requirements would be considered relevant and appropriate because the release to the groundwater would not be planned.

The Commonwealth of Kentucky is an NRC Agreement State and has promulgated regulations for radiation protection of the public. The Kentucky radiation protection standard for individual members of the public is 0.1 rem (100 mrem) EDE per year or less (902 KAR 100:019 Section 10), which is equivalent to the DOE radiation protection standard found in DOE Order 5400.5.

Due to the differing views and values among NRC, EPA, and DOE total EDE for members of the general public, EPA and DOE have agreed not to finalize their respective standards until an agreement can be reached. In the interim, DOE Order 5400.5 is identified as TBC information and the NRC standard is identified as relevant and appropriate. Therefore, the radiation protection standard identified within the NRC regulations at 10 *CFR* 20 Subpart E requiring an EDE of 25 mrem/year or less shall be used as the exposure limit for the general public.

Chemical-specific ARAR summary. The chemical-specific ARARs associated with the implementation of this alternative are outlined in Table 4.3. Implementation of this alternative would not result in attainment of the chemical-specific ARARs associated with the off-site groundwater plumes. Attainment of the identified ARARs would be met in the future as implementation progresses. Continued monitoring of the groundwater will be used during the five-year reviews to ensure that the identified goals are met and that concentrations of COCs continue to decrease.

Potential location-specific ARARs. The potential location-specific ARARs for this alternative are summarized in the following paragraphs.

Wetlands. Although no wetlands have been identified within the area where construction activities will occur, certain jurisdictional wetlands have been identified in on-site drainage ditches within the plant boundary. In order to comply with these applicable requirements, wetlands shall be avoided.

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, 40 *CFR* 6.302(a), 40 *CFR* 6 Appendix A, 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. Although not anticipated, if this alternative results in impacts to wetlands that cannot be avoided, the substantive requirements of the nationwide permit (NWP) 38 (33 *CFR* 330) will be met.

Off-site operations shall not impact wetlands, and all treatment will be conducted either *in situ* or in units already in operation.

Endangered Species and Migratory Birds. Actions taken by federal agencies are prohibited from impacting T&E species or adversely modifying critical habitat (50 CFR 17.94) in accordance with the Endangered Species Act (16 USCA 1531 et seq. Section (7)(a)(2)). These requirements are potential ARARs in the event T&E species or their habitats are found at or near areas where remedial action is to occur. An ecological resource investigation inside the PGDP security fence did not detect any T&E species or their preferred habitats (CDM Federal 1994). The U.S. Fish and Wildlife Service (USFWS) has not designated critical habitat for any species within the DOE property. However, outside the PGDP fence on the DOE property, potential habitats for federally listed T&E species was reviewed and Indiana bat habitat was evaluated during the COE (1994) environmental investigation. The COE study determined that total potential bat habitat consisted of 20% of the 994-ha (2,456-acre) study area. Remedial activities must be evaluated to ensure that such actions do not adversely impact areas identified as critical habitat for any identified endangered species.

In addition, Executive Order 13186 directs federal agencies to enter into an MOU with the USFWS to further the purposes of the Migratory Bird Treaty Act (16 U.S.C. 703-711). Until such time as the memorandum of understanding (MOU) between DOE and the USFWS is finalized, Federal agencies are encouraged immediately to begin implementing the conservation measures set forth in the Executive Order. The requirements of the Executive Order are applicable and must be considered during planning and design of the remedial action.

Potential action-specific ARARs. The potential action-specific ARARs for Vapor Extraction Technology are summarized in the following paragraphs.

Monitoring well installation requirements. This alternative includes the installation of additional monitoring and extraction wells. Installation of these wells would have to be conducted in a manner to maintain existing natural protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole (401 KAR 6:310 Section 13). These requirements also mandate the construction materials required for well construction, well design criteria, well completion activities, and well abandonment methodologies. These requirements are considered applicable to design and installation of monitoring and extraction wells associated with the implementation of this alternative.

Fugitive dust emissions. Construction activities on-site may result in the production of particulate airborne pollutants (dust). The Kentucky Air Quality standards found in 401 KAR 63:010 include requirements governing fugitive dust emissions. These standards require that dust-suppression measures be undertaken that include activities such as use of water or chemicals to control emissions, placement of asphalt or concrete, and stockpiling of soils. The standards also require that visible dust generated from the implementation of the remedial alternative not be discharged beyond the property boundary of the site. Trucks transporting material outside the property boundary, where materials could become airborne, must be covered. These requirements are considered to be applicable to the implementation of this alternative and will be complied with careful planning to ensure that excavated materials are sufficiently wetted or protected to control dust generation. Specific activities that could result in the generation of fugitive dust that must be considered during the design phase include well installation and construction.

Radionuclide emission standards. Airborne emissions of radionuclides may occur as a result of on-site construction activities. Although this potential is low for such emissions to occur, the regulations at 40 *CFR* 61.92 would require that the emissions not exceed amounts that would cause an EDE to the public of 10 mrem/year. In order to determine whether the alternative complied with this applicable requirement, computer modeling using the CAP-88 or other EPA-approved models must be undertaken. If the modeling demonstrates the radionuclide emission to be in excess of 1% of the 10 mrem/year standard, emission rates must be measured as required by 40 *CFR* 61.93. This ARAR shall be complied with by planning activities in such a manner as to control fugitive emissions from construction and excavation activities.

Toxic emission standards. Although toxic emissions are not expected as a result of construction activities or with the pumping of the groundwater to the on-site water treatment facility, these emission requirements would be applicable if such emissions do occur. Due to organic concentrations found in the groundwater and potentially within the subsurface soils at depth, there is a low potential for such emissions to occur. The regulations at 401 KAR 63:022 require that the emissions be evaluated to determine whether they are significant for each specific toxic air pollutant. If analysis indicates the toxic emission requirements are triggered, the regulations specify that no source may exceed the allowable emission limit specified in Appendix A of 401 KAR 63:022. If applicable, these rules would require the application of best available control technology to limit toxic emissions. If calculations indicate that the emission rates specified within the rule are not exceeded, the calculation package may be used to demonstrate compliance with these requirements. Activities that must be considered include excavation and treatment of contaminated groundwater.

Stormwater discharge. Construction activities will be subject to the substantive requirements associated with the KPDES permit that requires the use of BMPs and sediment/erosion controls to control transport of sediment in stormwater runoff. These requirements are considered to be applicable.

Waste management requirements. Hazardous materials and wastes shall be generated during the implementation of this alternative. It is anticipated that these wastes will be low-level radioactive wastes and, therefore, subject to the DOE Order 435.1 requirements that apply to the management of all radioactive wastes generated at DOE facilities. This requirement is TBC rather than applicable or relevant and appropriate because it is a DOE Order rather than a federal or state regulation or standard.

The potential also exists that some or all of the wastes generated from treatment may be RCRA hazardous wastes as defined in 40 *CFR* 261 of the federal program. All wastes generated shall be subject to the hazardous waste determination requirements of 40 *CFR* 262 and 401 KAR 32:010. If it is determined that any wastes are, in fact, hazardous wastes, the materials must be managed in accordance with the substantive requirements found in 40 *CFR* 262 through 40 *CFR* 268 (401 KAR 32 through 37). These standards include storage requirements, transportation requirements, and disposal requirements. Specific requirements applicable to each waste stream must be identified after characterization of the material is complete. These requirements shall be complied with through the development of a waste management plan (WMP) during the design phase of implementation. If materials are identified as RCRA hazardous waste, these requirements are applicable.

Although considered unlikely, the potential exists that wastes generated from the implementation of this alternative may contain PCBs regulated under the Toxic Substances Control Act (TSCA). These regulations would be applicable to this alternative if PCB concentrations were found in soil or water that exceeded 50 ppm or PCBs were found and attributable to a source whose concentration exceeded 50 ppm PCBs. The substantive requirements for management of PCB wastes found in 40 *CFR* 761 would be applicable and include standards for storage, shipment, and equipment decontamination. These requirements shall be complied with through the development of a WMP during the design phase of implementation. If materials are identified as TSCA PCB regulated material, these requirements are applicable.

Action-specific ARAR summary. This alternative will trigger action-specific ARARs with regard to the treatment and handling of the contaminated groundwater removed from the aquifer. These include the requirements for compliance with the substantive requirements to control of sedimentation during construction activities and the applicability of the RCRA requirements for wastes generated as a result of implementation. In addition, the requirements of TSCA will be applicable if regulated PCB-containing materials are identified. This alternative will comply with these requirements during the planning phase to include compliant waste handling, storage, and disposition components. If wastes from treatment of groundwater or excavation of soils is determined to be hazardous wastes under RCRA, the substantive requirements for storage, management, and disposal of hazardous wastes shall be incorporated into the alternative during the planning phase. Activities that may be required for RCRA and TSCA compliance include use of appropriate containers, labeling of containers, appropriate storage area design and operation (secondary containment or storage for less than 90 days in a compliant accumulation area), and transportation of wastes.

A summary of the ARARs for the implementation of Primary Source Area Vapor Extraction Technology are presented in Table 4.3.

Compliance with ARARs summary. Implementation of this alternative would not achieve immediate compliance with the MCL for TCE. Compliance at the fenceline has been calculated to occur in approximately 1,000 years. Compliance with the MCL at the DOE property boundary and Little Bayou Creek is calculated to occur in approximately 1,000 years.

In addition, this alternative addresses the reduction of source areas and control of groundwater plumes via *in situ* treatment and addresses organic constituents. The MCLs applicable to antimony, chromium (action level), and alpha-emitting radionuclides would be exceeded at the point of compliance (plant fenceline) and points of exposure (DOE property boundary, Ohio River) if contaminants were allowed to continue to migrate off-site from source areas, according to the modeling used in the development of this FS. As stated in the risk assessment, the metals and radionuclides based upon historic observations are far less mobile than current modeling indicates. Based on the time frames illustrated in the model required for migration to the point of compliance and the historical observations associated with migration of metals and radionuclides at the PGDP, exceedance of the associated MCLs is considered unlikely.

In order to comply with the identified chemical-specific ARARs, an ARAR waiver will be required due to the time frames required to meet the specified concentrations within the GWOU at the point of compliance and points of exposure.

As discussed, no potential location-specific ARARs have been identified within the area where remedial action will occur. However, to ensure that jurisdictional wetlands are not impacted, all construction activities associated with this alternative will be reviewed as a safeguard. The protection of wetlands is not considered a location-specific ARAR at this time, as jurisdictional wetlands have not been identified within the areas impacted by the implementation of this alternative.

Construction and implementation of the alternative may trigger several action-specific ARARs such as the requirements associated with well installation and abandonment, fugitive-dust emissions, radionuclide emissions, and toxic emissions. The requirements associated with the installation and abandonment of groundwater wells will be met though use of well designs and materials of construction, as specified at 401 KAR 6:310 Section 13. All well installations and abandonment practices incorporated into the approved Remedial Design shall comply with the substantive requirements of 401 KAR 6:310.

Fugitive dust emissions that may occur during construction activities will be controlled as required by 401 KAR 63:010. BMPs such as wetting or covering of potential sources of fugitive dust will be incorporated into the remedial design. The specific actions to be developed shall control potential emission sources to ensure that dust emissions do not migrate from the immediate area where construction activities occur. It is anticipated that, in most cases, the moisture content in the soil will be sufficient to control dust emissions during well installation. However, practices such as the wetting of disturbed soils, collection of soils, or reseeding activities shall be considered and incorporated into the remedial design, as necessary, to ensure compliance with these requirements. Radionuclide emissions at construction sites also must be considered during the implementation phase. In order to ensure that the emission standard of 10 mrem/year EDE to the public is met, concentrations of radionuclides in soils and groundwater must be evaluated. If the potential for such emissions is identified, modeling using the CAP-88 or other EPA-approved methods must be undertaken during the design phase of the alternative. It is anticipated that the primary conveyance of airborne radionuclides will be in particulate form; therefore, control of fugitive dust emissions also will result in compliance with the emission standards applicable to radionuclides. If radiological contamination from plant activities is found in soils where construction activities are planned, the soil will be protected or containerized to prevent airborne migration. Measures necessary to prevent airborne emissions or radionuclides shall be evaluated and incorporated, as appropriate, into the remedial design in order to comply with these requirements during implementation of this alternative.

Emissions of toxins such as volatile organics also must be evaluated before implementation. Although the potential for exceedance of toxic air emissions is considered to be low, an evaluation of the potential for such emissions must be undertaken during the remedial design. Potential emissions must be evaluated for each toxin present in the plumes (i.e., TCE, vinyl chloride, etc.) to determine whether the contaminant levels found in the subsurface could result in airborne emissions in excess of the allowable limits specified in Appendix A of 401 KAR 63:022. Compliance with the emissions standards shall be achieved for this alternative through the evaluation process or the application of the best available control technology where emissions are calculated to exceed allowable levels. Emission control equipment will be incorporated into implementation activities during the remedial design, as necessary, based upon the initial evaluation. This requirement will be complied with during implementation of the alternative.

The construction activities associated with this alternative will require that BMPs for sedimentation/erosion controls be established. This requirement will be complied with through the use of sediment fences or other appropriate means. The remedial design shall incorporate the specific controls necessary to ensure that the construction sites do not allow sedimentation and/or erosion of disturbed areas in order to comply with this requirement during implementation of this alternative.

Treatment of groundwater may result in the generation of secondary wastes that will trigger the characterization requirements associated with RCRA. The implementing regulations found at 40 *CFR* 262 and 401 KAR 32:010 require that generators of solid wastes (or contaminated environmental media) must determine whether the waste also is a hazardous waste. If the materials generated from the implementation of this alternative are found to be hazardous wastes, the materials shall be containerized and managed as such. The requirements mandate that hazardous wastes be properly labeled and stored in areas that comply with the technical standards for storage of hazardous waste in containers. These standards shall be complied with through testing of soils before excavation activities. If the soils are found to be hazardous, appropriate storage areas shall be constructed and maintained. All hazardous waste generated during the implementation of this alternative shall be shipped for off-site disposal using the EPA Identification Number for the PGDP. Hazardous wastes shall be shipped to facilities permitted to treat, store, or dispose of the hazardous waste(s) being shipped. These activities shall be incorporated into the remedial design for this alternative in order to comply with these requirements.

Secondary wastes generated during the implementation of this alternative also may be subject to regulation under TSCA as PCB remediation waste and DOE Order 435.1 as LLW. Characterization of these materials will be required in order to determine whether specific wastes are regulated under these requirements. If it is determined that the waste generated is a PCB or LLW, appropriate management standards will be incorporated into the Remedial Design. Existing information will be used where practicable to determine the regulatory status of all waste to be generated before implementation.

Long-Term Effectiveness and Permanence. This evaluation addresses the results of the vapor extraction alternative in terms of risk remaining at the site after completion of the action and the effects of required long-term controls. A discussion of the magnitude of residual risk at the site and adequacy and reliability of controls is presented in the following sections.

Magnitude of residual risks. The vapor extraction alternative is designed to remediate contaminated groundwater by reducing COC volumes in source areas. However, nonaqueous phase COCs are likely to remain in place following treatment of the UCRS by vapor extraction. As long as the VOCs and ^{99}Tc levels remain high in the source areas, the residual risk would remain high in the source area and downgradient areas. For a prolonged period following the startup of the alternative remedial action, the residual risk would remain consistent with the risk present prior to taking the action. VOC levels would remain elevated for approximately 2,000 years for the areas of worst DNAPL contamination after implementation of this alternative. Vapor extraction would have to be implemented in concert with other UCRS and RGA technologies to achieve MCLs at the Points of Compliance in a reduced time frame.

Five-year reviews, mandated by CERCLA [40 *CFR* §300.430(f)(4)(ii)], would be required to demonstrate the integrity and effectiveness of controls and to confirm that additional exposure pathways have not developed.

Adequacy and reliability of controls. The vapor extraction alternative would have a moderate to high reliability for operation and control. The components that make up the vapor extraction systems, catalytic oxidizer, and ion exchange system have been used extensively for the treatment of air and water and have proven to be reliable. Due to the potential for high COC concentrations, the system design likely would require redundancy in treatment equipment to ensure acceptable COC removal from effluents. Because of this redundancy in air strippers, pumps, etc., the system would have flexibility, allowing the system to continue effective operation at a reduced capacity. The complete system, with extraction and monitoring wells, would be located inside the secure area of PGDP. The long-term control for this alternative (i.e., groundwater monitoring) is adequate and reliable.

Environmental impacts and mitigative measures. The following text describes potential long-term impacts to resources and mitigative measures to offset any potential impacts. The depth of impact analysis and mitigative measures is correlated to the degree to which a resource may be impacted.

Land use. Implementation of this alternative would result in minimal adverse impacts to land use. Long-term impacts would be related primarily to monitoring wells. Following construction of the alternative, the bulk of the land disturbed during construction would be returned to its prior use. A LUCIP would be developed, as necessary, per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomics. The socioeconomic conditions of the PGDP and surrounding area would not be expected to change as a result of implementing the vapor extraction alternative. Construction contractors would perform the construction and operation of the facilities for the alternative. The permanent jobs that could develop as a result of this action are small in relation to the size of the population of the surrounding area. The implementation of the vapor extraction alternative would also not result in a substantial decrease or increase in the personnel at PGDP. However, the presence of contaminants in the groundwater would prevent its use and may limit economic development opportunities until the groundwater is brought back to beneficial use.

Air quality and noise. Long-term degradation of air quality is not expected as a result of the implementation of this alternative. The VOCs, which are removed from the extracted soil gas and groundwater, are destroyed by catalytic oxidation afterwards and do not become air COCs. The potential for a temporary increase in fugitive dust emissions during construction would be mitigated by keeping dust-prone areas watered to suppress dust.

No long-term increase in noise is expected from this alternative. During construction, there would be local increases in noise levels because of operating machinery. However, the noise increase would be in a limited area and would not affect human receptors. Hearing protection would be used to protect the workers constructing the system.

Vegetation. Construction of the vapor extraction system would be located in the active industrial section of the PGDP and would only impact replanted grasses. Once construction is concluded, disturbed vegetation could be restored through seeding and natural regeneration. Therefore, no long-term impacts to vegetation are expected from the implementation of this remedy. The installation of the extraction and monitoring well system is expected to take three months.

Wildlife. Activities associated with this alternative could result in a limited, temporary disruption of the habitat of birds, mammals, and reptiles inhabiting the immediate area surrounding the extraction and monitoring wells. However, no long-term impacts to wildlife would be expected.

No adverse impacts are expected for aquatic life in the KPDES outfalls and creeks. The implementation of the vapor extraction alternative would not require construction activity in the creeks and outfall tributaries.

Threatened and endangered species. No adverse impacts were identified that would result from implementing this alternative. The potential roosting areas of the Indiana bat, as identified by Bryan (COE 1993), are not located in the expected area for this alternative.

Cultural resources. No long-term effects are anticipated for this alternative.

Groundwater. The on-site activities associated with this alternative are designed to reduce the UCRS sources of VOCs and, to a limited degree, the ^{99}Tc.

Surface water. The relative contribution of the discharges of treated groundwater to the flow of Bayou and Little Bayou Creeks would be small. Implementation of this alternative is not expected to impact surface water quality. Silt and erosion controls would be used during construction activities. The treatment system would be designed to remove the COCs from the extracted groundwater and to meet substantive release requirements of the PGDP's KPDES permits.

Floodplains. No impacts are expected with the implementation of the vapor extraction alternative. The action would not take place in any floodplain of any stream at PGDP.

Wetlands. The implementation of this alternative should not impact the hydrology of wetlands in the area. All construction activities are expected to be within the main area of the PGDP and outside of wetland areas.

Soils and prime farmland. No long-term impacts are expected from the implementation of this alternative. Minor impacts would occur to soils in the areas of construction during implementation of the vapor extraction alternative. Impacts would be mitigated through the use of standard construction practices of placing erosion and drainage control in the construction areas as necessary. During well installation, testing, and operation, the potential exists for the release or spill of small volumes of contaminated water. These potential releases would be mitigated through the use of engineering measures to contain spills and contaminated soils. The area impacted would be small and would be affected only for a short time.

Transportation. No long-term direct or indirect effects are anticipated for this alternative. The implementation of the vapor extraction alternative would result in transportation of environmental soil and groundwater samples to laboratories. During the operation of the alternative, ion exchange resins would be transported to treatment, storage, or disposal facilities. Standard engineering practices would be used to ship these waste materials. Also, all applicable regulatory requirements for shipment of LLW materials would be followed.

Cumulative impacts. Cumulative impacts are defined as the incremental impact of an action when added to other past, present, and reasonable, foreseeable future actions, regardless of what agency or person undertakes other such actions. Cumulative impacts resulting from this alternative would have to be identified at a later time during development of site specific GWOU decision documents.

Reduction in Toxicity, Mobility, or Volume Through Treatment. Implementation of the vapor extraction alternative would result in source volume reduction. Passive and standard SVE would address only volatile organic contamination. High vacuum extraction would remove condensate that could contain ^{99}Tc. Vapor extraction of all DNAPL zones would be expected to remove up to 90% of the UCRS DNAPL.. Any contaminated water that may be extracted as part of the SVE would be treated to remove the VOCs and ^{99}Tc before releasing the treated water to the area creeks. Air stripping, for the VOCs, and ion exchange, for the ^{99}Tc, would be the primary means of treating the wastewater stream. The resulting vapor phase would be passed through a catalytic oxidizer to destroy VOCs. The ^{99}Tc would remain adsorbed to the ion-exchange resin and is not destroyed. Nearly 100% of the extracted contaminants would be treated and/or destroyed. However, since the VOCs and ^{99}Tc are only incrementally removed, the toxicity of the COCs would continue for an extended period after the implementation of this alternative.

The vapor extraction alternative is reversible. Source reduction can be stopped without irreversible damage to the chemical and physical soil properties. The VOC levels in the UCRS would be reestablished once the operations are discontinued. However, the implementation of this alternative may shrink the UCRS DNAPL zone, leading to a reduced area of impact in the RGA, and should significantly reduce the time over which the VOCs would persist in a DNAPL phase.

This alternative would meet the preference for treatment via an *ex situ* treatment system. Following treatment of the extracted groundwater and soil gas, treatment residuals would exist. The VOCs are destroyed through catalytic oxidation. Sodium chloride, produced from the scrubbing of the off-gas, would be a primary treatment residual. Spent ion-exchange resin, from the treatment of the ^{99}Tc, also would be a primary treatment residual. The spent ion-exchange resin would be a low-level waste.

Short-Term Effectiveness. This criterion involves the evaluation of alternatives for community protection, worker protection, environmental impacts, and the time until remedial response actions are achieved. A discussion of each is provided in the following paragraphs.

Community protection. The potential for adverse impacts to the community from the implementation of this alternative is minimal. Engineering controls would be used to reduce off-gas emissions. This alternative would be implemented within the PGDP or just outside the security fence and should not result in danger to the surrounding community. Restrictions would be used to limit the access of persons that may be in the area during construction. This would include warning signs, temporary control fencing, and periodic security patrols. Also, environmental monitoring would be conducted during the construction of extraction and monitoring wells where COCs may be present.

Worker protection. Implementation of the vapor extraction alternative has the potential for worker exposure to contaminated subsurface soils and groundwater during environmental sampling, well installation, and remedial operations. Potential exposure pathways include inhalation of dust containing contaminated soils, dermal contact with subsurface soils, and dermal contact with contaminated groundwater. The potential for worker exposure is very unlikely due to the PGDP risk management requirements (i.e., worker protection procedures, PPE, and engineering controls for off-gas treatment).

Potential environmental impacts and mitigating measures. Short-term environmental impacts and mitigative measures are qualitatively assessed and include an evaluation of the impacts on environmentally and potentially sensitive ecological resources, short-term impacts on socioeconomic and cultural resources, and cumulative impacts of the remedial construction.

Land use. Implementation of this alternative would result in minimal adverse impacts to land use related to treatment facilities and monitoring wells. Following construction and operation of the alternative, the bulk of the land disturbed during construction would be returned to its prior use. A LUCIP would be developed as necessary per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomics. The socioeconomic conditions of the PGDP and surrounding area would not be affected. Construction contractors would perform construction and operation of the facilities for the vapor extraction alternative. The number of permanent jobs that could develop as a result of the action is small in relation to the size of the population of the surrounding area. Implementation of the vapor extraction alternative also would not result in a decrease or increase of personnel at the PGDP.

Air quality and noise. The potential for a short-term, temporary increase in fugitive dust emissions during construction would be mitigated by keeping dust-prone areas watered to suppress dust. Off-gas treatment would prevent degradation of air quality during operation. There would be local increases in noise levels due to operating machinery during construction and operation. However, the noise increase would be in a limited area. Hearing protection would be used to protect the workers constructing the system.

Vegetation. Construction of the vapor extraction systems would be located in the active industrial section of the PGDP and would impact only replanted grass. Once construction is concluded, disturbed vegetation could be restored through seeding and natural regeneration.

Wildlife. The implementation of the vapor extraction alternative would occur in the industrial portion of the PGDP and not require activity to take place in the creeks and PGDP outfall tributaries. No adverse impacts are expected for aquatic life. During construction, the potential impacts to the wildlife and creeks are through migration of sediments and erosion. Standard engineering practices of providing erosion control fencing, materials, and fabrics in the construction areas would minimize these impacts. The volume of water expected to be released would be minimal. This would occur following construction over approximately a 3-year period while the SVE is operating.

Threatened and endangered species. No adverse impacts have been identified that would result from the implementation of the alternative. The Indiana bat, which regionally has suitable habitat, is not expected to be impacted by this alternative. The potential roosting areas of the Indiana bat, as identified by Bryan (COE 1993), are not located in the expected area for this alternative

Cultural resources. No long-term effects are anticipated for this alternative.

Groundwater. The on-site activities associated with this alternative are designed to reduce levels of VOCs and, to a limited extent, ^{99}Tc in the UCRS DNAPL zones. This alternative is not expected to result in additional groundwater degradation.

Surface water. The implementation of this alternative is not expected to impact surface water quality. Silt and erosion controls would be used during construction activities. The treatment system to remove the COCs from the extracted groundwater would be designed to meet substantive release requirements of the PGDP's KPDES permits. The relative contribution of the discharges of treated groundwater to the flow of Bayou and Little Bayou Creeks from the implementation of this alternative would be insignificant.

Floodplains. No impacts are expected with the implementation of the vapor extraction alternative. The actions would not take place in any floodplain of any stream at the PGDP.

Wetlands. This alternative would be implemented within the main industrial area of the PGDP and should not impact the hydrology of wetlands. Silt and erosion control measures would be used during construction activities to minimize impacts to wetlands.

Soils and prime farmland. No significant short-term impacts are expected from the implementation of this alternative. Impacts would be mitigated through the use of standard construction practices of placing erosion and drainage control in the construction areas as necessary. During well installation, testing, and treatment facility operation, the potential exists for the release and spill of contaminated water. These potential releases would be mitigated through the use of engineering measures to contain spills and contaminated soils.

Transportation. Only minimal short-term direct or indirect effects are anticipated for this alternative. The implementation of the vapor extraction alternative would result in transportation of environmental soil groundwater samples to laboratories. During the operation of the alternative, it would be necessary to transport ion-exchange resins to treatment, storage, or disposal facilities. Standard engineering practices would be used to ship these waste materials. Also, all applicable regulatory requirements for shipment of low-level waste materials would be followed.

Cumulative impacts. Cumulative impacts are defined as the incremental impact of an action when added to other past, present, and reasonable, foreseeable future actions, regardless of what agency or person undertakes other such actions. Site-specific GWOU decision documents would have to identify cumulative impacts resulting from the implementation of this alternative, if selected.

Time until remedial response objectives are achieved. The vapor extraction alternative would not result in achievement of RAOs specified for the GWOU or MCLs without the implementation of additional groundwater remedial measures. However, achievement of targeted contaminant reductions at each specific source zone would be completed in less than 4 years from the beginning of implementation at each source zone. This alternative, alone, would not provide protection for the groundwater or surface water user for approximately 2,000 years.

Implementability. Activities to be conducted under the vapor extraction alternative include:

- implementing Dual Phase Extraction to reduce specific sources of contamination in the UCRS;

- maintaining on-site groundwater monitoring to provide protection until the remedial actions have been completed;

- maintaining off-site groundwater monitoring to provide protection until the remedial actions have been completed; and

- performing five-year reviews of the alternative as required by CERCLA.

Technical feasibility. Vapor extraction is a standard remediation technology available from multiple vendors. Construction of SVE extraction wells and monitoring wells is technically feasible using standard equipment and technologies. However, it is expected that the industrial setting of the PGDP may create difficulties in some source zone areas. The equipment that would be used in a water treatment facility and the pipelines to convey the contaminated water is also standard and proven technology. Downtime is expected to be minimal for maintenance and repairs. Effluent sampling of the released water and off-gas would ensure that the treatment systems are meeting the effectiveness goals of the alternative.

SVE has been used successfully at other contaminated sites. The low conductivity of the UCRS soils may have an adverse impact on this technology. If the soil conductivity in the subsurface is not sufficient to permit sufficient air flow to remove the COCs, a means of inducing secondary conductivity may be needed or the period of performance for the technology may need to be increased.

The construction and operation of this alternative would not prohibit the implementation of other GWOU technologies.

Administrative feasibility. The alternative is administratively feasible. Treated water and air meeting the substantive requirements of the state and federal regulations would be discharged as part of this alternative. Treatment, handling, and transportation and disposal of the residuals would require proper procedures; however, no difficulties are expected. An ARARs waiver will be required for this alternative since MCLs would not be attained in a timely manner.

Availability of services and materials. Services and materials for the construction of this alternative are readily available. Ready availability of multiple vendors would increase the likelihood of competitive bids.

This alternative would result in the generation of waste soil cuttings and drilling and development water from the construction of extraction wells and monitoring wells. The construction of treatment facilities may generate clean concrete, wire, and pipe construction debris. All of these materials either would be treated, as necessary, and released, as in the development water, or disposed of appropriately.

The operation of the treatment system would result in the generation of sodium chloride, from the scrubbing of the catalytic oxidizer off-gas, and ion-exchange resins spent with ^{99}Tc. Both of these materials would be stored until appropriate disposal can be arranged.

Cost. Table 4.4 summarizes the preliminary unit cost estimates for the vapor extraction alternative. These preliminary unit cost estimates are based upon FS-level scoping and are intended to aid with selection of a preferred alternative. The estimates have an expected accuracy of -30% to +50% for the proposed scope of action (EPA 1988a). The capital cost estimate represents those expenditures required to implement this remedial alternative. The O&M cost estimates represent expenditures required to maintain the remedy after the initial phase of remedial action construction is completed. The total contingency cost presented includes direct, indirect, and all O&M-associated contingency costs. The total cost includes all capital costs, direct and indirect with O&M and associated reports, plus 25% contingency costs, for a 30-year term of comparison. All estimates have been escalated using DOE-approved annual rates and a schedule for the various activities based on similar project experience. Present worth values also are included using a discount factor of 5% (EPA 1988b). (Additional information regarding the preliminary cost estimates is presented in Appendix C7.)

Table 4.4. Preliminary unit cost estimates for the vapor extraction alternative

Total unit capital costs (per acre-foot)	$229,117
Total operation and maintenance costs	$78,023
Overhead	$242,977
Total contingency	$137,529
Total cost	**$687,648**
Total cost (present worth)	**$554,393**

Note: preliminary cost estimates are per acre-foot, escalated and presented in dollars.

State/Commonwealth Acceptance. The Commonwealth of Kentucky acceptance or nonacceptance of this alternative would be addressed in the ROD should the vapor extraction alternative be selected as the preferred alternative.

Community Acceptance. Following a formal public comment period on the PRAP for the GWOU, comments from the community would be addressed formally in a responsiveness summary, which would be presented in the ROD.

Evaluation summary of the vapor extraction alternative

The vapor extraction alternative would involve implementation of UCRS source zone remedial actions and environmental media monitoring to track COC migration. UCRS source zone remedial actions would remove large quantities of COC mass in a short period of time, resulting in lowering the COC concentrations in migrating groundwater in the RGA. Implementation of monitoring would provide an indirect protection, as monitoring COC migration allows for minimizing the potential for exposure to contaminated environmental media through avoidance. Because the source areas would be aggressively remediated, the residual risks left in place would be reduced but not removed. However, residual risk in the source areas would not be unacceptable under future industrial land use. Residual risk also would remain in the off-site plumes until remediation of the whole plume is completed and successful. Short-term risks to construction workers would exist, due to potential exposure to contaminated groundwater during environmental monitoring activities and maintenance of the treatment systems. Additional exposure is possible due to dermal and inhalation contact during changeout of treatment media. However, risks to workers would be minimized by strict adherence to approved risk management procedures (e.g., health and safety plan and use of PPE).

Implementation of the vapor extraction alternative would require high capital for implementation and moderate O&M costs. Input from the Commonwealth of Kentucky and the community has not yet been received but would be added to a ROD once the public comment period has been completed.

4.2.2.2 Primary Source Area – Direct Heating Technology

The following subsections contain a description of Primary Source Area – Direct Heating Technology Alternative and its detailed analysis.

Description of Primary Source Area – Direct Heating Technology

Direct heating is a developing technology with some proven applications in the restoration of vadose zone soil containing volatile and semi-volatile contaminants. As the soil is heated, the contaminants more readily partition to a gaseous state that can be recovered, through soil vapor extraction or a surface plenum, or released to the atmosphere. In other applications, direct heating may be used to stimulate biological restoration of subsurface contaminants.

A number of approaches have been tried to direct heat soils and/or water and contaminants of the vadose zone. The two most developed methods induce resistive heating of the soil using radio frequency energy or electrical energy. A secondary benefit of resistive heating is that the low-permeability soils that typically require the longest time to remediate are naturally, preferentially heated. Thus, the energy is focused on those areas that typically require the most effort. Direct heating has the added benefit that the generation of steam and desiccation of soil leads to an increase of soil permeability. Soil gas containing contaminants is able to more readily migrate to a collection or release point. Electrical resistive heating, applied as Six-Phase Heating, is the selected process option for the direct heating alternative that is evaluated in this FS.

Six-Phase Heating uses a 7-electrode array, with 6 electrodes arranged in a perimeter hexagonal pattern and a neutral electrode located in the center of the hexagon (see Fig. 4.2). A typical array diameter is 8-11 m (25-35 ft), with the heated zone diameter being approximately 40% greater. An electrical conditioner splits the common 3-phase, 60 Hz power source into 6 distinct phases. The power supplied to each of the perimeter electrodes is out of phase with one another. Thus, electrical energy flows among all 7 electrodes, producing near-uniform soil resistance heating. As applied at the PGDP, each of the 7 electrodes would be constructed to serve also as a soil vapor extraction well.

Six-Phase Heating and similar systems are capable of remediating the vadose zone and saturated zone of the UCRS together. As the soil below the water table is heated, the contaminants are heated to the point of boiling (many VOCs boil at temperatures less than the boiling point of water). The gaseous contaminant rises to the water table, due to buoyancy, and partitions to the soil gas. Thus, contaminants may be recovered with or without significant generation of water steam. Direct heating technologies are applicable to both dissolved phase VOCs and DNAPL within the target remediation zones. Direct heating technologies, like Six Phase Heating, that remove water also are capable of remediating ^{99}Tc-contaminated sites.

The direct heating alternative, if it is limited to the primary sources (those in the UCRS), provides no RGA source zone volume reduction or treatment of dissolved phase plumes. In the absence of a Secondary Source Area action, the worst RGA source zones can be expected to contaminate on-site groundwater with VOC levels in excess of MCLs for approximately 1,000 years. Alone, direct heating of the worst UCRS source zones is expected to leave enough residual to contaminate groundwater with VOCs above MCLs for 350 years. Dissolved phase actions could reduce contaminant levels outside of the Primary and Secondary Source Areas to below MCLs in less than 100 years. However, the dissolved phase actions would be required to continue for the 1,000 years until the RGA source zones are depleted.

The direct heating alternative consists of the following primary components:

- implementing Six-Phase Heating to reduce sources of contamination in the UCRS;
- implementing a groundwater monitoring system to monitor the post-action effectiveness of the remedial measure and to provide protection;
- restricting PGDP worker access to groundwater; and
- performing five-year reviews of the alternative as required by CERCLA.

Descriptions of these components are provided in the following sections. Figure 4.2 summarizes the components of the direct heating alternative. The direct heating alternative features significant DNAPL mass reduction in the UCRS DNAPL source zones.

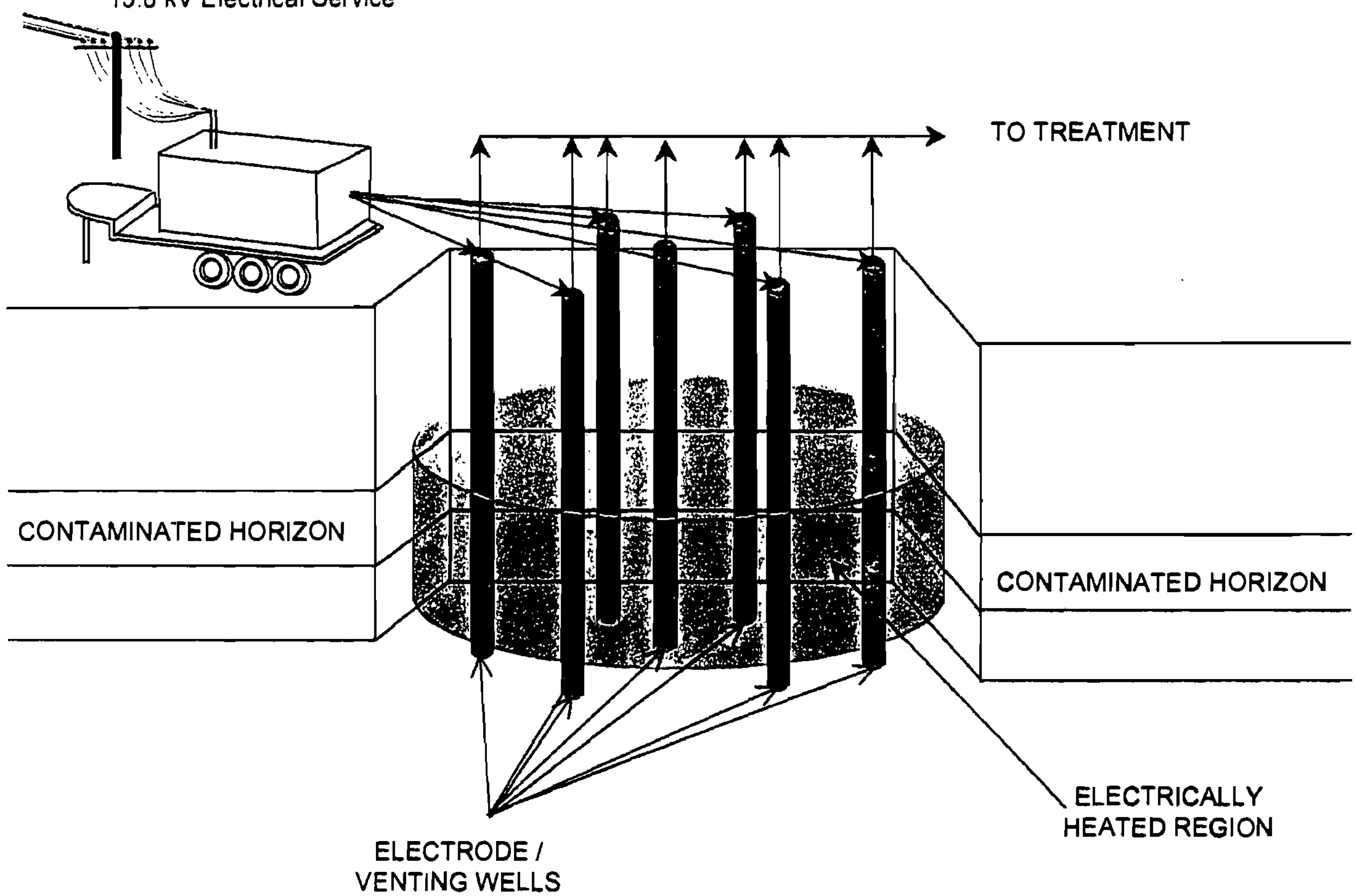


Fig. 4.2. Primary source area - direct heating technology.

U. S. DEPARTMENT OF ENERGY
DOE OAK RIDGE OPERATIONS
PADUCAH GASEOUS DIFFUSION PLANT

BECHTEL JACOBS COMPANY, LLC
MANAGED FOR THE US DEPARTMENT OF ENERGY UNDER
US GOVERNMENT CONTRACT DE-AC-05-98OR22700
Oak Ridge, Tennessee • Paducah, Kentucky • Portsmouth, Ohio

Science Applications
International Corporation
P.O. Box 2502
Oak Ridge, Tennessee 37831

FIGURE No. FS4-2
DATE 05-25-01

Access Restrictions. The primary source areas and highest concentration portions of the groundwater contamination addressed by the GWOU are located within portions of the PGDP that are within security fences. On-site workers are, and would continue to be, alerted to potential exposure hazards at these units through the use of work permits, administrative controls, and safety programs.

Source Reduction Activities in the UCRS. Source reduction activities would be conducted onsite in the UCRS to reduce the level of COCs that are entering the RGA, which is the uppermost aquifer.

Environmental Media Monitoring. The existing groundwater monitoring program would be continued to monitor the movement of COCs. The monitoring program would integrate existing PGDP monitoring wells, where possible, with additional monitoring wells to be installed, as needed, following a review of the existing program.

CERCLA Five-Year Review. It is anticipated that this remedial alternative would result in "contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure"; therefore, this remedial action would be reviewed "no less often than every five years" in accordance with 40 *CFR* 300.430 (f)(4)(ii).

Assessment of Direct Heating Alternative

A detailed analysis of the performance of the direct heating alternative against the nine CERCLA criteria is provided.

Overall Protection of Human Health and the Environment. Implementation of this alternative provides for COC volume reduction in soils and groundwater in UCRS source zone areas. This technology is primarily targeted for DNAPL areas but also has limited effectiveness for the removal of dissolved-phase ^{99}Tc.

The off-gas waste stream would require subsequent surface treatment. It is not expected that ^{99}Tc would contaminate vapor-phase emissions because the radionuclide has a high affinity for liquid water. However, the off-gas waste stream may entrain some liquid water within the vapor extraction system. Thus, the treatment system would include a water treatment system to trap ^{99}Tc on ion exchange resin. The resin would be disposed of or regenerated by an approved mechanism. Processing through a catalytic oxidizer would destroy VOCs produced from vapor extraction.

The continuation of a groundwater monitoring program would provide indirect protection for human health and the environment by minimizing the potential exposure to contaminated groundwater through early identification and avoidance.

Although the direct heating alternative, alone, would not satisfy the Remedial Action Objectives (RAOs) for the GWOU with regards to projection of human health and the environment, this alternative would support the achievement of RAOs when implemented in concert with other source reduction and dissolved phase GWOU technologies.

Compliance with ARARs

Potential chemical-specific ARARs

Chemical contamination. The aquifers are known to contain chemical contaminants in the form of metals and organics. The federal and state water quality requirements include standards that would be applicable ARARs. The regulations that apply are found in 40 *CFR* 141 (National Primary Drinking Water

Standards); 40 *CFR* 143 (Secondary Drinking Water Standards); 401 KAR 5:029 (General Provisions); and 401 KAR 5:031 (Surface Water Standards). These standards, summarized in Table 4.5, include general state standards, domestic water supply standards, and standards applicable to warm water aquatic habitat. These are applicable, based upon the classification of the designation for surface water use associated with the area (Ohio River, River Mile 940.7 to River Mile 943.3), as specified in 401 KAR 5:026. All potentially applicable chemical ARARs for COCs have been included in the table for completeness. Those standards that must be achieved in order to meet the applicable requirements are the lowest of the applicable standards, which in most cases are the MCLs.

Radiological contamination. The GWOU is known to be contaminated with radionuclides such as ^{99}Tc, radon, uranium, and uranium daughter products. The DOE's Order on Radiation Protection of the Public and Environment, DOE Order 5400.5, as codified at 10 *CFR* 835, is TBC information for cleanup of radionuclides at DOE sites. The order requires that remediation activities must not result in radiation exposures to members of the general public greater than an EDE of 100 mrem/year from all exposure pathways. Exposure to the general public also must be ALARA (DOE 1990).

DOE Order 5400.5 also contains reference values, known as DCGs, for operational DOE facilities. Based on the DCGs, radionuclide concentrations in air and drinking water must not exceed an EDE of 10 mrem/year and 4 mrem/year, respectively, to the total body or any organ.

The NRC also has set criteria for decommissioning standards at nuclear facilities at 10 *CFR* 20 Subpart E. These rules require that residual radioactivity at nuclear sites meet a total EDE of 25 mrem/year for unrestricted release. In addition to the NRC standards, EPA has issued guidance for cleanup levels at CERCLA sites with radioactive contamination. EPA has disagreed with the protectiveness specified within the NRC standard and has specified that a 15 mrem/year EDE be used as the risk level that is protective of human health and the environment. EPA also has codified exposure limits for environmental radiation protection standards for nuclear power operations at 40 *CFR* 190. These requirements apply to operations involved in uranium fuel cycle and include enrichment operations. Subpart B of these requirements specifies that the annual dose equivalent to the public not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughter products excepted, to the general environment from uranium fuel cycle operations and the radiation from these operations. These requirements would be considered relevant and appropriate since the release to the groundwater would not be planned releases.

The Commonwealth of Kentucky is an NRC Agreement State and has promulgated regulations for radiation protection of the public. The Kentucky radiation protection standard for individual members of the public is 0.1 rem (100 mrem) EDE per year or less (902 KAR 100:019 Section 10), which is equivalent to the DOE radiation protection standard found in DOE Order 5400.5.

Due to the differing view and values among NRC, EPA, and DOE total EDE for members of the general public, EPA and DOE have agreed not to finalize their respective standards until an agreement can be reached. In the interim, DOE Order 5400.5 is identified as TBC information and the NRC standard is identified as relevant and appropriate. Therefore, the radiation protection standard identified within the NRC regulations at 10 *CFR* 20 Subpart E requiring an EDE of 25 mrem/year or less shall be used as the exposure limit for the general public.

Chemical-specific ARAR summary. The chemical-specific ARARs associated with the implementation of this alternative are outlined in Table 4.5. Implementation of this alternative would not result in immediate attainment of the chemical-specific ARARs associated with the off-site groundwater plumes or surface-water groundwater interfaces (i.e., Warm Water Aquatic Habitat Criteria). Attainment of the identified ARARs would be met in the future as implementation progresses. Although a TBC, the radiological

Table 4.5. Summary of Potential ARARs for Primary Source Area – Direct Heating

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
Chemical-Specific ARARs			
National Primary Drinking Water Standards	40 *CFR* 141	Provides chemical-specific numeric standards for toxic pollutants expressed as MCLs and MCLGs.	These requirements are relevant and appropriate due to the nature of the contaminants found within the groundwater.
National Secondary Drinking Water Standards	40 *CFR* 143	Provides secondary MCLs for public water systems.	These requirements are TBCs, as they have been established as guidelines for the states and are not federally enforceable.
Kentucky Surface Standards including • Warm Water Aquatic Habitat Criteria • Kentucky Domestic Water Supply • Kentucky General Standards • Kentucky Outstanding State Resource Waters	401 KAR 5:031 and 5:026	Provides chemical-specific numeric standards for pollutants discharged or found in surface waters. Provides chemical-specific numeric standards for pollutants in domestic water supplies.	These standards are applicable to the segment of the Ohio River into which the Little Bayou Creek discharges. The requirements found in these standards are applicable due to the groundwater to surface water interface to Little Bayou Creek and subsequently to the Ohio River. Note: CWA Water Quality Criteria are not relevant and appropriate because Kentucky has promulgated these state standards determined to be appropriate for Kentucky waters.
Radiation Exposure of the General Public at DOE Facilities	DOE Order 5400.5	Specifies that the general public must not received an effective dose equivalent of >100 mrem/year from all exposure pathways. In addition, all releases of radioactive materials resulting in doses to the general public must meet the ALARA criteria.	This requirement is TBC information.
Decommissioning Standards at Nuclear Facilities	10 *CFR* 20, Subpart E	Specifies a residual activity at nuclear facilities for unrestricted release of 25 mrem/year.	These standards are considered to be applicable to the GWOU.
Environmental Radiation Protection Standards for Nuclear Power Operations	40 *CFR* 190, Subpart B	Requires that the annual dose equivalent to the public must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment from uranium fuel cycle operations and radiation from these operations.	These standards are considered to be relevant and appropriate and are equivalent to the NRC standards.

Table 4.5. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
Location-Specific ARARs			
Protection of Wetlands	10 *CFR* Section 1022 Executive Order 11990 40 *CFR* 230.10 33 *CFR* 330.5	Activities must avoid or minimize impacts to wetlands to preserve and enhance their natural and beneficial value. If wetland resources are not avoided, measures must be taken to address ecologically sensitive areas and mitigate adverse effects. Such measures may include, minimum grading requirements, runoff controls, design and construction considerations. Allows minor discharges of dredge and fill material or other minor activities for which there is no practicable alternative provided that the pertinent requirements of the NWP system are met.	These requirements are applicable due to the presence of wetlands but will be met through avoidance of wetlands during construction and implementation of alternatives.
Endangered Species Act	16 U.S.C. 1531 et seq. Section 7(a)(2)	Actions that jeopardize the existence of listed species or result in the destruction of adverse modification of critical habitat must be avoided or reasonable and prudent mitigation measures taken.	Action that is likely to jeopardize fish, wildlife, or plant species or destroy or adversely modify critical habitat-applicable.
Migratory Bird Treaty Act	16 U.S.C. 703-711 Executive Order 13186	Federal Agencies are encouraged (until requirements are established under a formal MOU) to do the following: • avoid or minimize, to the extent practicable, adverse impacts on migratory bird resources when conducting agency actions; • restore and enhance the habitats of migratory birds, as practicable; • prevent or abate the pollution or detrimental alteration of the environment for the benefit of migratory birds, as practicable; • ensure that environmental analysis of federal actions required by the NEPA or other established environmental review processes evaluate the effects of actions and agency plans of migratory birds, with emphasis on species of concern; and • identify where unintentional take will likely result from agency actions and develop standards and/or practices to minimize such unintentional take.	Action that is likely to impact migratory birds, habitats, and resources-applicable.

Table 4.5. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Action-Specific ARARs	
Fugitive Dust Emissions during site preparation and construction activities.	401 KAR 63:010	Precautions must be taken to prevent particulate matter from becoming airborne. Such precautions must be incorporated into the planning and design of activities and include actions such as • wetting or adding chemicals to control dust from construction activities; • using materials such as asphalt or concrete (or other suitable chemicals/fixing agents) on roads or material stockpiles to prevent fugitive emissions; and • using covers on trucks when transporting materials to and from the construction site(s). The requirement specifies that for on-site construction activities, no visible emissions may occur at the PGDP fenceline. Similar points of compliance shall be identified for construction activities that occur outside the fence.	These requirements are applicable and will be met through the use of appropriate dust control practices identified during alternative design phase.
Toxic Emissions	401 KAR 63:022	The regulations require that a determination of toxic emissions be made in order to assess the applicability of required controls. Calculations of the significant emission levels are compared to the allowable emission limits specified in Appendix A of 401 KAR 63:022. If emission levels are exceeded, the best available control technologies must be incorporated into equipment/process design.	These requirements are considered to be applicable and shall be complied with through calculation of significant emission levels for toxic materials and application of the best available control technology, as necessary, during the design of the alternative.
Monitoring Well Installation	401 KAR 6:310	Monitoring wells (including extraction wells) must be constructed in a manner to maintain existing protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole. In addition, abandoned wells must be plugged and abandoned in accordance with the requirements specified.	These requirements are considered to be applicable. Compliance with well design and protection standards shall be achieved through the use of approved well design and materials of construction. While in service, wells shall be secured as required. Abandoned wells shall be plugged and abandoned as required.
Discharge of Stormwater and Treated Groundwater	40 *CFR* 122 401 KAR 5:055	Stormwater discharges from construction activities on-site are subject to the requirements of the KPDES permit. This requires the BMPs to control stormwater runoff and sedimentation be employed. Although off-plant construction activities within the contaminated area are not subject to the permit, these requirements should be considered relevant and appropriate and be incorporated into any off-site construction activities. Discharge of treated groundwater will be conducted in compliance with the substantive requirements of the KPDES program and the CWA.	These requirements are considered applicable for all on-site construction or treatment activities where a discharge of stormwater or treated groundwater occurs. For off-site construction activities, these requirements are considered relevant and appropriate and will be adhered to. Compliance with these ARARs shall be achieved by application of required controls during the design phase of the alternative.

Table 4.5. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
Hazardous Waste Management	40 *CFR* 260 through 264 and 268 401 KAR 31 through 34, 36 and 37	All wastes or environmental media containing wastes must be characterized to determine whether the waste also is a hazardous waste in accordance with 40 *CFR* 262.11 and 401 KAR 32:010. If it is determined that a waste is a hazardous waste or that environmental media contain a hazardous waste subject to the RCRA regulation, the substantive requirements of 40 *CFR* 262 through 268 are applicable. These standards include design and operation of storage and accumulation areas, waste handling and shipment, and treatment technologies or numeric standards applicable to wastes prior to disposal.	These requirements are applicable and will be complied with through characterization of wastes and environmental media generated as a result of implementation of the alternative. Waste management will be predicated upon the characterization and will comply with all substantive requirements associated with hazardous waste management, if identified as such.
PCB Waste Management	40 *CFR* 761	TSCA requirements for the management of PCB wastes or items containing >50 ppm PCBs or from a source of 50 ppm or greater. Requirements include the following: • management of waste and material; • characterization of PCB-containing materials; • labeling and storage for disposal; • manifest completion for shipment off-site; • decontamination of affected equipment or items; and • disposal of PCB wastes. These requirements will be complied with in the event that PCBs are found at concentrations requiring compliance with this part.	These requirements are applicable if PCBs are found or result from items or equipment regulated under 40 *CFR* 761. Activities necessary to comply with these ARARs shall be incorporated into the planning phase of the alternative implementation.

ALARA = as low as reasonably achievable
ARAR = applicable or relevant and appropriate requirement
BMP = best management practice
CFR = *Code of Federal Regulations*
CWA = Clean Water Act
DOE = U.S. Department of Energy
GWOU = groundwater operable unit
KAR = Kentucky Administrative Regulation
KPDES = Kentucky Pollutant Discharge Elimination System
MCL = maximum contaminant level
MCLG = maximum containment level goal
NRC = Nuclear Regulatory Commission
NWP = Nationwide Permit
PCB = polychlorinated biphenyl
PGDP = Paducah Gaseous Diffusion Plant
RCRA = Resource Conservation and Recovery Act
TBC = to be considered
TSCA = Toxic Substances Control Act

exposure standards included in DOE Order 5400.5 shall be achieved and will be confirmed through monitoring. Continued monitoring of the groundwater will be used during the five-year reviews to ensure that identified goals are met and that concentrations of COCs continue to decrease.

Potential location-specific ARARs

Wetlands. Although no wetlands have been identified within the area where construction activities will occur, certain jurisdictional wetlands have been identified in on-site drainage ditches within the plant boundary. In order to comply with these applicable requirements, wetlands shall be avoided.

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, 40 *CFR* 6.302(a), 40 *CFR* 6 Appendix A, 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 the 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. Although not anticipated, if this alternative results in impacts to wetlands that cannot be avoided, the substantive requirements of the NWP 38 (33 *CFR* 330) will be met.

Implementation of this alternative is not anticipated to impact wetlands during the construction or implementation phase. Compliance with these applicable requirements shall be attained to the greatest extent possible through careful planning during the location of the specific areas for installation. All treatment activities conducted *in situ* and *ex situ* are not anticipated to result in the discharge of COCs to wetlands, thereby complying with the requirements.

Endangered Species and Migratory Birds. Actions taken by federal agencies are prohibited from impacting T&E species or adversely modifying critical habitats (50 *CFR* 17.94) in accordance with the Endangered Species Act (16 USCA 1531 et *seq*. Section (7)(a)(2)). These requirements are potential ARARs in the event T&E species or their habitats are found at or near areas where remedial action is to occur. An ecological resource investigation inside the PGDP security fence did not detect any T&E species or their preferred habitats (CDM Federal 1994). The USFWS has not designated critical habitat for any species within the DOE property. However, outside the PGDP fence on the DOE property, potential habitat for federally listed T&E species was reviewed, and Indiana bat habitat was evaluated during the COE (1994) environmental investigation. The COE study determined that total potential bat habitat consisted of 20% of the 994-ha (2,456-acre) study area. Remedial activities must be evaluated to ensure that such actions do not adversely impact areas identified as critical habitat for any identified endangered species.

In addition, Executive Order 13186 directs federal agencies to enter into an MOU with the USFWS to further the purposes of the Migratory Bird Treaty Act (16 U.S.C. 703-711). Until such time as the MOU between DOE and the USFWS is finalized, federal agencies are encouraged immediately begin implementing the conservation measures set forth in the Executive Order. The requirements of the Executive Order are applicable and must be considered during planning and design of the remedial action.

Potential action-specific ARARs

Monitoring well installation requirements. This alternative includes the installation of additional monitoring and extraction wells. Installation of these wells would have to be conducted in a manner to maintain existing natural protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole (401 KAR 6:310 Section 13). These requirements also mandate the construction materials required for well construction, well design criteria, well completion activities, and well abandonment methodologies. These requirements are considered applicable to design and installation of monitoring and extraction wells associated with the implementation of this alternative.

Fugitive dust emissions. Construction activities on-site and off-site may result in the production of particulate airborne pollutants (dust). The Kentucky Air Quality standards found in 401 KAR 63:010 include requirements governing fugitive dust emissions. These standards require that dust suppression measures be undertaken, which include activities such as the use of water or chemicals to control emissions, placement of asphalt or concrete, and stockpiling of soils. The standards also require that visible dust generated from the implementation of the remedial alternative not be discharged beyond the property boundary of the site. These requirements are considered to be applicable to the implementation of this alternative and will be complied with through careful planning to ensure that disturbed or excavated materials are sufficiently wetted or protected to control dust generation. Specific activities that could result in the generation of fugitive dust that must be considered during the design phase include construction, well installation and excavation/disposal of contaminated soils. For off-site construction activities, the point of compliance for airborne dust emissions must be identified, in addition to the application of material-handling practices necessary to control such emissions.

Radionuclide emission standards. Airborne emissions of radionuclides may occur as a result of on-site construction and treatment activities. Although the potential is low for such emissions to occur, the regulations, which require that the emissions not exceed amounts that would cause an EDE to the public of 10 mrem/year, at 40 *CFR* 61.92 would be applicable. In order to determine whether the alternative complied with this applicable requirement, computer modeling using the CAP-88 or other EPA-approved model must be undertaken. If the modeling demonstrates that the radionuclide emission is in excess of 1% of the 10 mrem/year standard, emission rates must be measured as required by 40 *CFR* 61.93. This ARAR shall be complied with by planning activities in such a manner as to control fugitive emissions from construction activities.

Toxic emission standards. Increases in toxic emissions are expected as a result of treatment activities; therefore, emission requirements associated with toxic emissions would be applicable. The regulations at 401 KAR 63:022 require that the emissions be evaluated to determine whether they are significant for each specific toxic air pollutant. If analysis indicates the toxic emission requirements are triggered, the regulations specify that no source may exceed the allowable emission limit specified in Appendix A of 401 KAR 63:022. In order to demonstrate compliance with these requirements, estimates of emission rates must be made. These estimates and subsequent calculations will be used to determine whether significant emissions requiring engineering controls can be expected though application of the thermal treatment. If applicable, these rules would require the application of best available control technology to limit toxic emissions. If calculations indicate that the emission rates specified within the rule are not exceeded, then the calculation package may be used to demonstrate compliance with these requirements. Activities that must be considered include thermal treatment of soils and contaminated groundwater.

Stormwater discharge. Construction activities will be subject to the substantive requirements associated with the KPDES permit that requires the use of BMPs and sediment/erosion controls to control transport of sediment in stormwater runoff for construction activities. BMPs shall be developed during the planning and design phase of the implementation of the alternative. These shall include erosion control and sedimentation features such as silt fences and grading, as necessary, in order to comply with this ARAR.

Action-specific ARAR summary. Fugitive emission requirements for dust shall be complied with through the application of appropriate engineering and material management controls such as wetting or covering of materials during construction. Specific actions shall be developed during the planning phase of alternative implementation. In addition, points of compliance for fugitive dust emissions shall be established.

Emissions associated with radionuclides and toxic materials are expected to increase as a result of the thermal treatment associated with this alternative. Emission estimates and required modeling to ensure that receptors are not put at risk during the construction and operations phases are required to demonstrate compliance with the requirements, at a minimum. In the event emissions are identified that require emission controls, these controls shall be incorporated into the design of the treatment system, as necessary, to ensure compliance with the identified standards.

Compliance with stormwater runoff and sediment control requirements shall be considered either as applicable or relevant and appropriate standards. BMPs shall be developed during the planning and design phase to ensure that stormwater discharge requirements are met. Treatment of contaminated groundwater shall be conducted in order to meet the substantive requirements of the KPDES program and the CWA.

A summary of the ARARs for the implementation of Primary Source Zone Direct Heating Technology Alternative is presented in Table 4.5.

Compliance with ARARs summary. Implementation of this alternative would not achieve immediate compliance with the MCL for TCE. In addition this alternative would not address any contamination of soils or groundwater with metals or radionuclides.

In order to comply with the identified chemical-specific ARARs, an ARAR waiver will be required due to the time frames required to meet the specified concentrations within the GWOU at the point of compliance and points of exposure.

As discussed, no potential location-specific ARARs have been identified within the area in which remedial action will occur. However, to ensure that jurisdictional wetlands are not impacted, all construction activities (well installation) associated with this alternative will be reviewed as a safeguard. The protection of wetlands is not considered a location-specific ARAR at this time because jurisdictional wetlands have not been identified within the areas impacted by the implementation of this alternative.

Construction and implementation of the alternative may trigger several action-specific ARARs such as the requirements associated with well installation and abandonment, fugitive dust emissions, radionuclide emissions, toxic emissions, and discharge of stormwater and treated groundwater. The requirements associated with the installation and abandonment of groundwater wells will be triggered and met though the use of well designs and materials of construction as specified at 401 KAR 6:310 Section 13. All well installation and abandonment practices incorporated into the remedial design shall comply with the substantive requirements of 401 KAR 6:310. Specific designs will be developed and approved before implementation of this alternative.

Fugitive dust emissions that may occur during construction activities will be controlled as required by 401 KAR 63:010. BMPs, such as the wetting or covering of potential sources of fugitive dust, will be incorporated into the remedial design. The specific actions to be developed shall control potential emission sources to ensure that dust emissions do not migrate from the immediate area where construction activities occur. It is anticipated that, in most cases, the moisture content in the soil will be sufficient to control dust emissions during well installation. However, practices such as wetting of disturbed soils, collection of soils, or reseeding activities shall be considered and incorporated into the remedial design, as necessary, to ensure compliance with these requirements. Radionuclide emissions at construction sites also must be considered during the implementation phase. To ensure that the emission standards of 10 mrem/year EDE to the public is met, concentrations of radionuclides in soils and groundwater must be evaluated. If the potential for such emissions is identified, modeling using the CAP-88 or other EPA-approved methods must be undertaken during the design phase of the alternative. It is anticipated that the primary conveyance of airborne radionuclides will be in particulate form; therefore, control of fugitive dust emissions also will result in compliance with the emission standards applicable to radionuclides. If radiological contamination from plant activities is found in soils where construction activities are planned, the soil will be protected or containerized to prevent airborne migration. Measures necessary to prevent airborne emissions or radionuclides shall be evaluated and incorporated, as appropriate, into the remedial design in order to comply with these requirements during implementation of this alternative.

Emissions of toxins such as volatile organics also must be evaluated before implementation. Although the potential for exceedance of toxic air emissions is considered to be low, an evaluation of the potential for such emissions must be undertaken during the remedial design. Potential emissions must be evaluated for each toxin present in the plumes (i.e., TCE, vinyl chloride, etc.) to determine whether the contaminant levels found in the subsurface could result in airborne emissions in excess of the allowable limits specified in Appendix A of 401 KAR 63:022. Compliance with the emissions standards shall be achieved for this alternative through the evaluation process or the application of best available control technology where emissions are calculated to exceed allowable levels. Emission control equipment will be incorporated into implementation activities during the remedial design, as necessary, based upon the initial evaluation. This evaluation shall be conducted for each activity that has the potential to emit toxics. This requirement will be complied with during implementation of the alternative.

The construction activities associated with this alternative may require that BMPs for sedimentation/ erosion controls be established if the extent of the disturbed area exceeds regulatory trigger levels. These requirements will be complied with through use of sediment fences or other appropriate means. The control of sedimentation and runoff is a TBC in the event that the areal extent of the construction does not exceed the five acres specified within the rules. The remedial design shall incorporate the specific controls necessary to ensure that the construction sites do not allow sedimentation and or erosion of disturbed areas in order to comply with this requirement during implementation of this alternative.

Soils from the installation of wells as a part of this alternative will trigger the characterization requirements associated with RCRA. The implementing regulations found at 40 *CFR* 262 and 401 KAR 32:010 require that generators of solid wastes (or contaminated environmental media) must determine whether the waste also is a hazardous waste. If the materials generated from the implementation of this alternative are found to be hazardous wastes, the materials shall be containerized and managed as such. The requirements mandate that hazardous wastes must be properly labeled and stored in areas that comply with the technical standards for storage of hazardous waste in containers. These standards shall be complied with though testing of soils before excavation activities. If the soils are found to be hazardous, appropriate storage areas shall be constructed and maintained. All hazardous waste generated during the implementation of this alternative shall be disposed of in an approved landfill. These activities shall be incorporated into the remedial design for this alternative in order to comply with these requirements.

This alternative also may result in the generation of soils that contain regulated PCBs. As required under 40 CFR 761, soils will be characterized to determine their regulatory status under the rule and, therefore, be managed accordingly. If soils are found to be regulated PCB remediation wastes they shall be stored in conforming storage that is properly marked and in proper containers before disposal at an approved facility. Equipment that becomes contaminated with PCBs during the remedial action must be decontaminated, as required under the decontamination standards, and tested before release. Testing using the swipe method shall be conducted, and no equipment shall be released until it is demonstrated that the surface concentration of PCBs is below 100 mg/100 cm^2.

Soils found to contain radiological contamination also must comply with the requirements of DOE Order 435.1 for the handling of low-level radioactive wastes at DOE facilities. All containers of soils that are low-level radioactive waste shall be properly marked and stored (if necessary) before disposal.

Long-Term Effectiveness and Permanence. This evaluation addresses the results of the direct heating alternative in terms of risk remaining at the site after completion of the action and the effects of required long-term controls. A discussion of the magnitude of residual risk at the site and adequacy and reliability of controls is presented in the following sections.

Magnitude of residual risks. The direct heating alternative is designed to remediate contaminated groundwater by reducing COC volumes in source areas. Nonaqueous phase VOCs are likely to remain in place following treatment of the UCRS by direct heating. However, it is expected that direct heating would have a greater efficiency of contaminant removal than vapor phase extraction. As long as the VOCs and ^{99}Tc levels remain high in the source areas, the residual risk would remain high in the source area and downgradient areas. For a prolonged period following the startup of the alternative remedial action, the residual risk would remain consistent with the risk present prior to taking the action. Residual VOC levels would remain elevated for approximately 350 years for the areas of worst DNAPL contamination after implementation of this alternative. Direct heating would have to be implemented in concert with other UCRS and RGA technologies to achieve MCLs at the Points of Compliance in a reduced time frame.

Five-year reviews, mandated by CERCLA [40 *CFR* §300.430(f)(4)(ii)], would be required to demonstrate the integrity and effectiveness of controls and confirm that additional exposure pathways have not developed.

Adequacy and reliability of controls. The direct heating alternative would have a moderate reliability for operation and control. Six-Phase Heating has been applied successfully at six full-scale cleanups. Catalytic oxidation and ion exchange have been used extensively for the treatment of air and water and have proven to be reliable. Due to the potential for high COC concentrations, the system design likely would require redundancy in treatment equipment to ensure acceptable COC removal from effluents. Because of this redundancy of treatment units, pumps, etc., the system would have flexibility, allowing the system to continue effective operation at a reduced capacity. The complete system, with electrodes and monitoring wells, would be located inside the secure area of PGDP. The long-term control for this alternative (i.e., groundwater monitoring) is adequate and reliable.

Environmental impacts and mitigative measures. The following text describes potential long-term impacts to resources and mitigative measures to offset any potential impacts. The depth of impact analysis and mitigative measures is correlated to the degree to which a resource may be impacted.

Land use. Implementation of this alternative would result in minimal adverse impacts to land use. Long-term impacts would be related primarily to monitoring wells. Following construction of the alternative, the bulk of the land disturbed during construction would be returned to its prior use. A LUCIP would be developed, as necessary, per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomics. The socioeconomic conditions of the PGDP and surrounding area would not be expected to change as a result of implementing the direct heating alternative. Construction contractors would perform the construction and operation of the facilities for the alternative. The permanent jobs that could develop as a result of this action are small in relation to the size of the population of the surrounding area. The implementation of the direct heating alternative also would not result in a substantial decrease or increase in the personnel at PGDP. However, the presence of contaminants in the groundwater may prevent groundwater's use and may limit economic development opportunities until the groundwater is brought back to beneficial use.

Air quality and noise. Long-term degradation of air quality is not expected as a result of the implementation of this alternative. The VOCs that are removed from the extracted soil gas are destroyed by catalytic oxidation and do not become air COCs. The potential for a temporary increase in fugitive dust emissions during construction would be mitigated by keeping dust prone areas watered to suppress dust.

No long-term increase in noise is expected from this alternative. During construction, there would be local increases in noise levels because of operating machinery. However, the noise increase would be in a limited area and would not affect human receptors. Hearing protection would be used to protect the workers constructing the system.

Vegetation. Construction of the direct heating system would be located in the active industrial section of the PGDP and would impact only replanted grasses. Once construction is concluded, disturbed vegetation could be restored through seeding and natural regeneration. Therefore, no long-term impacts to vegetation are expected from the implementation of this remedy. The installation of the electrode and monitoring well system may take several months.

Wildlife. Activities associated with this alternative could result in a limited, temporary disruption of the habitat of birds, mammals, and reptiles inhabiting the immediate area surrounding the electrodes. However, no long-term impact to wildlife would be expected.

No adverse impacts are expected for aquatic life in the KPDES outfalls and creeks. The implementation of the direct heating alternative would not require construction activity in the creeks and outfall tributaries.

Threatened and endangered species. No adverse impacts were identified that would result from implementing this alternative. The potential roosting areas of the Indiana bat, as identified by Bryan (COE 1993), are not located in the expected area for this alternative.

Cultural resources. No long-term effects are anticipated for this alternative.

Groundwater. The on-site activities associated with this alternative are designed to reduce the UCRS sources of VOCs and, to a limited degree, the ^{99}Tc.

Surface water. The relative contribution of the discharges of treated groundwater to the flow of Bayou and Little Bayou Creeks would be small. Implementation of this alternative is not expected to impact surface water quality. Silt and erosion controls would be used during construction activities. The treatment system would be designed to remove the COCs from the extracted groundwater and to meet substantive release requirements of the PGDP's KPDES permits.

Floodplains. No impacts are expected with the implementation of the direct heating alternative. The action would not take place in any floodplain of any stream at PGDP.

Wetlands. The implementation of this alternative should not impact the hydrology of wetlands in the area. All construction activities are expected to be within the main area of the PGDP and outside of wetland areas.

Soils and prime farmland. No long-term impacts are expected from the implementation of this alternative. Minor impacts would occur to soils in the areas of construction during implementation of the direct heating alternative. Impacts would be mitigated through the use of standard construction practices of placing erosion and drainage control in the construction areas as necessary. During electrode installation, testing, and operation, the potential exists for the release or spill of small volumes of contaminated water. These potential releases would be mitigated through the use of engineering measures to contain spills and contaminated soils. The area impacted would be small and would be affected only for a short time.

Transportation. No long-term direct or indirect effects are anticipated for this alternative. The implementation of the direct heating alternative would result in transportation of environmental soil and groundwater samples to laboratories. During the operation of the alternative, ion exchange resins would be transported to treatment, storage, or disposal facilities. Standard engineering practices would be used to ship these waste materials. Also, all applicable regulatory requirements would be followed for shipment of LLW materials.

Cumulative impacts. Cumulative impacts are defined as the incremental impact of an action when added to other past, present, and reasonable, foreseeable future actions, regardless of what agency or person undertakes other such actions. Cumulative impacts resulting from this alternative would have to be identified at a later time during development of site specific GWOU decision documents.

Reduction in Toxicity, Mobility, or Volume Through Treatment. Implementation of the direct heating alternative would result in source volume reduction. Although direct heating is primarily effective for the removal of VOCs, some reduction in dissolved phase ^{99}Tc may be realized. Direct heating of all DNAPL zones would be expected to remove up to 99% of the UCRS DNAPL. Any contaminated water that may be extracted as part of direct heating would be treated to remove ^{99}Tc before releasing the water to the area creeks. The ^{99}Tc would remain adsorbed to the ion-exchange resin and would not be destroyed. Any entrained water should be effectively heated and air stripped within the off-gas collection system. The resulting vapor phase would be passed through a catalytic oxidizer to destroy VOCs. Nearly 100% of the extracted contaminants would be treated and/or destroyed. However, since the VOCs and ^{99}Tc are only incrementally removed, the toxicity of the COCs would continue for an extended period after the implementation of this alternative.

Source reduction can be stopped before completion of the remediation goals. However, it is expected that the direct heating alternative would cause some irreversible changes to the area soils. The soil texture likely would be disrupted by desiccation. Moreover, direct heating may induce precipitation of mineral cements.

The VOC levels in the UCRS would be reestablished once the operations are discontinued. However, the implementation of this alternative may shrink the UCRS DNAPL zone, leading to a reduced area of impact in the RGA, and should significantly reduce the time over which the VOCs would persist in a DNAPL phase. Direct heating is anticipated to leave less residual contamination than vapor extraction.

This alternative would meet the preference for treatment via an *ex situ* treatment system. Following treatment of the extracted soil gas, treatment residuals would exist. The VOCs are destroyed through catalytic oxidation. Sodium chloride, produced from the scrubbing of the off-gas, would be a primary treatment residual. Spent ion-exchange resin, from the treatment of the ^{99}Tc, also would be a primary treatment residual. The spent ion-exchange resin would be a LLW.

Short-Term Effectiveness. This criterion involves the evaluation of alternatives for community protection, worker protection, environmental impacts, and the time until remedial response actions are achieved. A discussion of each is provided in the following paragraphs.

Community protection. The potential for adverse impacts to the community from the implementation of this alternative is minimal. Engineering controls would be used to reduce off-gas emissions. This alternative would be implemented within the PGDP or just outside the security fence and should not result in danger to the surrounding community. Restrictions would be used to limit the access of persons that may be in the area during construction. This would include warning signs, temporary control fencing, and periodic security patrols. Also, environmental monitoring would be conducted during the construction of electrodes and monitoring wells where COCs may be present.

Worker protection. Implementation of the direct heating alternative has the potential for worker exposure to contaminated subsurface soils and groundwater during environmental sampling, electrode installation, and remedial operations. The possible exposure pathways include inhalation of dust containing contaminated soils, dermal contact with subsurface soils, and dermal contact with contaminated groundwater. In addition, direct heating poses a potential contact-with-heated-elements hazard to the site worker. The large electrical loads required for Six-Phase Heating are associated with increased electrical hazards. However, worker exposure is very unlikely due to the PGDP risk management requirements (i.e., worker protection procedures, PPE, and engineering controls for off-gas treatment).

Potential environmental impacts and mitigating measures. Short-term environmental impacts and mitigative measures have been qualitatively assessed and include an evaluation of the impacts on environmentally and potentially sensitive ecological resources, short-term impacts on socioeconomic and cultural resources, and cumulative impacts of the remedial construction.

Land use. Implementation of this alternative would result in minimal adverse impacts to land use related to treatment facilities and electrodes. Following construction and operation of the alternative, the bulk of the land disturbed during construction would be returned to its prior use. A LUCIP would be developed as necessary per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomics. The socioeconomic conditions of the PGDP and surrounding area would not be affected. Construction contractors would perform construction and operation of the facilities for the direct heating alternative. The number of permanent jobs that could develop as a result of the action is small in relation to the size of the population of the surrounding area. Implementation of the direct heating alternative also would not result in a decrease or increase of personnel at the PGDP.

Air quality and noise. The potential for a short-term, temporary increase in fugitive dust emissions during construction would be mitigated by keeping dust-prone areas watered to suppress dust. Off-gas treatment would prevent degradation of air quality during operation. There would be local increases in noise levels due to operating machinery during construction. However, the noise increase would be in a limited area. Hearing protection would be used to protect the workers constructing the system.

Vegetation. Construction of the direct heating systems would be located in the active industrial section of the PGDP and would impact only replanted grass. Once construction is concluded, disturbed vegetation could be restored through seeding and natural regeneration.

Wildlife. The implementation of the direct heating alternative would occur in the industrial portion of the PGDP and not require activity to take place in the creeks and PGDP outfall tributaries. No adverse impacts are expected for aquatic life. During construction, the potential impacts to the wildlife and creeks are through migration of sediments and erosion. Standard engineering practices of providing erosion-control fencing, materials, and fabrics in the construction areas would minimize these impacts.

Threatened and endangered species. No adverse impacts have been identified that would result from the implementation of the alternative. The Indiana bat, which regionally has suitable habitat, is not expected to be impacted by this alternative. The potential roosting areas of the Indiana bat, as identified by Bryan (COE 1993), are not located in the expected area for this alternative

Cultural resources. No long-term effects are anticipated for this alternative.

Groundwater. The on-site activities associated with this alternative are designed to reduce levels of VOCs and, to a limited extent, ^{99}Tc in the UCRS DNAPL zones. This alternative is not expected to result in additional groundwater degradation.

Surface water. The implementation of this alternative is not expected to impact surface water quality. Silt and erosion controls would be used during construction activities. The treatment system would be designed to meet substantive release requirements of the PGDP's KPDES permits. The relative contribution of the discharges of treated groundwater to the flow of Bayou and Little Bayou Creeks from the implementation of this alternative would be insignificant.

Floodplains. No impacts are expected with the implementation of the direct heating alternative. The actions would not take place in any floodplain of any stream at the PGDP.

Wetlands. This alternative would be implemented within the main industrial area of the PGDP and should not impact the hydrology of wetlands. Silt and erosion control measures would be used during construction activities to minimize impacts to wetlands.

Soils and prime farmland. No significant short-term impacts are expected from the implementation of this alternative. Impacts would be mitigated through the use of standard construction practices of placing erosion and drainage control in the construction areas as necessary. During electrode installation, testing, and treatment facility operation, the potential exists for the release and spill of contaminated water. These potential releases would be mitigated through the use of engineering measures to contain spills and contaminated soils.

Transportation. Only minimal short-term direct or indirect effects are anticipated for this alternative. The implementation of the direct heating alternative would result in transportation of environmental soil and groundwater samples to laboratories. During the operation of the alternative, it would be necessary to transport ion-exchange resins to treatment, storage, or disposal facilities. Standard engineering practices would be used to ship these waste materials. Also, all applicable regulatory requirements would be followed for shipment of LLW materials.

Cumulative impacts. Cumulative impacts are defined as the incremental impact of an action when added to other past, present, and reasonable, foreseeable future actions, regardless of what agency or person undertakes other such actions. Site-specific GWOU decision documents would have to identify cumulative impacts resulting from the implementation of this alternative, if selected.

Time until remedial response objectives are achieved. The direct heating alternative would not result in achievement of RAOs specified for the GWOU or MCLs without the implementation of additional groundwater remedial measures. However, achievement of targeted contaminant reductions at each specific source zone would be completed in less than 2 years from the beginning of implementation at each source zone. This alternative, alone, would not provide protection for the groundwater or surface water user for approximately 1,000 years.

Implementability. Activities to be conducted under the direct heating alternative include:

- implementing Six-Phase Heating to reduce specific sources of contamination in the UCRS;
- maintaining on-site groundwater monitoring to provide protection until the remedial actions have been completed;
- maintaining off-site groundwater monitoring to provide protection until the remedial actions have been completed; and
- performing five-year reviews of the alternative as required by CERCLA.

Technical feasibility. Direct heating is a developing remediation technology available from a limited number of vendors. Construction of Six-Phase Heating electrodes is technically feasible. However, technology-specific equipment is required for operation. It is expected that the industrial setting of the PGDP may create difficulties in some source zone areas. The equipment that would be used in the vapor treatment facility is standard and proven technology. Downtime is expected to be minimal for maintenance and repairs. Effluent sampling of the released off-gas would ensure that the treatment systems are meeting the effectiveness goals of the alternative.

Direct heating has been used successfully at six other contaminated sites. The increase in soil conductivity (permeability) associated with direct heating would be advantageous in the low conductivity UCRS soils.

The construction and operation of this alternative would not prohibit the implementation of other GWOU technologies.

Administrative feasibility. The alternative is administratively feasible. Treated air meeting the substantive requirements of the state and federal regulations would be discharged as part of this alternative. Treatment, handling, and transportation and disposal of the residuals would require proper procedures; however, no difficulties are expected.

Availability of services and materials. Services and materials for the construction of this alternative are available from a limited number of vendors. It is estimated that less that six vendors are available and experienced in implementing direct heating technologies.

This alternative would result in the generation of waste soil cuttings from the construction of electrodes and soil vapor extraction wells. The construction of treatment facilities may generate clean concrete, wire, and pipe construction debris. All of these materials either would be treated, as necessary, and released or disposed of appropriately.

The operation of the treatment system would result in the generation of sodium chloride, from the scrubbing of the catalytic oxidizer off-gas, and ion-exchange resins spent with ^{99}Tc. Both of these materials would be stored until appropriate disposal can be arranged.

Cost. Table 4.6 summarizes the preliminary unit cost estimates for the direct heating alternative. These preliminary unit cost estimates are based upon FS-level scoping and are intended to aid with selection of a preferred alternative. The estimates have an expected accuracy of -30% to +50% for the proposed scope of action (EPA 1988a). The capital cost estimate represents those expenditures required to implement this remedial alternative. The O&M cost estimates represent expenditures required to maintain the remedy after the initial phase of remedial action construction is completed. The total contingency cost presented includes direct, indirect, and all O&M-associated contingency costs. The total cost includes all capital costs, direct and indirect with O&M and associated reports, plus 25% contingency costs, for a 30-year term of comparison. All estimates have been escalated using DOE-approved annual rates and a schedule for the various activities based on similar project experience. Present worth values also are included using a discount factor of 5% (EPA 1988b). (Additional information regarding the preliminary cost estimates is presented in Appendix C7.)

State/Commonwealth Acceptance. The Commonwealth of Kentucky acceptance or nonacceptance of this alternative would be addressed in the GWOU decision documents should the direct heating alternative be selected as the preferred alternative.

Table 4.6. Preliminary unit cost estimates for the direct heating alternative

Total capital costs (per acre-foot)	$460,948
Total operation and maintenance costs	$60,727
Overhead	$108,831
Total contingency	$64,329
Total cost	**$694,837**
Total cost (present worth)	**$434,759**

Note: preliminary cost estimates are per acre-foot, escalated and presented in dollars.

Community Acceptance. Following a formal public comment period on the PRAP for the GWOU, comments from the community would be addressed formally in a responsiveness summary, which would be presented in the appropriate GWOU ROD.

Evaluation summary of the direct heating alternative

The direct heating alternative would involve implementation of UCRS source zone remedial actions and environmental media monitoring to track COC migration. UCRS source zone remedial actions would remove large quantities of COC mass in a short period of time, resulting in lowering the COC concentrations available to impact migrating groundwater in the RGA. Implementation of monitoring would provide an indirect protection, as monitoring COC migration allows for minimizing the potential for exposure to contaminated environmental media through avoidance. Because the source areas would be aggressively remediated, the residual risks left in place would be reduced but not removed. However, residual risk in the source areas would not be unacceptable under future industrial land use. Residual risk also would remain in the off-site plumes until remediation of the whole plume is completed and successful. Short-term risks to construction workers would exist, due to potential exposure to contaminated groundwater during environmental monitoring activities and maintenance of the treatment systems. Additional exposure is possible due to dermal and inhalation contact during changeout of treatment media, exposure to heated surfaces, and exposure to electrical hazards. However, risks to workers would be minimized by strict adherence to approved risk management procedures (e.g., health and safety plan and use of PPE).

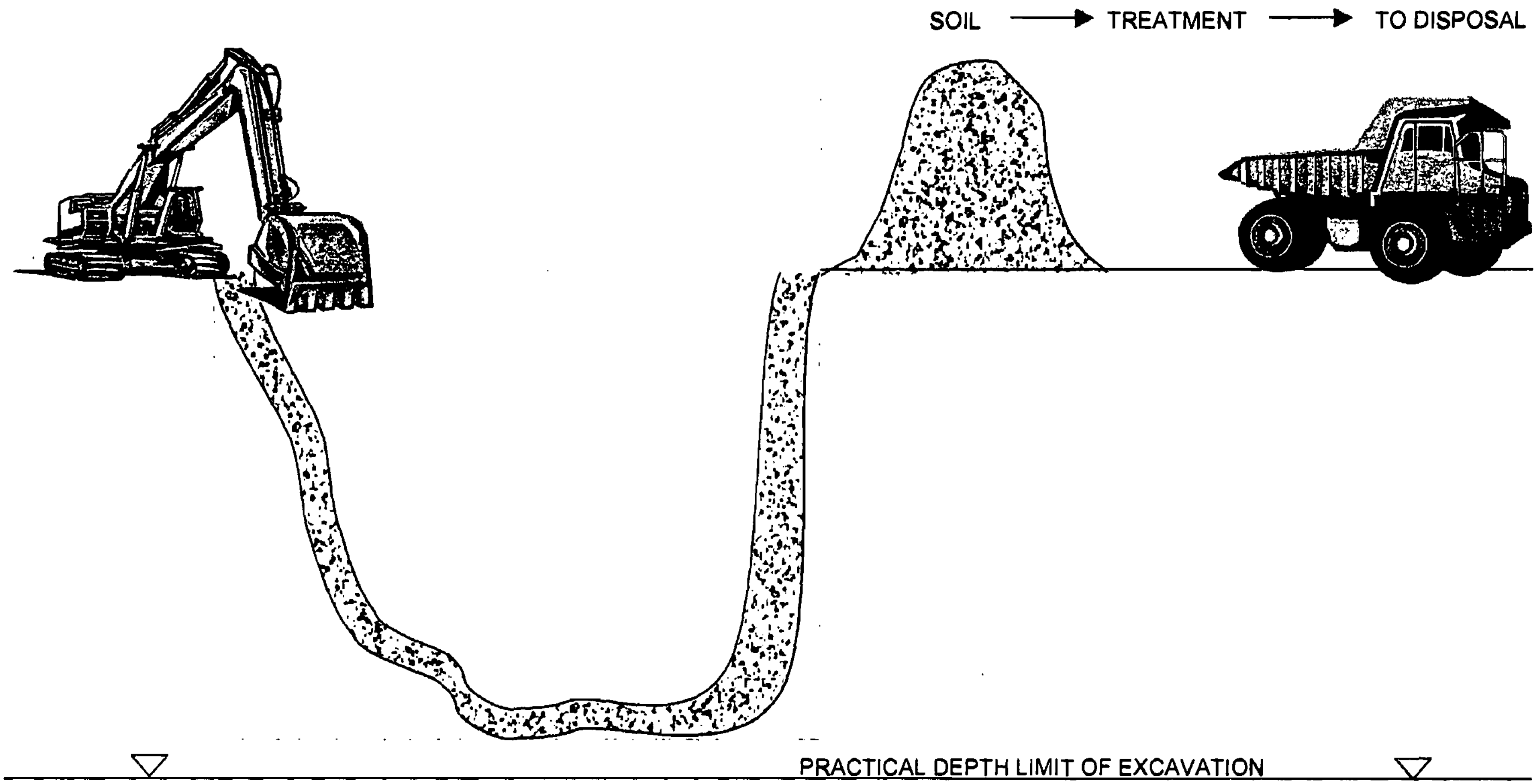
Implementation of the direct heating alternative would require high capital for implementation and moderate O&M costs. Input from the Commonwealth of Kentucky and the community has not yet been received but would be added to a GWOU ROD once the public comment period has been completed.

4.2.2.3 Primary Source Area — Excavation Technology

The following section contains a description of the Primary Source Area – Excavation Technology and its detailed analysis.

Description of Primary Source Area — Excavation

This technology for the GWOU provides for the excavation of primary contaminant source areas in the UCRS and the appropriate treatment/disposal of the excavated material. Fig. 4.3 contains a graphical "snapshot" representing the primary source excavation technology. Excavation would remove all contaminants from the source area, including DNAPL, thereby preventing additional COCs from entering the RGA. Laterally, excavation activities at the targeted source would be continued until soil samples collected from the sidewalls of the excavation indicated that all contamination above a predetermined cleanup level had been removed or until the practical limits of excavation were reached, based on site-specific conditions (i.e., presence of buildings, roads, etc.). Vertically, excavation would be continued until the first of the following three situations was encountered: (1) soil samples collected from the floor of the excavation



U. S. DEPARTMENT OF ENERGY
DOE OAK RIDGE OPERATIONS
PADUCAH GASEOUS DIFFUSION PLANT

BECHTEL JACOBS COMPANY, LLC
MANAGED FOR THE US DEPARTMENT OF ENERGY UNDER
US GOVERNMENT CONTRACT DE-AC-05-98OR22700
Oak Ridge, Tennessee • Paducah, Kentucky • Portsmouth, Ohio

Science Applications
International Corporation
P.O. Box 2502
Oak Ridge, Tennessee 37831

Fig. 4.3. Primary source area - excavation technology.

FIGURE No. FS4-3
DATE 05-25-01

indicated "clean" soils; (2) groundwater was encountered; or (3) the practical limit of excavation, given specific site characteristics, was reached. All contaminated soils excavated from the target area would be treated *ex situ,* and treatment residuals would be disposed of properly.

In those areas where complete excavation was possible, 100% of contamination would be removed from the source area and a CERCLA five-year review would not be required. However, if the primary source zone was not completely excavated and additional remedial alternatives were required to address residual soil and/or dissolved phase contamination, five-year reviews might be required.

Although excavation would remove all contamination to the extent practical from the source area, it would not address dissolved phase contamination present in the groundwater. Therefore, continued long-term monitoring of dissolved phase contaminate movement from the area would be required.

Excavation technology provides aggressive reduction of source zone volume by removing the COCs available for transmission to the RGA. In those primary source areas where complete excavation is possible, 100% reduction in TCE and ^{99}Tc would be achieved in the UCRS. If Excavation Technology were implemented at all Primary Source Areas, this technology would result in a 2.9% reduction in the volume of TCE present in the RGA over a period of 30 years.

Access Restrictions. The UCRS primary source areas that would be addressed by excavation under the GWOU are located inside the PGDP security fence. On-site workers are, and would continue to be, alerted to potential exposure hazards at these units through the use of work permits, administrative controls, and safety programs.

Environmental Media Monitoring. This technology would remove 100% of the contamination from the UCRS in those primary source areas where complete excavation was possible and would reduce the amount of contamination available for migration to groundwater. However, it would not address dissolved phase contamination already present in the RGA, and a long-term groundwater monitoring program would be required to assess the movement of dissolved phase contaminants from the source area.

CERCLA Five-Year Review. Due to the immediate and irreversible nature of the excavation technology, the CERCLA Five-Year Review process would not be required to monitor the effectiveness of the alternative.

Assessment of Primary Source Area – Excavation

A detailed analysis of the performance of the excavation technology against the nine CERCLA criteria is provided in the following sections.

Overall Protection of Human Health and the Environment

Implementation of the excavation alternative would reduce VOC and ^{99}Tc contamination in the UCRS target zones by removing contaminant mass and reducing DNAPL volume. Following excavation, the contaminated soil removed from the target zone would undergo a treatment process such as low- temperature thermal stripping to remove the hazardous characteristic presented by the volatile organics. Following treatment, excavated soils would be disposed of in a PGDP landfill.

Implementation of this alternative would reduce the amount of contamination available for migration to the RGA and would decrease the risk to a potential future groundwater user or to an ecological receptor that might be exposed to contaminated groundwater discharging to surface water. However, excavation of primary source areas within the UCRS will not, by itself, satisfy the RAOs for the GWOU. Achievement of RAOs would require the implementation of additional source reduction technologies to address those areas not fully accessible to excavation and the implementation of dissolved phase technologies to address contamination that already is present in the RGA.

Compliance with ARARs. An alternative must meet this threshold criterion to be eligible for selection. The following discussion summarizes the potential ARARs and TBC Guidance for Primary Source Area – Excavation Technology.

Potential chemical-specific ARARs. The potential chemical-specific ARARs for Primary Source Area – Excavation Technology are summarized in the following paragraphs.

Chemical contamination. The aquifers are known to contain chemical contaminants in the form of metals and organics. The federal and state water quality requirements include standards that would be applicable ARARs. The regulations that apply are found in 40 *CFR* 141 (National Primary Drinking Water Standards); 40 *CFR* 143 (Secondary Drinking Water Standards); 401 KAR 5:029 (General Provisions); and 401 KAR 5:031 (Surface Water Standards). These standards, summarized in Table 4.1, include general state standards, domestic water supply standards, and standards applicable to warm water aquatic habitat. These are applicable based upon the classification of the designation for surface water use associated with the area (Ohio River, River Mile 940.7 to River Mile 943.3) as specified in 401 KAR 5:026. All potentially applicable chemical ARARs for COCs have been included in the table for completeness. Those standards that must be achieved in order to meet the applicable requirements are the lowest of the applicable standards, which in most cases are the MCLs.

Radiological contamination. The OU is known to be contaminated with radionuclides such as ^{99}Tc, radon, uranium, and uranium daughter products. DOE's Order on Radiation Protection of the Public and Environment, DOE Order 5400.5, is TBC information for cleanup of radionuclides at DOE sites. The order requires that remediation activities must not result in radiation exposures to members of the general public greater than an EDE of 100 mrem/year from all exposure pathways. Exposure to the general public also must be ALARA (DOE 1990).

The DOE Order 5400.5 also contains reference values, known as DCGs, for operational DOE facilities. Based on the DCGs, radionuclide concentrations in air and drinking water must not exceed an EDE of 10 mrem/year and 4 mrem/year, respectively, to the total body or any organ.

The NRC also has set criteria for decommissioning standards at nuclear facilities at 10 *CFR* 20 Subpart E. These rules require that residual radioactivity at nuclear sites meet a total EDE of 25 mrem/year for unrestricted release. In addition to the NRC standards, EPA has issued guidance for cleanup levels at CERCLA sites with radioactive contamination. EPA has disagreed with the protectiveness specified within the NRC standard and has specified that a 15 mrem/year EDE be used as the risk level that is protective of human health and the environment. EPA also has codified exposure limits for environmental radiation protection standards for nuclear power operations at 40 *CFR* 190. These requirements apply to operations involved in the uranium fuel cycle and include enrichment operations. Subpart B of these requirements specifies that the annual dose equivalent to the public not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughter products excepted, to the general environment from uranium fuel cycle operations and to radiation from these operations. These requirements would be considered relevant and appropriate because the release to the groundwater would not be planned.

The Commonwealth of Kentucky is an NRC Agreement State and has promulgated regulations for radiation protection of the public. The Kentucky radiation protection standard for individual members of the public is 0.1 rem (100 mrem) EDE per year or less (902 KAR 100:019 Section 10), which is equivalent to the DOE radiation protection standard found in DOE Order 5400.5.

Due to the differing views and values among NRC, EPA, and DOE regarding total EDE for members of the general public, EPA and DOE have agreed not to finalize their respective standards until an agreement can be reached. In the interim, DOE Order 5400.5 is identified as TBC information and the NRC standard is identified as relevant and appropriate. Therefore, the radiation protection standard identified within the NRC regulations at 10 *CFR* 20 Subpart E requiring an EDE of 25 mrem/year or less shall be used as the exposure limit for the general public.

Chemical-specific ARAR summary. The chemical-specific ARARs associated with the implementation of this alternative are outlined in Table 4.7. Implementation of this alternative would not result in immediate attainment of the chemical-specific ARARs associated with the off-site groundwater plumes. Attainment of the identified ARARs would be met in the future as implementation progresses. Continued monitoring of the groundwater will be used during the five-year reviews to ensure that the identified goals are met and that concentrations of COCs continue to decrease.

Potential location-specific ARARs. The potential location-specific ARARs for excavation of source areas are summarized in the following paragraphs.

Wetlands. Although no wetlands have been identified within the area where construction/excavation activities will occur, certain jurisdictional wetlands have been identified in on-site drainage ditches within the plant boundary. In order to comply with these applicable requirements, wetlands shall be avoided.

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, 40 *CFR* 6.302(a), 40 *CFR* 6 Appendix A, 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. Although not anticipated, if this alternative results in impacts to wetlands that cannot be avoided, the substantive requirements of the NWP 38 (33 *CFR* 330) will be met.

Endangered Species and Migratory Birds. Actions taken by federal agencies are prohibited from impacting T&E species or adversely modifying critical habitat (50 CFR 17.94) in accordance with the Endangered Species Act (16 USCA 1531 *et seq.* Section (7)(a)(2)). These requirements are potential ARARs in the event T&E species or their habitats are found at or near areas where remedial action is to occur. An ecological resource investigation inside the PGDP security fence did not detect any T&E species or their preferred habitats (CDM Federal 1994). The USFWS has not designated critical habitats for any species within the DOE property. However, outside the PGDP fence on the DOE property, potential habitat for federally listed T&E species was reviewed and Indiana bat habitat was evaluated during the COE (1994) environmental investigation. The COE study determined that total potential bat habitat consisted of 20% of the 994-ha (2,456-acre) study area. Remedial activities must be evaluated to ensure that such actions do not adversely impact areas identified as critical habitat for any identified endangered species.

In addition, Executive Order 13186 directs federal agencies to enter into an MOU with the USFWS to further the purposes of the Migratory Bird Treaty Act (16 U.S.C. 703-711). Until such time as the MOU between DOE and the USFWS is finalized, federal agencies are encouraged to immediately begin implementing the conservation measures set forth in the Executive Order. The requirements of the Executive Order are applicable and must be considered during planning and design of the remedial action.

Potential action-specific ARARs. The potential action-specific ARARs for excavation of source areas are summarized in the following paragraphs.

Monitoring well installation requirements. This alternative includes the installation of additional monitoring. Installation of these wells would have to be conducted in a manner to maintain existing natural protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole (401 KAR 6:310 Section 13). These requirements also mandate the construction materials required for well construction, well design criteria, well completion activities, and well abandonment methodologies. These requirements are considered applicable to design and installation of monitoring and extraction wells associated with the implementation of this alternative.

Fugitive dust emissions. Construction/excavation activities may result in the production of particulate airborne pollutants (dust). The Kentucky Air Quality standards found in 401 KAR 63:010 include requirements governing fugitive dust emissions. These standards require that dust-suppression measures be undertaken that include activities such as use of water or chemicals to control emissions, placement of asphalt or concrete, and stockpiling of soils. The standards also require that visible dust generated from the implementation of the remedial alternative not be discharged beyond the property boundary of the site. Trucks transporting material outside the property boundary, where materials could become airborne, must be covered. These requirements are considered to be applicable to any excavation and will be complied with through careful planning to ensure that excavated materials are sufficiently wetted or protected to control dust generation. Activities that could result in the generation of fugitive dust that must be considered during the design phase include the excavation/disposal of contaminated soils.

Radionuclide emission standards. Airborne emissions of radionuclides may occur as a result of on-site construction activities. Although the potential is low for such emissions to occur, the regulations at 40 *CFR* 61.92 would require that the emissions not exceed amounts that would cause an EDE to the public of 10 mrem/year. In order to determine whether the alternative complied with this applicable requirement, computer modeling using the CAP-88 or other EPA-approved models must be undertaken. If the modeling demonstrates the radionuclide emission to be in excess of 1% of the 10 mrem/year standard, emission rates must be measured as required by 40 *CFR* 61.93. This ARAR shall be complied with by planning activities in such a manner as to control fugitive emissions from excavation activities.

Toxic emission standards. Although toxic emissions are not expected as a result of construction activities, these emission requirements would be applicable if such emissions do occur. Due to organic concentrations found in the groundwater and potentially within the subsurface soils at depth, there is a low potential for such emissions to occur. The regulations at 401 KAR 63:022 require that the emissions be evaluated to determine whether they are significant for each specific toxic air pollutant. If analysis indicates that the toxic emission requirements are triggered, the regulations specify that no source may exceed the allowable emission limit specified in Appendix A of 401 KAR 63:022. If applicable, these rules would require the application of best available control technology to limit toxic emissions. If calculations indicate that the emission rates specified within the rule are not exceeded, the calculation package may be used to demonstrate compliance with these requirements.

Stormwater discharge and KPDES requirements for groundwater treatment. Construction/excavation activities will be subject to the substantive requirements associated with the KPDES permit that requires the use of BMPs and sediment/erosion controls to control transport of sediment in stormwater runoff. In addition, groundwater will be treated in a wastewater treatment unit where discharge will be subject to the substantive requirements of the KPDES program. These requirements are considered to be applicable.

Waste management requirements. Hazardous materials and wastes may be generated during the implementation of this alternative. It is anticipated that these wastes (soils) will be low-level radioactive wastes and, therefore, subject to the DOE Order 435.1 requirements that apply to the management of all radioactive wastes generated at DOE facilities. This requirement is TBC rather than applicable or relevant and appropriate because it is a DOE Order rather than a federal or state regulation or standard.

The potential also exists that some or all of the wastes generated from treatment may be RCRA hazardous wastes as defined in 40 *CFR* 261 of the federal program. All wastes generated shall be subject to the hazardous waste determination requirements of 40 *CFR* 262 and 401 KAR 32:010. If it is determined that any wastes are, in fact, hazardous wastes, the materials must be managed in accordance with the substantive requirements found in 40 *CFR* 262 through 40 *CFR* 268 (401 KAR 32 through 37). These standards include storage requirements, transportation requirements, and disposal requirements. Specific requirements applicable to each waste stream must be identified after characterization of the material is complete. These requirements shall be complied with through the development of a (WMP) during the design phase of implementation. If materials are identified as RCRA hazardous waste, these requirements are applicable.

Although considered unlikely, the potential exists that wastes generated from the implementation of this alternative may contain PCBs regulated under the Toxic Substances Control Act (TSCA). These regulations would be applicable to this alternative if PCB concentrations were found in soil or water that exceeded 50 ppm or PCBs were found and attributable to a source whose concentration exceeded 50 ppm PCBs. The substantive requirements for management of PCB wastes found in 40 *CFR* 761 would be applicable and include standards for storage, shipment, and equipment decontamination. These requirements shall be complied with through the development of a WMP during the design phase of implementation. If materials are identified as TSCA PCB regulated material, these requirements are applicable.

Action-specific ARAR summary. This alternative will trigger action-specific ARARs with regard to the excavation and disposal of the source areas. These include the requirement for compliance with the substantive requirements of the KPDES program for the control of sedimentation and discharge of any treated groundwater (removed from soils or within excavations) and the applicability of the RCRA requirements for wastes generated as a result of implementation. In addition, the requirements of TSCA may be applicable if PCB-containing materials are identified. This alternative will comply with these requirements during the planning phase to include compliant waste handling, storage, and disposition components. The proposed alternative will comply with the substantive requirements of both the CWA and RCRA requirements, as the treatment and discharge of treated effluent in compliance with the CWA meets both requirements and such treatment is allowed under RCRA. If wastes from treatment of contaminated water or excavation of soils is determined to be hazardous wastes under RCRA, the substantive requirements for storage, management, and disposal of hazardous wastes shall be incorporated into the alternative during the planning phase. Activities that may be required for RCRA and TSCA compliance include use of appropriate containers, labeling of containers, appropriate storage area design and operation (secondary containment or storage for less than 90 days in a compliant accumulation area), and transportation of wastes.

A summary of the ARARs for the implementation of excavation are presented in Table 4.7.

Compliance with ARARs summary. Implementation of this alternative would not achieve immediate compliance with the MCL for TCE. Compliance at the fenceline and the DOE property boundary has been calculated to occur in approximately 1,000 years.

In addition, this alternative addresses the reduction of source areas but would not control groundwater plumes. The MCLs applicable to antimony, chromium (action level), and alpha-emitting radionuclides would be exceeded at the point of compliance (plant fenceline) and points of exposure (DOE property boundary, Ohio River) if contaminants were allowed to remain within the groundwater, according to the modeling used in the development of this FS. As stated in the risk assessment, the metals and radionuclides based upon historic observations are far less mobile than current modeling indicates. Based on the time frames illustrated in the model required for migration to the point of compliance and the historical observations associated with migration of metals and radionuclides at the PGDP, exceedance of the associated MCLs is considered unlikely.

Table 4.7. Summary of potential ARARs for Excavation

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
Chemical-Specific ARARs			
National Primary Drinking Water Standards	40 *CFR* 141	Provides chemical-specific numeric standards for toxic pollutants expressed as MCLs and MCLGs.	These requirements are relevant and appropriate due to the nature of the contaminants found within the groundwater.
National Secondary Drinking Water Standards	40 *CFR* 143	Provides secondary MCLs for public water systems	These requirements are TBCs, as they have been established as guidelines for the states and are not federally enforceable.
Kentucky Surface Standards including • Warm Water Aquatic Habitat Criteria • Kentucky Domestic Water Supply • Kentucky General Standards • Kentucky Outstanding State Resource Waters	401 KAR 5:031 and 5:026	Provides chemical-specific numeric standards for pollutants discharged or found in surface waters. Provides chemical-specific numeric standards for pollutants in domestic water supplies.	These standards are applicable to the segment of the Ohio River into which the Little Bayou Creek discharges. The requirements found in these standards are applicable due to the groundwater to surface water interface to Little Bayou Creek and subsequently to the Ohio River. Note: CWA Water Quality Criteria are not relevant and appropriate because Kentucky has promulgated state standards that Kentucky has determined to be appropriate for waters of the State.
Radiation Exposure of the General Public at DOE Facilities	DOE Order 5400.5	Specifies that the general public must not receive an effective dose equivalent of >100 mrem/year from all exposure pathways. In addition, all release of radioactive materials resulting in doses to the general public must meet the ALARA criteria.	This requirement is TBC information.
Decommissioning Standards at Nuclear Facilities	10 *CFR* 20, Subpart E	Specifies a residual activity at nuclear facilities for unrestricted release of 25 mrem/year.	These standards are considered to be applicable to the GWOU.
Environmental Radiation Protection Standards for Nuclear Power Operations	40 *CFR* 190, Subpart B	Requires that the annual dose equivalent to the public must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughter products excepted, to the general environment from uranium fuel cycle operations and the radiation from these operations.	These standards are considered to be relevant and appropriate and are equivalent to the NRC standards.

Table 4.7. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Location-Specific ARARs	
Protection of Wetlands	10 *CFR* Section 1022, Executive Order 11990 40 *CFR* 230.10 33 *CFR* 330.5	Activities must avoid or minimize impacts to wetlands to preserve and enhance their natural and beneficial value. If wetland resources are not avoided, measures must be taken to address ecologically sensitive areas and mitigate adverse effects. Such measures may include, minimum grading requirements, runoff controls, and design and construction considerations. Allows minor discharges of dredge and fill material, or other minor activities for which there are no practicable alternatives, provided that the pertinent requirements of the NWP system are met.	These requirements are applicable due to the presence of wetlands, but will be met though avoidance of wetlands during construction and implementation of alternatives.
Endangered Species Act	16 U.S.C. 1531 et seq. Section 7(a)(2)	Actions that jeopardize the existence of listed species or result in the destruction or adverse modification of critical habitat must be avoided or reasonable and prudent mitigation measures taken.	Action that is likely to jeopardize fish, wildlife, or plant species or destroy or adversely modify critical habitat-applicable.
Migratory Bird Treaty Act	16 U.S.C. 703-711 Executive Order 13186	Federal Agencies are encouraged (until requirements are established under a formal MOU) to do the following: • avoid or minimize, to the extent practicable, adverse impacts on migratory bird resources when conducting agency actions; • restore and enhance the habitats of migratory birds, as practicable; • prevent or abate the pollution or detrimental alteration of the environment for the benefit of migratory birds, as practicable; • ensure that environmental analysis of federal actions required by the NEPA or other established environmental review processes evaluate the effects of actions and agency plans on migratory birds, with emphasis on species of concern; • identify where unintentional take will likely result from agency actions and develop standards and/or practices to minimize such unintentional take.	Action that is likely to impact migratory birds, habitats, and resources-applicable.

Table 4.7. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Action-Specific ARARs	
Fugitive Dust Emissions during site preparation and construction activities.	401 KAR 63:010	Precautions must be taken to prevent particulate matter from becoming airborne. Such precautions must be incorporated into the planning and design of activities and include actions such as • wetting or adding chemicals to control dust from construction activities, • using materials such as asphalt or concrete (or other suitable chemicals/fixing agents) on roads or material stockpiles to prevent fugitive emissions, and • using covers on trucks when transporting materials to and from the construction site(s). The requirement specifies that for on-site construction activities, no visible emissions may occur at the PGDP fenceline. Similar points of compliance shall be identified for construction activities that occur outside the fence.	These requirements are applicable and will be met through the use of appropriate dust control practices identified during alternative design phase.
Toxic Emissions	401 KAR 63:022	The regulations require that a determination of toxic emissions be made in order to assess the applicability of required controls. Calculations of the significant emission levels are compared to the allowable emission limits specified in Appendix A of 63:022. If emission levels are exceeded, best available control technologies must be incorporated into equipment/process design.	These requirements are considered to be applicable and shall be complied with through calculation of significant emission levels for toxic materials and application of best available control technology as necessary during the design of the alternative.
Monitoring Well Installation	401 KAR 6:310	Monitoring wells (including extraction wells) must be constructed in a manner to maintain existing protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole. In addition, wells that have no further use must be plugged and abandoned in accordance with the requirements specified.	These requirements are considered to be applicable. Compliance with well design and protection standards shall be achieved through the use of approved well design and materials of construction. While in service, wells shall be secured as required. Wells that have no further use shall be plugged and abandoned as required.
Discharge of Contaminated Stormwater and Treated Groundwater	40 *CFR* 122, 401 KAR 5:055	Stormwater discharges from construction activities on-site are subject to the requirements of the KPDES permit. This requires that BMPs to control stormwater runoff and sedimentation be employed. Although off-plant construction activities within the contaminated area are not subject to the permit, these requirements should be considered relevant and appropriate and be incorporated into any off-site construction activities. Discharge of treated groundwater will be conducted in compliance with the substantive requirements of the KPDES program and the CWA.	These requirements are considered applicable for all on-site construction or treatment activities where a discharge of stormwater or treated groundwater occurs. For off-site construction activities, these requirements are considered relevant and appropriate and will be adhered to. Compliance with these ARARs shall be achieved by application of required controls during the design phase of the alternative

Table 4.7. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
Hazardous Waste Management	40 *CFR* 260 through 268, 401 KAR 32 through 37	All wastes or environmental media containing wastes must be characterized to determine whether the waste also is a hazardous waste in accordance with 40 *CFR* 262.11 and 401 KAR 32:010. If it is determined that a waste is a hazardous waste or that environmental media contain a hazardous waste subject to the RCRA regulation, the substantive requirements of 40 *CFR* 262 through 268 are applicable. These standards include design and operation of storage and accumulation areas, waste handling and shipment, and treatment technologies or numeric standards applicable to wastes before disposal.	These requirements are applicable and will be complied with through characterization of wastes and environmental media generated as a result of implementation of the alternative. Waste management will be predicated upon the characterization and comply with all substantive requirements associated with hazardous waste management, if identified as such.
PCB Waste Management	40 *CFR* 761	TSCA requirements for the management of PCB wastes or items containing >50 ppm PCBs or from a source of 50 ppm or greater. Requirements include these: • waste and material management; • characterization of PCB-containing materials; • labeling and storage for disposal; • manifest completion for shipment offsite; • decontamination of affected equipment or items; and • disposal of PCB wastes These requirements will be complied with if PCBs are found at concentrations requiring compliance.	These requirements are applicable if PCBs are found or result from items or equipment regulated under 40 *CFR* 761. Activities necessary to comply with these ARARs shall be incorporated into the planning phase of the alternative implementation.

ALARA = as low as reasonably achievable
ARAR = applicable or relevant and appropriate requirement
BMP = best management practice
CFR = *Code of Federal Regulations*
CWA = Clean Water Act
DOE = U.S. Department of Energy
GWOU = groundwater operable unit
KAR = Kentucky Administrative Regulation
KPDES = Kentucky Pollutant Discharge Elimination System
MCLGs = maximum containment level goals
MCLs = maximum contaminant level
NRC = Nuclear Regulatory Commission
NWP = Nationwide Permit
PCB = polychlorinated biphenyls
PGDP = Paducah Gaseous Diffusion Plant
TBC = to be considered
TSCA = Toxic Substances Control Act

In order to comply with the identified chemical-specific ARARs, an ARAR waiver will be required due to the time frames required to meet the specified concentrations within the GWOU at the point of compliance and points of exposure.

As discussed, no potential location-specific ARARs have been identified within the area where remedial action will occur. However, to ensure that jurisdictional wetlands are not impacted, all construction/excavation activities associated with this alternative will be reviewed as a safeguard. The protection of wetlands is not considered a location-specific ARAR at this time, as jurisdictional wetlands have not been identified within the areas impacted by the implementation of this alternative.

Implementation of the alternative may trigger several action-specific ARARs such as the requirements associated with soil disturbance, fugitive-dust emissions, radionuclide emissions, toxic emissions, disposal of contaminated media, and discharge of stormwater and treated water. The requirements associated with the installation and abandonment of groundwater wells will be met though use of well designs and materials of construction, as specified at 401 KAR 6:310 Section 13. All well installations and abandonment practices incorporated into the approved Remedial Design shall comply with the substantive requirements of 401 KAR 6:310.

Fugitive dust emissions that may occur during construction activities will be controlled as required by 401 KAR 63:010. BMPs such as wetting or covering of potential sources of fugitive dust will be incorporated into the remedial design. The specific actions to be developed shall control potential emission sources to ensure that dust emissions do not migrate from the immediate area where construction activities occur. It is anticipated that, in most cases, the moisture content in the soil will be sufficient to control dust emissions during excavation and well installation. However, practices such as the wetting of disturbed soils, collection of soils, or reseeding activities shall be considered and incorporated into the remedial design, as necessary, to ensure compliance with these requirements. Radionuclide emissions at construction sites also must be considered during the implementation phase. In order to ensure that the emission standards of 10 mrem/year EDE to the public is met, concentrations of radionuclides in soils and groundwater must be evaluated. If the potential for such emissions is identified, modeling using the CAP-88 or other EPA-approved methods must be undertaken during the design phase of the alternative. It is anticipated that the primary conveyance of airborne radionuclides will be in particulate form; therefore, control of fugitive dust emissions also will result in compliance with the emission standards applicable to radionuclides. If radiological contamination from plant activities is found in soils where construction activities are planned, the soil will be protected or containerized to prevent airborne migration. Measures necessary to prevent airborne emissions or radionuclides shall be evaluated and incorporated, as appropriate, into the remedial design in order to comply with these requirements during implementation of this alternative.

Emissions of toxins such as volatile organics also must be evaluated before implementation. Although the potential for exceedance of toxic air emissions is considered to be low, an evaluation of the potential for such emissions must be undertaken during the remedial design. Potential emissions must be evaluated for each toxin present in the source zones (i.e., TCE, vinyl chloride, etc.) to determine whether the contaminant levels found in the subsurface could result in airborne emissions in excess of the allowable limits specified in Appendix A of 401 KAR 63:022. Compliance with the emissions standards shall be achieved for this alternative through the evaluation process or the application of the best available control technology where emissions are calculated to exceed allowable levels. Emission control equipment will be incorporated into implementation activities during the remedial design, as necessary, based upon the initial evaluation. This requirement will be complied with during implementation of the alternative.

The construction/excavation activities associated with this alternative will require that BMPs for sedimentation/erosion controls be established. This requirement will be complied with through the use of sediment fences or other appropriate means. The remedial design shall incorporate the specific controls necessary to ensure that the construction sites do not allow sedimentation and/or erosion of disturbed areas in order to comply with this requirement during implementation of this alternative.

Excavation of contaminated soils and treatment of contaminated surface water and groundwater may result in the generation of wastes that will trigger the characterization requirements associated with RCRA. The implementing regulations found at 40 *CFR* 262 and 401 KAR 32:010 require that generators of solid wastes (or contaminated environmental media) must determine whether the waste also is a hazardous waste. If the materials generated from the implementation of this alternative are found to be hazardous wastes, the materials shall be containerized and managed as such. The requirements mandate that hazardous wastes be properly labeled and stored in areas that comply with the technical standards for storage of hazardous waste in containers. These standards shall be complied with through testing of soils before excavation activities. If the soils are found to be hazardous, appropriate storage areas shall be constructed and maintained. All hazardous waste generated during the implementation of this alternative shall be shipped for off-site disposal using the EPA Identification Number for the PGDP. Hazardous wastes shall be shipped to facilities permitted to treat, store, or dispose of the hazardous waste(s) being shipped. These activities shall be incorporated into the remedial design for this alternative in order to comply with these requirements.

Contaminated soils and secondary wastes generated during the implementation of this alternative also may be subject to regulation under TSCA as PCB remediation waste and DOE Order 435.1 as LLW. Characterization of these materials will be required in order to determine whether specific wastes are regulated under these requirements. If it is determined that the waste generated is a PCB or LLW, appropriate management standards will be incorporated into the Remedial Design. Existing information will be used where practicable to determine the regulatory status of all waste to be generated before implementation.

Long-Term Effectiveness and Permanence. This evaluation addresses the results of the alternative in terms of risk remaining at the site after completion of the action and the effects of the required long-term control. A discussion of the magnitude of the residual risks at the site and the adequacy and reliability of the controls is presented in the following section.

Magnitude of residual risks. The excavation technology is designed to remediate contaminated soils in the UCRS by removing those soils and their associated contamination from the source area for ex situ treatment. At those sources where excavation can be fully implemented, all residual risk associated with the contaminated soils would be eliminated upon completion of the excavation activities. However, due to constraints caused by the current industrial setting, full excavation of some primary source zones in the UCRS would not be possible and other source reduction technologies would have to be implemented to reduce residual risks associated with the remaining contaminated soil. In addition, this alternative is not designed to address dissolved phase contaminants, and additional technologies would be required to mitigate the risks associated with them.

In those areas where excavation was fully implemented and all residual soil contamination was removed, five-year reviews, as mandated by CERCLA [40 *CFR* §300.430(f)(4)(ii)], would not be required. However, if the primary source zone was not completely excavated and additional remedial alternatives were required to address residual soil and/or dissolved phase contamination, five-year reviews might be required to demonstrate the integrity and effectiveness of those controls and to confirm that additional exposure pathways had not developed.

Adequacy and reliability of controls. Excavation would be a very reliable method of contaminant reduction for those UCRS source areas where excavation is applicable and can be fully implemented. Since no contaminant residuals would remain at the source area, no long-term treatment controls would be required. The reliability of the alternative would, however, decrease in those areas where infrastructure impeded its unobstructed implementation.

Environmental impacts and mitigative measures. The following text provides a description of potential long-term impacts to resources and mitigative measures to offset any potential impacts. The extent of the impact analyses and mitigation measures are correlated to the degree to which a resource might be impacted.

Land use. Implementation of this alternative would not result in any changes to the current land use in the vicinity of the PGDP; however, local impacts to the subsurface soil and to land use in the vicinity of the target area would be major due to the effects of excavation. Following performance of the alternative, the surface of the disturbed area would be restored, to the extent possible, to its prior use.

Socioeconomic. The socioeconomic conditions of the PGDP and surrounding area would not be expected to change as a result of the implementation of this alternative. Existing socioeconomic structure would remain after excavation activities were implemented and long-term employment in the area would not be changed due to implementation of the alternative.

Air quality and noise. No long-term negative impacts on air quality would be experienced due to implementation of this technology. Engineering controls for dust abatement would be implemented during excavation as necessary.

No long-term increase in noise is expected as the result of this alternative.

Vegetation. Excavation of primary UCRS source zones would not be expected to occur outside of the industrialized areas located within the PGDP. Therefore, no long-term impacts to vegetation are expected from the implementation of this alternative.

Wildlife. Excavation activities associated with remediation of the primary source zones in the UCRS would be confined to areas located within the PGDP security fence and would not occur in the creeks and tributaries that surround the plant. Therefore, no long-term impacts to wildlife are expected due to the implementation of this alternative.

Threatened and endangered species. No long-term impacts to T&E species are anticipated for this alternative. The Indiana bat, which regionally has a suitable habitat, is not expected to be impacted by this alternative since the potential roosting areas of the Indiana bat, as identified by Bryan (COE 1993), are not located in areas that would be impacted by the implementation of this technology.

Cultural resources. No long-term effects to cultural resources are anticipated from this alternative.

Groundwater. Through excavation, potential UCRS contamination source zones would be fully or partially eliminated, depending on the degree of implementability of the alternative at the target area. Degradation of groundwater as a result of this alternative is not expected. However, due to the disturbance of soil structure, should areas not be cleaned but only disturbed by nearby excavation, the potential exists to increase the downward vertical migration of DNAPL.

Surface water. Due to the soil disturbance caused by excavation, implementation of the excavation technology would have the potential to increase sediment loads carried by surface water runoff from the plant. However, standard engineering controls using BMPs would be used to minimize the migration of sediments to the extent possible.

Floodplains. No long-term impact to floodplains would be expected from this alternative since excavation would not be conducted within the floodplains.

Wetlands. The implementation of this technology would not impact the integrity of the wetlands in vicinity of the PGDP. All excavation activities would be confined to the area of PGDP located within the security fence.

Soils and prime farmland. Prime farmland exists north of the PGDP and DOE property. No long-term impacts to this farmland would be expected from the implementation of this alternative since all excavation activity would be confined to areas located within the PGDP security fence. However, at the targeted UCRS source areas, surface and subsurface soil would be removed and replaced with clean backfill. Standard engineering controls using BMPs would be used during excavation to minimize impact due to erosion.

Transportation. No long-term direct or indirect effects to transportation are anticipated for this alternative.

Cumulative impacts. Cumulative impacts are defined as the incremental impacts of an action when added to other past, present, and reasonable, foreseeable future actions, regardless of what agency or person undertakes such actions. Cumulative impacts resulting from implementation of this alternative would have to be identified at a later time during development of site-specific GWOU decision documents.

Reduction of Toxicity, Mobility, or Volume through Treatment. The statutory preference is to select a remedial action that employs treatment to reduce the toxicity, mobility, or volume of hazardous substances. This criterion addresses the anticipated performance of the technologies that may be employed to achieve treatment goals. The treatment processes proposed in the alternative include excavation of contaminated soils to remove contaminant mass from the source zone and low-temperature thermal stripping of the excavated materials to remove the hazardous characteristic presented by the volatile organics. Following treatment, excavated soils will be disposed of in the PGDP landfill.

While TCE and ^{99}Tc are the primary COCs addressed by this FS, implementation of the excavation technology would address any non-dissolved phase contamination present within the source zone (i.e., volatile organics, metals, radionuclides, etc.). If the targeted area could be fully excavated, no contaminants would remain, thereby reducing toxicity, mobility, and volume of the contaminants remaining at the source area by 100%. Excavation and ex situ treatment is a non-reversible technology.

Contaminated soil excavated during the implementation of this alternative would require treatment prior to disposal to reduce the toxicity, mobility, and volume of contamination. It is assumed that a treatment process such as low-temperature thermal stripping would be performed on the excavated materials, thereby removing and destroying nearly 100% of the VOCs through catalytic oxidation. Residuals that would remain following this treatment would include the excavated soils (less VOC contamination), sodium chloride residual produced during scrubbing of the off-gas from the catalytic oxidizer, and ion exchange resin containing ^{99}Tc.

The majority of the ^{99}Tc contamination present in the excavated soil would not be removed by thermal stripping. This ^{99}Tc and any other non-VOC contaminants that remained in the excavated soil following treatment would be landfilled at the PGDP, providing nearly 100% reduction in mobility for these residuals by transferring them from an uncontrolled to a controlled environment.

Short-Term Effectiveness. The short-term effectiveness of an alternative is evaluated relative to its effect on human health and the environment. This involves evaluating the alternative for the criteria of community protection, worker protection, environmental impacts, and the time until remedial response actions are achieved. A discussion of each is provided in the following paragraphs.

Community protection. Implementation of this alternative could result in some short-term impacts to the community due to the potential for increased dust emissions and the release of volatilized contaminants to the air during excavation activities and treatment of the excavated material. However, excavation activities would be restricted to the area within the PGDP security fence and, since there are no residences in that immediate area, possible short-term impacts to the community are expected to be minimal. In addition, engineering controls would be utilized to minimize the dust and off-gas emissions associated with excavation, soil handling, and soil treatment.

Worker protection. This alternative has the potential for worker exposure to contaminated soil and groundwater during performance of the excavation activities. Potential exposure pathways would include dermal exposure and the inhalation of dust. Impacts to workers would be minimized through the use of formalized operating procedures, proper PPE, and engineering controls for off-gas treatment and dust emission reduction.

Potential environmental impacts and mitigating measures. Short-term environmental impacts and mitigative measures are qualitatively assessed and include an evaluation of the impacts on environmentally and potentially sensitive ecological resources, short-term impacts on socioeconomics and cultural resources, and cumulative impacts of the remedial measure.

Land use. Land use in the immediate area of the target zone would be disrupted during excavation activities. However, following completion of the excavation, the pit would be backfilled and the surface of the disturbed area would be restored, to the extent possible, to its prior use.

Socioeconomic. The socioeconomic conditions of the PGDP area would not change with implementation of this alternative. Construction contractors would perform excavation activities and the number of permanent jobs that would develop as a result of this action would be small in relation the size of the population in the surrounding areas. No increase or decrease in the personnel at PGDP would be expected to result from implementation of this alternative.

Air quality and noise. Some short-term impacts to air quality in the area would be expected due to the release of dust and volatilized contaminants during excavation activities. Engineering controls would be utilized to minimize the dust and off-gas emissions associated with excavation and soil handling.

During excavation there would be local increases in noise levels due to the operation of machinery; however, these increases are not expected to be above those noise levels that occur during normal plant operations. Hearing protection would be used to protect workers in the immediate vicinity of the excavation. Minor, short-term noise impacts to the area surrounding PGDP could result from transportation activities associated with the treatment and disposal of excavated material.

Vegetation. There would be limited adverse impacts to vegetation in the immediate vicinity of the target zone due to excavation and operation activities. Following completion of remedial activities, all necessary rehabilitation practices will be used to restore the vegetation, to the extent possible, to its condition prior to implementation of the alternative.

Wildlife. Short-term impacts to wildlife in the vicinity of PGDP due to the implementation of this alternative would be minimal. All excavation activity would be restricted to the industrial portion of the plant and no excavation would occur in the creeks or tributaries. Any potential impacts to wildlife and creeks associated with erosion and sediment migration resulting from excavation activities would be minimized to the extent possible through the use of standard engineering practices such as erosion control fencing and materials.

Threatened and endangered species. No adverse impacts to T&E species were identified that would result from the implementation of this alternative. The Indiana bat, which has suitable habitat located within the region, would not be impacted by this alternative. All excavation activities would be restricted to the industrial areas of PGDP and the potential roosting areas of the Indiana bat, as identified by Bryan (COE 1993), are not located within these areas.

Cultural resources. No short-term impacts to cultural resources would be expected to occur as a result of the implementation of this alternative.

Groundwater. Implementation of excavation technology would provide for the reduction or elimination of UCRS VOC sources that have the potential to supply contaminants to groundwater. There would also be a reduction or elimination of the volume of ^{99}Tc or any other contaminant present in the UCRS within the target zones. Degradation to groundwater would not be expected to occur as a result of excavation activities. However, due to the disturbance of soil structure, excavation could increase the potential for further downward vertical migration of DNAPL.

Surface water. The potential does exist for short-term impacts to surface water due to erosion and sediment migration associated with excavation activities. However, standard engineering controls using BMPs would be utilized to minimize sediment migration to the extent possible, and little or no increase in sediment discharge volume would be expected. Through the use of these engineering controls, no adverse impacts to surface water in the vicinity of PGDP would be expected as a result of the implementation of this alternative.

Floodplains. Implementation of this technology would not result in any short-term impacts to floodplains in the vicinity of PGDP. Excavation would not be conducted in the floodplain of any stream at PGDP.

Wetlands. Implementation of this alternative would not impact the integrity of wetlands in the vicinity of PGDP, since all excavation activities would be conducted within the industrial area of the plant.

Soils and prime farmland. No short-term impacts to farmland would occur as a result of the implementation of this alternative. Soils within the localized target zones would be impacted as a result of the excavation activities.

Transportation. During the performance of excavation activities, increased vehicle activity associated with the transport of excavated soil to the PGDP landfill would occur in the area surrounding the PGDP. In addition, implementation of this alternative would result in the transport of environmental soil samples to environmental laboratories and the transport of ion-exchange resins to treatment, storage, or disposal facilities. Standard engineering practices will be used to ship these materials safely. All regulatory shipping regulations will be used for the shipment of low-level waste materials.

Cumulative impacts. Cumulative impacts are defined as the incremental impact of an action when added to other past, present, and reasonable, foreseeable future actions, regardless of what agency or person undertakes other such actions. Cumulative impacts resulting from this alternative will have to be identified at a later time during development of site-specific GWOU decision documents.

Time until remedial response objectives are achieved. Implementation of the excavation technology alone would not result in the achievement of MCLs or of the RAOs specified for the GWOU. The implementation of additional groundwater remedial alternatives would be required to achieve these standards. However, if the RAOs specified for the GWOU were applied only to the targeted UCRS source area, implementation of this alternative would achieve RAOs at the source zone in less than 2 years from the time of implementation.

Implementability. Activities to be conducted under this alternative include excavation of contaminated soil from targeted source zones in the UCRS and the appropriate treatment of the excavated material prior to disposal in the PGDP landfill.

Technical feasibility. Excavation is a technically feasible, reliable, and proven method of soil remediation, and numerous vendors that could implement the technology are available within the area. However, excavation of the entire targeted source area may not be possible due to constraints imposed by the proximity of the area to structures and shoring up of nearby structures could be required. Also, contaminants present at depths below the water table would be inaccessible to this technology. Air monitoring would be required due to the potential for the release of VOCs during excavation. In addition, precipitation that occurred during implementation of this alternative would impact excavation activities and could create the need for treatment and/or disposal of water that collected in the excavated hole.

Administrative feasibility. Implementation of this alternative is administratively feasible. Compliance with substantive requirements associated with federal and state regulations would be necessary. Compliance with regulations associated with KPDES discharges, air treatment, and transportation also would be required. An ARARs waiver will be required since the MCLs for groundwater will not be attained in a timely manner.

Cost. Table 4.8 summarizes the preliminary cost estimates for implementation of an Excavation Technology in a Primary Source Area of the UCRS. These preliminary unit cost estimates are based upon FS-level scoping and are intended to aid in selection of a preferred alternative. The estimates have an expected accuracy of -30 to +50% for the proposed scope of action (EPA 1988a). The capital cost estimate represents those expenditures required to implement this remedial alternative. The O&M cost estimates represent expenditures required to maintain the remedy after the initial phase of remedial action is completed. The total contingency cost presented includes direct, indirect, and all O&M associated contingency costs. The total cost includes all capital costs, direct and indirect with O&M and associated reports, plus 25% contingency costs, for a 30-year term of comparison. All estimates have been escalated using DOE-approved annual rates and a schedule for the various activities based on similar project experience. Present worth values also are included using a discount factor of 5% (EPA 1988b). (Additional information regarding the preliminary cost estimates is presented in Appendix C.)

Table 4.8. Preliminary unit cost estimates for Primary Source Area – Excavation

Total capital costs/acre-foot	$3,482,401
Total operation and maintenance costs	$14,460
Overhead	$3,007,959
Total contingency	$1,626,205
Total cost	**$8,131,025**
Total cost (present worth)	**$5,930,929**

Note: preliminary cost estimates are per acre-foot, escalated and presented in dollars.

State/Commonwealth Acceptance. Comments received from the Commonwealth of Kentucky will be incorporated into this FS as appropriate following review of the draft report.

Community Acceptance. Following a formal public comment period on the PRAP for the GWOU, comments from the community will be addressed formally in a responsiveness summary, which will be presented in the ROD document.

Evaluation summary of Primary Source Area – Excavation Technology

Primary Source Area – Excavation Technology is a technically feasible, reliable, and proven method of soil remediation that would provide treatment for UCRS contaminant source areas by removing 100% of the contaminated media from the targeted zone in those areas where excavation was fully implementable. Excavated material would be treated to destroy nearly 100% of associated VOC contamination and then would be placed in the PGDP landfill to provide containment for any other contaminants remaining in the treated media. Due to the immediate and irreversible nature of the excavation technology, no long-term controls would be required to maintain remedial progress.

Excavation would eliminate residual risk and provide 100% contaminant volume reduction in the target area when site conditions allowed full implementation of the technology. However, due to proximity to structures or to the depth of the contamination beneath the water table, some source areas may not support full excavation and would require the implementation of additional technologies to provide contaminant remediation. These technical constraints would limit the appropriateness of this alternative for some UCRS source areas.

Finally, excavation of primary source areas within the UCRS will not, by itself, satisfy the RAOs for the GWOU. Achievement of RAOs would require the implementation of additional source reduction technologies to address those areas not fully accessible to excavation and the implementation of dissolved phase technologies to address contamination that is already present in the RGA.

4.2.3 Secondary Source Area

The following subsections provide a detailed analysis of alternatives for the Secondary Source Areas. A Secondary Source Area is defined for the purposes of this GWOU FS as those areas with the target contaminants of TCE, TCE degradation products, or ^{99}Tc present and having DNAPL concentrations in the RGA.

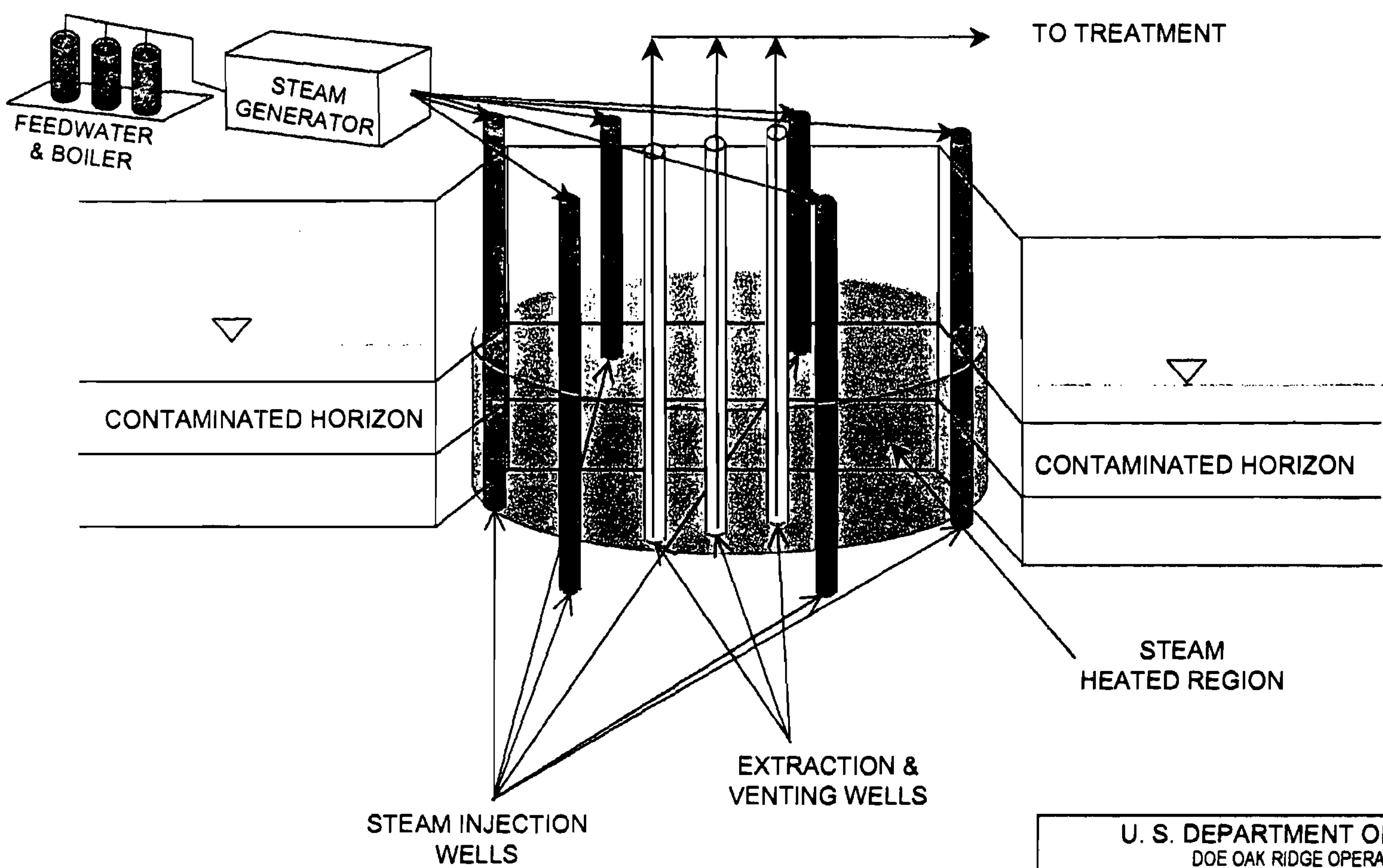
4.2.3.1 Secondary Source Area – Steam Extraction Technology

The following subsections contain a description of Secondary Source Area – Steam Extraction Technology alternative and the detailed analysis.

Description of Secondary Source Area – Steam Extraction Technology

This alternative would consist of implementing a Steam Extraction Technology in a DNAPL source zone area of the RGA. The purpose of the alternative would be to remove TCE DNAPL, other VOCs and ^{99}Tc contaminants from areas of the RGA that have sufficient TCE concentrations to be considered as having free phase TCE, or TCE DNAPL, present in the zone. The steam extraction would be performed by using a series of injection and extraction wells in the selected treatment area to inject steam into the subsurface area containing the contaminants. The injected steam would be used to volatilize the VOC contaminants, which then would be collected at the surface and treated. Additionally, liquids would be extracted that also would contain VOCs and ^{99}Tc. The liquids would be treated using surface treatment equipment to remove the contaminants prior to releasing the cleaned water to an outfall. The surface treatment most likely would consist of an air stripper to remove VOCs and an ion exchange system to capture the ^{99}Tc. The vapor phase would require treatment to remove any VOCs from that air stream. The most likely treatment for the vapor phase would be catalytic oxidation. The catalytic oxidation unit emissions would be scrubbed to prevent remove contaminants prior to releasing to the atmosphere.

Figure 4.4 contains a "snapshot" that graphically summarizes what is involved in the application of Steam Extraction Technology.



U. S. DEPARTMENT OF ENERGY
DOE OAK RIDGE OPERATIONS
PADUCAH GASEOUS DIFFUSION PLANT

BECHTEL JACOBS COMPANY, LLC
MANAGED FOR THE US DEPARTMENT OF ENERGY UNDER
US GOVERNMENT CONTRACT DE-AC-05-98OR22700
Oak Ridge, Tennessee • Paducah, Kentucky • Portsmouth, Ohio

Science Applications International Corporation
P.O. Box 2502
Oak Ridge, Tennessee 37831

Fig. 4.4. Secondary source area - steam extraction technology.

FIGURE No. FS4-4
DATE 05-25-01

The source-reduction efforts of implementing this technology will diminish the time until on-site groundwater VOC levels attributed to the DNAPL zone areas in the RGA reach the 5 μg/L MCL. However, due to the technology not effecting removal of the DNAPL TCE contaminants in the UCRS area, it is anticipated that groundwater will not return to the drinking water standard for TCE for approximately 7,000 years. The technology also will only remove ^{99}Tc in the local area of implementation. This is due to ^{99}Tc being impacted only as a result of produced water. The off-site portions of the groundwater plumes will be affected only by the reduced quantity of DNAPL present in the RGA that is available for dissolving and producing the migrating plumes.

The existing groundwater monitoring program, which is being implemented under a separate action, would be continued to monitor the movement of COCs within the RGA. The monitoring program will integrate existing PGDP monitoring wells, where possible, with additional monitoring wells to be installed, as needed, following a review of the existing program.

Five-Year Reviews. This remedial alternative would result in residual "contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure"; therefore, this remedial action would be reviewed "no less often than every five years" in accordance with 40 *CFR* 300.430 (f)(4)(ii).

Assessment of Secondary Source Area Steam Extraction Technology

The detailed analysis of this alternative, using the CERCLA criteria, is presented in the following subsections.

Overall Protection of Human Health and the Environment. Secondary Source Area Steam Extraction Technology includes the removal and treatment of VOCs, TCE DNAPL, and ^{99}Tc in the RGA. The technology would reduce VOC contamination in the RGA only. It would have only a moderate effectiveness on the ^{99}Tc contamination. This alternative alone will not satisfy the RAOs for the GWOU or protection of the ecological receptors that may be exposed to contaminated groundwater discharging to the surface water. It will support achieving the RAOs when implemented in concert with other source reduction and dissolved phase GWOU technologies.

Compliance with ARARs

Potential chemical-specific ARARs

Chemical contamination. The aquifers are known to contain chemical contaminants in the form of metals and organics. The federal and state water quality requirements include standards that would be applicable ARARs. The regulations that apply are found in 40 *CFR* 141 (National Primary Drinking Water Standards); 40 *CFR* 143 (Secondary Drinking Water Standards); 401 KAR 5:029 (General Provisions); and 401 KAR 5:031 (Surface Water Standards). These standards are summarized in Table 4.9 and include state general standards, domestic water supply standards, and standards applicable to warm water aquatic habitat. These are applicable based upon the classification of the designation for surface water use associated with the area (Ohio River, River Mile 940.7 to River Mile 943.3), as specified in 401 KAR 5:026. All potentially applicable chemical ARARs for COCs have been included in the table for completeness. Those standards that must be achieved in order to meet the applicable requirements are the lowest of the applicable standards, which in most cases are the MCLs.

Radiological contamination. The GWOU is known to be contaminated with radionuclides such as ^{99}Tc, radon, uranium, and uranium daughter products. The DOE's Order on Radiation Protection of the Public and Environment, DOE Order 5400.5, as codified at 10 *CFR* 835, is TBC information for cleanup of radionuclides at DOE sites. The order requires that remediation activities must not result in radiation

Table 4.9. Summary of Potential ARARs for Secondary Source Area – Steam Extraction Technology

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Chemical-Specific ARARs	
National Primary Drinking Water Standards	40 *CFR* 141	Provides chemical-specific numeric standards for toxic pollutants expressed as MCLs and MCLGs.	These requirements are relevant and appropriate due to the nature of the contaminants found within the groundwater.
National Secondary Drinking Water Standards	40 *CFR* 143	Provides secondary MCLs for public water systems.	These requirements are TBCs, as they have been established as guidelines for the states and are not federally enforceable.
Kentucky Surface Standards including • Warm Water Aquatic Habitat Criteria • Kentucky Domestic Water Supply • Kentucky General Standards • Kentucky Outstanding State Resource Waters	401 KAR 5:031 and 5:026	Provides chemical-specific numeric standards for pollutants discharged or found in surface waters. Provides chemical-specific numeric standards for pollutants in domestic water supplies.	These standards are applicable to the segment of the Ohio River into which Little Bayou Creek discharges. The requirements found in these standards are applicable due to the groundwater to surface water interface to Little Bayou Creek and, subsequently, to the Ohio River. Note: CWA Water Quality Criteria are not relevant and appropriate because Kentucky has promulgated these state standards that Kentucky has determined to be appropriate for state waters.
Radiation Exposure of the General Public at DOE Facilities	DOE Order 5400.5	Specifies that the general public must not receive an effective dose equivalent of >100 mrem/year from all exposure pathways. In addition, all releases of radioactive materials resulting in doses to the general public must meet the ALARA criteria.	This requirement is TBC information.
Decommissioning Standards at Nuclear Facilities	10 *CFR* 20, Subpart E	Specifies a residual activity at nuclear facilities for unrestricted releases of 25 mrem/year.	These standards are considered to be applicable to the GWOU.
Environmental Radiation Protection Standards for Nuclear Power Operations	40 *CFR* 190, Subpart B	Requires that the annual dose equivalent to the public must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughter products excepted, to the general environment from uranium fuel cycle operations, and radiation from these operations.	These standards are considered to be relevant and appropriate and are equivalent to the NRC standards.

Table 4.9. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Location-Specific ARARs	
Protection of Wetlands	10 *CFR* Section 1022; Executive Order 11990; 40 *CFR* 230.10; 33 *CFR* 330.5	Activities must avoid or minimize impacts to wetlands to preserve and enhance their natural and beneficial value. If wetland resources are not avoided, measures must be taken to address ecologically sensitive areas and mitigate adverse effects. Such measures may include minimum grading requirements, runoff controls, and design and construction considerations. Allows minor discharges of dredge and fill material, or other minor activities for which there is no practicable alternative, provided that the pertinent requirements of the NWP system are met.	These requirements are applicable due to the presence of wetlands but will be met though avoidance of wetlands during construction and implementation of alternatives.
Endangered Species Act	16 U.S.C. 1531 et seq. Section 7(a)(2)	Actions that jeopardize the existence of listed species or result in the destruction of adverse modification of critical habitat must be avoided or reasonable and prudent mitigation measures taken.	Action that is likely to jeopardize fish, wildlife, or plant species or destroy or adversely modify critical habitat-applicable.
Migratory Bird Treaty Act	16 U.S.C. 703-711 Executive Order 13186	Federal Agencies are encouraged (until requirements are established under a formal MOU) to do the following: • avoid or minimize, to the extent practicable, adverse impacts on migratory bird resources when conducting agency actions; • restore and enhance the habitats of migratory birds, as practicable; • prevent or abate the pollution or detrimental alteration of the environment for the benefit of migratory birds, as practicable; • ensure that environmental analysis of federal actions required by the NEPA or other established environmental review processes evaluate the effects of actions and agency plans for migratory birds, with emphasis on species of concern; and • identify where unintentional take likely will result from agency actions and develop standards and/or practices to minimize such unintentional take.	Action that is likely to impact migratory birds, habitats, and resources-applicable.
		Action-Specific ARARs	
Fugitive Dust Emissions during site preparation and construction activities.	401 KAR 63:010	Precautions must be taken to prevent particulate matter from becoming airborne. Such precautions must be incorporated into the planning and design of activities and include actions such as • wetting or adding chemicals to control dust from construction activities; • using materials such as asphalt or concrete (or other suitable chemicals/fixing agents) on roads or material stockpiles to prevent fugitive emissions and; • using covers on trucks when transporting materials to and from the construction site(s).	These requirements are applicable and will be met through the use of appropriate dust-control practices identified during alternative design phase.

Table 4.9. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
Fugitive Dust Emissions (continued)		The requirement specifies that for on-site construction activities, no visible emissions may occur at the PGDP fenceline. Similar points of compliance shall be identified for construction activities that occur outside the fence.	
Toxic Emissions	401 KAR 63:022	The regulations require that a determination of toxic emissions be made in order to assess the applicability of required controls. Calculations of the significant emission levels are compared to the allowable emission limits specified in Appendix A of 401 KAR 63:022. If emission levels are exceeded, the best available control technologies must be incorporated into equipment/process design.	These requirements are considered to be applicable and shall be complied with through calculation of significant emission levels for toxic materials and application of best available control technology, as necessary, during the design of the alternative.
Monitoring Well Installation	401 KAR 6:310	Monitoring wells (including extraction wells) must be constructed in a manner to maintain existing protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole. Wells with no further use wells must be plugged and abandoned in accordance with the requirements specified.	These requirements are considered to be applicable. Compliance with well design and protection standards shall be achieved through the use of approved well design and materials of construction. While in service, wells shall be secured as required. Well with no further use shall be plugged and abandoned as required.
Action-Specific ARARs			
Hazardous Waste Management	40 *CFR* 260 through 264 and 268; 401 KAR 31 through 34, 36, and 37	All wastes or environmental media containing wastes must be characterized to determine whether the waste also is a hazardous waste in accordance with 40 *CFR* 262.11 and 401 KAR 32:010. If it is determined that a waste is hazardous or that environmental media contain a hazardous waste that is subject to the RCRA regulation, the substantive requirements of 40 *CFR* 262 through 268 are applicable. These standards include design and operation of storage and accumulation areas, waste handling and shipment, and treatment technologies or numeric standards applicable to wastes prior to disposal.	These requirements are applicable and will be complied with through characterization of wastes and environmental media generated as a result of implementation of the alternative. Waste management will be predicated upon the characterization and will comply with all substantive requirements associated with hazardous waste management, if identified as such.

ALARA = as low as reasonably achievable
ARAR = applicable or relevant and appropriate requirement
CFR = *Code of Federal Regulations*
CWA = Clean Water Act
DOE = U.S. Department of Energy
GWOU = groundwater operable unit
KAR = Kentucky Administrative Regulations
MCL = maximum contaminant level
MCLG = maximum containment level goal
NRC = U.S. Nuclear Regulatory Commission
NWP = Nationwide Permit
PGDP = Paducah Gaseous Diffusion Plant
RCRA = Resource Conservation and Recovery Act
TBC = to be considered

exposures to members of the general public greater than an EDE of 100 mrem/year from all exposure pathways. Exposure to the general public also must be ALARA (DOE 1990).

DOE Order 5400.5 also contains reference values, known as DCGs, for operational DOE facilities. Based on the DCGs, radionuclide concentrations in air and drinking water must not exceed an EDE of 10 mrem/year and 4 mrem/year, respectively, to the total body or any organ.

The NRC also has set criteria for decommissioning standards at nuclear facilities in 10 *CFR* 20 Subpart E. These rules require that residual radioactivity at nuclear sites meet a total EDE of 25 mrem/year for unrestricted release. In addition to the NRC standards, EPA has issued guidance for cleanup levels at CERCLA sites with radioactive contamination.

EPA has disagreed with the protectiveness specified within the NRC standard and has specified that a 15 mrem/year EDE be used as the risk level that is protective of human health and the environment. EPA also has codified exposure limits for environmental radiation protection standards for nuclear power operations in 40 *CFR* 190. These requirements apply to operations involved in the uranium fuel cycle and include enrichment operations. Subpart B of these requirements specifies that the annual dose equivalent to the public not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughter products excepted, to the general environment from uranium fuel cycle operations and the radiation from these operations. These requirements would be considered relevant and appropriate because release to the groundwater would not be planned.

The Commonwealth of Kentucky is an NRC Agreement State and has promulgated regulations for radiation protection of the public. The Kentucky radiation protection standard for individual members of the public is 0.1 rem (100 mrem) EDE per year or less (902 KAR 100:019 Section 10), which is equivalent to the DOE radiation protection standard found in DOE Order 5400.5.

Due to the differing views and values among NRC, EPA, and DOE total EDE for members of the general public, EPA and DOE have agreed not to finalize their respective standards until an agreement can be reached. In the interim, DOE Order 5400.5 is identified as TBC information, and the NRC standard is identified as relevant and appropriate. Therefore, the radiation protection standard identified within the NRC regulations in 10 *CFR* 20 Subpart E, requiring an EDE of 25 mrem/year or less, shall be used as the exposure limit for the general public.

Chemical-specific ARAR summary. The chemical-specific ARARs associated with the implementation of this alternative are outlined in Table 4.9. Implementation of this alternative would not result in immediate attainment of the chemical-specific ARARs associated with the off-site groundwater plumes. Attainment of the identified ARARs would be met in the future as implementation progresses. Although TBC information, the radiological exposure standards included in DOE Order 5400.5 shall be achieved and will be confirmed through monitoring. Continued monitoring of the groundwater will be used during the five-year reviews to ensure that the identified goals are met and that concentrations of COCs continue to decrease.

Potential location-specific ARARs

Wetlands. Although no wetlands have been identified within the area where construction activities will occur, certain jurisdictional wetlands have been identified in on-site drainage ditches within the plant boundary. In order to comply with these applicable requirements, wetlands shall be avoided.

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, 40 *CFR* 6.302(a), 40 *CFR* 6 Appendix A, and 10 *CFR* 1022]. These applicable requirements include avoiding construction in wetlands, avoiding (to the extent practicable) long-term 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. Although not anticipated, if this alternative results in impacts to wetlands that cannot be avoided, the substantive requirements of the NWP 38 (33 *CFR* 330) will be met.

Operations shall not impact wetlands, and all treatment will be conducted either *in situ* or in units already in operation.

Endangered Species and Migratory Birds. Actions taken by federal agencies are prohibited from impacting T&E species or adversely modifying critical habitat (50 *CFR* 17.94) in accordance with the Endangered Species Act (16 USCA 1531 *et seq.* Section (7)(a)(2)). These requirements are potential ARARs in the event T&E species or their habitats are found at or near areas where remedial action is to occur. An ecological resource investigation inside the PGDP security fence did not detect any T&E species or their preferred habitats (CDM Federal 1994). The USFWS has not designated critical habitats for any species within the DOE property. However, outside the PGDP fence on the DOE property, potential habitats for federally listed T&E species were reviewed, and Indiana bat habitat was evaluated during the COE (1994) environmental investigation. The COE study determined that total potential bat habitat consisted of 20% of the 994-ha (2,456-acre) study area. Remedial activities must be evaluated to ensure that such actions do not adversely impact areas identified as critical habitat for any identified endangered species.

In addition, Executive Order 13186 directs federal agencies to enter into an MOU with the USFWS to further the purposes of the Migratory Bird Treaty Act (16 U.S.C. 703-711). Until such time as the MOU between DOE and the USFWS is finalized, federal agencies are encouraged immediately to begin implementing the conservation measures set forth in the Executive Order. The requirements of the Executive Order are applicable and must be considered during planning and design of the remedial action.

Potential action-specific ARARs

Monitoring well/injection installation requirements. This alternative includes the installation of additional monitoring wells, injection wells, and extraction wells. Installation of these wells would have to be conducted in a manner to maintain existing natural protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole (401 KAR 6:310 Section 13). These requirements also mandate the construction materials required for well construction, well design criteria, well completion activities, and well abandonment methodologies. These requirements are considered applicable to design and installation of monitoring, injection, and extraction wells associated with the implementation of this alternative.

Fugitive dust emissions. Construction activities may result in the production of particulate airborne pollutants (dust). The Kentucky Air Quality standards found in 401 KAR 63:010 include requirements governing fugitive dust emissions. These standards require that dust-suppression measures be undertaken, including activities such as use of water or chemicals to control emissions, placement of asphalt or concrete, and stockpiling of soils. The standards also require that visible dust generated from the implementation of the remedial alternative not be discharged beyond the property boundary of the site. For the purpose of compliance with these requirements, the site boundary is interpreted to mean the DOE site boundary or the immediate boundary of construction activities that occur on non-DOE property. Trucks transporting materials outside the DOE property boundary, where materials could become airborne, must be covered. These requirements are considered to be applicable to the implementation of this alternative and will be complied with through careful planning to ensure that excavated materials are sufficiently wetted or protected to control dust generation.

Radionuclide emission standards. Airborne emissions of radionuclides may occur as a result of on-site construction activities. Although the potential is low for such emissions to occur, the regulations in 40 *CFR* 61.92 would be applicable, requiring that the emissions not exceed amounts that would cause an EDE to the public of 10 mrem/year. In order to determine whether the alternative complies with this applicable requirement, computer modeling using the CAP-88 or other EPA-approved models must be undertaken. If the modeling demonstrates that the radionuclide emission is in excess of 1% of the 10 mrem/year standard, emission rates must be measured as required by 40 *CFR* 61.93. This ARAR shall be complied with by planning activities in such a manner as to control fugitive emissions from construction and treatment activities.

Toxic emission standards. Although toxic emissions are not expected as a result of construction activities or with the pumping of the groundwater to the on-site water treatment facility, these emission requirements would be applicable if such an emission does occur. Due to organic concentrations found in the groundwater and potentially within the subsurface soils, there is a low potential for such emissions to occur. The regulations at 401 KAR 63:022 require that emissions be evaluated to determine whether they are significant for each specific toxic air pollutant. If analysis indicates the toxic emission requirements are triggered, the regulations specify that no source may exceed the allowable emission limit specified in Appendix A of 401 KAR 63:022. If applicable, these rules would require application of the best available control technology to limit toxic emissions. If calculations indicate that the emission rates specified within the rule are not exceeded, then the calculation package may be used to demonstrate compliance with these requirements. Activities that must be considered include collection and treatment of contaminated groundwater, vapors extracted, and steam.

Stormwater discharge. Construction activities will be subject to the substantive requirements associated with the KPDES permit that requires the use of BMPs and sediment/erosion controls to control transport of sediment in stormwater runoff. These requirements are considered to be applicable.

Waste management requirements. Secondary wastes may be generated during the implementation of this alternative in the form of treatment residuals and potentially contaminated environmental media. All wastes generated shall be subject to the hazardous waste determination requirements of 40 *CFR* 262 and 401 KAR 32:010. Soils and treatment residuals shall be assessed to determine whether they contain a hazardous waste. If it is determined that any wastes are, in fact, hazardous wastes, the materials must be managed in accordance with the substantive requirements found in 40 *CFR* 262 through 40 *CFR* 268 (401 KAR 32 through 37). These standards include storage requirements, transportation requirements, and disposal requirements. Specific requirements applicable to each waste stream must be identified after characterization of the material is complete. These requirements shall be complied with through the development of a WMP during the design phase of implementation. If materials are identified as RCRA-hazardous wastes, these requirements are applicable.

Action-specific ARAR summary. This alternative will trigger action-specific ARARs with regard to the treatment of the contaminated groundwater. In addition, the requirements of RCRA may be applicable if hazardous waste is generated. This alternative will comply with these requirements during the planning phase to include compliant waste handling, storage, and disposition components.

A summary of the ARARs for the implementation of this alternative is presented in Table 4.9.

Compliance with ARARs summary. Implementation of this alternative would not achieve compliance with the MCL for TCE. In addition this technology does not address contamination from metals or radionuclides present within the soils or groundwater. Because this alternative does not immediately meet the stated MCLs, an ARAR waiver or agreed schedule of compliance would have to be sought as part of the ROD and PRAP.

To comply with the identified chemical-specific ARARs, an ARAR waiver will be required due to the time frames required to meet the specified concentrations within the GWOU at the point of compliance and points of exposure.

As discussed, no potential location-specific ARARs have been identified within the area in which remedial action will occur. However, to ensure that jurisdictional wetlands are not impacted, all construction activities associated with the installation of the extraction wells, monitoring wells, and injection wells will be reviewed as a safeguard. The protection of wetlands is not considered a location-specific ARAR at this time because jurisdictional wetlands have not been identified within the areas impacted by the implementation of this alternative.

Construction and implementation of the alternative may trigger several action-specific ARARs, such as the requirements associated with well installation and abandonment, fugitive dust emissions, radionuclide emissions, and toxic emissions. The requirements associated with the installation and abandonment of groundwater wells will be met though the use of well designs and materials of construction, as specified at 401 KAR 6:310 Section 13. All well installation and abandonment practices incorporated into the approved remedial design shall comply with the substantive requirements of 401 KAR 6:310.

The treatment of groundwater will require the injection of steam into the subsurface and extraction of groundwater, vapors and steam. During the remedial design assessment, all materials used in the construction will be reviewed to ensure that materials that could further impact water quality are not used or are limited in use.

The construction activities associated with this alternative may require that BMPs for sedimentation/ erosion controls be established. Sedimentation control is required if the area to be disturbed during construction exceeds regulatory limits. Regardless of the size of the construction area(s) sedimentation controls will be TBC information. This requirement will be complied with through the use of sediment fences or other appropriate means. The remedial design shall incorporate the specific controls necessary to ensure that the construction site(s) do not allow sedimentation and/or erosion of disturbed areas to comply with this requirement during implementation of this alternative.

Fugitive dust emissions that may occur during construction activities will be controlled as required by 401 KAR 63:010. BMPs, such as the wetting or covering of potential sources of fugitive dust, will be incorporated into the remedial design. The specific actions to be developed shall control potential emission sources to ensure that dust emissions do not migrate from the immediate area where construction activities occur. It is anticipated that, in most cases, the moisture content in the soil will be sufficient to control dust emissions during well installation. However, practices such as wetting of disturbed soils, collection of soils, or reseeding activities shall be considered and incorporated into the remedial design, as necessary, to ensure compliance with these requirements. Radionuclide emissions at construction sites also must be considered during the implementation phase. In order to ensure that the emission standard of 10 mrem/year EDE to the public is met, concentrations of radionuclides in soils and groundwater must be evaluated. If the potential for such emissions is identified, modeling using the CAP-88 or other EPA-approved method must be undertaken during the design phase of the alternative. It is anticipated that the primary conveyance of airborne radionuclides will be in particulate form. Therefore control of fugitive dust emissions also will result in compliance with the emission standards applicable to radionuclides. If radiological contamination from plant activities is found in soils where construction activities are planned, the soil will be protected or containerized to prevent airborne migration. Measures necessary to prevent airborne emissions or radionuclides shall be evaluated and incorporated as appropriate into the remedial design in order to comply with these requirements during implementation of this alternative.

Emissions of toxins, such as volatile organics, also must be evaluated before implementation. Although the potential for exceedance of toxic air emissions is considered to be low, an evaluation of the potential for such emissions must be undertaken during the remedial design. Potential emissions must be evaluated for each toxin present in the plumes (i.e., TCE, vinyl chloride and other degradation products) to determine whether the contaminant levels found in the subsurface could result in airborne emissions in excess of the allowable limits specified in Appendix A of 401 KAR 63:022. Compliance with the emissions standards shall be achieved for this alternative through the evaluation process or the application of best available control technology where emissions are calculated to exceed allowable levels. It is anticipated that through the use of an extraction system, all air emission standards will be met. Appropriate emission control equipment will be incorporated into the treatment system utilized. The specifications for this equipment shall be identified during the remedial design based upon the initial evaluation. This requirement will be complied with during implementation of the alternative.

Excavated soils and secondary wastes generated from the *in situ* treatment of groundwater will result in the generation of wastes that will trigger the characterization requirements associated with the RCRA regulation. The implementing regulations found at 40 *CFR* 262 and 401 KAR 32:010 require that generators of solid wastes (or contaminated environmental media) must determine whether the waste also is a hazardous waste. If the materials generated from the implementation of this alternative are found to be hazardous wastes, the materials shall be containerized and managed as such. The requirements mandate that hazardous wastes be properly labeled and stored in areas that comply with the technical standards for storage of hazardous waste in containers. These standards shall be complied with though testing of soils before excavation activities and testing of secondary wastes generated during groundwater treatment. If any of these materials are found to be hazardous waste regulated under RCRA, appropriate storage areas shall be constructed and maintained. All hazardous waste generated during the implementation of this alternative that is required to be shipped for off-site disposal shall use the EPA Identification Number for the PGDP. Hazardous wastes shall be shipped to facilities permitted to treat, store, or dispose of the hazardous waste(s) being shipped, if on-site treatment or disposal is not allowable. These activities shall be incorporated into the remedial design for this alternative in order to comply with these requirements.

Secondary wastes and soils generated during the implementation of this alternative also may be subject to regulation under TSCA (as PCB remediation waste) and DOE Order 435.1 (as LLW). Characterization of these materials will be required to determine whether specific wastes are regulated under these requirements. If it is determined that the waste generated is a PCB or LLW, appropriate management standards will be incorporated into the remedial design. Existing information will be used where practicable to determine the regulatory status of all waste to be generated before implementation. This alternative will comply with all TSCA and LLW requirements.

Long-Term Effectiveness and Permanence. Secondary Source Zone Steam Extraction Technology offers a relatively high level of long-term control for VOCs and DNAPL TCE contaminants located in areas of the RGA that may be subject to treatment. There would only be a moderate impact to ^{99}Tc located in the treated areas since removal is limited to that which is entrained in produced groundwater as a result of the operation. The implementation of this technology only in the RGA will provide little to no control over target contaminants located in the UCRS or the dissolved phase plume areas.

Magnitude of residual risk. Residual risk in the RGA will remain in place after implementation of a Steam Extraction Technology. The technology will require assistance from other technologies either in the UCRS or RGA to meet the MCLs at the point of compliance. This alternative will reduce VOCs, TCE DNAPL, and ^{99}Tc by extracting them from the RGA with the assistance of heat generated from the injection of steam in the targeted areas. The technology will have little to no impact on contaminants present in the UCRS or the dissolved phase plume areas unless those areas are targeted for the treatment.

Following treatment of the selected RGA areas, residual COCs would contribute to long-term risks. However, the five-year reviews, mandated by CERCLA [40 *CFR* §300.430(f)(4)(ii)], would be an effective means to demonstrate that contaminant levels were reduced from the technologies implementation and additional exposure pathways have not developed.

Adequacy and reliability of controls. The reliability for operation and control of Steam Extraction Technology would be high because the components that make up the treatment systems have been used with some success at a small number of hazardous waste sites throughout the nation. Thermal computer modeling would be used to design the site-specific location, injection and extraction well layouts, and flowrates of the Steam Extraction Technology to ensure appropriate capture zones. However, should extended interruptions of electrical power, fuel, or other vital systems occur, the potential would exist for COCs to escape from the treatment system area. Long-term groundwater monitoring will be required to monitor the extended effectiveness of the treatment following its completion.

Intrusive activities onsite will be prevented as necessary through the use of work permits and safety programs, thereby limiting the access of plant personnel to the contaminated groundwater.

Environmental impacts and mitigative measures. The following paragraphs summarize potential long-term impacts to resources and mitigative measures to offset any potential impacts. The depth of impact analysis and mitigative measures is correlated to the degree to which a resource may be impacted.

Land use. Long-term land use impacts would be minimal, as the current land use classifications would not change. The minimal long-term impacts would be related to the monitoring wells and monitoring facilities that would remain following the technology's implementation. A LUCIP would be developed as necessary per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomics. The presence of contaminants in the groundwater will prevent its use and may limit economic development opportunities until the groundwater is brought back to beneficial use. However, no long-term effects to socioeconomics would result from the implementation of this technology. There would be few changes to permanent jobs within the PGDP area as a result of implementing this technology.

Air quality and noise. No long-term effects to air quality and ambient noise levels would result from implementation of this alternative.

Vegetation. No long-term effects to vegetation would result from this alternative.

Wildlife. No long-term effects to wildlife or T&E species would result from this alternative. Construction in creeks and tributaries will not occur as a result of implementing this technology. The likely target areas for the implementation of this technology are in areas of existing industrial buildings or other industrial facilities.

Threatened and endangered species. Long-term impacts to T&E species are not expected to occur. Construction in creeks and tributaries or other habitat areas is not expected to occur. The likely target areas for the implementation of this technology are in areas of existing industrial buildings or other industrial facilities.

Cultural resources. No long-term effects to cultural resources are anticipated for this alternative.

Groundwater. As a result of implementing a Steam Extraction Technology in Secondary Source Areas, potential RGA VOC sources and ^{99}Tc are either reduced or eliminated. As a result of the use of heat from the steam injection, physical and chemical changes may occur to DNAPL. These changes may result in undesired migration of contaminants to noncontaminated areas. Groundwater monitoring systems will be used to monitor the migration of contaminants to noncontaminated areas.

Surface water. No adverse impacts to streams are expected to result from implementing Steam Extraction Technology in a Secondary Source Area (RGA). No adverse impacts to wetlands are expected to occur either. There will be only small increases in water discharge volumes to outfalls.

Floodplains. No long-term impacts to floodplains are expected as a result implementing this alternative. No additional, significant, long-term, adverse effects to floodplains have been identified as resulting from this alternative.

Wetlands. No long-term impacts to wetlands have been identified as resulting from implementing this alternative. This alternative would be implemented within the main fenced area of the PGDP.

Soils and prime farmland. Prime farmland would not be impacted by the implementation of this alternative as the area has been previously disturbed and; consequently, is not classified as prime farmland.

Transportation. No long-term direct, indirect, or cumulative effects to transportation are anticipated from implementing this alternative.

Cumulative Impacts. Cumulative impacts are defined as the incremental impact of an action when added to other past, present, and reasonable foreseeable future actions, regardless of what agency or person undertakes other such actions. Cumulative impacts resulting from this alternative will have to be identified at a later time during development of site-specific GWOU decision documents.

Reduction of Mobility, Toxicity, or Volume Through Treatment. Steam Extraction Technology would be used to remove VOCs, TCE DNAPL, and ^{99}Tc contaminants from source areas located in the RGA. The produced water resulting from the steam extraction would be air stripped to remove VOCs. The vapor phase from the air stripper would be treated by catalytic oxidation for VOCs. The produced water also would be treated by ion exchange for removal of ^{99}Tc. Since all extracted groundwater is treated sufficiently, the amount of hazardous materials destroyed or treated depends directly upon the design and efficiency of the Steam Extraction Technology and the amount of contaminant present in the targeted treatment area. It is expected that 70% to 95 % of the VOC contaminants in the target could be removed by the steam extraction. Nearly 100% of the VOC contaminants removed would be destroyed by surface treatment system. The Ion Exchange Technology would not result in the destruction of the ^{99}Tc, since the material is only captured on the treatment resin.

The implementation of a Steam Extraction Technology would reduce the long-term volume of VOCs, DNAPL, and ^{99}Tc contamination present in the RGA through the extraction of those contaminants. The implementation of this technology would not be expected to alter the chemical and physical soil properties of the RGA and, as such, would not prevent the subsequent implementation of an additional technology, should it be determined that additional treatment is needed for the target areas.

The type and characteristics of residual subsurface contamination would be similar to that of the contaminants prior to treatment. Residual contaminants would pose a risk although contaminant quantities would be reduced following treatment. Residuals from the treatment of contaminants in the surface equipment would consist of salt from the scrubbing of the off-gas from the catalytic oxidizer, treated groundwater, and ion exchange resin containing the ^{99}Tc produced. As a result of the destruction of VOCs in the catalytic oxidizer, the use of a Steam Extraction Technology may meet the statutory preference for treatment as a principal element of the remedial action under CERCLA. In addition to the above residuals, there would be miscellaneous materials from the treatment including lime from the off-gas scrubber, PPE, and other miscellaneous wastes.

Short-Term Effectiveness. The short-term effectiveness of implementing a Steam Extraction Technology in a Secondary Source Area of the RGA was evaluated relative to its effect on community protection, worker protection, environmental impact, and the time until RAOs are achieved. Environmental impact was further evaluated for NEPA values. This information is presented in the following subsections.

Community protection. The potential for adverse impacts to the community from the implementation of this alternative is minimal. Engineering controls, as discussed above, can be implemented to reduce the off-site gas emissions related to the air stripping of the groundwater to remove VOCs. The likely target areas for treatment will be located in the main industrial area of the PGDP. Restrictions will be used to limit the access of persons that may be in the area during construction. This will include warning signs, temporary control fencing, and periodic security patrols. Also, environmental monitoring would be conducted during the construction of monitoring wells where COCs may be present. Following completion of the construction activities, only temporary periodic access will be required for sampling of the monitoring wells used to check the long-term effectiveness of the action on the RGA.

Transportation of residual wastes from the *ex situ* treatment processes, which will be limited in volume, may introduce increased risks to off-site communities. However, proper packaging and other required safety features would be used to limit releases as a result of accidents.

Worker protection. During the implementation of a Steam Extraction Technology, workers could be exposed to COCs during short periods of time. Potential exposure could result from direct contact with contaminated soil and/or groundwater during construction and *ex situ* treatment activities. The production and injection of steam associated with implementation poses a potentially serious risk to workers, and potential concerns exist regarding the potential migration and breakout of steam at the surface. However, short-term risks are not expected to exceed acceptable limits. Health and safety requirements and PGDP procedures would further control the exposures.

Environmental impacts and mitigative measures. The following paragraphs summarize potential short-term impacts to resources and mitigative measures to offset any potential impacts. The depth of impact analysis and mitigative measures is correlated to the degree to which a resource may be impacted.

Land use. The areas expected to be targeted for implementation of a Steam Extraction Technology would be located inside the main PGDP facility. To that end, short-term land use would not be affected by this alternative, as the current land-use classifications would not change. There would be minimal impacts to land use. These short-term impacts would be related to the presence of treatment facilities and monitoring wells. A LUCIP would be developed, as necessary, per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomics. This alternative would not be expected to change the economic conditions in the nearby area. There would be a minimal increase in temporary jobs related to the construction and operation of the facilities.

Air quality and noise. Heavy equipment traffic and operation associated with construction would provide a minimal increase dust and vehicular emission levels. The use of BMPs during construction would reduce short-term direct impacts to air quality from dust. Noise associated with construction activities would occur in the immediate vicinity of the PGDP. There also would be treated emissions associated with the treatment operation. These emissions can be expected to provide a short-term degradation of air quality in the vicinity of the operation. The emissions, however, would be treated to remove contaminants, and these emissions would comply with federal, state, and local regulations concerning air contaminant releases.

Vegetation. There would be some short-term impacts to vegetation in the construction area. However, the area impacted is expected to be less than 5 acres. After construction is complete, vegetation would be restored.

Wildlife and threatened and endangered species. The likely target areas for the treatment by Steam Extraction Technology are located within the industrial portion of the PGDP. No construction is expected to occur in the creeks and tributaries; therefore, the impacts to wildlife are expected to be minimal. Very little or no wildlife habitat is associated with these areas. Some small mammals and birds may use these areas and, consequently, some small mammals may perish. Indirect effects such as displacement during construction would occur due to disturbance of habitats, noise, and activities associated with construction; however, after construction is completed, revegetation and natural repopulation to pre-construction conditions likely would occur. No effects to T&E species would result from implementing this alternative.

Cultural resources. No short-term effects on cultural resources would be anticipated to occur from the implementation of this alternative.

Groundwater. As a result of implementing a Steam Extraction Technology in Secondary Source Areas, potential RGA VOC sources and ^{99}Tc are either reduced or eliminated, thereby producing a positive effect. As a result of the use of heat from the steam injection, physical and chemical changes may occur to DNAPL. These changes may result in undesired migration of contaminants to noncontaminated areas. Groundwater monitoring systems will be used to monitor the migration of contaminants to noncontaminated areas.

Surface water. No short-term adverse impacts to streams are expected to result from implementing a Steam Extraction Technology in a Secondary Source Area (RGA). No adverse impacts to wetlands are expected to occur either. There will be only small increases in water discharge volumes to outfalls during the operation.

Floodplains. No short-term impacts to floodplains are expected as a result of implementing this alternative.

Wetlands. No short-term impacts to wetlands have been identified as resulting from implementing this alternative. This alternative likely would be implemented within the main fenced industrial area of the PGDP.

Soils and prime farmland. Prime farmland would not be impacted by the implementation of this alternative, as the area has been previously disturbed and, consequently, is not classified as prime farmland.

Transportation. There would a small increase in short-term direct, indirect, or cumulative effects to transportation are anticipated from implementing this alternative. These impacts would be the result of equipment transportation during construction and transportation of residual wastes during the treatment operation. However, proper packaging and other required safety features would be used to limit releases as a result of accidents when transporting the waste residuals.

Time until action is complete. Implementation of this alternative will not result in achievement of the GWOU RAOs specified or groundwater MCLs. Approximately 7,000 years will be required before groundwater may be used following the application of Steam Extraction Technologies only in the Secondary Source Areas of the RGA. The reduction of sources within the RGA only will not prevent the Primary Source Areas located within the UCRS from continuing to impact the groundwater. It will be necessary to implement other source reduction and dissolved phased technologies in conjunction with Steam Extraction Technologies in the Secondary Source Areas to reduce the time the groundwater will remain unusable.

Implementability. The implementability of Steam Extraction Technologies in the Secondary Source Areas of the RGA was evaluated based upon its technical feasibility, administrative feasibility, and the availability of services and materials. This information is summarized in the following subsections.

Technical feasibility. Implementation of Steam Extraction Technologies is technically feasible. These technologies have been implemented at other hazardous waste sites, and the necessary equipment may be readily obtained. The technology is believed to be reliable if adequate monitoring is provided and the technology is allowed to operate for an adequate time period. With regard to reliability, potential concerns exist for the potential migration and breakout of steam at the surface; however, steam breakouts during previous applications at other sites have been corrected easily without adverse consequences to the operation. Implementation difficulties may arise due to the industrial areas of the PGDP, which have large buildings high concentrations of utility corridors that may provide migration pathways for the steam and also interfere with injection and extraction well placement.

Implementation of an *ex situ* treatment system for treating the extracted groundwater is technically feasible. *Ex situ* treatment using a similar process option is being conducted currently at the PGDP. All components of the treatment system use proven technologies that are readily available. The equipment used is proven and reliable, and downtime is expected to be minimal for maintenance and repairs. The effectiveness of the treatment system in removing the COCs would be monitored by effluent sampling to ensure that the released water is in compliance with regulatory requirements.

Administrative feasibility. This alternative is administratively feasible. All activities would be conducted in accordance with substantive federal, state, and local requirements. Waivers of ARARs are anticipated to be necessary to implement these actions since the MCLs for groundwater will not be obtained in a timely manner.

Availability of material and services. The services and materials necessary to implement this alternative are readily available. The potential exception would be personnel/vendors necessary to implement the Steam Extraction Technology. The equipment is standard industrial equipment used in other fields such as petroleum production. However, the number of vendors experience at implementing steam extraction in the environmental remediation arena is limited.

The construction of this alternative will result in the generation of waste soil cuttings and drilling and development water from the construction of injection, extraction, and monitoring wells. Additionally, the alternative will generate construction debris during the building of the treatment facility. All of these materials either will be treated as necessary and released, as in the development water, or disposed of appropriately.

The operation of the treatment system will result in the generation of sodium chloride from the scrubbing of the catalytic oxidizer off-gas and ion exchange resins spent with ^{99}Tc. Both of these materials will be stored until appropriate disposal can be arranged. Due to temporal variations, the availability of adequate, on-site, storage space would need to be assessed (or made available) immediately prior to implementing this alternative.

Cost. Table 4.10 summarizes the preliminary unit cost estimates for implementation of a Steam Extraction Technology in a Secondary Source Area of the RGA. These preliminary unit cost estimates are based upon FS-level scoping and are intended to aid with selection of a preferred alternative. The estimates have an expected accuracy of -30 to +50% for the proposed scope of action (EPA 1988a). The capital cost estimate represents those expenditures required to implement this remedial alternative. The O&M cost estimates represent expenditures required to maintain the remedy after the initial phase of remedial action is completed. The total contingency cost presented includes direct, indirect, and all O&M associated contingency costs. The total cost includes all capital costs, direct and indirect with O&M and associated reports, plus 25% contingency costs, for a 30-year term of comparison. All estimates have been escalated using DOE-approved annual rates and a schedule for the various activities based on similar project experience. Present worth values also are included using a discount factor of 5% (EPA 1988b). (Additional information regarding the preliminary cost estimates is presented in Appendix C7.)

Table 4.10. Preliminary unit cost estimates for Secondary Source Area Steam Extraction Technology

Total capital costs/acre-foot	$780,268
Total operation and maintenance costs	$136,096
Overhead	$750,576
Total contingency	$416,735
Total cost	**$2,083,677**
Total cost (present worth)	**$1,042,276**

Note: preliminary cost estimates are per acre-foot, escalated and presented in dollars.

State/Commonwealth Acceptance. Commonwealth of Kentucky acceptance or nonacceptance of this alternative will be addressed in the ROD should this alternative be selected as the preferred alternative.

Community Acceptance. Following a formal public comment period on the PRAP for the GWOU, comments from the community will be addressed formally in a responsiveness summary, which will be presented in the ROD.

Evaluation Summary of Secondary Source Area Steam Extraction Technology

This alternative consists of implementing a Steam Extraction Technology in a Secondary Source Zone of the RGA to remove VOCs, TCE DNAPL, and ^{99}Tc contaminants present in the RGA in the targeted area; monitoring of the action; and conducting five-year reviews as required by CERCLA. Monitoring COC migration allows the potential for exposure to contaminated groundwater to be prevented or minimized, and it also allows the effectiveness of the remedial actions to be evaluated. Although the Secondary Source Area in the RGA would be reduced following the implementation, the residual contamination and risks would remain. These residual risks in the RGA, as well as risks that still may be present in the UCRS and the dissolved phased plumes, will prevent the use of the groundwater for an estimated 7,000 years. It also would be necessary to conduct other source area reductions and dissolved phased plume actions to reduce the time the groundwater would be unusable.

Implementation of this alternative alone will not be protective of human health and the environment. It must be combined with other source area and dissolved phase plume actions. Steam Extraction Technologies can be implemented in compliance with ARARs. Long-term effectiveness could be achieved to an acceptable degree (70%-95% mass removal within with the RGA Secondary Source Area within 15 years of implementation); however, because of the nature of the soil and groundwater contamination associated with the GWOU, it will take several years and other actions to remediate completely. Residual contamination will remain in the groundwater, with TCE levels exceeding the MCL for approximately 7,000 years. The volume of COCs would be reduced by *ex situ* treatments. Limited short-term risks to workers would exist during the construction and operation phase of the alternative. The alternative is technically and administratively feasible to implement. The unit cost of this alternative, which is intended to address only the Secondary Source Areas of the RGA in the GWOU at the PGDP, is quite significant. Input from the Commonwealth of Kentucky and the community has not yet been received, but it will be added to later versions of this FS report and the corresponding ROD once the respective comment periods have been completed.

4.2.3.2 Secondary Source Area – Pump-and-Treat Technology

The following subsections contain a description of Secondary Source Area – Pump-and-Treat Technology Alternative and the detailed analysis.

Description of Secondary Source Area - Pump-and-Treat Technology

This alternative would consist of implementing a Pump-and-Treat Technology in a DNAPL source zone area of the RGA. The purpose of the alternative would be to remove TCE DNAPL, other VOCs, and ^{99}Tc contaminants from areas of the RGA that have sufficient TCE concentrations to be considered as having free phase TCE, or TCE DNAPL, present in the zone. This technology requires a series of extraction wells installed in the RGA in the secondary source areas of contamination. The wells will extract groundwater containing both VOCs and ^{99}Tc. The produced water will be conveyed to a regional treatment facility for COC removal prior to being released. The treatment of the water to remove the COCs will be by air stripping for TCE and ion exchange for the ^{99}Tc. The treated water will be tested before being released to an outfall.

Figure 4.5 contains a "snapshot" that graphically summarizes the components of the Secondary Source Area Pump-and-Treat Technology alternative.

The source reduction efforts for the implementation of this alternative will diminish the time until on-site groundwater VOC levels attributed to the DNAPL zone areas are below the MCL. However, due to the technology not effecting removal of the DNAPL TCE contaminants in the UCRS area, it is anticipated that groundwater will not be returned to the drinking water standard for TCE for approximately 7,000 years. The off-site portions of the groundwater plumes will only be affected by the reduced quantity of DNAPL present in the RGA that is available for dissolving and producing migrating plumes.

If the UCRS sources are effectively removed by a companion treatment technology, the secondary sources of DNAPL in the RGA can reach the MCLs by the Pump-and-Treat Technology in approximately 100 years.

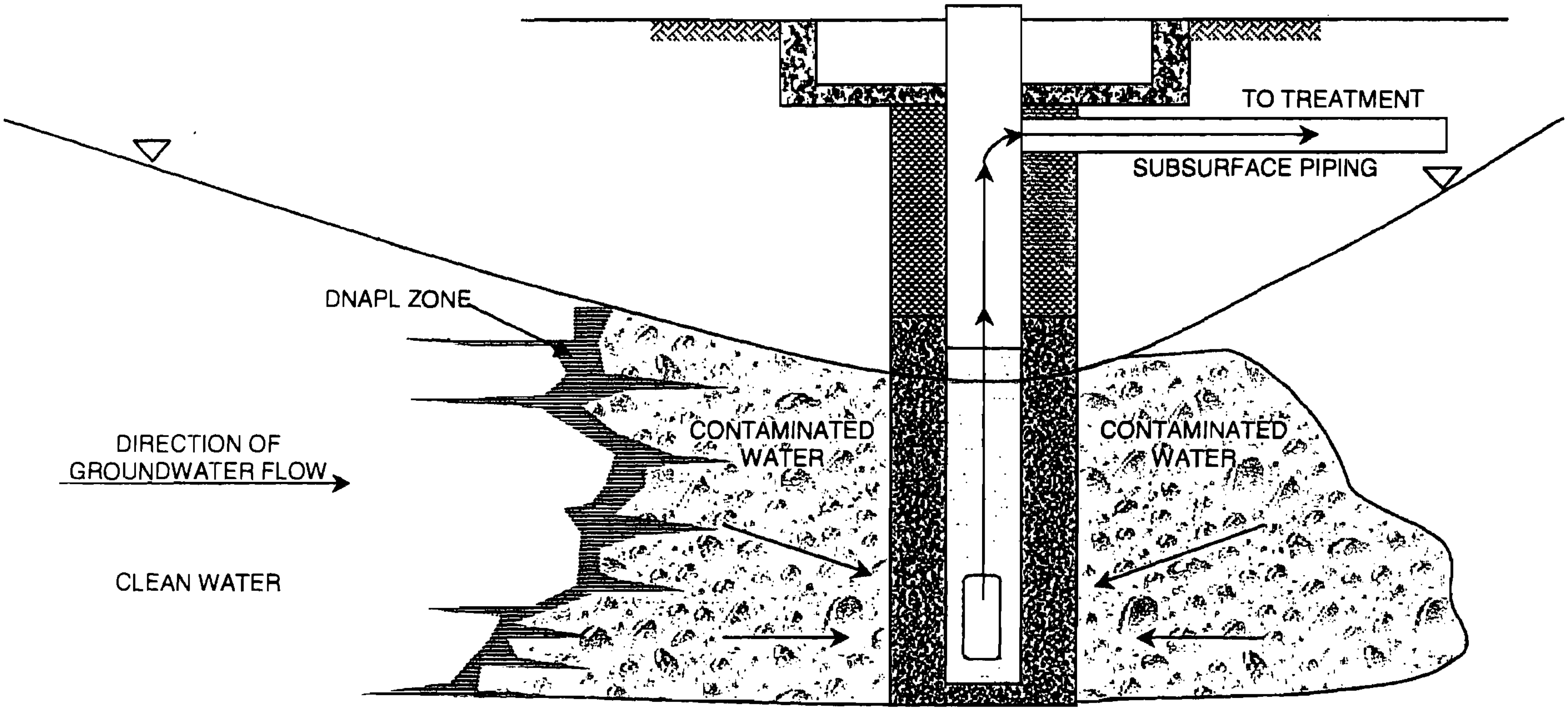
The existing groundwater monitoring program would be continued to monitor the movement of COCs within the RGA. The monitoring program will integrate existing PGDP monitoring wells, where possible, with additional monitoring wells to be installed, as needed, following a review of the existing program.

CERCLA Five-Year Review. The CERCLA Five-Year Review process will be used to monitor the effectiveness of the alternative and to identify any needed changes.

Assessment of Secondary Source Area Pump-and-Treat Technology Alternative

A detailed analysis of the performance of the Secondary Source Area Pump-and-Treat Technology alternative against the nine CERCLA criteria is provided.

Overall Protection of Human Health and the Environment. This alternative would reduce VOC contamination in the RGA and also would prevent COC migration from source areas to downgradient areas and sustaining the plume contaminant concentrations. However, the effectiveness of Pump-and-Treat is limited by the dissolution rate of VOCs in water. The volatile COCs are removed from the groundwater system and air stripped. In addition, Pump-and-Treat will have high effectiveness on the ^{99}Tc contamination. The ^{99}Tc is removed from the groundwater system and trapped on an ion-exchange resin.



U. S. DEPARTMENT OF ENERGY
DOE OAK RIDGE OPERATIONS
PADUCAH GASEOUS DIFFUSION PLANT

BECHTEL JACOBS COMPANY, LLC
MANAGED FOR THE US DEPARTMENT OF ENERGY UNDER US GOVERNMENT CONTRACT DE-AC-05-98OR22700
Oak Ridge, Tennessee • Paducah, Kentucky • Portsmouth, Ohio

Science Applications International Corporation
P.O. Box 2502
Oak Ridge, Tennessee 37831

Fig. 4.5. Secondary source area - pump and treat technology.

FIGURE No. FS4-5
DATE 05-25-01

Although this alternative alone would not satisfy the RAOs for the GWOU by protecting ecological receptors that may be exposed to contaminated groundwater discharging to surface water, it would support achieving the RAOs when implemented in concert with other source reduction and dissolved phase GWOU technologies. If pump-and-treat technology is implemented in the RGA at all secondary source zones, hydraulic containment of contaminants migrating in the plumes would be effected. This would result in achieving RAOs and MCLs in the dissolved phase plume areas within approximately 100 years based on groundwater modeling results.

The continuation of the groundwater monitoring programs will provide indirect protection for human health and the environment by minimizing the potential exposure to contaminated groundwater through early identification and avoidance.

Compliance with ARARs

Potential chemical-specific ARARs

Chemical Contamination. The aquifers are known to contain chemical contaminants in the form of metals and organics. The federal and state water quality requirements include standards that would be applicable ARARs. The regulations that apply are found in 40 *CFR* 141 (National Primary Drinking Water Standards); 40 *CFR* 143 (Secondary Drinking Water Standards); 401 KAR 5:029 (General Provisions); and 401 KAR 5:031 (Surface Water Standards). These standards, summarized in Table 4.11, include general state standards, domestic water supply standards, and standards applicable to warm water aquatic habitat. These are applicable, based upon the classification of the designation for surface water use associated with the area (Ohio River, River Mile 940.7 to River Mile 943.3) as specified in 401 KAR 5:026. All potentially applicable chemical ARARs for COCs have been included in the table for completeness. Those standards that must be achieved in order to meet the applicable requirements are the lowest of the applicable standards, which in most cases are the MCLs.

Radiological contamination. The GWOU is known to be contaminated with radionuclides such as ^{99}Tc, radon, uranium, and uranium daughter products. DOE's Order on Radiation Protection of the Public and Environment, DOE Order 5400.5, as codified at 10 *CFR* 835, is TBC information for cleanup of radionuclides at DOE sites. The order requires that remediation activities must not result in radiation exposures to members of the general public greater than an EDE of 100 mrem/year from all exposure pathways. Exposure to the general public also must be ALARA (DOE 1990).

DOE Order 5400.5 also contains reference values, known as DCGs, for operational DOE facilities. Based on the DCGs, radionuclide concentrations in air and drinking water must not exceed an EDE of 10 mrem/year and 4 mrem/year, respectively, to the total body or any organ.

The NRC also has set criteria for decommissioning standards at nuclear facilities in 10 *CFR* 20 Subpart E. These rules require that residual radioactivity at nuclear sites meet a total EDE of 25 mrem/year for unrestricted release. In addition to the NRC standards, EPA has issued guidance for cleanup levels at CERCLA sites with radioactive contamination. EPA has disagreed with the protectiveness specified within the NRC standard and has specified that a 15 mrem/year EDE be used as the risk level that is protective of human health and the environment. EPA has also codified exposure limits for environmental radiation protection standards for nuclear power operations in 40 *CFR* 190. These requirements apply to operations involved in uranium fuel cycle and include enrichment operations. Subpart B of these requirements specifies that the annual dose equivalent to the public must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment from uranium fuel cycle operations and to radiation from these operations. These requirements would be considered relevant and appropriate since the release to the groundwater would not be planned.

Table 4.11. Summary of potential ARARs for Secondary Source Area Pump-and-Treat Technology

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Chemical-Specific ARARs	
National Primary Drinking Water Standards	40 *CFR* 141	Provides chemical-specific numeric standards for toxic pollutants expressed as MCLs and MCLGs.	These requirements are relevant and appropriate due to the nature of the contaminants found within the groundwater.
National Secondary Drinking Water Standards	40 *CFR* 141	Provides secondary MCLs for public water systems.	These requirements are TBCs, as they have been established as guidelines for the states and are not federally enforceable.
Kentucky Surface Standards including • Warm Water Aquatic Habitat Criteria • Kentucky Domestic Water Supply • Kentucky General Standards • Kentucky Outstanding State Resource Waters	401 KAR 5:031 and 5:026	Provides chemical-specific numeric standards for pollutants discharged or found in surface waters. Provides chemical-specific numeric standards for pollutants in domestic water supplies.	These standards are applicable to the segment of the Ohio River into which the Little Bayou Creek discharges. The requirements found in these standards are applicable due to the groundwater to surface water interface at Little Bayou Creek and subsequently the Ohio River. Note: CWA Water Quality Criteria are not relevant and appropriate because Kentucky has promulgated these state standards, determined to be appropriate for Kentucky waters.
Radiation Exposure of the General Public at DOE Facilities	DOE Order 5400.5	Specifies that the general public must not receive an effective dose equivalent of >100 mrem/year from all exposure pathways. In addition, all releases of radioactive materials resulting in doses to the general public must meet the ALARA criteria.	This requirement is considered TBC information.
Decommissioning Standards at Nuclear Facilities	10 *CFR* 20, Subpart E	Specifies a residual activity at nuclear facilities for unrestricted release of 25 mrem/year.	These standards are considered to be applicable to the GWOU.
Environmental Radiation Protection Standards for Nuclear Power Operations	40 *CFR* 190, Subpart B	Requires that the annual dose equivalent to the public must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughter products excepted, to the general environment from uranium fuel cycle operations and radiation from these operations.	These standards are considered to be relevant and appropriate and are equivalent to the NRC standards.

Table 4.11. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Location-Specific ARARs	
Protection of Wetlands	10 *CFR* Section 1022; Executive Order 11990; 40 *CFR* 230.10; 33 *CFR* 330.5	Activities must avoid or minimize impacts to wetlands to preserve and enhance their natural and beneficial value. If wetland resources are not avoided, measures must be taken to address ecologically sensitive areas and mitigate adverse effects. Such measures may include, minimum-grading requirements, runoff controls, and design and construction considerations. Allows minor discharges of dredge and fill material, or other minor activities for which there are no practicable alternatives, provided that the pertinent requirements of the NWP system are met.	These requirements are applicable due to the presence of wetlands, but they will be met through avoidance of wetlands during construction and implementation of alternatives.
Endangered Species Act	16 U.S.C. 1531 et seq. Section 7(a)(2)	Actions that jeopardize the existence of listed species or result in the destruction of adverse modification of critical habitat must be avoided or reasonable and prudent mitigation measures taken.	Action that is likely to jeopardize fish, wildlife, or plant species or destroy or adversely modify critical habitat-applicable.
Migratory Bird Treaty Act	16 U.S.C. 703-711; Executive Order 13186	Federal Agencies are encouraged (until requirements are established under a formal MOU) to do the following: • avoid or minimize, to the extent practicable, adverse impacts on migratory bird resources when conducting agency actions; • restore and enhance the habitats of migratory birds, as practicable; • prevent or abate the pollution or detrimental alteration of the environment for the benefit of migratory birds, as practicable; • ensure that environmental analysis of federal actions required by the NEPA or other established environmental review processes evaluate the effects of actions and agency plans of migratory birds, with emphasis on species of concern; and • identify where unintentional take likely will result from agency actions, and develop standards and/or practices to minimize such unintentional take.	Action that is likely to impact migratory birds, habitats, and resources-applicable.

Table 4.11. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Action-Specific ARARs	
Fugitive Dust Emissions during site preparation and construction activities.	401 KAR 63:010	Precautions must be taken to prevent particulate matter from becoming airborne. Such precautions must be incorporated into the planning and design of activities and include actions such as • wetting or adding chemicals to control dust from construction activities; • using materials such as asphalt or concrete (or other suitable chemicals/fixing agents) on roads or material stockpiles to prevent fugitive emissions; and • using covers on trucks when transporting materials to and from the construction site(s). The requirement specifies that for on-site construction activities, no visible emissions may occur at the PGDP fenceline. Similar points of compliance shall be identified for construction activities that occur outside the fence.	These requirements are applicable and will be met through the use of appropriate dust control practices identified during the alternative design phase.
Toxic Emissions	401 KAR 63:022	The regulations require that a determination of toxic emissions be made in order to assess the applicability of required controls. Calculations of the significant emission levels are compared to the allowable emission limits specified in Appendix A of 401 KAR 63:022. If emission levels are exceeded, best available control technologies must be incorporated into equipment/process design.	These requirements are considered to be applicable and shall be met through calculation of significant emission levels for toxic materials and application of best available control technology, as necessary, during the design of the alternative.
Monitoring Well Installation	401 KAR 6:310	Monitoring wells (including extraction wells) must be constructed in a manner to maintain existing protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole. In addition, abandoned wells must be plugged and abandoned in accordance with the requirements specified.	These requirements are considered to be applicable. Compliance with well design and protection standards shall be achieved through the use of approved well design and materials of construction. While in service, wells shall be secured as required. Abandoned wells shall be plugged and abandoned as required.
		Action-Specific ARARs	
Discharge of Stormwater and Treated Groundwater	40 *CFR* 122 401 KAR 5:055	Stormwater discharges from construction activities onsite are subject to the requirements of the KPDES permit. This requires that BMPs to control stormwater runoff and sedimentation be employed. Although off-plant construction activities within the contaminated area are not subject to the permit, these requirements should be considered relevant and appropriate and be incorporated into any off-site construction activities. Discharge of treated groundwater will be conducted in compliance with the substantive requirements of the KPDES program and the CWA.	These requirements are considered applicable for all on-site construction or treatment activities where a discharge of stormwater or treated groundwater occurs. For off-site construction activities, these requirements are considered relevant and appropriate and will be adhered to. Compliance with these ARARs shall be achieved by application of required controls during the design phase of the alternative.

Table 4.11. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
Hazardous Waste Management	40 *CFR* 260 through 264 and 268; 401 KAR 31 through 34, 36, and 37	All wastes or environmental media containing wastes must be characterized to determine whether the wastes are hazardous in accordance with 40 *CFR* 262.11 and 401 KAR 32:010. If it is determined that a waste is a hazardous waste or that environmental media contain a hazardous waste subject to the RCRA regulation, the substantive requirements of 40 *CFR* 262 through 268 are applicable. These standards include design and operation of storage and accumulation areas, waste handling and shipment, and treatment technologies or numeric standards applicable to wastes prior to disposal.	These requirements are applicable and will be met through characterization of wastes and environmental media generated as a result of implementation of the alternative. Waste management will be predicated upon the characterization and comply with all substantive requirements associated with hazardous waste management if identified as such.
		Action-Specific ARARs	
PCB Waste Management	40 *CFR* 761	TSCA requirements for the management of PCB wastes or items containing >50 ppm PCBs or from a source of 50 ppm or greater. Requirements include the following: • management of waste and material; • characterization of PCB-containing materials; • labeling and storage for disposal; • manifest completion for shipment offsite; • decontamination of affected equipment or items; and • disposal of PCB wastes. These requirements will be complied with in the event that PCBs are found at concentrations requiring compliance.	These requirements are applicable if PCBs are found or result from items or equipment regulated under 40 *CFR* 761. Activities necessary to comply with these ARARs shall be incorporated into the planning phase of the alternative implementation.

ALARA = as low as reasonably achievable
ARAR = applicable or relevant and appropriate requirement
CFR = *Code of Federal Regulations*
DOE = Department of Energy
GWOU = Groundwater Operable Unit
KAR = Kentucky Administrative Regulations
KPDES = Kentucky Pollutant Discharge Elimination System
MCL = maximum containment level
MCLG = maximum containment level goal
NRC = U.S. Nuclear Regulatory Commission
NWP = Nationwide Permit
PCB = polychlorinated biphenyl
PGDP = Paducah Gaseous Diffusion Plant
RCRA = Resource Conservation and Recovery Act
TBC = to be considered
TSCA = Toxic Substances Control Act

The Commonwealth of Kentucky is an NRC Agreement State and has promulgated regulations for radiation protection of the public. The Kentucky radiation protection standard for individual members of the public is 0.1 rem (100 mrem) EDE per year or less (902 KAR 100:019 Section 10), which is equivalent to the DOE radiation protection standard found in DOE Order 5400.5.

Due to the differing view and values among NRC, EPA, and DOE total EDE for members of the general public, EPA and DOE have agreed not to finalize their respective standards until an agreement can be reached. In the interim, DOE Order 5400.5 is identified as TBC information and the NRC standard is identified as relevant and appropriate. Therefore, the radiation protection standard identified within the NRC regulations in 10 *CFR* 20 Subpart E, requiring an EDE of 25 mrem/year or less, shall be used as the exposure limit for the general public.

Chemical-specific ARAR summary. The chemical-specific ARARs associated with the implementation of this alternative are outlined in Table 4.11. Implementation of this alternative would not result in immediate attainment of the chemical-specific ARARs associated with the off-site groundwater plumes. Attainment of the identified ARARs would be met in the future as implementation progresses. Although TBC information, the radiological exposure standards included in DOE Order 5400.5 shall be achieved through monitoring. Continued monitoring of the groundwater will be used during the five-year reviews to ensure the identified goals are met and that concentrations of COCs continue to decrease.

Potential location-specific ARARs

Wetlands. Although no wetlands have been identified within the area where construction activities will occur, certain jurisdictional wetlands have been identified in on-site drainage ditches within the plant boundary. In order to comply with these applicable requirements, wetlands shall be avoided.

As stated in the regulations, construction activities must avoid or minimize adverse impacts to wetlands and act to preserve and enhance their natural and beneficial values [Executive Order 11990; 40 *CFR* 6.302(a), 40 *CFR* 6 Appendix A, 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. Although not anticipated, if this alternate results in impacts to wetlands that cannot be avoided, the substantive requirements of the NWP 38 (33 *CFR* 330) will be met.

This alternative shall comply with these requirements by siting construction locations in areas where wetlands do not occur. Engineering controls shall be established as necessary to ensure operations shall not impact wetlands.

Endangered Species and Migratory Birds. Actions taken by federal agencies are prohibited from impacting T&E species or adversely modifying critical habitats (50 CFR 17.94) in accordance with the Endangered Species Act (16 USCA 1531 *et seq.* Section (7)(a)(2)). These requirements are potential ARARs in the event T&E species or their habitats are found at or near areas where remedial action is to occur. An ecological resource investigation inside the PGDP security fence did not detect any T&E species or their preferred habitats (CDM Federal 1994). The USFWS has not designated critical habitat for any species within the DOE property. However, outside the PGDP fence on the DOE property, potential habitats for federally listed T&E species were reviewed, and Indiana bat habitat was evaluated during the COE (1994) environmental investigation. The COE study determined that total potential bat habitat consisted of 20% of the 994-ha (2,456-acre) study area. Remedial activities must be evaluated to ensure that such actions do not adversely impact areas identified as critical habitat for any identified endangered species.

In addition, Executive Order 13186 directs federal agencies to enter into an MOU with the USFWS to further the purposes of the Migratory Bird Treaty Act (16 U.S.C. 703-711). Until such time as the MOU between DOE and the USFWS is finalized, federal agencies are encouraged immediately to begin implementing the conservation measures set forth in the Executive Order. The requirements of the Executive Order are applicable and must be considered during planning and design of the remedial action.

Potential action-specific ARARs

Monitoring well installation requirements. This alternative includes the installation of additional monitoring and extraction wells. Installation of these wells would have to be conducted in a manner to maintain existing natural protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole (401 KAR 6:310 Section 13). These requirements also mandate the construction materials required for well construction, well design criteria, well completion activities, and well abandonment methodologies. These requirements are considered applicable to design and installation of monitoring and extraction wells associated with the implementation of this alternative.

Fugitive dust emissions. Construction activities onsite and offsite may result in the production of particulate airborne pollutants (dust). The Kentucky Air Quality standards found in 401 KAR 63:010 include requirements governing fugitive dust emissions. These standards require that dust suppression measures be undertaken, which include activities such as the use of water or chemicals to control emissions, the placement of asphalt or concrete, and the stockpiling of soils. The standards also require that visible dust generated from the implementation of the remedial alternative not be discharged beyond the property boundary of the site. For the purposes of compliance with these requirements, the site boundary is interpreted to mean the DOE site boundary or the immediate boundary of construction activities for construction that occurs on non-DOE property. Trucks transporting material outside the DOE property boundary, where materials could become airborne, must be covered. These requirements are considered applicable to the implementation of Pump-and-Treat Technology and will be complied with through careful planning to ensure that excavated materials are sufficiently wetted or protected to control dust generation. Specific activities that could result in the generation of fugitive dust that must be considered during the design phase include construction and well installation.

Radionuclide emission standards. Airborne emissions of radionuclides may occur as a result of construction activities. Although the potential is low for such emissions to occur, the regulations at 40 *CFR* 61.92 would be applicable, requiring that the emissions not exceed amounts that would cause an EDE to the public of 10 mrem/year. To determine whether the alternative complies with this applicable requirement, computer modeling using the CAP-88 or other EPA-approved models must be undertaken. If the modeling demonstrates the radionuclide emission in excess of 1% of the 10 mrem/year standard, emission rates must be measured as required by 40 *CFR* 61.93. This ARAR shall be complied with by planning activities in such a manner as to control fugitive emissions from construction and excavation activities.

Toxic emission standards. Although toxic emissions are not expected as a result of construction activities or with the pumping of the groundwater to the water treatment facility, these emission requirements would be applicable if such an emission does occur. Due to organic concentrations found in the groundwater, the potential for such emission to occur is low. The regulations at 401 KAR 63:022 require that the emissions be evaluated to determine whether they are significant for each specific toxic air pollutant. If analysis indicates the toxic emission requirements are triggered, the regulations specify that no source may exceed the allowable emission limit specified in Appendix A of 401 KAR 63:022. If applicable, these rules would require the application of the best available control technology to limit toxic emissions. If calculations indicate that the emission rates specified within the rule are not exceeded, then the calculation package may be used to demonstrate compliance with these requirements. Activities that must be considered include pumping and treatment of contaminated groundwater.

Stormwater discharge and KPDES requirements for groundwater treatment. Construction activities will be subject to the substantive requirements of the KPDES Permit, requiring the use of BMPs and sediment/erosion controls to direct transport of sediment in stormwater runoff. In addition, groundwater will be treated in a wastewater treatment unit whose discharge will be subject to the substantive requirements of the KPDES program. These requirements are considered to be applicable.

Waste management requirements. It is anticipated that these wastes generated from the treatment of contaminated groundwater will be low-level radioactive wastes and, therefore, subject to DOE Order 435.1 requirements that apply to the management of all radioactive wastes generated at DOE facilities. This requirement is TBC rather than applicable or relevant and appropriate, as it is a DOE order rather than a federal or state regulation or standard.

The potential also exists for some or all of the wastes generated from treatment to be RCRA hazardous wastes as defined in 40 *CFR* 261 of the federal program. All wastes generated shall be subject to the hazardous waste determination requirements of 40 *CFR* 262 and 401 KAR 32:010. If it is determined that any wastes are, in fact, hazardous wastes, the materials must be managed in accordance with the substantive requirements found in 40 *CFR* 262 through 40 *CFR* 268 (401 KAR 32 through 37). These standards include storage requirements, transportation requirements, and disposal requirements. Specific requirements applicable to each waste stream must be identified after characterization of the material is complete. These requirements shall be complied with through the development of a WMP during the design phase of implementation. If materials are identified as RCRA hazardous wastes, these requirements are applicable.

Although considered unlikely, the potential exists that wastes generated from the implementation of this alternative may contain PCBs regulated under TSCA. These regulations would be applicable to this alternative if PCB concentrations were found in soil or water that exceeded 50 ppm or PCBs were found and attributable to a source whose concentration exceeded 50 ppm PCBs. The substantive requirements for management of PCB wastes found in 40 *CFR* 761 would be applicable and should include standards for storage, shipment, and equipment decontamination. These requirements shall be complied with through the development of a WMP during the design phase of implementation. If materials are identified as TSCA PCB regulated material, these requirements are applicable.

Action-specific ARAR summary. This alternative will trigger action-specific ARARs with regard to the treatment and handling of the contaminated groundwater removed from the aquifer. These include the substantive requirement under the KPDES program and the CWA for discharge of treated groundwater and the applicability of the RCRA requirements for wastes generated as a result of implementation. In addition, the requirements of TSCA may be applicable if PCB-containing materials are identified. This alternative will comply with these requirements during the planning phase to include compliant waste handling and storage and disposition components. The proposed alternative will comply with both the requirements of the CWA of 1972 and RCRA because the treatment and discharge of treated effluent from CWA compliant outfall is allowed under RCRA. If waste from treatment of groundwater is determined to be hazardous under RCRA, the substantive requirements for storage, management, and disposal of hazardous wastes shall be incorporated into the alternative during the planning phase. Activities that may be required for RCRA and TSCA compliance include these: use of appropriate containers, labeling of containers, appropriate storage area design and operation (secondary containment or storage for less than 90 days in a compliant accumulation area), and transportation of wastes.

A summary of the ARARs for the implementation of Secondary Source Zone Area – Pump-and-Treat technology are presented in Table 4.11.

Compliance with ARARs summary. Implementation of this alternative would not achieve compliance with the MCLs for TCE. It has been calculated that meeting MCLs would not occur for 7,000 years due to the presence of the Primary Sources. If the pump and treat is performed to provide total containment, compliance with the MCL at the DOE property boundary is calculated to occur in approximately 15 years. If the area targeted for total containment is near the Little Bayou Creek, MCLs may be obtained in approximately 15 years. Because this alternative does not immediately meet the stated MCLs, an ARAR waiver or agreed schedule of compliance would have to be sought as part of the ROD and PRAP.

In order to comply with the identified chemical-specific ARARs, an ARAR waiver will be required due to the time frames required to meet the specified concentrations within the GWOU at the point of compliance and points of exposure.

As discussed, no potential location-specific ARARs have been identified within the area in which remedial action will occur. However, to ensure that jurisdictional wetlands are not impacted, all construction activities associated with the installation of all monitoring, extraction, and injection wells necessary to implement Pump-and-Treat Technology will be reviewed as a safeguard. The protection of wetlands is not considered a location-specific ARAR at this time, because jurisdictional wetlands have not been identified within the areas impacted by the implementation of this alternative.

Construction and implementation of the alternative may trigger several action-specific ARARs such as the requirements associated with well installation and abandonment, fugitive dust emissions, radionuclide emissions, toxic emissions, and discharge of stormwater and treated groundwater. The requirements associated with the installation and abandonment of groundwater wells will be met though the use of well designs and materials of construction as specified in 401 KAR 6:310 Section 13. All well installation and abandonment practices incorporated into the approved remedial design shall comply with substantive requirements of 401 KAR 6:310.

Fugitive dust emissions that may occur during construction activities will be controlled as required by 401 KAR 63:010. BMPs, such as wetting or covering of potential sources of fugitive dust, will be incorporated into the remedial design. The specific actions to be developed shall control potential emission sources to ensure that dust emissions do not migrate from the immediate area where construction activities occur. It is anticipated that, in most cases, the moisture content in the soil will be sufficient to control dust emissions during well installation. However, practices such as wetting of disturbed soils, collection of soils, or reseeding activities shall be considered and incorporated into the remedial design, as necessary, to ensure compliance with these requirements. Radionuclide emissions at construction sites also must be considered during the implementation phase. In order to ensure that the emission standard of 10 mrem/ year EDE to the public is met, concentrations of radionuclides in soils and groundwater must be evaluated. If the potential for such emissions is identified, modeling using the CAP-88 or other EPA-approved method must be undertaken during the design phase of the alternative. It is anticipated that the primary conveyance of airborne radionuclides will be in particulate form. Therefore, control of fugitive dust emissions also will result in compliance with the emission standards applicable to radionuclides. If radiological contamination from plant activities is found in soils where construction activities are planned, the soil will be protected or containerized to prevent airborne migration. Measures necessary to prevent airborne emissions or radionuclides shall be evaluated and incorporated, as appropriate, into the remedial design to comply with these requirements during implementation of this alternative.

Emissions of toxins such as volatile organics also must be evaluated before implementation. Although the potential for exceedance of toxic air emissions is considered to be low, an evaluation of the potential for such emissions must be undertaken during the remedial design. Potential emissions must be evaluated for each toxin present in the plumes (i.e., TCE, vinyl chloride, etc.) to determine whether the contaminant levels found in the subsurface could result in airborne emissions in excess of the allowable limits specified in Appendix A of 401 KAR 63:022. Compliance with the emissions standards shall be achieved for this alternative through the evaluation process or application of the best available control technology where emissions are calculated to exceed allowable levels. Emission control equipment will be incorporated into implementation activities during the remedial design, as necessary, based upon the initial evaluation. This requirement will be complied with during implementation of the alternative.

The construction activities associated with this alternative may require that BMPs for sedimentation/ erosion controls be established if the areal extent of the disturbed area exceeds regulatory trigger levels. These requirements will be complied with through the use of sediment fences or other appropriate means. The control of sedimentation and runoff shall be a TBC in the event that the areal extent of the construction does not exceed the 5 acres specified within the rules. The remedial design shall incorporate the specific controls necessary to ensure that the construction site(s) does not allow sedimentation and/or erosion of disturbed areas in order to comply with this requirement during implementation of this alternative.

This alternative results in the removal and treatment of contaminated groundwater using Pump-and-Treat Technology. Groundwater collected as part of the pumping activities must be treated to meet discharge effluent limits before release. This requirement shall be met through the vapor extraction system and discharge to a KPDES permitted outfall. The treatment system shall be designed to meet current KPDES discharge limits.

Long-Term Effectiveness and Permanence. This evaluation addresses the results of the alternative in terms of risk remaining at the site after completion of the action and the effects of required long-term controls. A discussion of the magnitude of residual risk at the site and adequacy and reliability of controls is presented in the following sections.

Magnitude of residual risk. The Secondary Source Area Pump-and-Treat Technology alternative is designed to remediate contaminated groundwater in the on-site source areas of DNAPL in the RGA. However, residual risk in the RGA will remain in place after implementation, due to the presence of the Primary and Secondary Source Areas. In the near term, following the startup of this alternative remedial action, the residual risk will remain consistent with the risk present before taking the action. Following startup and continued long-term operation of the remedy, the residual risk will decrease for a groundwater user in the area outside the site if hydraulic containment is affected. This residual risk will continue to decrease as the containment system continues to prevent further COC migration from the source areas.

The technology will require assistance from other technologies, either UCRS or RGA, to meet the MCLs at the point of compliance. Groundwater modeling results for the COC concentrations in the RGA, as discussed above, indicate that MCLs will be reached for TCE in approximately 200 years in the area of the source. The Pump-and-Treat Technology will have the slowest decline in residual risk.

Five-year reviews, mandated by CERCLA [40 *CFR* §300.430(f)(4)(ii)], will be required to demonstrate the integrity and effectiveness of the controls and confirm that additional exposure pathways have not developed.

Adequacy and reliability of controls. Secondary Source Area Pump-and-Treat Technology will have high reliability for operation and control. The components that make up the treatment systems have been used extensively for the treatment of water and wastewater and have proven to be adequate and reliable. The Pump-and-Treat Technology alternative will require extensive maintenance due to the extended period of time the operation must continue.

Pump-and-treat systems of the size required for this alternative, by design, have partial redundancy due to independent operating systems (i.e., multiple pumps, air strippers, etc.). Also, the system can be designed to be modular with critical systems, such as power distribution, designed with additional capacity to handle future additions of extraction wells or treatment equipment to the remedy. An example could be the addition of extraction wells in a given area to ensure complete containment of the migrating COCs. Numerical modeling will be used to size and place extraction wells such that an appropriate capture zone is developed. However, should extended interruptions of electrical power occur, the potential would exist for COCs to escape from the system.

The pump-and-treat system will generate spent ion-exchange resins used to remove the ^{99}Tc. Additionally, treatment of vapor phase effluents will result in the generation of a waste material used to capture the TCE. Intrusive activities onsite will be prevented, as necessary, through the use of work permits and safety programs, thereby limiting the access of plant personnel to the contaminated groundwater.

Environmental impacts and mitigative measures. The following paragraphs summarize potential long-term impacts to resources and mitigative measures to offset any potential impacts. The depth of impact analysis and mitigative measures is correlated to the degree to which a resource may be impacted.

Land use. Implementation of this alternative would result in minimal impacts to land use and no changes to the population surrounding the PGDP. Following construction of the alternative, the bulk of the land disturbed during construction would be returned to its prior use. Long-term impacts would be related to the operating facilities, extraction wells, and monitoring wells. A LUCIP will be developed as necessary per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomics. The socioeconomic conditions of the PGDP and surrounding area would not be expected to be impacted by the implementation of the Secondary Source Area Pump-and-Treat Technology alternative. The construction and operation of the facilities for this alternative would be performed by construction contractors. The number of permanent jobs that could develop as a result of the action is small in relation to the size of the population of the surrounding area. The implementation of this alternative also would not result in a decrease or increase in the personnel at PGDP. However, the presence of contaminants in the groundwater will prevent its use and may limit economic development opportunities until the groundwater is brought back to beneficial use.

Air quality and noise. A long-term degradation in air quality is not expected as a result of the implementation of this alternative; however, there will be a long-term emission of TCE from the operation of the facility. The TCE, which is removed from the extracted groundwater, is destroyed by catalytic oxidation afterwards and would not be an air-contaminant concern. The potential for a temporary increase in fugitive dust emissions during construction would be mitigated by keeping dust prone areas watered to suppress dust.

No long-term increase in noise is expected from this alternative. During construction, there will be local increases in noise levels due to operating machinery. However, the noise increase will be in a limited area and will not affect human receptors. Hearing protection would be used to protect the worker constructing the system.

Vegetation. This alternative likely would be implemented in target areas within the existing industrial area of buildings and facilities; therefore, no long-term impacts to vegetation is expected from the implementation of this remedy. Once construction is concluded, any disturbed vegetation could be restored through seeding and natural regeneration.

Wildlife. This alternative likely would be implemented in target areas within the existing industrial area of buildings and facilities. Therefore, no long-term impacts to wildlife are expected from the implementation of this remedy. In addition, no long-term adverse impacts are expected for aquatic life in the KPDES outfalls and creeks. Construction in creeks and tributaries will not occur. Large volumes of water are expected to be released; however, the actual quantities will be determined in the development of the PRAP. Should it become necessary, the treated groundwater that would be released could be split among several outfalls to distribute flow between the Bayou and Little Bayou Creeks.

Threatened and endangered species. No long-term adverse impacts were identified for this alternative. The Indiana bat, which regionally has suitable habitat, is not expected to be impacted by this alternative. The potential roosting areas of the Indiana bat, as identified by Bryan (COE 1993), are not located in the expected area for this alternative.

Cultural resources. No long-term impacts to cultural resources are anticipated for this alternative.

Groundwater. Through implementation of this alternative, potential RGA VOC sources to groundwater either are reduced or eliminated over an extended period of time by indirect dissolution of the sources. In addition, there will be moderate reduction to ^{99}Tc. If successful, the potential exists for the RGA to be restored to full use after the downgradient portions of the plumes are attenuated. Degradation to groundwater is not expected; however, potential adverse impacts of the alternative would be the unlikely, but possible, migration of TCE DNAPL from current areas as a result of the extraction and drawdown of the aquifer.

The array of extraction wells should be sufficient to eliminate the addition of COCs to the off-site portions of the plumes. It is not expected that the extraction rate of the pump-and-treat system would substantially deplete the amount of water in the RGA. The water resources in the RGA are sufficient to sustain the rate of extraction. However, the extraction rate, due to drawdown of the aquifer, may temporarily impact wells screened in the upper RGA. Should excessive drawdown result from the expected extraction rate, the volume of water produced potentially could be reduced to a level that produces a capture zone necessary to contain the COC migration. The increased pumping rate potentially could affect water levels in the upgradient Terrace Gravel. However, no significant decline in water levels is expected; moreover, no water supply wells in the Terrace Gravel are located in the proximity of the PGDP.

Surface water. No adverse impacts to streams are expected to occur. However, due to increased pumping and treating of groundwater, there will be large increases in the KPDES discharges volumes. The actual quantities will be determined in the development of the PRAP. Currently, the outfalls that contribute to Bayou Creek have a combined yearly flow of 0.720 mgd, a maximum flow of 15.85 mgd, and an average flow of 5.5 mgd. PGDP currently provides approximately 85% of the flow to Bayou on average, and during periods of low base flow, nearly 100% (Geotrans 1993). Flow in the Bayou Creek is highly variable depending on activities at the PGDP, season, and recent precipitation. The mean monthly flows of Bayou Creek vary from 20.5 to 38.8 mgd. The creek also accommodates high energy episodes as evidenced by many deposits of sand and gravel along its banks.

Surface water quality is not expected to be impacted with the implementation of this remedy. The treatment system to remove the COCs from the extracted groundwater will be designed to meet the release requirements of the KPDES permit. Also, controls for silt and erosion will be used during the construction activities.

Floodplains. No long-term impacts are expected with the implementation of this alternative. The action would not take place in any floodplain of any stream at PGDP.

Wetlands. No significant impacts to the integrity of wetlands are expected. This alternative would be implemented within the on-site industrial area of the PGDP. However, the potential exists that wetlands may be impacted along the nearby creeks due to the increased water discharges and construction activities. The wetlands in the area of the PGDP occur due to surface flow into poorly drained soils and not from recharge from the RGA. The exception to this would be the area of Little Bayou Creek near the TVA Shawnee Steam Plant that does receive recharge from the RGA. This is approximately two miles from where the Secondary Source Area treatments would occur.

Soils and prime farmland. No long-term impacts to soils and prime farmland are expected from the implementation of this alternative. Minor impacts will occur to the soils in the area of construction during implementation of this alternative. Impacts would be mitigated through the use of standard construction practices of placing erosion and drainage control in the construction areas, as necessary. During well installation, testing, and treatment facility operation, the potential exists for the release and spill of contaminated water. These potential releases will be mitigated through the use of engineering measures to contain spills and contaminated soils.

Prime farmland exists north of the PGDP and DOE property. The NRCS has identified prime farmland as the Calloway, Waverly, and Grenada soil series in the area between the PGDP and the TVA Shawnee Steam Plant. This alternative would be implemented within the on-site industrial area of the PGDP within the security fence; therefore, it would not affect the off-site prime farmland to the north.

Transportation. No long-term direct or indirect impacts to transportation are anticipated for this alternative. The implementation of this alternative will result in transportation of environmental soil and groundwater samples to environmental laboratories. During the operation of the alternative, ion-exchange resins will be transported to treatment storage or disposal facilities. Standard engineering practices will be used to ship these waste materials. Also, all applicable regulatory requirements for shipment of LLW materials also will be followed.

Cumulative impact. Cumulative impacts are defined as the incremental impact of an action when added to other past, present, and reasonable, foreseeable future actions, regardless of what agency or person undertakes other such actions. Cumulative Impacts resulting from this alternative will have to be identified at a later time during development of site specific GWOU decision documents.

Reduction in Toxicity, Mobility, or Volume Through Treatment. This alternative implementation will result in pumping and treating in the vicinity of the source area to remove VOCs and ^{99}Tc. Depending on the design and layout of the pumping system, hydraulic containment may be effected that would prevent further migration of contaminants from the site. Such a containment field will be produced via a pump-and-treat system. The contaminated water will be treated to remove the VOCs and ^{99}Tc through the use of air strippers for VOC reductions and ion exchange resin for ^{99}Tc before releasing the treated water to an outfall. Once the TCE is air stripped, the resulting vapor phase will be passed through a catalytic oxidizer with a scrubber for emission reduction to destroy the TCE. The ^{99}Tc will remain adsorbed to the ion exchange resin and will not be destroyed. Nearly 100% of the extracted contaminants would be treated and/or destroyed through the use of catalytic oxidation and ion exchange.

Since TCE and ^{99}Tc are only incrementally removed from the groundwater plume, the toxicity of the TCE and ^{99}Tc in the groundwater plume will remain. After long-term operation of the alternative, approximately 100% of the VOC and ^{99}Tc contamination would be removed; therefore, the toxicity of the plumes will dissipate due to the removal of the COCs via the pump-and-treat system.

Implementation of this alternative would not affect the chemical and physical soil properties within the treatment area. This alternative provides no direct reduction in COC mobility.

The implementation of this alternative will result in the complete removal of the sources (after prolonged operational period). However, the alternative is reversible. Should the operation of the alternative be terminated, the groundwater plumes will reestablish with some reduction in COC concentrations.

Following treatment of the extracted groundwater, the treatment residuals will exist. The TCE is destroyed through treatment of the catalytic oxidizer. The treatment residual from this process is production of sodium chloride from the scrubbing of off-gas from the oxidizer. The treatment of the ^{99}Tc also will result in a treatment residual in the form of a spent ion exchange resin. The spent ion exchange resin will be a LLW. This alternative may meet the preference for treatment through the use off-gas VOC treatment systems.

Short-Term Effectiveness. This criterion involves evaluating alternatives for community protection, worker protection, environmental impacts, and the time until remedial response actions are achieved. A discussion of each is provided in the following paragraphs.

Community protection. The potential for short-term adverse impacts to the community from the implementation of this alternative is minimal. This alternative would be implemented within the on-site industrial area of the PGDP within the security fence; therefore, it would not affect the surrounding community. Also, environmental monitoring will be conducted during the construction of extraction and monitoring wells where COCs may be present. Engineering controls can be implemented to reduce off-gas emissions.

Worker protection. Implementation of this alternative has the potential for worker exposure to contaminated subsurface soils and groundwater during environmental sampling and well installation. Potential exposure pathways include inhalation of dust that contains contaminated soils, dermal contact with subsurface soils, and dermal contact with contaminated groundwater. Impacts to on-site workers would be minimized through use of engineering controls for off-gas treatment, PPE, and formalized operating procedures.

Environmental impacts and mitigative measures. Short-term environmental impacts and mitigative measures are qualitatively assessed and include an evaluation of the impacts on environmentally and potentially sensitive ecological resources, short-term impacts on socioeconomics and cultural resources, and cumulative impacts of the remedial construction.

Land use. Implementation of this alternative would result in minimal adverse impacts to land use with no changes to the population surrounding the PGDP. Following construction of the alternative, the bulk of the land disturbed during construction would be returned to its prior use. All short-term impacts would be related to treatment facilities and monitoring wells. The areas expected to be targeted for this technology are anticipated to be within the industrial areas of the PGDP facility. A LUCIP will be developed as necessary per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomics. The short-term socioeconomic conditions of the PGDP and surrounding area would not be expected to be impacted by the implementation of this alternative. The construction and operation of the facilities for this alternative would be performed by construction contractors. There would be minimal temporary jobs resulting from construction and operations of this alternative. The number of permanent jobs that could develop as a result of the action is small in relation to the size of the population of the surrounding area. Also, the implementation of this alternative would not result in a decrease or increase in the personnel at PGDP.

Air quality and noise. Short-term degradation of air quality is not expected since off-gas treatment will be included as part of this alternative. The potential for a short-term temporary increase in fugitive dust emissions during construction would be mitigated by keeping dust prone areas watered to suppress dust. Also, during construction there will be some local short-term increases in noise levels due to operating machinery. However, the noise increase will be in a limited area and will not affect human receptors. Hearing protection would be used to protect the workers constructing the system.

Vegetation. This alternative likely would be implemented in target areas within the existing industrial area of buildings and facilities; therefore, no adverse impacts to vegetation are expected from the implementation of this remedy. Once construction is concluded, any disturbed vegetation could be restored through seeding and natural regeneration.

Wildlife. Short-term impacts to wildlife are expected to be minimal since most of the activity will be contained within the industrial portion of the PGDP. Construction in creeks and tributaries may be required to address increased discharges of water from the treatment process. However, no adverse impacts are expected for aquatic life in the KPDES outfalls and creeks. Should it become necessary, due to increased volumes of discharged water, the treated groundwater that would be released could be split among several outfalls to distribute flow between the Bayou and Little Bayou Creeks.

Threatened and endangered species. Short-term adverse impacts to T&E species is not likely to occur since implementation of this alternative would be confined to the PGDP industrial area. The Indiana bat, which regionally has a suitable habitat, is not expected to be impacted by this alternative. The potential roosting areas of the Indiana bat, as identified by Bryan (COE 1993), are not located in the expected area for this alternative.

Cultural resources. No short-term impacts to cultural resources are expected for this alternative.

Groundwater. Through implementation of this alternative, potential RGA VOC sources to groundwater either are reduced or eliminated over an extended period of time by indirect dissolution of the sources. In addition, there will be moderate reduction to ^{99}Tc. If successful, the potential exists for the RGA to be restored to full use after the downgradient portions of the plumes are attenuated. Degradation to groundwater is not expected; however, potential adverse impacts of the alternative would be the unlikely, but possible, migration of TCE DNAPL from current areas as a result of the extraction and drawdown of the aquifer.

The array of extraction wells should be sufficient to eliminate the addition of COCs to the off-site portions of the plumes. It is not expected that the extraction rate of the system would substantially deplete the amount of water in the RGA. The water resources in the RGA are sufficient to sustain the rate of extraction. However, the extraction rate, due to drawdown of the aquifer, may temporarily impact wells screened in the upper RGA. Should excessive drawdown result from the expected extraction rate, the volume of water produced potentially could be reduced to a level that produces a capture zone necessary to contain the COC migration. The increased pumping rate potentially could affect water levels in the upgradient Terrace Gravel. However, no significant decline in water levels is expected; moreover, no water supply wells in the Terrace Gravel are located in the proximity of the PGDP.

Surface water. No short-term adverse impacts to surface water are expected from implementing this remedy. However, there will be large increases in discharge volumes as a result of treatment of extracted groundwater. During construction, controls for silt and erosion will be used to minimize impacts to the surface water.

Floodplains. No short-term impacts are expected with the implementation of this alternative. The action would not take place in any floodplain of any stream at PGDP.

Wetlands. No significant impacts to the integrity of wetlands are expected. This alternative would be implemented within the on-site industrial area of the PGDP. However, the potential exists that wetlands may be impacted along the nearby creeks due to the increased water discharges and construction activities. The wetlands in the area of the PGDP occur due to surface flow into poorly drained soils and not from recharge from the RGA.

Soils and prime farmland. No short-term impacts to soils and prime farmland are expected from the implementation of this alternative. Minor impacts will occur to the soils in the area of the construction during implementation of this alternative. Impacts would be mitigated through the use of standard construction practices of placing erosion and drainage control in the construction areas as necessary. During well installation, testing, and treatment facility operation, the potential exists for the release and spill of contaminated water. These potential releases will be mitigated through the use of engineering measures to contain spills and contaminated soils.

Prime farmland exists north of the PGDP and DOE property. The NRCS has identified prime farmland as the Calloway, Waverly, and Grenada soil series in the area between the PGDP and the TVA Shawnee Steam Plant. This alternative would be implemented within the on-site industrial area of the PGDP within the security fence; therefore, it would not affect the off-site prime farmland to the north.

Transportation. Minimal impacts to transportation may occur during construction activities. The implementation of this alternative will result in transportation of environmental soils samples and groundwater samples to environmental laboratories. During the operation of the alternative, ion exchange resins will be transported to treatment, storage, or disposal facilities. Standard engineering practices will be used to ship these waste materials. Also, all applicable regulatory requirements for shipment of LLW materials also will be followed.

Cumulative impact. Cumulative impacts are defined as the incremental impact of an action when added to other past, present, and reasonable, foreseeable future actions, regardless of what agency or person undertakes other such actions. Cumulative Impacts resulting from this alternative will have to be identified at a later time during development of site specific GWOU decision documents.

Time until action is complete. Implementation of this alternative will not result in achievement of the specified GWOU RAOs for groundwater MCLs. Approximately 7,000 years will be required before groundwater may be used following the application of the Pump-and-Treat Technology only in the Secondary Source Areas of the RGA. The reduction of sources only within the RGA will not prevent the Primary Source Areas located within the UCRS from continuing to impact the groundwater. It will be necessary to implement other Source Reduction and Dissolved Phase Plume technologies in conjunction with Pump-and-Treat Technologies in the Secondary Source Areas to reduce the time the groundwater will remain unusable.

Implementability. The implementability of Pump-and-Treat Technology in the Secondary Source Areas of the RGA was evaluated based upon its technical feasibility, administrative feasibility, and the availability of services and materials. The information is summarized in the following subsections.

Technical feasibility. The construction of extraction wells and monitoring wells is a presumptive remedy that is technically feasible using standard equipment and technologies and available from multiple vendors. In addition, the equipment that would be used in constructing a water treatment facility and pipelines to convey the contaminated water also are standard. The treatment equipment types used in treating the water are proven technologies. Equipment that is used is proven and reliable, and downtime is expected to be minimal for maintenance and repairs. However, the alternative will require extensive maintenance due to the extended period of time the operation must continue. In addition, some difficulties may arise during installation due to the industrial setting of the PGDP. Construction of this alternative would not prohibit the implementation of other GWOU technologies.

The effectiveness of the treatment system in removing the COCs will be monitored by effluent sampling to ensure the released water is in compliance with regulatory requirements. Air and groundwater monitoring would be required.

Administrative feasibility. This alternative is administratively feasible. Compliance with substantive requirements associated with federal and state regulations would be necessary. Treated water would be discharged to an outfall. Treatment of the residuals, handling, and transportation and disposal would require proper procedures; however, no difficulties are expected. An ARAR waiver will be required for this alternative since MCLs are not achieved in timely manner.

Availability of services and materials. Commercially available services and materials for the construction of this alternative are readily available. Additionally, numerous vendors will increase the likelihood of competitive bids.

The construction of this alternative will result in the generation of waste soil cuttings, drilling, and development water from the extraction wells and monitoring well construction. Additionally, the construction will generate clean concrete, wire, and pipe construction debris during the building of the treatment facility. All of these materials either will be treated as necessary and released, as in the development water, or disposed of appropriately.

The operation of the treatment system will result in the generation of sodium chloride from the scrubbing of the catalytic oxidizer off-gas and ion exchange resins spent with ^{99}Tc. Both of these materials will be stored until appropriate disposal can be arranged.

Cost. Table 4.12 summarizes the preliminary unit cost estimates for implementation of the Secondary Source Area Pump-and-Treat Technology alternative for the RGA. These preliminary unit cost estimates are based upon FS-level scoping and are intended to aid with selection of a preferred alternative. The estimates have an expected accuracy of -30 to +50% for the proposed scope of action (EPA 1988a). The capital cost estimate represents those expenditures required to implement this remedial alternative. The O&M cost estimates represent expenditures required to maintain the remedy after the initial phase of remedial action construction is completed. The total contingency cost presented includes direct, indirect, and all O&M associated contingency costs. The total cost includes all capital costs, direct and indirect with O&M and associated reports, plus 25% contingency costs, for a 30-year term of comparison. All estimates have been escalated using DOE-approved annual rates and a schedule for the various activities based on similar project experience. Present worth values also are included using a discount factor of 5% (EPA 1988b). Additional information regarding the preliminary cost estimates is presented in Appendix C7.

Table 4.12. Preliminary unit cost estimate for Secondary Source Area Pump-and-Treat Technology

Total unit capital costs (per acre-foot)	$353,106
Total operation and maintenance costs	$767,963
Overhead	$733,498
Total contingency	$463,642
Total cost	**$2,318,211**
Total cost (present worth)	**$1,076,353**

Note: preliminary cost estimates are per acre-foot, escalated and presented in dollars.

State/Commonwealth Acceptance. The Commonwealth of Kentucky acceptance or nonacceptance of this alternative will be addressed in the ROD should Secondary Source Area Pump-and-Treat Technology be selected as the preferred alternative.

Community Acceptance. Following a formal public comment period on the PRAP for the GWOU, comments from the community will be addressed formally in a responsiveness summary that will be presented in the ROD.

Evaluation summary of Secondary Source Area Pump-and-Treat Technology

Secondary Source Area Pump-and-Treat Technology would involve pump and treating for source reduction of the on-site secondary source areas of the RGA and environmental media monitoring to track COC migration. Pumping and treating of the high-concentration secondary sources removes COC mass from the groundwater and can control the migration of the source. Implementation of monitoring will provide an indirect protection, as monitoring COC migration allows for minimizing the potential for exposure to contaminated environmental media through avoidance.

Residual risk will remain in the off-site plumes for 7,000 years. If the Pump-and-Treat Technology system effects total hydraulic containment, risk will remain until dispersion and degradation cause the plumes to dissipate. Short-term risks to construction workers would exist because of potential exposure to contaminated groundwater during environmental monitoring activities and maintenance of the groundwater treatment systems. Additional exposure is possible due to dermal and inhalation contact during changeout of treatment media. However, risks to workers will be minimized by strict adherence to approved risk management procedures (e.g., health and safety plan and use of PPE).

Implementation of Secondary Source Area Pump-and-Treat Technology would require moderate capital and high O&M costs due to continuous pumping and treating of groundwater. Input from the Commonwealth of Kentucky and the community has not yet been received, but these will be added to a ROD once the public comment period has been completed.

4.2.3.3 Secondary Source Area – Oxidation Technology

The following subsections contain a description of Secondary Source Area – Oxidation Technology Alternative and the detailed analysis.

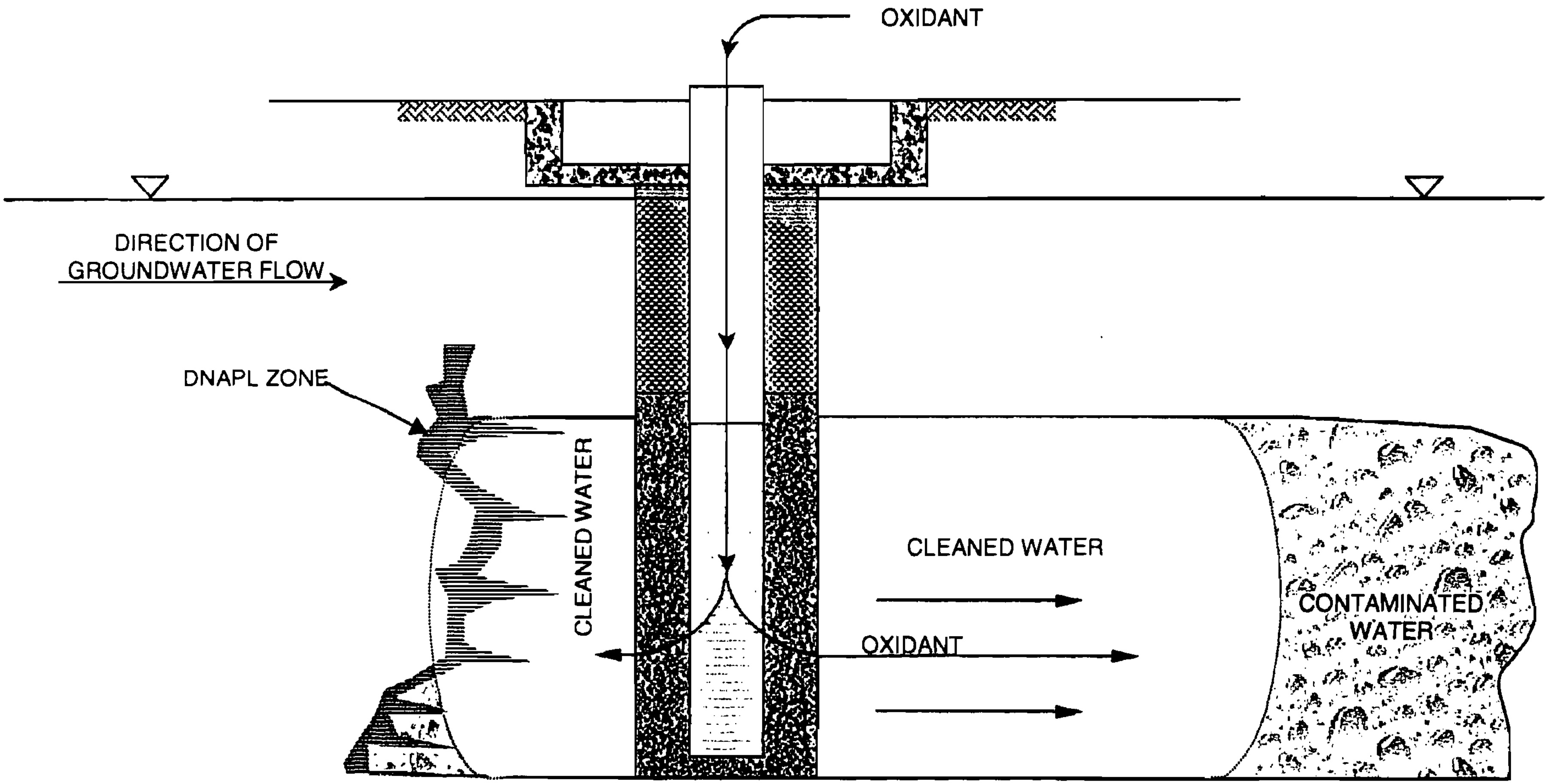
Description of Secondary Source Area – Oxidation Technology

This alternative would consist of implementing an Oxidation Technology in a DNAPL source zone area of the RGA. The purpose of the alternative would be to remove TCE DNAPL and other VOC contaminants from areas of the RGA that have sufficient TCE concentrations to be considered as sites of free phase TCE, or TCE DNAPL. In this technology, a series of injection wells would be drilled into the RGA in the target areas. The injection wells then would be used to inject into the zone of interest, the RGA, an oxidizing compound such as potassium permanganate or sodium permanganate. The oxidizing compound then would react with the VOCs, or TCE DNAPL, and they would be destroyed in the reaction with the oxidant. The ^{99}Tc contamination would not be remediated by the oxidation technology. This alternative is an *in situ* treatment and would not require any *ex situ* treatment of produced water or release of air emissions. It will, however, require the placement of injection wells and injection equipment to effect the introduction of oxidant into the RGA.

Figure 4.6 contains a "snapshot" that graphically summarizes what is involved in the application of Oxidation Technology.

The source-reduction efforts of implementing this technology will diminish the time until on-site groundwater VOC levels attributed to the DNAPL zone areas in the RGA reach the 5 μg/L MCL. However, because the technology does not remove the TCE DNAPL in the associated UCRS area, it is anticipated that groundwater will not be returned to the drinking water standard for TCE for approximately 7,000 years. Oxidation Technologies will not remove ^{99}Tc as part of the operation. This is because ^{99}Tc is not destroyed as a result of oxidation. The off-site portions of the groundwater plumes will be affected only by the reduced quantity of DNAPL present in the RGA that is available for dissolving and producing the migrating plumes.

The existing groundwater monitoring program, which is being implemented under a separate action, would be continued to monitor the movement of COCs within the RGA. The monitoring program will integrate existing PGDP monitoring wells, where possible, with additional monitoring wells to be installed as needed following a review of the existing program.



U. S. DEPARTMENT OF ENERGY
DOE OAK RIDGE OPERATIONS
PADUCAH GASEOUS DIFFUSION PLANT

BECHTEL JACOBS COMPANY, LLC
MANAGED FOR THE US DEPARTMENT OF ENERGY UNDER
US GOVERNMENT CONTRACT DE-AC-05-98OR22700
Oak Ridge, Tennessee • Paducah, Kentucky • Portsmouth, Ohio

Science Applications
International Corporation
P.O. Box 2502
Oak Ridge, Tennessee 37831

Fig. 4.6. Secondary source area - oxidant technology.

FIGURE No. FS4-6
DATE 05-25-01

Five-year Reviews. This remedial alternative would result in residual "contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure"; therefore, this remedial action would be reviewed "no less often than every five years" in accordance with 40 *CFR* 300.430 (f)(4)(ii).

Assessment of Secondary Source Area – Oxidation Technology

The detailed analysis of this alternative using the CERCLA criteria is presented in the following subsections.

Overall Protection of Human Health and the Environment. Secondary Source Area Oxidation Technology includes the *in situ* treatment of VOCs and TCE DNAPL in the RGA. The technology would reduce VOC contamination in the RGA only. It is not expected that oxidation would have any impact on the ^{99}Tc contamination present in the treatment area. The ^{99}Tc present in the RGA is chemically oxidized to it highest potential state of TcO_4. However, should the oxidant encounter ^{99}Tc in a reduced state, the oxidant may increase dissolved levels of ^{99}Tc in the groundwater. This alternative alone will not satisfy the RAOs for the GWOU or protection of the ecological receptors that may be exposed to contaminated groundwater discharging to the surface water. It will support achieving the RAOs when implemented in concert with other source reduction and dissolved phase GWOU technologies.

Compliance with ARARs. An alternative must meet this threshold criterion to be eligible for selection. The following discussion summarizes the potential ARARs and TBC Guidance for use of Secondary Source Area – Oxidation Technology.

Potential chemical-specific ARARs. The potential chemical-specific ARARs for this alternative are summarized in the following paragraphs.

Chemical contamination. The aquifers are known to contain chemical contaminants in the form of metals and organics. The federal and state water quality requirements include standards that would be applicable ARARs. The regulations that apply are found in 40 *CFR* 141 (National Primary Drinking Water Standards); 40 *CFR* 143 (Secondary Drinking Water Standards); 401 KAR 5:029 (General Provisions); and 401 KAR 5:031 (Surface Water Standards). These standards, summarized in Table 4.13, include general state standards, domestic water supply standards, and standards applicable to warm water aquatic habitat. These are applicable based upon the classification of the designation for surface water use associated with the area (Ohio River, River Mile 940.7 to River Mile 943.3) as specified in 401 KAR 5:026. All potentially applicable chemical ARARs for COCs have been included in the table for completeness. Those standards that must be achieved in order to meet the applicable requirements are the lowest of the applicable standards, which in most cases are the MCLs.

Radiological contamination. The OU is known to be contaminated with radionuclides such as ^{99}Tc, radon, uranium, and uranium daughter products. DOE's Order on Radiation Protection of the Public and Environment, DOE Order 5400.5, is TBC information for cleanup of radionuclides at DOE sites. The order requires that remediation activities not result in radiation exposures to members of the general public greater than an EDE of 100 mrem/year from all exposure pathways. Exposure to the general public also must be ALARA (DOE 1990).

DOE Order 5400.5 also contains reference values, known as DCGs, for operational DOE facilities. Based on the DCGs, radionuclide concentrations in air and drinking water must not exceed an EDE of 10 mrem/year and 4 mrem/year, respectively, to the total body or any organ.

The NRC also has set criteria for decommissioning standards at nuclear facilities at 10 *CFR* 20 Subpart E. These rules require that residual radioactivity at nuclear sites meet a total EDE of 25 mrem/year

Table 4.13. Summary of potential ARARs for Secondary Source Zone – Oxidation Technology

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Chemical-Specific ARARs	
National Primary Drinking Water Standards	40 *CFR* 141	Provides chemical-specific numeric standards for toxic pollutants expressed as MCLs and MCLGs.	These requirements are relevant and appropriate due to the nature of the contaminants found within the groundwater.
National Secondary Drinking Water Standards	40 *CFR* 143	Provides secondary MCLs for public water systems	These requirements are TBCs, as they have been established as guidelines for the states and are not federally enforceable.
Kentucky Surface Standards including • Warm Water Aquatic Habitat Criteria • Kentucky Domestic Water Supply • Kentucky General Standards • Kentucky Outstanding State Resource Waters	401 KAR 5:031 and 5:026	Provides chemical-specific numeric standards for pollutants discharged or found in surface waters. Provides chemical-specific numeric standards for pollutants in domestic water supplies.	These standards are applicable to the segment of the Ohio River into which the Little Bayou Creek discharges. The requirements found in these standards are applicable due to the groundwater to surface water interface to Little Bayou Creek and subsequently to the Ohio River. Note: CWA Water Quality Criteria are not relevant and appropriate because Kentucky has promulgated state standards that Kentucky has determined to be appropriate for waters of the Commonwealth.
Radiation Exposure of the General Public at DOE Facilities	DOE Order 5400.5	Specifies that the general public must not receive an effective dose equivalent of >100 mrem/year from all exposure pathways. In addition, all release of radioactive materials resulting in doses to the general public must meet the ALARA criteria.	This requirement is TBC information.
Decommissioning Standards at Nuclear Facilities	10 *CFR* 20, Subpart E	Specifies a residual activity at nuclear facilities for unrestricted release of 25 mrem/year.	These standards are considered to be applicable to the GWOU.
Environmental Radiation Protection Standards for Nuclear Power Operations	40 *CFR* 190, Subpart B	Requires that the annual dose equivalent to the public must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughter products excepted, to the general environment from uranium fuel cycle operations and the radiation from these operations.	These standards are considered to be relevant and appropriate and are equivalent to the NRC standards.

Table 4.13. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Location-Specific ARARs	
Protection of Wetlands	10 *CFR* Section 1022; Executive Order 11990; 40 *CFR* 230.10; 33 *CFR* 330.5	Activities must avoid or minimize impacts to wetlands to preserve and enhance their natural and beneficial value. If wetland resources are not avoided, measures must be taken to address ecologically sensitive areas and mitigate adverse effects. Such measures may include, minimum grading requirements, runoff controls, and design and construction considerations. Allows minor discharges of dredge and fill material, or other minor activities for which there are no practicable alternatives, provided that the pertinent requirements of the NWP system are met.	These requirements are applicable due to the presence of wetlands, but will be met through avoidance of wetlands during construction and implementation of alternatives.
Endangered Species Act	16 U.S.C. 1531 et seq. Section 7(a)(2)	Actions that jeopardize the existence of listed species or result in the destruction of adverse modification of critical habitat must be avoided or reasonable and prudent mitigation measures taken.	Action that is likely to jeopardize fish, wildlife, or plant species or destroy or adversely modify critical habitat-applicable.
Migratory Bird Treaty Act	16 U.S.C. 703-711; Executive Order 13186	Federal Agencies are encouraged (until requirements are established under a formal MOU) to: • avoid or minimize, to the extent practicable, adverse impacts on migratory bird resources when conducting agency actions; • restore and enhance the habitats of migratory birds, as practicable; • prevent or abate the pollution or detrimental alteration of the environment for the benefit of migratory birds, as practicable; • ensure that environmental analysis of federal actions required by the NEPA or other established environmental review processes evaluate the effects of actions and agency plans on migratory birds, with emphasis on species of concern; and • identify where unintentional take will likely result from agency actions and develop standards and/or practices to minimize such unintentional take.	Action that is likely to impact migratory birds, habitats, and resources-applicable.

Table 4.13. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Action-Specific ARARs	
Fugitive Dust Emissions during site preparation and construction activities.	401 KAR 63:010	Precautions must be taken to prevent particulate matter from becoming airborne. Such precautions must be incorporated into the planning and design of activities and include actions such as • wetting or adding chemicals to control dust from construction activities; • using materials such as asphalt or concrete (or other suitable chemicals/fixing agents) on roads or material stockpiles to prevent fugitive emissions; and • using covers on trucks when transporting materials to and from the construction site(s). The requirement specifies that for on-site construction activities, no visible emissions may occur at the PGDP fenceline. Similar points of compliance shall be identified for construction activities that occur outside the fence.	These requirements are applicable and will be met through the use of appropriate dust control practices identified during alternative design phase.
Toxic Emissions	401 KAR 63:022	The regulations require that a determination of toxic emissions be made in order to assess the applicability of required controls. Calculations of the significant emission levels are compared to the allowable emission limits specified in Appendix A of 63:022. If emission levels are exceeded, best available control technologies must be incorporated into equipment/process design.	These requirements are considered to be applicable and shall be complied with through calculation of significant emission levels for toxic materials and application of best available control technology as necessary during the design of the alternative.
Monitoring Well Installation	401 KAR 6:310	Monitoring wells (including injection wells) must be constructed in a manner to maintain existing protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole. In addition, wells that have no further use must be plugged and abandoned in accordance with the requirements specified.	These requirements are considered to be applicable. Compliance with well design and protection standards shall be achieved through the use of approved well design and materials of construction. While in service, wells shall be secured as required. Wells that have no further use, shall be plugged and abandoned as required.
Discharge of Stormwater	40 *CFR* 122; 401 KAR 5:055	Stormwater discharges from construction activities on-site are subject to the requirements of the KPDES permit. This requires that BMPs to control stormwater runoff and sedimentation be employed. Although off-plant construction activities within the contaminated area are not subject to the permit, these requirements should be considered relevant and appropriate and be incorporated into any off-site construction activities.	These requirements are considered applicable for all on-site construction or treatment activities where a discharge of stormwater or treated groundwater occurs. For off-site construction activities, these requirements are considered relevant and appropriate and will be adhered to. Compliance with these ARARs shall be achieved by application of required controls during the design phase of the alternative

Table 4.13. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
Hazardous Waste Management	40 *CFR* 260 through 268; 01 KAR 32 through 37	All wastes or environmental media containing wastes must be characterized to determine whether the waste is also a hazardous waste in accordance with 40 *CFR* 262.11 and 401 KAR 32:010. If it is determined that a waste is a hazardous waste or that environmental media contain a hazardous waste subject to the RCRA regulation, the substantive requirements of 40 *CFR* 262 through 268 are applicable. These standards include design and operation of storage and accumulation areas, waste handling and shipment, and treatment technologies or numeric standards applicable to wastes before disposal.	These requirements are applicable and will be complied with through characterization of wastes and environmental media generated as a result of implementation of the alternative. Waste management will be predicated upon the characterization and comply with all substantive requirements associated with hazardous waste management if identified as such.
PCB Waste Management	40 *CFR* 761	TSCA requirements for the management of PCB wastes or items containing >50 ppm PCBs or from a source of 50 ppm or greater. Requirements include the following: • management of waste and material; • characterization of PCB-containing materials; • labeling and storage for disposal; • manifest completion for shipment off-site; • decontamination of affected equipment or items; and • disposal of PCB wastes. These requirements will be complied with if PCBs are found at concentrations requiring compliance.	These requirements are applicable if PCBs are found or result from items or equipment regulated under 40 *CFR* 761. Activities necessary to comply with these ARARs shall be incorporated into the planning phase of the alternative implementation.

ALARA = as low as reasonably achievable
ARAR = applicable or relevant and appropriate requirement
BMP = best management practice
CFR = *Code of Federal Regulations*
CWA = Clean Water Act
DOE = U.S. Department of Energy
GWOU = groundwater operable unit
KAR = Kentucky Administrative Regulation
KPDES = Kentucky Pollutant Discharge Elimination System
MCLGs = maximum containment level goals
MCLs = maximum contaminant level
NRC = Nuclear Regulatory Commission
NWP = Nationwide Permit
PCB = polychlorinated biphenyls
PGDP = Paducah Gaseous Diffusion Plant
TBC = to be considered
TSCA = Toxic Substances Control Act

for unrestricted release. In addition to the NRC standards, EPA has issued guidance for cleanup levels at CERCLA sites with radioactive contamination. EPA has disagreed with the protectiveness specified within the NRC standard and has specified that a 15 mrem/year EDE be used as the risk level that is protective of human health and the environment. EPA also has codified exposure limits for environmental radiation protection standards for nuclear power operations at 40 *CFR* 190. These requirements apply to operations involved in the uranium fuel cycle and include enrichment operations. Subpart B of these requirements specifies that the annual dose equivalent to the public not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughter products excepted, to the general environment from uranium fuel cycle operations and to radiation from these operations. These requirements would be considered relevant and appropriate because the release to the groundwater would not be planned.

The Commonwealth of Kentucky is an NRC Agreement State and has promulgated regulations for radiation protection of the public. The Kentucky radiation protection standard for individual members of the public is 0.1 rem (100 mrem) EDE per year or less (902 KAR 100:019 Section 10), which is equivalent to the DOE radiation protection standard found in DOE Order 5400.5.

Due to the differing views and values among NRC, EPA, and DOE regarding total EDE for members of the general public, EPA and DOE have agreed not to finalize their respective standards until an agreement can be reached. In the interim, DOE Order 5400.5 is identified as TBC information and the NRC standard is identified as relevant and appropriate. Therefore, the radiation protection standard identified within the NRC regulations at 10 *CFR* 20 Subpart E requiring an EDE of 25 mrem/year or less shall be used as the exposure limit for the general public.

Chemical-specific ARAR summary. The chemical-specific ARARs associated with the implementation of this alternative are outlined in Table 4.13. Implementation of this alternative would not result in immediate attainment of the chemical-specific ARARs associated with the off-site groundwater plumes. Attainment of the identified ARARs would be met in the future as implementation progresses. Continued monitoring of the groundwater will be used during the five-year reviews to ensure the identified goals are met and that concentrations of COCs continue to decrease.

Potential location-specific ARARs. The potential location-specific ARARs for Secondary Source Zone – Oxidation Technology are summarized in the following paragraphs.

Wetlands. Although no wetlands have been identified within the area where construction activities will occur, certain jurisdictional wetlands have been identified in on-site drainage ditches within the plant boundary. In order to comply with these applicable requirements, wetlands shall be avoided.

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, 40 *CFR* 6.302(a), 40 *CFR* 6 Appendix A, and 10 *CFR* 1022). These applicable requirements include avoiding construction in wetlands, avoiding (to the extent practicable) long-term 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. Although not anticipated, if this alternative results in impacts to wetlands that cannot be avoided, the substantive requirements of the NWP 38 (33 *CFR* 330) will be met.

Off-site operations shall not impact wetlands, and all treatment will be conducted either *in situ* or in units already in operation.

Endangered Species and Migratory Birds. Actions taken by federal agencies are prohibited from impacting T&E species or adversely modifying critical habitat (50 CFR 17.94) in accordance with the Endangered Species Act (16 USCA 1531 *et seq.* Section (7)(a)(2)). These requirements are potential ARARs in the event T&E species or their habitats are found at or near areas where remedial action is to occur. An ecological resource investigation inside the PGDP security fence did not detect any T&E species or their preferred habitats (CDM Federal 1994). The USFWS has not designated critical habitats for any species within the DOE property. However, outside the PGDP fence on the DOE property, potential habitats for federally listed T&E species were reviewed, and Indiana bat habitat was evaluated during the COE (1994) environmental investigation. The COE study determined that total potential bat habitat consisted of 20% of the 994-ha (2,456-acre) study area. Remedial activities must be evaluated to ensure that such actions do not adversely impact areas identified as critical habitats for any identified endangered species.

In addition, Executive Order 13186 directs federal agencies to enter into an MOU with the USFWS to further the purposes of the Migratory Bird Treaty Act (16 U.S.C. 703-711). Until such time as the MOU between DOE and the USFWS is finalized, federal agencies are encouraged immediately to begin implementing the conservation measures set forth in the Executive Order. The requirements of the Executive Order are applicable and must be considered during planning and design of the remedial action.

Potential action-specific ARARs. The potential action-specific ARARs for this alternative are summarized in the following paragraphs.

Monitoring and injection well installation requirements. This alternative includes the installation of additional monitoring and injection wells. Installation of these wells would have to be conducted in a manner to maintain existing natural protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole (401 KAR 6:310 Section 13). These requirements also mandate the construction materials required for well construction, well design criteria, well completion activities, and well abandonment methodologies. These requirements are considered applicable to design and installation of monitoring and extraction wells associated with the implementation of this alternative.

Fugitive dust emissions. Construction activities for well installation onsite may result in the production of particulate airborne pollutants (dust). The Kentucky Air Quality standards found in 401 KAR 63:010 include requirements governing fugitive dust emissions. These standards require that dust-suppression measures be undertaken that include activities such as use of water or chemicals to control emissions, placement of asphalt or concrete, and stockpiling of soils. The standards also require that visible dust generated from the implementation of the remedial alternative not be discharged beyond the property boundary of the site. These requirements are considered to be applicable to the implementation of this alternative and will be complied with through planning to ensure construction activities incorporate appropriate controls (e.g., wetting, covering, etc.) to control dust generation. Specific activities that could result in the generation of fugitive dust that must be considered during the design phase include construction and well installation.

Radionuclide emission standards. Airborne emissions of radionuclides may occur as a result of on-site construction activities. Although the potential is low for such emissions to occur, the regulations at 40 *CFR* 61.92 would require that the emissions not exceed amounts that would cause an EDE to the public of 10 mrem/year. In order to determine whether the alternative complied with this applicable requirement, computer modeling using the CAP-88 or other EPA-approved models must be undertaken. If the modeling demonstrates the radionuclide emission to be in excess of 1% of the 10 mrem/year standard, emission rates must be measured as required by 40 *CFR* 61.93. This ARAR shall be complied with by planning activities in such a manner as to control fugitive emissions from construction activities.

Toxic emission standards. Although toxic emissions are not expected as a result of construction activities or with the pumping of groundwater to an on-site water treatment facility, these emission requirements would be applicable if such emissions do occur. Due to organic concentrations found in the groundwater and potentially within the subsurface soils at depth, there is a low potential for such emissions to occur. The regulations at 401 KAR 63:022 require that the emissions be evaluated to determine whether they are significant for each specific toxic air pollutant. If analysis indicates the toxic emission requirements are triggered, the regulations specify that no source may exceed the allowable emission limit specified in Appendix A of 401 KAR 63:022. If applicable, these rules would require the application of best available control technology to limit toxic emissions. If calculations indicate that the emission rates specified within the rule are not exceeded, the calculation package may be used to demonstrate compliance with these requirements.

Stormwater discharge. Construction/well installation activities will be subject to the substantive requirements associated with the KPDES permit that requires the use of BMPs and sediment/erosion controls to control transport of sediment in stormwater runoff. In addition, groundwater will be treated in a wastewater treatment unit where discharge will be subject to the substantive requirements of the KPDES program. These requirements are considered to be applicable.

Waste management requirements. Hazardous materials and wastes may be generated during the implementation of this alternative. It is anticipated that these wastes will be low-level radioactive wastes and, therefore, subject to the DOE Order 435.1 requirements that apply to the management of all radioactive wastes generated at DOE facilities. This requirement is TBC rather than applicable or relevant and appropriate because it is a DOE Order rather than a federal or state regulation or standard.

The potential exists that some of the wastes generated may be RCRA-hazardous wastes as defined in 40 *CFR* 261 of the federal program. All wastes generated shall be subject to the hazardous waste determination requirements of 40 *CFR* 262 and 401 KAR 32:010. If it is determined that any wastes are, in fact, hazardous wastes, the materials must be managed in accordance with the substantive requirements found in 40 *CFR* 262 through 40 *CFR* 268 (401 KAR 32 through 37). These standards include storage requirements, transportation requirements, and disposal requirements. Specific requirements applicable to each waste stream must be identified after characterization of the material is complete. These requirements shall be complied with through the development of a WMP during the design phase of implementation. If materials are identified as RCRA-hazardous waste, these requirements are applicable.

. Although considered unlikely, the potential exists that wastes generated from the implementation of this alternative may contain PCBs regulated under the Toxic Substances Control Act (TSCA). These regulations would be applicable to this alternative if PCB concentrations were found in soil or water that exceeded 50 ppm or PCBs were found and attributable to a source whose concentration exceeded 50 ppm PCBs. The substantive requirements for management of PCB wastes found in 40 *CFR* 761 would be applicable and include standards for storage, shipment, and equipment decontamination. These requirements shall be complied with through the development of a WMP during the design phase of implementation. If materials are identified as TSCA PCB-regulated material, these requirements are applicable.

Action-specific ARAR summary. This alternative will trigger action-specific ARARs with regard to the installation of wells and the handling of the potentially contaminated soils from well installation. All wells installed must be conducted in a manner to maintain existing natural protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole (401 KAR 6:310 Section 13). Generated wastes must meet the requirements for compliance with the RCRA requirements for wastes generated as a result of implementation. In addition, the requirements of TSCA may be applicable if PCB-containing materials are identified. This alternative will comply with these requirements during the planning phase to include compliant waste handling, storage, and disposition components. The proposed alternative will comply with the substantive requirements of both the CWA and RCRA because the discharge of treated effluent in compliance with the CWA meets both requirements, and because such treatment is allowed under RCRA. If wastes from treatment of groundwater or excavation of soils is determined to be hazardous wastes under RCRA, the substantive requirements for storage, management, and disposal of hazardous wastes shall be incorporated into the alternative during the planning phase. Activities that may be required for RCRA and TSCA compliance include use of appropriate containers, labeling of containers, appropriate storage area design and operation (secondary containment or storage for less than 90 days in a compliant accumulation area), and transportation of wastes.

A summary of the ARARs for the implementation of this alternative are presented in Table 4.13.

Compliance with ARARs summary. Implementation of this alternative would not achieve compliance with the MCL for TCE. Compliance at the fenceline and DOE property boundary has been calculated to occur in approximately 7,000 years. The MCLs applicable to antimony, chromium (action level), and alpha-emitting radionuclides would be exceeded at the point of compliance (plant fenceline) and points of exposure (DOE property boundary, Ohio River) if contaminants were allowed to continue to migrate offsite from source areas, according to the modeling used in the development of this FS. As stated in the risk assessment, the metals and radionuclides based upon historic observations are far less mobile than current modeling indicates. Based on the time frames illustrated in the model required for migration to the point of compliance and the historical observations associated with migration of metals and radionuclides at the PGDP, exceedance of the associated MCLs is considered unlikely.

In order to comply with the identified chemical-specific ARARs, an ARAR waiver will be required due to the time frames required to meet the specified concentrations within the GWOU at the point of compliance and points of exposure.

As discussed, no potential location-specific ARARs have been identified within the area where remedial action will occur. However, to ensure that jurisdictional wetlands are not impacted, all construction activities associated with this alternative will be reviewed as a safeguard. The protection of wetlands is not considered a location-specific ARAR at this time because jurisdictional wetlands have not been identified within the areas impacted by the implementation of this alternative.

Construction and implementation of the alternative may trigger several action-specific ARARs such as the requirements associated with well installation and abandonment, fugitive-dust emissions, radionuclide emissions, toxic emissions, and discharge of stormwater and treated groundwater. The requirements associated with the installation and abandonment of wells will be met though use of well designs and materials of construction as specified at 401 KAR 6:310 Section 13. All well installations and abandonment practices incorporated into the approved Remedial Design shall comply with the substantive requirements of 401 KAR 6:310.

Fugitive dust emissions that may occur during construction activities will be controlled as required by 401 KAR 63:010. BMPs, such as wetting or covering of potential sources of fugitive dust, will be incorporated into the remedial design. The specific actions to be developed shall control potential emission sources to ensure that dust emissions do not migrate from the immediate area where construction activities occur. It is anticipated that, in most cases, the moisture content in the soil will be sufficient to control dust emissions during well installation. However, practices such as the wetting of disturbed soils, collection of soils, or reseeding activities shall be considered and incorporated into the remedial design, as necessary, to ensure compliance with these requirements. Radionuclide emissions at construction sites also must be considered during the implementation phase. In order to ensure that the emission standards of 10 mrem/year EDE to the public is met, concentrations of radionuclides in soils and groundwater must be evaluated. If the potential for such emissions is identified, modeling using the CAP-88 or other EPA-approved methods must be undertaken during the design phase of the alternative. It is anticipated that the primary conveyance of airborne radionuclides will be in particulate form. Therefore, control of fugitive dust emissions also will result in compliance with the emission standards applicable to radionuclides. If radiological contamination from plant activities is found in soils where construction activities are planned, the soil will be protected or containerized to prevent airborne migration. Measures necessary to prevent airborne emissions of radionuclides shall be evaluated and incorporated, as appropriate, into the remedial design in order to comply with these requirements during implementation of this alternative.

Emissions of toxins such as volatile organics also must be evaluated before implementation. Although the potential for exceedance of toxic air emissions is considered to be low, an evaluation of the potential for such emissions must be undertaken during the remedial design. Potential emissions must be evaluated for each toxin present in the plumes (i.e., TCE, vinyl chloride, etc.) to determine whether the contaminant levels found in the subsurface could result in airborne emissions in excess of the allowable limits specified in Appendix A of 401 KAR 63:022. Compliance with the emissions standards shall be achieved for this alternative through the evaluation process or the application of the best available control technology where emissions are calculated to exceed allowable levels. Emission control equipment will be incorporated into implementation activities during the remedial design, as necessary, based upon the initial evaluation. This requirement will be complied with during implementation of the alternative.

The construction activities associated with this alternative will require that BMPs for sedimentation/ erosion controls be established. This requirement will be complied with through the use of sediment fences or other appropriate means. The remedial design shall incorporate the specific controls necessary to ensure that the construction sites do not allow sedimentation and/or erosion of disturbed areas in order to comply with this requirement during implementation of this alternative.

Wastes, including secondary wastes generated from the installation of wells, will trigger the characterization requirements associated with RCRA. The implementing regulations found at 40 *CFR* 262 and 401 KAR 32:010 require that generators of solid wastes (or contaminated environmental media) must determine whether the waste also is a hazardous waste. If the materials generated from the implementation of this alternative are found to be hazardous wastes, the materials shall be containerized and managed as such. The requirements mandate that hazardous wastes be properly labeled and stored in areas that comply with the technical standards for storage of hazardous waste in containers. These standards shall be complied with through testing of soils before excavation activities. If the soils are found to be hazardous, appropriate storage areas shall be constructed and maintained. All hazardous waste generated during the implementation of this alternative shall be shipped for off-site disposal using the EPA Identification Number for the PGDP. Hazardous wastes shall be shipped to facilities permitted to treat, store, or dispose of the hazardous waste(s) being shipped. These activities shall be incorporated into the remedial design for this alternative in order to comply with these requirements.

Wastes, including secondary wastes generated during the implementation of this alternative, also may be subject to regulation under TSCA, as PCB remediation waste, and under DOE Order 435.1, as LLW. Characterization of these materials will be required in order to determine whether specific wastes are regulated under these requirements. If it is determined that the waste generated is a PCB or LLW, appropriate management standards will be incorporated into the Remedial Design. Existing information will be used where practicable to determine the regulatory status of all waste to be generated before implementation.

Long-Term Effectiveness and Permanence. Secondary Source Zone Oxidation Technology offers a relatively high level of long-term control for VOCs and DNAPL TCE contaminants located in areas of the RGA that may be subject to treatment. There would no positive impact to ^{99}Tc concentrations located in the treated areas since ^{99}Tc cannot be destroyed by oxidation. The implementation of this technology alone in the RGA will provide little to no control over target contaminants located in the UCRS or the dissolved phase plume areas.

Magnitude of residual risk. Residual risk in the RGA will remain in place after implementation of an Oxidation Technology. The technology will require assistance from other technologies either in the UCRS or RGA to meet the MCLs at the point of compliance. This alternative will reduce VOCs and TCE DNAPL by *in situ* oxidation using an oxidant to react with the contamination. The technology will have no impact on contaminants present in the UCRS or the dissolved phase plume areas.

Following treatment of the selected RGA areas, residual COCs would contribute to long-term risks. However, the five-year reviews mandated by CERCLA [40 *CFR* §300.430(f)(4)(ii)] would be an effective means to demonstrate that contaminant levels were reduced from the technology's implementation and additional exposure pathways have not developed. The Oxidation Technologies will achieve residual risk in the shortest amount of time in comparison to the other Secondary Source Area technologies evaluated. The reaction with the oxidant is instantaneous upon contact between the contaminant and the oxidant.

Adequacy and reliability of controls. The reliability for operation and control of Oxidation Technology would be moderate. The components that make up the treatment systems such as an oxidant, injection wells, metering pumps, etc., are common industrial items that have been used for many years successfully. However, the limiting factor in the reliability of the oxidation process is ensuring that the contaminants and oxidants come into contact with one another and allow the reaction to occur. The contact of the two compounds is largely controlled by the subsurface conditions of the RGA and whether liquids can be injected into the areas. The RGA has high permeability; therefore, this limitation is not expected to be encountered. Another limiting factor is the presence of large amounts of organic material being present in the treatment zone. The oxidant will react with VOCs as well as with any other organic compounds present. If large quantities of organics are present, the oxidant is spent on reacting with these extraneous organic compounds and not reacting with the contaminants. Computer modeling would be used to design the site-specific location, injection-well layouts to ensure appropriately sized treatment zones and that contaminants are not migrated to noncontaminated areas due to the injection process. However, should extended interruptions of electrical power, fuel, or other vital systems occur, the potential would exist for COCs to escape from the treatment system area. Long-term groundwater monitoring will be required to assess the extended effectiveness of the treatment following its completion.

Intrusive activities onsite will be prevented, as necessary, through the use of work permits and safety programs, thereby limiting the access of plant personnel to the contaminated groundwater.

Environmental impacts and mitigative measures. The following paragraphs summarize potential long-term impacts to resources and mitigative measures to offset any potential impacts. The depth of impact analysis and mitigative measures is correlated to the degree to which a resource may be impacted.

Land use. Long-term land use impacts would be minimal, as the current land-use classifications would not change. The minimal long-term impacts would be related to the monitoring wells and monitoring facilities that would remain following the technology's implementation. A LUCIP would be developed, as necessary, per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomics. The presence of contaminants in the groundwater will prevent its use and may limit economic development opportunities until the groundwater is brought back to beneficial use. However, no long-term effects to socioeconomics would result from the implementation of this technology. There would be few changes to permanent jobs within the PGDP area as a result of implementing this technology.

Air quality and noise. No long-term effects to air quality and ambient noise levels would result from implementation of this alternative.

Vegetation. No long-term effects to vegetation would result from this alternative.

Wildlife. No long-term effects to wildlife or T&E species would result from this alternative. Construction in creeks and tributaries will not occur as a result of implementing this technology. The likely target areas for the implementation of this technology are in areas of existing industrial buildings or other industrial facilities.

Threatened and endangered species. Long-term impacts to T&E species are not expected to occur. Construction in creeks and tributaries or other habitat areas is not expected to occur. The likely target areas for the implementation of this technology are in areas of existing industrial buildings or other industrial facilities.

Cultural resources. No long-term effects to cultural resources are anticipated for this alternative.

Groundwater. As a result of implementing an Oxidation Technology in Secondary Source Areas, potential RGA VOC sources either are reduced or eliminated. As a result of the use of injecting an oxidant into the groundwater, an aesthetic change in the quality of the groundwater may occur due to the precipitation of manganese dioxide. There will no reduction in ^{99}Tc contaminant levels. If ^{99}Tc in a non-fully oxidized state is encountered by the oxidant, the dissolved phase ^{99}Tc concentrations may increase. This is not expected to occur, however, since, the ^{99}Tc in the RGA is expected to be already fully oxidized. Groundwater monitoring systems will be used to monitor contaminant levels and to assess the migration of contaminants to noncontaminated areas due to the injection process.

Surface water. No adverse impacts to streams are expected to result from implementing an Oxidation Technology in a Secondary Source Area (RGA). No adverse impacts to wetlands are expected to occur either. There will be no increases in water discharge volumes to outfalls as a result of this alternative.

Floodplains. No long-term impacts to floodplains are expected as a result implementing this alternative. The Oxidation Technology for Secondary Source Areas likely will be implemented only within the industrial areas of PGDP.

Wetlands. No long-term impacts to wetlands have been identified as resulting from implementing this alternative. This alternative likely would only be implemented within the main fenced area of the PGDP.

Soils and prime farmland. Prime farmland would not be impacted by the implementation of this alternative as the area has been previously disturbed and, consequently, is not classified as prime farmland. Prime farmland exists north of the PGDP and DOE property. The NRCS has identified prime farmland as the Calloway, Waverly, and Grenada soil series in the area between the PGDP and the TVA Shawnee Steam Plant.

Transportation. No long-term direct, indirect, or cumulative effects to transportation are anticipated from implementing this alternative.

Cumulative Impacts. Cumulative impacts are defined as the incremental impact of an action when added to other past, present, and reasonable foreseeable future actions, regardless of what agency or person undertakes other such actions. Cumulative impacts resulting from this alternative will have to be identified at a later time during development of site-specific GWOU decision documents.

Reduction of Mobility, Toxicity, or Volume Through Treatment. Oxidation Technology would be used to destroy VOCs and TCE DNAPL in source areas located in the RGA. The process is by *in situ* destruction. It is expected that 60%-90% of the VOC contaminants in the target area could be expected to be destroyed by the oxidant. The Oxidant Technologies will have no positive effect on the ^{99}Tc contaminant levels in the treatment area.

The implementation of an Oxidation Technology would reduce the long-term volume and toxicity of VOCs and DNAPL present in the RGA through the destruction of those contaminants. The implementation of this technology is expected to alter the chemical and physical soil properties of the RGA and, as such, may prevent subsequent implementation of an additional technology, should it be determined that additional treatment is needed for the target areas. One identified physical alteration is the precipitation of manganese dioxide in the RGA formation.

The type and characteristics of residual subsurface contamination would be similar to that of the contaminants prior to treatment. Residual contaminants would pose a risk, although contaminant quantities would be reduced following treatment. Since the treatment occurs *in situ*, there will be no residuals contaminant to be disposed of from any surface or *ex situ* treatment. Oxidation Technology may meet the statutory preference for treatment as a principal element of the remedial action under CERCLA.

Short-Term Effectiveness. The short-term effectiveness of implementing an Oxidation Technology in a Secondary Source Area of the RGA was evaluated relative to its effect on community protection, worker protection, environmental impact, and the time until RAOs are achieved. Environmental impact was further evaluated for NEPA values. This information is presented in the following subsections.

Community protection. The potential for adverse impacts to the community from the implementation of this alternative is minimal. The potential impacts identified include spillage of the oxidant during injection and inadvertent surface release of oxidant during injection. The target area for the injected oxidant in a Secondary Source Areas is the RGA that lies at a depth of greater than 50 ft. The injection of the oxidant will be through tubing or pipe. Due to the depth, the oxidant is likely not to surface as a result of the injection process. The Little Bayou Creek, into which the RGA discharges near the Ohio River, is approximately two miles away from the area likely to be treated inside the PGDP fences. Due to this distance, the oxidant will have become ineffective prior to its flowing into the Little Bayou Creek many years after the injection. Also, engineering controls, including appropriate packaging and handling mechanisms, will be used prevent a spill of oxidant that could impact the community. The likely target areas for treatment will be located in the main industrial area of the PGDP. Restrictions will be used to limit the access of persons that may be in the area during construction. This will include warning signs, temporary control fencing, and periodic security patrols. Also, environmental monitoring would be conducted during the construction of monitoring wells where COCs may be present. Following completion of the construction activities, only temporary periodic access will be required for sampling of the monitoring wells used to check the long-term effectiveness of the action on the RGA.

Transportation of oxidant will be required periodically from manufacturing facilities to PGDP. Proper packaging and other required safety features would be used to limit releases as a result of accidents when shipping the oxidant materials.

Worker protection. During the implementation of an Oxidation Technology, workers could be exposed to COCs during short periods of time. Potential exposure could result from direct contact with contaminated soil and/or groundwater during construction of the injection wells. The workers also will be exposed to oxidant, a hazardous substance, during injection operations. Appropriate handling procedures, injection equipment, and PPE would be utilized to minimize the potential for worker exposure or injury while handling the oxidant. However, short-term risks are not expected to exceed acceptable limits. Health and safety requirements and PGDP procedures would further control the exposures.

Environmental impacts and mitigative measures. The following paragraphs summarize potential short-term impacts to resources and mitigative measures to offset any potential impacts. The depth of impact analysis and mitigative measures are correlated to the degree to which a resource may be impacted.

Land use. The areas expected to be targeted for implementation of an Oxidation Technology in a Secondary Source Area likely will be located inside the main PGDP facility. To that end, short-term land use would not be affected by this alternative, as the current land-use classifications would not change. There would be minimal short-term impacts to land use. These short-term impacts would be related to the presence of injection wells and monitoring wells. A LUCIP would be developed, as necessary, per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomics. This alternative would not be expected to change the short-term economic conditions in the nearby area. There would be a minimal increase in temporary jobs related to the construction of injection wells and injection operations.

Air quality and noise. Heavy equipment traffic and operation associated with construction of the injection wells would provide a minimal increase in dust and vehicular emission levels. The use of BMPs during construction would reduce short-term direct impacts to air quality from dust. Noise associated with construction activities would occur in the immediate vicinity of the PGDP. There would be no air emissions as a result of implementing an oxidation technology.

Vegetation. There would be some short-term impacts to vegetation in the area of construction of the injection wells. However, the area impacted is expected to be less than 2 ha (5 acres). After construction is complete, vegetation would be restored.

Wildlife and threatened and endangered species. The likely target areas for treatment by Oxidation Technology are located within the industrial portion of the PGDP. No construction is expected to occur in the creeks and tributaries. Therefore, the impacts to wildlife are expected to be minimal. Very little or no wildlife habitat is associated with these areas. Some small mammals and birds may use these areas and, consequently, some small mammals may perish. Indirect effects such as displacement during construction would occur due to disturbance of habitats by noise, and activities associated with construction; however, after construction is completed, revegetation and natural repopulation to pre-construction conditions likely would occur. No effects to T&E species would result from implementing this alternative.

Cultural resources. No short-term effects on cultural resources would be anticipated to occur from the implementation of this alternative.

Groundwater. As a result of implementing an Oxidation Technology in a Secondary Source Area, potential RGA VOC sources are either reduced or eliminated, thereby producing a positive effect. The oxidation process results in the precipitation of manganese dioxide that can have a negative aesthetic impact to groundwater. The ^{99}Tc contamination levels will not be impacted by the oxidation process. Groundwater monitoring systems will be used to monitor the effectiveness of the oxidation process.

Surface water. No short-term adverse impacts to streams are expected to result from implementing an Oxidation Technology in a Secondary Source Area (RGA). No adverse impacts to wetlands are expected to occur either. There will no increases in water discharge volumes to outfalls during the operation.

Floodplains. No short-term impacts to floodplains are expected as a result of implementing this alternative.

Wetlands. No short-term impacts to wetlands have been identified as resulting from implementing this alternative. This alternative likely would be implemented within the main fenced industrial area of the PGDP.

Soils and prime farmland. Prime farmland would not be impacted by the implementation of this alternative as the area has been previously disturbed and, consequently, is not classified as prime farmland.

Transportation. Minimal short-term direct, indirect, or cumulative effects to transportation are anticipated from implementing this alternative. These impacts would be the result of equipment transportation during construction and transportation of oxidant raw materials during the treatment operation. However, proper packaging and other required safety features would be used to limit releases as a result of accidents when transporting these materials.

Time until action is complete. Implementation of this alternative will not result in achievement of the specified GWOU RAOs or groundwater MCLs. Approximately 7,000 years will be required before groundwater may be used following the application of an Oxidant Technology only in the Secondary Source Areas of the RGA. The reduction of sources only within the RGA will not prevent the Primary Source Areas located within the UCRS from continuing to impact the groundwater. It will be necessary to implement other source reduction and dissolved phased technology's in conjunction with Oxidation Technology's in the Secondary Source Areas to reduce the time the groundwater will remain unusable.

Implementability. The implementability of Oxidation Technology in the Secondary Source Areas of the RGA was evaluated based upon its technical feasibility, administrative feasibility, and the availability of services and materials. This information is summarized in the following subsections.

Technical feasibility. Implementation of Oxidation Technology is technically feasible. This technology, although innovative, has been implemented at other hazardous waste sites, and the necessary equipment may be readily obtained. Oxidation uses standard commercially available equipment. The technology is available from a limited number of vendors. Implementation difficulties may arise related to the industrial areas of the PGDP, which have large buildings and high concentrations of utility corridors that may interfere with injection well placement. A monitoring network will be necessary to monitoring the effectiveness of the treatment operations.

Administrative feasibility. This alternative is administratively feasible. All activities would be conducted in accordance with substantive federal, state, and local requirements. Waivers of ARARs are anticipated to be necessary to implement these actions since MCLs will not be attained in a timely manner.

Availability of material and services. The services and materials necessary to implement this alternative are readily available. The potential exception would be personnel/vendors necessary to implement the Oxidation Technology. The equipment is standard industrial equipment used in other fields such as wastewater treatment. However, the number of vendors experienced at implementing oxidation in the environmental remediation arena is limited.

The construction of this alternative will result in the generation of waste soil cuttings and drilling and development water from the construction of injection and monitoring wells. Additionally, the construction will generate construction debris during the building of any required injection facilities. All of these materials either will be treated as necessary and released, as in the development water, or disposed of appropriately.

Cost. Table 4.14 summarizes the preliminary unit cost estimates for implementation of Oxidation Technology in a Secondary Source Area of the RGA. These preliminary unit cost estimates are based upon FS-level scoping and are intended to aid with selection of a preferred alternative. The estimates have an expected accuracy of -30 to +50% for the proposed scope of action (EPA 1988a). The capital cost estimate represents those expenditures required to implement this remedial alternative. The O&M cost estimates represent expenditures required to maintain the remedy after the initial phase of remedial action is completed. The total contingency cost presented includes direct, indirect, and all O&M associated contingency costs. The total cost includes all capital costs, direct and indirect with O&M, and associated reports, plus 25% contingency costs, for a 30-year term of comparison. All estimates have been escalated using DOE-approved annual rates and a schedule for the various activities based on similar project experience. Present worth values also are included using a discount factor of 5% (EPA 1988b). (Additional information regarding the preliminary cost estimates is presented in Appendix C7.)

Table 4.14. Preliminary unit cost estimates for Secondary Source Area Oxidation Technology

Total capital costs/acre-foot	$213,347
Total operation and maintenance costs	$6,072,038
Overhead	$3,558,054
Total contingency	$2,460,860
Total cost	**$12,304,300**
Total cost (present worth)	**$12,218,892**

Note: preliminary cost estimates are per acre-foot, escalated and presented in dollars.

State/Commonwealth Acceptance. Commonwealth of Kentucky acceptance or nonacceptance of this alternative will be addressed in the ROD should this alternative be selected as the preferred alternative.

Community Acceptance. Following a formal public comment period on the PRAP for the GWOU, comments from the community will be addressed formally in a responsiveness summary, which will be presented in the ROD.

Evaluation summary of Secondary Source Area Oxidation Technology

This alternative consists of implementing Oxidation Technology in a Secondary Source Zone of the RGA to remove VOCs and TCE DNAPL present in the RGA in the targeted area, monitoring of the action, and conducting five-year reviews as required by CERCLA. Monitoring COC migration allows the potential for exposure to contaminated groundwater to be prevented or minimized, and it also allows the effectiveness of the remedial actions to be evaluated. Although the Secondary Source in the RGA would be reduced following the implementation, residual contamination and risks would remain. These residual risks in the RGA, as well as risks that may still be present in the UCRS and the dissolved phased plumes, will prevent the use of the groundwater for an estimated 7,000 years. It also would be necessary to conduct other source area reductions and dissolved phased plume actions to reduce the time the groundwater would be unusable.

Implementation of this alternative alone will not be protective of human health and the environment. It must be combined with other source area and dissolved phase plume actions. Oxidation Alternatives can be implemented in compliance with ARARs. Long-term effectiveness could be achieved to an acceptable degree (60%-90% mass removal within with the RGA Secondary Source Area within 15 years of implementation). However, because of the nature of the soil and groundwater contamination associated with the GWOU, it will take several years and other actions to remediate completely. Residual contamination will remain in the groundwater, with TCE levels exceeding the MCL for approximately 7,000 years. The volume and toxicity of the VOCs would be reduced by *in situ* destruction. Limited short-term risks to workers would exist during the construction and operation phase of the alternative. The alternative is technically and administratively feasible to implement. Implementation of this alternative, which is intended to address only the Secondary Source Areas of the RGA in the GWOU at the PGDP, requires a high capital cost. Input from the Commonwealth of Kentucky and the community has not yet been received, but it will be added to later versions of this FS report and the corresponding ROD once the respective comment periods have been completed.

4.2.4 Dissolved Phase Plume Area

The following subsections provide a detailed analysis of alternatives for the Dissolved Phase Plume Areas. A Dissolved Phase Plume Area is defined for the purposes of this GWOU FS as those areas in the RGA with the target contaminants of TCE, TCE degradation products, or ^{99}Tc but having no DNAPL concentrations present.

4.2.4.1 Dissolved Phase Plume Area – Pump-and-Treat Technology

The following subsections contain a description of Dissolved Phase Plume Area – Pump-and-Treat Technology Alternative and the detailed analysis.

Pump-and-Treat Technology

This alternative would consist of implementing a Pump-and-Treat Technology in portions of or over the entire RGA dissolved phase plume areas located both in the PGDP On-site Secure Area and the Off-site Unsecure Area. The purpose of the alternative would be to remove TCE dissolved phase concentrations, other volatile organic contaminants, and ^{99}Tc contaminants from areas of the RGA. Unlike the Secondary Source Area technologies evaluated above, the Pump-and-Treat Technology in this alternative would be designed only to remove dissolved phase contaminant concentrations. In this technology a series of extraction wells would be installed in a blanket type fashion in which wells would be spaced periodically across the entire plume area or in a linear arrangement allowing discrete sections of the plume to be remediated over a given time period. The wells will extract groundwater containing both VOCs and ^{99}Tc. The produced water will be conveyed to a regional treatment facility for COC removal prior to being released. The treatment of the water to remove the COCs will be by air stripping for TCE and ion exchange for the ^{99}Tc. The treated water will be tested before being released to a KPDES system outfall.

Figure 4.7 contains a "snapshot" that graphically summarizes the components of the Dissolved Phase Plume Area Pump-and-Treat Technology alternative.

The dissolved phase contaminant reduction efforts of implementing this technology in the dissolved phase plume areas will have only minimal impact to returning groundwater to beneficial use. This is due to the fact that without removal of Primary and Secondary Sources located beneath the PGDP plant areas, the plumes will regenerate over time due to the presence of dissolving DNAPL concentrations of TCE. Therefore, due to the technology's not effecting removal of the DNAPL TCE contaminants in the UCRS and RGA areas (Primary and Secondary Source Areas), it is anticipated that groundwater will not be returned to the drinking water standard for TCE for approximately 7,000 years.

The existing groundwater monitoring program would be continued to monitor the movement of COCs within the RGA. The monitoring program will integrate existing PGDP monitoring wells, where possible, with additional monitoring wells to be installed, as needed, following a review of the existing program.

Five-Year Review. The CERCLA Five-Year Review process will be used to monitor the effectiveness of the alternative and to identify any needed changes.

Assessment of Dissolved Phase Plume Area Pump-and-Treat Technology

A detailed analysis of the performance of Dissolved Phase Plume Area Pump-and-Treat Technology against the nine CERCLA criteria is provided.

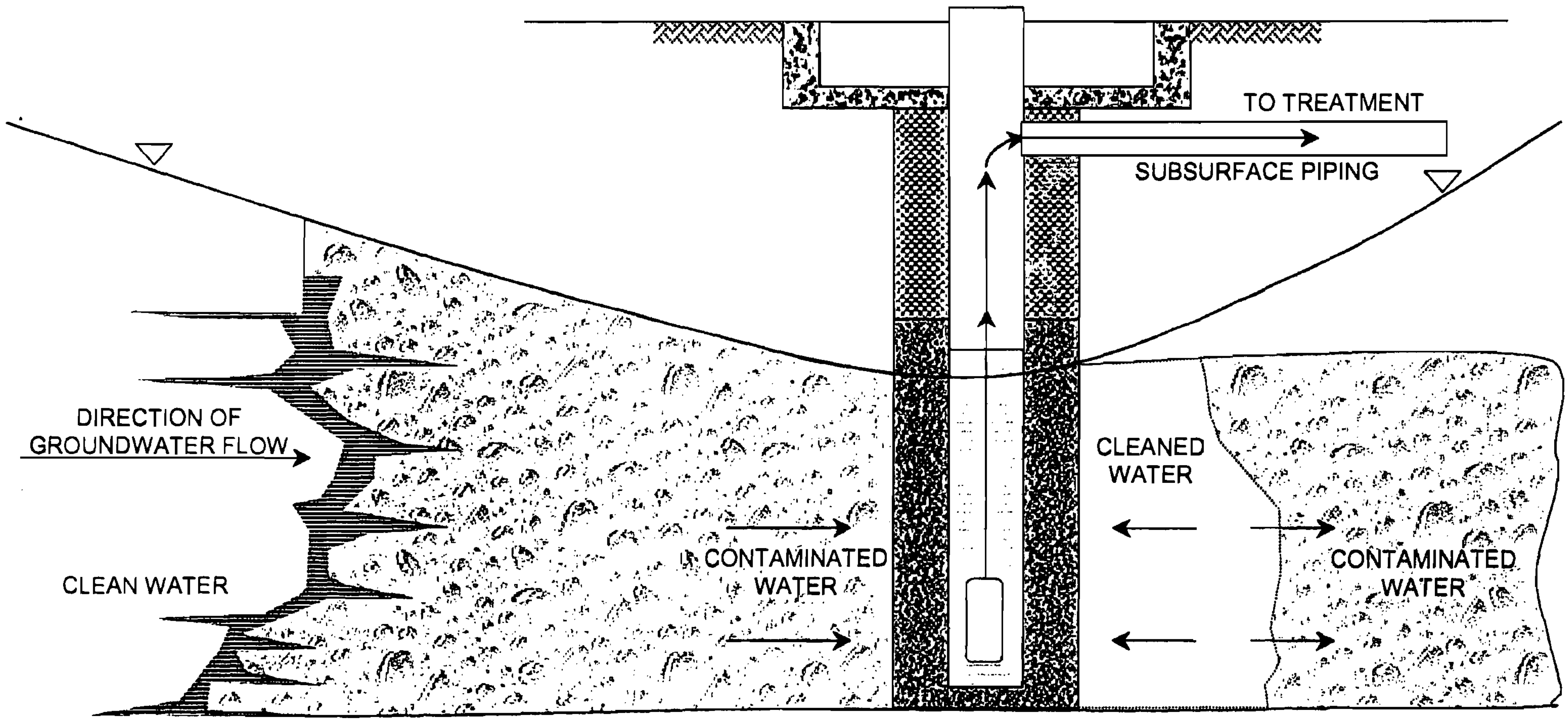


Fig. 4.7. Dissolved phase plume area - pump and treat technology.

U. S. DEPARTMENT OF ENERGY
DOE OAK RIDGE OPERATIONS
PADUCAH GASEOUS DIFFUSION PLANT

BECHTEL JACOBS COMPANY, LLC
MANAGED FOR THE US DEPARTMENT OF ENERGY UNDER
US GOVERNMENT CONTRACT DE-AC-05-98OR22700
Oak Ridge, Tennessee • Paducah, Kentucky • Portsmouth, Ohio

Science Applications International Corporation
P.O. Box 2502
Oak Ridge, Tennessee 37831

FIGURE No. FS4-7
DATE 05-25-01

Overall Protection of Human Health and the Environment. This alternative would reduce dissolved phase VOC contamination in the RGA and would have high effectiveness on the ^{99}Tc contamination. The volatile COCs are removed from the groundwater system and air stripped. The ^{99}Tc is removed from the groundwater system and trapped on an ion-exchange resin.

Although this technology is applicable to the reduction of Secondary Source Area concentrations, this detailed analysis is for only dissolved phase areas of the plumes.

Although this alternative alone would not satisfy the RAOs for the GWOU, it would support achieving the RAOs when implemented in concert with primary and secondary source reduction technologies. Without the removal of Primary and Secondary Sources, the MCLs upgradient will not be achieved for an estimated 7,000 years. If the pump-and-treat system effects total hydraulic containment, this alternative would result in achieving RAOs and MCLs in the dissolved phase plume areas within approximately 15 years based on groundwater analysis. This alternative may satisfy the RAO for protecting ecological receptors that may be exposed to contaminated groundwater discharging to surface water. However, in order for this to be effective when implemented alone, an extended operational period will be required.

The continuation of the groundwater monitoring programs will provide indirect protection for human health and the environment by minimizing the potential exposure to contaminated groundwater through early identification and avoidance.

Compliance with ARARs

Potential chemical-specific ARARs

Chemical Contamination. The aquifers are known to contain chemical contaminants in the form of metals and organics. The federal and state water quality requirements include standards that would be applicable ARARs. The regulations that apply are found in 40 *CFR* 141 (National Primary Drinking Water Standards); 40 *CFR* 143 (Secondary Drinking Water Standards); 401 KAR 5:029 (General Provisions); and 401 KAR 5:031 (Surface Water Standards). These standards, summarized in Table 4.15, include general state standards, domestic water supply standards, and standards applicable to warm water aquatic habitat. These are applicable, based upon the classification of the designation for surface water use associated with the area (Ohio River, River Mile 940.7 to River Mile 943.3) as specified in 401 KAR 5:026. All potentially applicable chemical ARARs for COCs have been included in the table for completeness. Those standards that must be achieved in order to meet the applicable requirements are the lowest of the applicable standards, which in most cases are the MCLs.

Radiological contamination. The GWOU is known to be contaminated with radionuclides such as ^{99}Tc, radon, uranium, and uranium daughter products. DOE's Order on Radiation Protection of the Public and Environment, DOE Order 5400.5, as codified at 10 *CFR* 835, is TBC information for cleanup of radionuclides at DOE sites. The order requires that remediation activities must not result in radiation exposures to members of the general public greater than an EDE of 100 mrem/year from all exposure pathways. Exposure to the general public also must be ALARA (DOE 1990).

DOE Order 5400.5 also contains reference values, known as DCGs, for operational DOE facilities. Based on the DCGs, radionuclide concentrations in air and drinking water must not exceed an EDE of 10 mrem/year and 4 mrem/year, respectively, to the total body or any organ.

The NRC also has set criteria for decommissioning standards at nuclear facilities in 10 *CFR* 20 Subpart E. These rules require that residual radioactivity at nuclear sites meet a total EDE of 25 mrem/year for unrestricted release. In addition to the NRC standards, EPA has issued guidance for cleanup levels at

CERCLA sites with radioactive contamination. EPA has disagreed with the protectiveness specified within the NRC standard and has specified that a 15 mrem/year EDE be used as the risk level that is protective of human health and the environment. EPA has also codified exposure limits for environmental radiation protection standards for nuclear power operations in 40 *CFR* 190. These requirements apply to operations involved in uranium fuel cycle and include enrichment operations. Subpart B of these requirements specifies that the annual dose equivalent to the public must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment from uranium fuel cycle operations and to radiation from these operations. These requirements would be considered relevant and appropriate since the release to the groundwater would not be planned.

The Commonwealth of Kentucky is an NRC Agreement State and has promulgated regulations for radiation protection of the public. The Kentucky radiation protection standard for individual members of the public is 0.1 rem (100 mrem) EDE per year or less (902 KAR 100:019 Section 10), which is equivalent to the DOE radiation protection standard found in DOE Order 5400.5.

Due to the differing view and values among NRC, EPA, and DOE total EDE for members of the general public, EPA and DOE have agreed not to finalize their respective standards until an agreement can be reached. In the interim, DOE Order 5400.5 is identified as TBC information and the NRC standard is identified as relevant and appropriate. Therefore, the radiation protection standard identified within the NRC regulations in 10 *CFR* 20 Subpart E, requiring an EDE of 25 mrem/year or less, shall be used as the exposure limit for the general public.

Chemical-specific ARAR summary. The chemical-specific ARARs associated with the implementation of this alternative are outlined in Table 4.15. Implementation of this alternative would not result in immediate attainment of the chemical-specific ARARs associated with the off-site groundwater plumes. Attainment of the identified ARARs would be met in the future as implementation progresses. Although TBC information, the radiological exposure standards included in DOE Order 5400.5 shall be achieved through monitoring. Continued monitoring of the groundwater will be used during the five-year reviews to ensure the identified goals are met and that concentrations of COCs continue to decrease.

Potential location-specific ARARs

Wetlands. Wetlands have been identified within the area where construction activities will occur, certain jurisdictional wetlands have been identified in on-site drainage ditches within the plant boundary. In order to comply with these applicable requirements, wetlands shall be avoided as possible.

As stated in the regulations, construction activities must avoid or minimize adverse impacts to wetlands and act to preserve and enhance their natural and beneficial values [Executive Order 11990, 40 *CFR* 6.302(a), 40 *CFR* 6 Appendix A, 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. Although not anticipated, if this alternate results in impacts to wetlands that cannot be avoided, the substantive requirements of the NWP 38 (33 *CFR* 330) will be met.

This alternative shall comply with these requirements by siting construction locations to the extent possible in areas where wetlands do not occur. Engineering controls shall be established as necessary to ensure operations shall not impact wetlands.

Table 4.15. Summary of potential ARARs for dissolved Phase Plume – Pump-and-Treat Technology

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Chemical-Specific ARARs	
National Primary Drinking Water Standards	40 *CFR* 141	Provides chemical-specific numeric standards for toxic pollutants expressed as MCLs and MCLGs.	These requirements are relevant and appropriate due to the nature of the contaminants found within the groundwater.
National Secondary Drinking Water Standards	40 *CFR* 141	Provides secondary MCLs for public water systems.	These requirements are TBCs, as they have been established as guidelines for the states and are not federally enforceable.
Kentucky Surface Standards including • Warm Water Aquatic Habitat Criteria • Kentucky Domestic Water Supply • Kentucky General Standards • Kentucky Outstanding State Resource Waters	401 KAR 5:031 and 5:026	Provides chemical-specific numeric standards for pollutants discharged or found in surface waters. Provides chemical-specific numeric standards for pollutants in domestic water supplies.	These standards are applicable to the segment of the Ohio River into which the Little Bayou Creek discharges. The requirements found in these standards are applicable due to the groundwater to surface water interface at Little Bayou Creek and, subsequently, the Ohio River. Note: CWA Water Quality Criteria are not relevant and appropriate because Kentucky has promulgated these state standards, determined to be appropriate for Kentucky waters.
Radiation Exposure of the General Public at DOE Facilities	DOE Order 5400.5	Specifies that the general public must not receive an effective dose equivalent of >100 mrem/year from all exposure pathways. In addition, all releases of radioactive materials resulting in doses to the general public must meet the ALARA criteria.	This requirement is considered TBC information.
Decommissioning Standards at Nuclear Facilities	10 *CFR* 20, Subpart E	Specifies a residual activity at nuclear facilities for unrestricted release of 25 mrem/year.	These standards are considered to be applicable to the GWOU.
Environmental Radiation Protection Standards for Nuclear Power Operations	40 *CFR* 190, Subpart B	Requires that the annual dose equivalent to the public must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment from uranium fuel cycle operations and radiation from these operations.	These standards are considered to be relevant and appropriate and are equivalent to the NRC standards.
		Location-Specific ARARs	
Protection of Wetlands	10 *CFR* Section 1022; Executive Order 11990; 40 *CFR* 230.10; 33 *CFR* 330.5	Activities must avoid or minimize impacts to wetlands to preserve and enhance their natural and beneficial value. If wetland resources are not avoided, measures must be taken to address ecologically sensitive areas and mitigate adverse effects. Such measures may include, minimum-grading requirements, runoff controls, and design and construction considerations. Allows minor discharges of dredge and fill material or other minor activities for which there are no practicable alternatives, provided that the pertinent requirements of the NWP system are met.	These requirements are applicable due to the presence of wetlands, but they will be met through avoidance of wetlands during construction and implementation of alternatives.

Table 4.15. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
Endangered Species Act	16 U.S.C. 1531 et seq. Section 7(a)(2)	Actions that jeopardize the existence of listed species or result in the destruction of adverse modification of critical habitat must be avoided or reasonable and prudent mitigation measures taken.	Action that is likely to jeopardize fish, wildlife, or plant species or destroy or adversely modify critical habitat-applicable.
Migratory Bird Treaty Act	16 U.S.C. 703-711; Executive Order 13186	Federal Agencies are encouraged (until requirements are established under a formal MOU) to do the following: • avoid or minimize, to the extent practicable, adverse impacts on migratory bird resources when conducting agency actions; • restore and enhance the habitats of migratory birds, as practicable; • prevent or abate the pollution or detrimental alteration of the environment for the benefit of migratory birds, as practicable; • ensure that environmental analysis of federal actions required by the NEPA or other established environmental review processes evaluate the effects of actions and agency plans of migratory birds, with emphasis on species of concern; and • identify where unintentional take likely will result from agency actions, and develop standards and/or practices to minimize such unintentional take.	Action that is likely to impact migratory birds, habitats, and resources-applicable.
Action-Specific ARARs			
Fugitive Dust Emissions during site preparation and construction activities.	401 KAR 63:010	Precautions must be taken to prevent particulate matter from becoming airborne. Such precautions must be incorporated into the planning and design of activities and include actions such as • wetting or adding chemicals to control dust from construction activities; • using materials such as asphalt or concrete (or other suitable chemicals/fixing agents) on roads or material stockpiles to prevent fugitive emissions; and • using covers on trucks when transporting materials to and from the construction site(s). The requirement specifies that for on-site construction activities, no visible emissions may occur at the PGDP fenceline. Similar points of compliance shall be identified for construction activities that occur outside the fence.	These requirements are applicable and will be met through the use of appropriate dust control practices identified during the alternative design phase.

Table 4.15. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
Toxic Emissions	401 KAR 63:022	The regulations require that a determination of toxic emissions be made in order to assess the applicability of required controls. Calculations of the significant emission levels are compared to the allowable emission limits specified in Appendix A of 401 KAR 63:022. If emission levels are exceeded, best available control technologies must be incorporated into equipment/process design.	These requirements are considered to be applicable and shall be met through calculation of significant emission levels for toxic materials and application of best available control technology, as necessary, during the design of the alternative.
Monitoring Well Installation	401 KAR 6:310	Monitoring wells (including extraction wells) must be constructed in a manner to maintain existing protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole. In addition, abandoned wells must be plugged and abandoned in accordance with the requirements specified.	These requirements are considered to be applicable. Compliance with well design and protection standards shall be achieved through the use of approved well design and materials of construction. While in service, wells shall be secured as required. Abandoned wells shall be plugged and abandoned as required.
Discharge of Stormwater and Treated Groundwater	40 *CFR* 122 401 KAR 5:055	Stormwater discharges from construction activities onsite are subject to the requirements of the KPDES permit. This requires that BMPs to control stormwater runoff and sedimentation be employed. Although off-plant construction activities within the contaminated area are not subject to the permit, these requirements should be considered relevant and appropriate and be incorporated into any off-site construction activities. Discharge of treated groundwater will be conducted in compliance with the substantive requirements of the KPDES program and the CWA.	These requirements are considered applicable for all on-site construction or treatment activities where a discharge of stormwater or treated groundwater occurs. For off-site construction activities, these requirements are considered relevant and appropriate and will be adhered to. Compliance with these ARARs shall be achieved by application of required controls during the design phase of the alternative.
Hazardous Waste Management	40 *CFR* 260 through 264 and 268; 401 KAR 31 through 34, 36, and 37	All wastes or environmental media containing wastes must be characterized to determine whether the wastes are hazardous in accordance with 40 *CFR* 262.11 and 401 KAR 32:010. If it is determined that a waste is a hazardous waste or that environmental media contain a hazardous waste subject to the RCRA regulation, the substantive requirements of 40 *CFR* 262 through 268 are applicable. These standards include design and operation of storage and accumulation areas, waste handling and shipment, and treatment technologies or numeric standards applicable to wastes prior to disposal.	These requirements are applicable and will be met through characterization of wastes and environmental media generated as a result of implementation of the alternative. Waste management will be predicated upon the characterization and comply with all substantive requirements associated with hazardous waste management if identified as such.

Table 4.15. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
PCB Waste Management	40 *CFR* 761	TSCA requirements for the management of PCB wastes or items containing >50 ppm PCBs or from a source of 50 ppm or greater. Requirements include the following: • management of waste and material; • characterization of PCB-containing materials; • labeling and storage for disposal; • manifest completion for shipment offsite; • decontamination of affected equipment or items; • disposal of PCB wastes; These requirements will be complied with in the event that PCBs are found at concentrations requiring compliance.	These requirements are applicable if PCBs are found or result from items or equipment regulated under 40 *CFR* 761. Activities necessary to comply with these ARARs shall be incorporated into the planning phase of the alternative implementation.

ALARA = as low as reasonably achievable
ARAR = applicable or relevant and appropriate requirement
CFR = *Code of Federal Regulations*
DOE = Department of Energy
GWOU = Groundwater Operable Unit
KAR = Kentucky Administrative Regulations
KPDES = Kentucky Pollutant Discharge Elimination System
MCL = maximum containment level
MCLG = maximum containment level goal
NRC = U.S. Nuclear Regulatory Commission
NWP = Nationwide Permit
PCB = polychlorinated biphenyl
PGDP = Paducah Gaseous Diffusion Plant
RCRA = Resource Conservation and Recovery Act
TBC = to be considered
TSCA = Toxic Substances Control Act

Endangered Species and Migratory Birds. Actions taken by federal agencies are prohibited from impacting T&E species or adversely modifying critical habitats (50 *CFR* 17.94) in accordance with the Endangered Species Act (16 USCA 1531 *et seq.* Section (7)(a)(2)). These requirements are potential ARARs in the event T&E species or their habitats are found at or near areas where remedial action is to occur. An ecological resource investigation inside the PGDP security fence did not detect any T&E species or their preferred habitats (CDM Federal 1994). The USFWS has not designated critical habitat for any species within the DOE property. However, outside the PGDP fence on the DOE property, potential habitats for federally listed T&E species were reviewed and Indiana bat habitat was evaluated during the COE (1994) environmental investigation. The COE study determined that total potential bat habitat consisted of 20% of the 994-ha (2,456-acre) study area. Remedial activities must be evaluated to ensure that such actions do not adversely impact areas identified as critical habitat for any identified endangered species.

In addition, Executive Order 13186 directs federal agencies to enter into an MOU with the USFWS to further the purposes of the Migratory Bird Treaty Act (16 U.S.C. 703-711). Until such time as the MOU between DOE and the USFWS is finalized, federal agencies are encouraged immediately to begin implementing the conservation measures set forth in the Executive Order. The requirements of the Executive Order are applicable and must be considered during planning and design of the remedial action.

Potential action-specific ARARs

Monitoring well installation requirements. This alternative includes the installation of additional monitoring and extraction wells. Installation of these wells would have to be conducted in a manner to maintain existing natural protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole (401 KAR 6:310 Section 13). These requirements also mandate the construction materials required for well construction, well design criteria, well completion activities, and well abandonment methodologies. These requirements are considered applicable to design and installation of monitoring and extraction wells associated with the implementation of this alternative.

Fugitive dust emissions. Construction activities onsite and offsite may result in the production of particulate airborne pollutants (dust). The Kentucky Air Quality standards found in 401 KAR 63:010 include requirements governing fugitive dust emissions. These standards require that dust suppression measures be undertaken, which include activities such as the use of water or chemicals to control emissions, the placement of asphalt or concrete, and the stockpiling of soils. The standards also require that visible dust generated from the implementation of the remedial alternative not be discharged beyond the property boundary of the site. For the purposes of compliance with these requirements, the site boundary is interpreted to mean the DOE site boundary or the immediate boundary of construction activities for construction that occurs on non-DOE property. Trucks transporting material outside the DOE property boundary, where materials could become airborne, must be covered. These requirements are considered applicable to the implementation of Pump-and-Treat technology and will be complied with through careful planning to ensure that excavated materials are sufficiently wetted or protected to control dust generation. Specific activities that could result in the generation of fugitive dust that must be considered during the design phase include construction and well installation.

Radionuclide emission standards. Airborne emissions of radionuclides may occur as a result of construction activities. Although the potential is low for such emissions to occur, the regulations at 40 *CFR* 61.92 would be applicable, requiring that the emissions not exceed amounts that would cause an EDE to the public of 10 mrem/year. To determine whether the alternative complies with this applicable requirement, computer modeling using the CAP-88 or other EPA-approved models must be undertaken. If the modeling demonstrates the radionuclide emission in excess of 1% of the 10 mrem/year standard, emission rates must be measured as required by 40 *CFR* 61.93. This ARAR shall be complied with by planning activities in such a manner as to control fugitive emissions from construction and excavation activities.

Toxic emission standards. Although toxic emissions are not expected as a result of construction activities or with the pumping of the groundwater to the water treatment facility, these emission requirements would be applicable if such an emission does occur. Due to organic concentrations found in the groundwater, the potential for such emission to occur is low. The regulations at 401 KAR 63:022 require that the emissions be evaluated to determine whether they are significant for each specific toxic air pollutant. If analysis indicates the toxic emission requirements are triggered, the regulations specify that no source may exceed the allowable emission limit specified in Appendix A of 401 KAR 63:022. If applicable, these rules would require the application of the best available control technology to limit toxic emissions. If calculations indicate that the emission rates specified within the rule are not exceeded, then the calculation package may be used to demonstrate compliance with these requirements. Activities that must be considered include pumping and treating of contaminated groundwater.

Stormwater discharge and KPDES requirements for groundwater treatment. Construction activities will be subject to the substantive requirements of the KPDES Permit, requiring the use of BMPs and sediment/erosion controls to direct transport of sediment in stormwater runoff. In addition, groundwater will be treated in a wastewater treatment unit whose discharge will be subject to the substantive requirements of the KPDES program. These requirements are considered to be applicable.

Waste management requirements. It is anticipated that these wastes generated from the treatment of contaminated groundwater will be low-level radioactive wastes and, therefore, subject to DOE Order 435.1 requirements that apply to the management of all radioactive wastes generated at DOE facilities. This requirement is TBC rather than applicable or relevant and appropriate, as it is a DOE order rather than a federal or state regulation or standard.

The potential also exists for some or all of the wastes generated from treatment to be RCRA hazardous wastes as defined in 40 *CFR* 261 of the federal program. All wastes generated shall be subject to the hazardous waste determination requirements of 40 *CFR* 262 and 401 KAR 32:010. If it is determined that any wastes are, in fact, hazardous wastes, the materials must be managed in accordance with the substantive requirements found in 40 *CFR* 262 through 40 *CFR* 268 (401 KAR 32 through 37). These standards include storage requirements, transportation requirements, and disposal requirements. Specific requirements applicable to each waste stream must be identified after characterization of the material is complete. These requirements shall be complied with through the development of a WMP during the design phase of implementation. If materials are identified as RCRA hazardous wastes, these requirements are applicable.

Although considered unlikely, the potential exists that wastes generated from the implementation of this alternative may contain PCBs regulated under TSCA. These regulations would be applicable to this alternative if PCB concentrations were found in soil or water that exceeded 50 ppm or PCBs were found and attributable to a source whose concentration exceeded 50 ppm PCBs. The substantive requirements for management of PCB wastes found in 40 *CFR* 761 would be applicable and should include standards for storage, shipment, and equipment decontamination. These requirements shall be complied with through the development of a WMP during the design phase of implementation. If materials are identified as TSCA PCB regulated material, these requirements are applicable.

Action-Specific ARAR summary. This alternative will trigger action-specific ARARs with regard to the treatment and handling of the contaminated groundwater removed from the aquifer. These include the substantive requirement under the KPDES program and the CWA for discharge of treated groundwater and the applicability of the RCRA requirements for wastes generated as a result of implementation. In addition, the requirements of TSCA may be applicable if PCB-containing materials are identified. This alternative will comply with these requirements during the planning phase to include compliant waste handling and storage and disposition components. The proposed alternative will comply with both the requirements of the CWA of 1972 and RCRA because the treatment and discharge of treated effluent from CWA compliant outfall is allowed under RCRA. If waste from treatment of groundwater is determined to be hazardous under RCRA, the substantive requirements for storage, management, and disposal of hazardous wastes shall be incorporated into the alternative during the planning phase. Activities that may be required for RCRA and TSCA compliance include these: use of appropriate containers, labeling of containers, appropriate storage area design and operation (secondary containment or storage for less than 90 days in a compliant accumulation area), and transportation of wastes.

A summary of the ARARs for the implementation of Pump-and-Treat Technology is presented in Table 4.15.

Compliance with ARARs summary. Implementation of this alternative would not achieve compliance with the MCL for TCE due to the existence of Primary and Secondary Sources remaining in place. If the Pump-and-Treat Technology is used to provide total containment, compliance at the fenceline has been calculated to occur in approximately 15 years. If total containment is effected, compliance with the MCL at the DOE property boundary and Little Bayou Creek is calculated to occur in approximately 15 years. Because this alternative does not immediately meet the stated MCLs, an ARAR waiver or agreed schedule of compliance would have to be sought as part of the ROD and proposed plan.

In order to comply with the identified chemical-specific ARARs, an ARAR waiver will be required due to the time frames required to meet the specified concentrations within the GWOU at the point of compliance and points of exposure.

As discussed, no potential location-specific ARARs have been identified within the area in which remedial action will occur. However, to ensure that jurisdictional wetlands are not impacted, all construction activities associated with the installation of all monitoring, extraction, and injection wells necessary to implement Pump-and-treat technology will be reviewed as a safeguard. The protection of wetlands is not considered a location-specific ARAR at this time because jurisdictional wetlands have not been identified within the areas impacted by the implementation of this alternative.

Construction and implementation of the alternative may trigger several action-specific ARARs such as the requirements associated with well installation and abandonment, fugitive dust emissions, radionuclide emissions, toxic emissions, and discharge of stormwater and treated groundwater. The requirements associated with the installation and abandonment of groundwater wells will be met though the use of well designs and materials of construction as specified at 401 KAR 6:310 Section 13. All well installation and abandonment practices incorporated into the approved remedial design shall comply with substantive requirements of 401 KAR 6:310.

Fugitive dust emissions that may occur during construction activities will be controlled as required by 401 KAR 63:010. BMPs such as wetting or covering of potential sources of fugitive dust will be incorporated into the remedial design. The specific actions to be developed shall control potential emission sources to ensure that dust emissions do not migrate from the immediate area where construction activities occur. It is anticipated that, in most cases, the moisture content in the soil will be sufficient to control dust emissions during well installation. However, practices such as wetting of disturbed soils, collection of soils, or reseeding activities shall be considered and incorporated into the remedial design, as necessary, to ensure compliance with these requirements. Radionuclide emissions at construction sites also must be considered during the implementation phase. In order to ensure that the emission standard of 10 mrem/year EDE to the public is met, concentrations of radionuclides in soils and groundwater must be evaluated. If the potential for such emissions is identified, modeling using the CAP-88 or other EPA-approved method must be undertaken during the design phase of the alternative. It is anticipated that the primary conveyance of airborne radionuclides will be in particulate form. Therefore, control of fugitive dust emissions also will result in compliance with the emission standards applicable to radionuclides. If radiological contamination from plant activities is found in soils where construction activities are planned, the soil will be protected or containerized to prevent airborne migration. Measures necessary to prevent airborne emissions or radionuclides shall be evaluated and incorporated as appropriate into the remedial design to comply with these requirements during implementation of this alternative.

Emissions of toxins such as volatile organics also must be evaluated before implementation. Although the potential for exceedance of toxic air emissions is considered to be low, an evaluation of the potential for such emissions must be undertaken during the remedial design. Potential emissions must be evaluated for each toxin present in the plumes (i.e., TCE, vinyl chloride, etc.) to determine whether the contaminant levels found in the subsurface could result in airborne emissions in excess of the allowable limits specified in Appendix A of 401 KAR 63:022. Compliance with the emissions standards shall be achieved for this alternative through the evaluation process or application of the best available control technology where emissions are calculated to exceed allowable levels. Emission control equipment will be incorporated into implementation activities during the remedial design, as necessary, based upon the initial evaluation. This requirement will be complied with during implementation of the alternative.

The construction activities associated with this alternative may require that BMPs for sedimentation/ erosion controls be established if the areal extent of the disturbed area exceeds regulatory trigger levels. These requirements will be complied with through the use of sediment fences or other appropriate means. The control of sedimentation and runoff shall be a TBC in the event that the areal extent of the construction does not exceed the 5 acres specified within the rules. The remedial design shall incorporate the specific controls necessary to ensure that the construction site(s) do not allow sedimentation and or erosion of disturbed areas in order to comply with this requirement during implementation of this alternative.

This alternative results in the removal and treatment of contaminated groundwater using pump-and-treat technology. Groundwater collected as part of the pump-and-treat activities must be treated to meet discharge effluent limits before release. This requirement shall be met through the vapor extraction system and discharge to a KPDES permitted outfall. The treatment system shall be designed to meet current KPDES discharge limits.

Long-Term Effectiveness and Permanence. This evaluation addresses the results of the alternative in terms of risk remaining at the site after completion of the action and the effects of required long-term controls. A discussion of the magnitude of residual risk at the site and adequacy and reliability of controls is presented in the following sections.

Magnitude of residual risk. The Dissolved Phase Plume Area Pump-and-Treat Technology is designed to remediate contaminated groundwater by preventing further migration of the COCs from DOE property to off-site areas. In the near term, following the startup of this alternative remedial action, the residual risk will remain consistent with the risk present before taking the action. Following startup and continued long-term operation of the remedy, the residual risk will decrease for a groundwater user in the area targeted by the alternative. This residual risk will continue to decrease as the system continues to prevent further COC migration in the dissolved phase plume.

However, residual risk in RGA located upgradient of the pump and treatment system will remain in place in the source zone areas during implementation for approximately 7,000 years. This is because of nonaqueous phase concentrations of TCE in the source areas. The source areas for the TCE contamination have concentrations that provide indications that TCE is present in a nonaqueous phase. Nonaqueous phase COCs will remain in place, dissolving slowly into migrating groundwater for long periods of time. This will allow the plumes to redevelop over a period of time should pump-and-treat be terminated. As long as the TCE and ^{99}Tc concentrations remain high in the source areas, the residual risk will remain high in the source area and downgradient areas before the pump-and-treat extraction wells.

The technology will require assistance from other technologies in the UCRS and the RGA to meet the MCLs upgradient of pump-and-treat system location. Groundwater modeling results for the COC concentrations in the RGA, as discussed above, indicate that MCLs will be reached for TCE in approximately 15 years if the technology is implemented in concert with primary and secondary source reduction technologies.

Five-year reviews, mandated by CERCLA [40 *CFR* §300.430(f)(4)(ii)], will be required to demonstrate the integrity and effectiveness of the controls and confirm that additional exposure pathways have not developed.

Adequacy and reliability of controls-Dissolved Phase Plume Area. Pump-and-Treat Technology will have high reliability for operation and control. The components that make up the treatment systems have been used extensively for the treatment of water and wastewater and have proven to be adequate and reliable. The pump-and-treat alternative will require extensive maintenance due to the extended period of time the operation must continue.

Pump-and-treat systems of the size required for this alternative, by design, have partial redundancy due to independent operating systems (i.e., multiple pumps, air strippers, etc.). Also, the system can be designed to be modular with critical systems such as power distribution designed with additional capacity to handle future additions of extraction wells or treatment equipment to the remedy. An example could be the addition of extraction wells in a given area to ensure complete containment of the migrating COCs. Numerical modeling will be used to size and place extraction wells such that an appropriate capture zone is developed. However, should extended interruptions of electrical power occur, the potential would exist for COCs to escape from the pump and treat system.

The pump-and-treat system, and portions of the groundwater monitoring system likely will be located outside of the security area of PGDP on government and, to some extent, private or public land. The complete systems, with many extraction and monitoring wells, will be spread over a large area; therefore, only limited periodic security realistically could be provided. However, security fences could be relocated to provide additional security to portions of the remedial action located near the current security area if it were determined to be necessary.

The pump-and-treat system will generate spent ion-exchange resins used to remove the ^{99}Tc. Additionally, treatment of vapor phase effluents will result in the generation of a waste material used to capture the TCE.

Environmental impacts and mitigative measures. The following paragraphs summarize potential long-term impacts to resources and mitigative measures to offset any potential impacts. The depth of impact analysis and mitigative measures is correlated to the degree to which a resource may be impacted.

Land use. Implementation of this alternative would result in moderate impacts to land use but with no changes to the population surrounding the PGDP. Following construction of the alternative, the bulk of the land disturbed during construction would be returned to its prior use. However, the long-term impacts to land use would be related to the operating facilities, extraction wells, monitoring wells, treatment facilities, and associated access roads, electric utilities, and pipelines. A LUCIP will be developed as necessary per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomics. The socioeconomic conditions of the PGDP and surrounding area would not be expected to be impacted by the implementation of the Dissolved Phase Plume Area Pump-and-Treat Technology alternative. The construction and operation of the facilities for this alternative would be performed by construction contractors. The number of permanent jobs that could develop as a result of the action is small in relation to the size of the population of the surrounding area. The implementation of this alternative would also not result in a decrease or increase in the personnel at PGDP. However, the presence of contaminants in the groundwater will prevent its use and may limit economic development opportunities until the groundwater is brought back to beneficial use.

Air quality and noise. A long-term degradation in air quality is not expected as a result of the implementation of this alternative; however, there will be a long-term emission from the operation of the facility. The TCE, which is removed from the extracted groundwater, is destroyed by catalytic oxidation afterwards and would not be an air-contaminant concern. The potential for a temporary increase in fugitive dust emissions during construction would be mitigated by keeping dust prone areas watered to suppress dust.

No long-term increase in noise is expected from this alternative. During construction, there will be local increases in noise levels due to operating machinery. However, the noise increase will be in a limited area and will not affect human receptors. Hearing protection would be used to protect the worker constructing the system.

Vegetation. There will be long-term impacts to vegetation expected from the implementation of this alternative. The alternative will require the installation of operating facilities, extraction wells, monitoring wells, and treatment facilities. There also will be associated roads, electric utilities, pipelines for the facilities. The long-term impacts will be the removal of trees for the placement of the facilities. In addition, activities associated with this alternative would result in a limited temporary disruption of the habitats of birds, mammals, and reptiles inhabiting the immediate area surrounding the wells or treatment system. However, considerable habitat is available in the contiguous area for displaced mammals. The quantities of trees that would be removed have not been determined as the total target areas have not been identified. However, the system can be designed to minimize the removal of trees by aligning access roads to miss trees as feasible. Once construction is concluded, portions of the disturbed vegetation could be restored through seeding and natural regeneration.

Wildlife. Long-term impacts to wildlife are expected for aquatic life in the KPDES outfalls and creeks due to construction in the creeks, tributaries and wetlands. Large volumes of water are expected to be released; however, the actual quantities will be determined in the development of the PRAP. Should it become necessary, the treated groundwater that would be released could be split among several outfalls to distribute flow between the Bayou and Little Bayou Creeks.

In addition, activities associated with this alternative would result in a limited temporary disruption of the habitat of birds, mammals, and reptiles inhabiting the immediate area surrounding the wells or treatment system. However, considerable habitat is available in the contiguous area for displaced mammals. The quantities of trees that would be removed have not been determined as the total target areas have not been identified. However, the system can be designed to minimize the removal of trees by aligning access roads to miss trees as feasible. Once construction is concluded, portions of the disturbed vegetation could be restored through seeding and natural regeneration.

Threatened and endangered species. Long-term adverse impacts to T&E species are likely to occur. The Indiana bat, which regionally has suitable habitat, will likely be impacted by this alternative The potential roosting areas of the Indiana bat, as identified by Bryan (COE 1993), indicate that the increased density of potential habitat occurs at the extreme ends of the dissolved phase Northwest Plume. The actual target areas for implementation of this alternative have not been determined at this time; therefore, the impacts to the habitat cannot be determined. However, the placement of the wells and access roads can be strategically placed to minimize impacts as feasible. After a detailed design of the extraction well field with associated monitoring wells and access roads is completed, a reanalysis of potential impacts to the Indiana bat habitat will need to be completed.

Cultural resources. No long-term impacts to cultural resources are anticipated for this alternative.

Groundwater. Through implementation of this alternative, RGA contaminant concentrations of VOCs and ^{99}Tc either are reduced or eliminated over an extended period of time. Activities associated with this alternative are designed to contain the source of the TCE and ^{99}Tc and facilitate the remediation of the source areas through long-term indirect dissolution of the sources. If successful, the potential exists for the RGA to be restored to full use after the downgradient portions of the plumes are attenuated. Degradation to groundwater is not expected; however, potential adverse impacts of the alternative would be the unlikely, but potential migration of TCE DNAPL from current areas as a result of the extraction and drawdown of the aquifer.

The array of extraction wells should be sufficient to eliminate the addition of COCs to the off-site portions of the plumes. It is not expected that the extraction rate of the pumping system would substantially deplete the amount of water in the RGA. The water resources in the RGA are sufficient to sustain the rate of extraction. However, the extraction rate, due to drawdown of the aquifer, may temporarily impact wells screened in the upper RGA. Should excessive drawdown result from the expected extraction rate, the volume of water produced potentially could be reduced to a level that produces a capture zone necessary to contain the COC migration. The increased pumping rate potentially could affect water levels in the upgradient Terrace Gravel. However, no significant decline in water levels is expected; moreover, no water supply wells in the Terrace Gravel are located in the proximity of the PGDP.

Surface water. There will be impacts to streams due to increased pumping and treating of groundwater causing large increases in the KPDES discharges volumes. The actual quantities will be determined in the development of the PRAP. Currently, the outfalls that contribute to Bayou Creek have a combined yearly flow of 0.720 mgd, a maximum flow of 15.85 mgd, and an average flow of 5.5 mgd. PGDP currently provides approximately 85% of the flow to Bayou on average, and during periods of low base flow, nearly 100% (Geotrans 1993). Flow in the Bayou Creek is highly variable depending on activities at the PGDP, season, and recent precipitation. The mean monthly flows of Bayou Creek vary from 20.5 to 38.8 mgd. The creek also accommodates high energy episodes as evidenced by many deposits of sand and gravel along its banks.

Surface water quality is not expected to be impacted with the implementation of this remedy. The treatment system to remove the COCs from the extracted groundwater will be designed to meet the release requirements of the KPDES permit. This alternative may result in the elimination or reduction of contaminants being discharged to Little Bayou Creek. Also, controls for silt and erosion will be used during the construction activities.

Floodplains. No long-term impacts are expected with the implementation of this alternative. The action would not take place in any floodplain of any stream at PGDP.

Wetlands. This alternative will impact wetlands during construction and after implementation of the system. The wetlands may be impacted along the nearby creeks due to the increased water discharges and construction activities. However, the implementation of this alternative should not impact the hydrology of wetlands in the area. The wetlands in the area of the PGDP occur as a result of surface water flow into poorly drained soils and not recharge from the RGA.

To the extent practicable, extraction and monitoring wells would be located outside wetlands. The construction in wetlands would only cause a temporary disruption to the wetlands functions. Most of the expected impacts will be as a result of access ways to the drilling sites and pipelines transporting the groundwater to the treatment facility.

Natural regeneration and local site conditions would help restore wetlands disturbed by construction activities. Silt and erosion control measures will be used during the construction activities to minimize impacts to wetlands. Also, other measures such as requiring low soil pressure equipment and working on mats will be used to minimize impacts to the wetlands as necessary. The wetlands also will be recontoured to the original surface following construction.

Soils and prime farmland. This alternative will cause impacts to soils and prime farmland. The impacted areas will be limited to areas with access roads, pipelines, extraction wells and monitoring wells. The exact number of acres of prime farmland impacted cannot be determined until the design of the well field is completed. Impacts would be mitigated through the use of standard construction practices of placing erosion and drainage control in the construction areas, as necessary. During well installation, testing, and treatment facility operation, the potential exists for the release and spill of contaminated water. These potential releases will be mitigated through the use of engineering measures to contain spills and contaminated soils.

Prime farmland exists north of the PGDP and DOE property. The NRCS has identified prime farmland as the Calloway, Waverly, and Grenada soil series in the area between the PGDP and the TVA Shawnee Steam Plant. After completion of the well installations, only the areas occupied by the wells, pipelines, and associated access roads will be affected. All other areas will be returned to their normal state. The impacts will be in the form of mowed vegetation, potential spills, and vehicle traffic. Impacts will be mitigated through the use of standard construction practices of placing erosion and drainage control in the construction areas and using engineering measures to contain spills and contaminated soils.

Transportation. No long-term direct or indirect effects are anticipated for this alternative. The implementation of this alternative will result in transportation of environmental soils samples and groundwater samples to environmental laboratories. During the operation of the alternative, ion-exchange resins will be transported to treatment storage or disposal facilities. Standard engineering practices will be used to ship these waste materials. Also, all applicable regulatory requirements for shipment of LLW materials also will be followed.

Cumulative impact. Cumulative impacts are defined as the incremental impact of an action when added to other past, present, and reasonable, foreseeable future actions, regardless of what agency or person undertakes other such actions. Cumulative Impacts resulting from this alternative will have to be identified at a later time during development of site specific GWOU decision documents.

Reduction in Toxicity, Mobility, or Volume Through Treatment. This alternative's implementation will result in pumping and treating of the dissolved phase plume area to ensure that migrating COCs are captured. The contaminated water will be treated to remove the TCE and ^{99}Tc through the use of air strippers for VOC reductions and ion exchange resin for ^{99}Tc before releasing the treated water to a KPDES outfall. Once the TCE is air stripped, the resulting vapor phase will be passed through a catalytic oxidizer to destroy the TCE. The ^{99}Tc will remain adsorbed to the ion exchange resin and will not be destroyed. Nearly 100% of the extracted contaminants would be treated and/or destroyed through the use of catalytic oxidation and ion exchange.

Since TCE and ^{99}Tc are only incrementally removed from the groundwater plume, the toxicity of the TCE and ^{99}Tc in the groundwater plume will remain. After long-term operation of the alternative, approximately 100% of the VOC and ^{99}Tc contamination would be removed; therefore, the toxicity of the plumes will dissipate due to the removal of the COCs via the pump-and-treat system.

Implementation of this alternative would not affect the chemical and physical soil properties within the treatment area. This alternative provides no direct reduction in COC mobility.

The implementation of this alternative will result in the complete removal of the sources (after prolonged operational period). However, the alternative is reversible. Should the operation of the alternative be terminated, the groundwater plumes will reestablish with some reduction in COC concentrations.

Following treatment of the extracted groundwater, the treatment residuals will exist. The TCE is destroyed through treatment in the catalytic oxidizer. The treatment residual from this process is production of sodium chloride from the scrubbing of off-gas from the oxidizer. The treatment of the ^{99}Tc also will result in a treatment residual in the form of a spent ion exchange resin. The spent ion exchange resin will be a LLW.

Short-Term Effectiveness. The short-term effectiveness of implementing a Pump-and-Treat Technology in the Dissolved Phase Plume Area of the RGA was evaluated relative to its effect on community protection, worker protection, environmental impacts, and the time until RAOs are achieved. Environmental impact was further evaluated for NEPA values. A discussion of each is provided in the following paragraphs.

Community protection. The potential for short-term adverse impacts to the community from the implementation of this alternative is minimal. The likely target areas will be the dissolved phase portions of the groundwater plumes that lie between PGDP and the Ohio River. The areas specifically contain property of DOE, TVA, the WKWMA, and also a parcel of privately held land. The likely target area of the alternative does not have residences in the immediate vicinity and is used periodically by sportsmen utilizing the WKWMA. Restrictions will be used to limit the access of persons who may be in the area during construction. This will include warning signs, temporary control fencing, and periodic security patrols. Also, environmental monitoring will be conducted during the construction of extraction and monitoring wells where COCs may be present. Engineering controls can be implemented to reduce off-gas emissions.

Worker protection. Implementation of this alternative has the potential for worker exposure to contaminated subsurface soils and groundwater during environmental sampling and well installation. Potential exposure pathways include inhalation of dust that contains contaminated soils, dermal contact with subsurface soils, and dermal contact with contaminated groundwater. Impacts to on-site workers would be minimized through use of engineering controls for off-gas treatment, PPE, and formalized operating procedures.

Environmental impacts and mitigative measures. The following paragraphs summarize potential short-term impacts to resources and mitigative measures to offset any potential impacts. The depth of impact analysis and mitigative measures is correlated to the degree to which a resource may be impacted.

Land use. Implementation of this alternative would result in moderate adverse impacts to land use surrounding the PGDP. No changes to the population surrounding the PGDP are anticipated. Following construction of the alternative, the bulk of the land disturbed during construction would be returned to its prior use. All short-term impacts would be associated with the installation of access roads, treatment facilities, pipelines, and monitoring wells. A LUCIP will be developed as necessary per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomics. The short-term socioeconomic conditions of the PGDP and surrounding area would be slightly impacted by the implementation of this alternative. The construction and operation of the facilities for this alternative would be performed by construction contractors. A moderate number of temporary construction jobs would be associated with construction of treatment facilities, wells, and roads. The number of permanent jobs that could develop as a result of the action is small in relation to the size of the population of the surrounding area. Also, the implementation of this alternative would not result in a decrease or increase in the personnel at PGDP.

Air quality and noise. Short-term degradation of air quality is not expected since off-gas treatment will be included as part of this alternative. The potential for a short-term temporary increase in fugitive dust emissions during construction would be mitigated by keeping dust prone areas watered to suppress dust. Also, during construction there will be local increases in noise levels due to operating machinery. However, the noise increase will be in a limited area and will not affect human receptors. Hearing protection would be used to protect the worker constructing the system.

Vegetation. There will be large short-term impacts to vegetation resulting from construction and operation activities primarily associated with mowing, clearing, accessing the drill sites. Activities associated with this alternative would result in a limited temporary disruption of the habitat of birds, mammals, and reptiles inhabiting the immediate area surrounding the wells or treatment system. However, considerable habitat is available in the contiguous area for displaced mammals. The quantities of trees that would be removed have not been determined, as the total target areas have not been identified. However, the system can be designed to minimize the removal of trees by aligning access roads to miss trees as feasible. Once construction is concluded, disturbed vegetation could be restored through seeding and natural regeneration.

Wildlife. Short-term impacts to wildlife are expected to be moderate. Construction in creeks and tributaries may be required to address increased discharges of water form the treatment process. However, no adverse impacts are expected for aquatic life in the KPDES outfalls and creeks. A temporary disruption of the habitat of birds, mammals, and reptiles inhabiting the immediate area surrounding the wells or treatment system is anticipated. Should it become necessary, the treated groundwater that would be released could be split among several outfalls to distribute flow between the Bayou and Little Bayou Creeks. It is anticipated that the impact to wildlife with be primarily reversed after the installation of the alternative is completed.

Threatened and endangered species. Short-term adverse impacts to wildlife are expected to be moderate from implementing this alternative. The Indiana bat, which regionally has suitable habitat, likely will be impacted by this alternative The potential roosting areas of the Indiana bat, as identified by Bryan (COE 1993), indicate that the increased density of potential habitat occurs at the extreme ends of the dissolved phase Northwest Plume. The actual target areas for implementation of this alternative have not been determined at this time; therefore, the impacts to the habitat cannot be determined. However, the placement of the wells and access roads can be strategically located to minimize impacts as feasible. After a detailed design of the extraction well field with associated monitoring wells and access roads is completed, a reanalysis of potential impacts to the Indiana bat habitat will need to be completed.

Cultural resources. No short-term impacts to cultural resources are expected for this alternative.

Groundwater. Through implementation of this alternative, RGA contaminant concentrations of VOCs and ^{99}Tc either are reduced or eliminated over an extended period of time. Activities associated with this alternative are designed to contain the source of the TCE and ^{99}Tc and facilitate the remediation of the source areas through long-term indirect dissolution of the sources. If successful, the potential exists for the RGA to be restored to full use after the downgradient portions of the plumes are attenuated. Degradation to groundwater is not expected; however, potential adverse impacts of the alternative would be the unlikely, but potential, migration of TCE DNAPL from current areas as a result of the extraction and drawdown of the aquifer.

The array of extraction wells should be sufficient to eliminate the addition of COCs to the off-site portions of the plumes. It is not expected that the extraction rate of the pumping system would substantially deplete the amount of water in the RGA. The water resources in the RGA are sufficient to sustain the rate of extraction. However, the extraction rate, due to drawdown of the aquifer, may temporarily impact wells screened in the upper RGA. Should excessive drawdown result from the expected extraction rate, the volume of water produced potentially could be reduced to a level that produces a capture zone necessary to contain the COC migration. The increased pumping rate potentially could affect water levels in the upgradient Terrace Gravel. However, no significant decline in water levels is expected; moreover, no water supply wells in the Terrace Gravel are located in the proximity of the PGDP.

Surface water. No short-term adverse impacts to surface water are expected from implementing this remedy. However, there will be impacts to the streams due to large increases in the discharge volumes because of the increased pumping and treating of groundwater. The actual quantities will be determined in the development of the proposed remedial action plan. During construction, controls for silt and erosion will be used to minimize impacts to the surface water. This alternative may result in the reduction or elimination of contaminants being discharged to Little Bayou Creek.

Floodplains. No short-term impacts to floodplains are expected with the implementation of this alternative. The action would not take place in any floodplain of any stream at PGDP.

Wetlands. There will be short-term impacts to the wetlands. Most of the expected impacts will be as result of access ways to the drilling sites and the construction of pipelines to transport the groundwater to the treatment facility. In addition, this alternative will result in increased flows in the creeks due to increased discharges from the pump-and-treat system.

The wetlands in the area of the PGDP occur due to surface flow into poorly drained soils and not recharge from the RGA. To the extent practicable, extraction wells would be located outside wetlands. The construction in wetlands would only cause a temporary disruption to the wetland's functions. Natural regeneration and local site conditions would help restore wetlands disturbed by construction activities. Silt and erosion control measures will be used during the construction activities to minimize impacts to wetlands. Also, other measures such as requiring low soil pressure equipment and working on mats will be used to minimize impacts to the wetlands as necessary. The wetlands will also be re-contoured to the original surface following construction.

Soils and prime farmland. This alternative will cause impacts to soils and prime farmland. The impacted areas will be limited to areas with access roads, pipelines, extraction wells and monitoring wells. The exact number of acres of prime farmland impacted cannot be determined until the design of the well field is completed. Impacts would be mitigated through the use of standard construction practices of placing erosion and drainage control in the construction areas as necessary. During well installation, testing, and treatment facility operation, the potential exists for the release and spill of contaminated water. These potential releases will be mitigated through the use of engineering measures to contain spills and contaminated soils.

Prime farmland exists north of the PGDP and DOE property. The NRCS has identified prime farmland as the Calloway, Waverly, and Grenada soil series in the area between the PGDP and the TVA Shawnee Steam Plant. After completion of the well installations, only the areas occupied by the wells, pipelines, and associated access roads will be affected. All other areas will be returned to their normal state. The impacts will be in the form of mowed vegetation, potential spills, and vehicle traffic. Impacts will be mitigated through the use of standard construction practices of placing erosion and drainage control in the construction areas and using engineering measures to contain spills and contaminated soils.

Transportation. No significant impacts to transportation are expected during construction activities of this alternative. The implementation of this alternative will result in transportation of environmental soils samples and groundwater samples to environmental laboratories. During the operation of the alternative, ion-exchange resins will be transported to treatment storage or disposal facilities. Standard engineering practices will be used to ship these waste materials. Also, all applicable regulatory requirements for shipment of LLW materials also will be followed.

Cumulative impact. Cumulative impacts are defined as the incremental impact of an action when added to other past, present, and reasonable, foreseeable future actions, regardless of what agency or person undertakes other such actions. Cumulative Impacts resulting from this alternative will have to be identified at a later time during development of site specific GWOU decision documents.

Time until action is complete. Implementation of alternative will not result in achievement of RAOs specified for GWOU or groundwater MCLs. Approximately 7,000 years will be required before groundwater may be used following the implementation of Pump-and-Treat Technology only in the Dissolved Phase Plume Areas of the RGA. Without the reduction of DNAPL sources, the plumes will regenerate over time. It will be necessary to implement Primary and Secondary source reduction technologies in conjunction with the Pump-and-Treat Technology in the Dissolved Phase Plume Area in order to reduce the time the groundwater remains unusable.

Implementability. The implementability of the Pump-and-Treat Technologies in the Dissolved Phase Plume Areas was evaluated based upon its technical feasibility, administrative feasibility, and the availability of services and materials. This information is summarized in the following subsections.

Technical feasibility. The construction of extraction wells and monitoring wells is a presumptive remedy that is technically feasible using standard equipment and technologies and available from multiple vendors. In addition, the equipment that would be used in constructing a water treatment facility and pipelines to convey the contaminated water also are standard. The treatment equipment types used in treating the water are proven technologies. Equipment that is used is proven and reliable, and downtime is expected to be minimal for maintenance and repairs. However, the alternative will require extensive maintenance due to the extended period of time the operation must continue. Implementation difficulties may arise due to attempting to design the well fields around sensitive areas in the target area. Some of these items may include wetland, Indiana bat habitat, and creeks. Construction of this alternative would not prohibit the implementation of other GWOU technologies.

The effectiveness of the treatment system in removing the COCs will be monitored by effluent sampling to ensure the released water is in compliance with regulatory requirements. Air and groundwater monitoring would be required.

Administrative feasibility. This alternative is administratively feasible. Compliance with substantive requirements associated with federal and state regulations would be necessary. Treated water would be discharged to a KPDES permitted outfall. Treatment of the residuals, handling, and transportation and disposal would require proper procedures; however, no difficulties are expected. An ARARs waiver will be required, since MCLs will not be achieved in a timely manner.

Availability of services and materials. Commercially available services and materials for the construction of this alternative are readily available. Additionally numerous vendors will increase the likelihood of competitive bids.

The construction of this alternative will result in the generation of waste soil cuttings, drilling, and development water from the extraction wells and monitoring well construction. Additionally, the construction will generate clean concrete, wire, and pipe construction debris during the building of the treatment facility. All of these materials either will be treated as necessary and released, as in the development water, or disposed of appropriately.

The operation of the treatment system will result in the generation of sodium chloride from the scrubbing of the catalytic oxidizer off-gas and ion exchange resins spent with ^{99}Tc. Both of these materials will be stored until appropriate disposal can be arranged.

It is expected that an ARAR waiver will be need since MCLs will not be attained in a timely manner.

Cost. Table 4.16 summarizes the preliminary unit cost estimates for the Dissolved Phase Plume Pump-and-Treat Technology alternative. These preliminary unit cost estimates are based upon FS-level scoping and are intended to aid with selection of a preferred alternative. The estimates have an expected accuracy of -30 to +50% for the proposed scope of action (EPA 1988a). The capital cost estimate represents those expenditures required to implement this remedial alternative. The O&M cost estimates represent expenditures required to maintain the remedy after the initial phase of remedial action construction is completed. The total contingency cost presented includes direct, indirect, and all O&M associated contingency costs. The total cost includes all capital costs, direct and indirect with O&M and associated reports, plus 25% contingency costs, for a 30-year term of comparison. All estimates have been escalated using DOE-approved annual rates and a schedule for the various activities based on similar project experience. Also, present worth values are included using a discount factor of 5% (EPA 1988b). (Additional information regarding the preliminary cost estimates is presented in Appendix C7.)

Table 4.16. Preliminary unit cost estimates for Dissolved Phase Pump-and-Treat Technology

Total unit capital costs (acre-feet)	$130,436
Total operation and maintenance costs	$199,866
Overhead	$223,860
Total contingency	$138,540
Total cost	**$692,703**
Total cost (present worth)	**$361,039**

Note: preliminary cost estimates are per acre-feet, escalated and presented in dollars.

State/Commonwealth Acceptance. The Commonwealth of Kentucky acceptance or nonacceptance of this alternative will be addressed in the ROD should Dissolved Phase Plume Pump-and-Treat Technology be selected as the preferred alternative.

Community Acceptance. Following a formal public comment period on the PRAP for the GWOU, comments from the community will be addressed formally in a responsiveness summary that will be presented in the ROD.

Evaluation Summary of Dissolved Phase Plume Pump-and-Treat Technology

Dissolved Phase Plume Pump-and-Treat Technology, would involve pumping and treating of the plumes, environmental media monitoring to track COC migration, and conducting five-year reviews as required by CERCLA. Pumping and treating of the plumes removes COC mass from the groundwater and controls the migration of the COCs. Implementation of monitoring will provide an indirect protection, as monitoring COC migration allows for minimizing the potential for exposure to contaminated environmental media through avoidance. The pump and treat system may prevent the further migration of COCs offsite.

Implementation of this alternative alone will not be protective of human health and the environment. The residual risks would remain at the site because the toxicity or volume of the source area contamination would not be reduced except through dissolution and dispersion in groundwater. Residual contamination will remain in the groundwater with TCE levels exceeding the MCL for approximately 7,000 years.

Short-term risks to construction workers would exist because of potential exposure to contaminated groundwater during environmental monitoring activities and maintenance of the wells and groundwater treatment systems. Additional exposure is possible due to dermal and inhalation contact during changeout of treatment media. However, risks to workers will be minimized by strict adherence to approved risk management procedures (e.g., health and safety plan and use of PPE).

Implementation of Dissolved Phase Plume Pump-and-Treat Technology would require moderate capital and high O&M costs due to continuous pumping and treating of groundwater. Input from the Commonwealth of Kentucky and the community has not yet been received, but these will be added to a ROD once the public comment period has been completed.

4.2.4.2 Dissolved Phase Plume Area – Ozonation Technology

The following subsections contain a description of Dissolved Phase Plume Areas – Ozonation Technology Alternative and the detailed analysis.

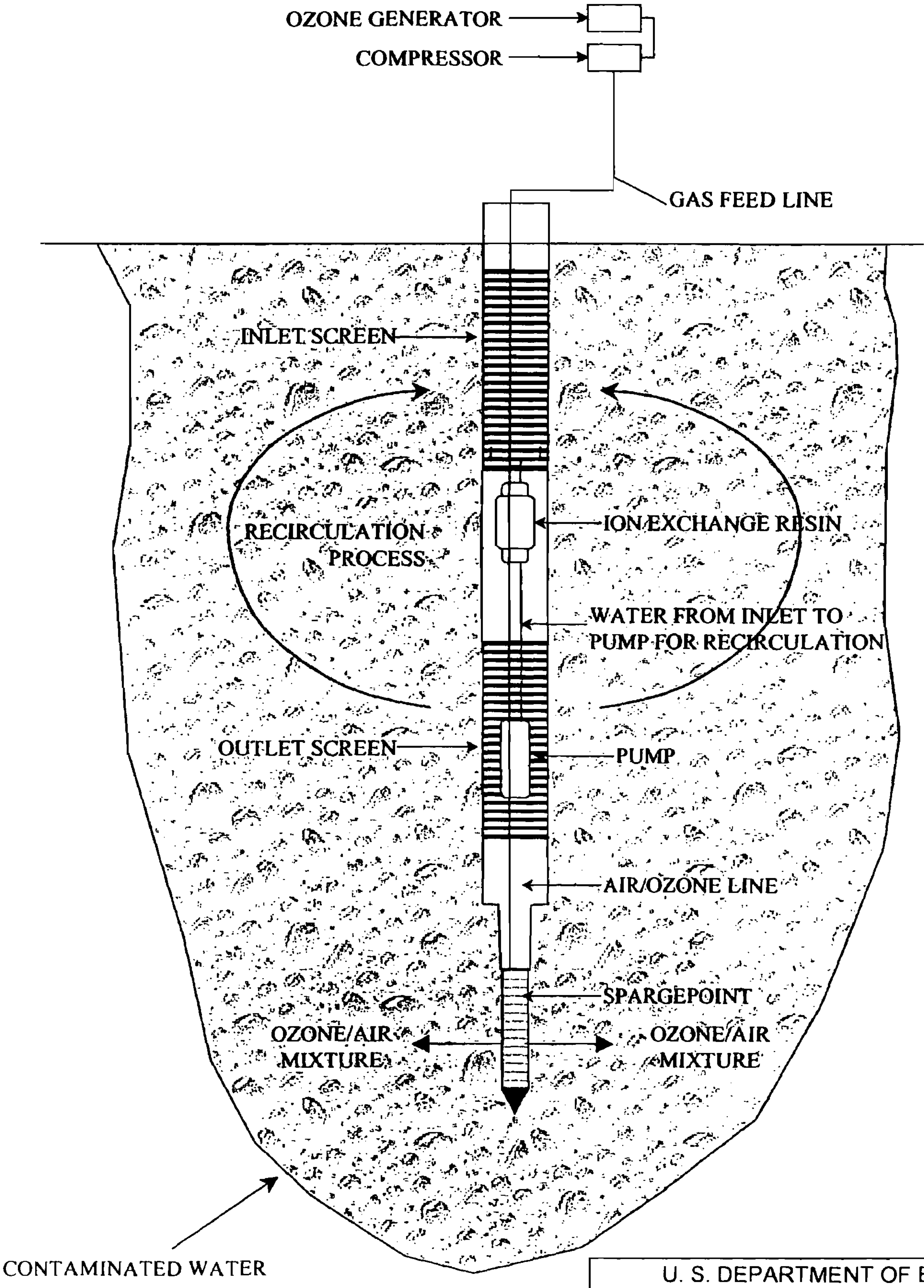
Description of Dissolved Phase Plume Area – Ozonation Technology

This alternative would consist of implementing an Ozonation Technology in the RGA Dissolved Phase Plume, or portions thereof. The RGA Dissolved Phase Plume Areas are located in both the PGDP On-site Secure Area and the Off-site Unsecure Area. The purpose of the alternative would be to remove the TCE dissolved phase concentrations, other VOCs, and ^{99}Tc contaminants from areas of the RGA. Unlike the Secondary Source Area technologies evaluated above, the Ozonation Technology described in this alternative would be designed to remove only dissolved phase contaminant concentrations. In this technology a number of injection wells would be drilled into the RGA at the target locations. The injection wells could be installed in a linear pattern transecting the plume migration route; or they could be installed a blanket-type fashion in which wells would be installed uniformly across the entire plume area. The injection wells then would be used to inject ozone into the RGA. The ozone then would react with, and destroy, VOCs. If the linear transect pattern is used, the distance between transects would be such that the VOC-destroying ozone would not be depleted from the groundwater before reaching the next downgradient injection transect. If a "blanket" installation were selected, the wells would be spaced in a pattern to allow the ozone to be injected over the entire target area, thereby treating the entire area of concern. The ^{99}Tc groundwater contamination also would be remedied by the use of ozonation technology. The injection wells will be configured in a manner that will force groundwater to circulate through the injection well (see Fig. 4.8). Water passing through the well bore will cross an ion exchange media that will capture ^{99}Tc. The use of this alternative will be performed *in situ* and will not require any *ex situ* treatment of produced water or release of air emissions.

As this technology will target only the Dissolved Phase Plume Areas, it would have only minimal impact to returning the groundwater to beneficial use. This is due the fact that without the removal of Primary and Secondary Sources located beneath the PGDP plant areas, the plumes will regenerate over time due to the presence of dissolving DNAPL concentrations of TCE. Because the technology would not remove the DNAPL TCE contaminants in the UCRS and RGA areas (Primary and Secondary Source Areas), it is anticipated that groundwater will not be returned to the drinking water standard for TCE for approximately 7,000 years.

The existing groundwater monitoring program, which is being implemented under a separate action, would be continued to monitor the movement of COCs within the RGA. The monitoring program will integrate existing PGDP monitoring wells, where possible, with additional monitoring wells to be installed, as needed, following a review of the existing program.

Five-Year Reviews. This remedial alternative would result in residual "contaminants remaining at the PGDP site above levels that allow for unlimited use and unrestricted exposure"; therefore, this remedial action would be reviewed "no less often than every five years" in accordance with 40 *CFR* 300.430 (f)(4)(ii).



	U. S. DEPARTMENT OF ENERGY DOE OAK RIDGE OPERATIONS PADUCAH GASEOUS DIFFUSION PLANT
	BECHTEL JACOBS COMPANY, LLC MANAGED FOR THE US DEPARTMENT OF ENERGY UNDER US GOVERNMENT CONTRACT DE-AC-05-98OR22700 Oak Ridge, Tennessee • Paducah, Kentucky • Portsmouth, Ohio
Fig. 4.8. Dissolved phase plume area - ozonation technology.	Science Applications International Corporation P.O. Box 2502 Oak Ridge, Tennessee 37831

FIGURE No. FS4-8

Assessment of Dissolved Phase Plume Area – Ozonation Technology

The detailed analysis of this alternative using the CERCLA criteria is presented in the following subsections.

Overall Protection of Human Health and the Environment. Dissolved Phase Plume Area Ozonation Technology includes the *in situ* treatment of dissolved phase concentrations of VOCs and ^{99}Tc in the RGA. Although this technology is applicable to the reduction of Secondary Source Area concentrations, this detailed analysis is for only dissolved phase areas of the plumes. The technology would reduce VOC and ^{99}Tc contamination in the RGA only. This alternative alone will not satisfy the RAOs for the GWOU. It will support achieving the RAOs when implemented in concert with source reduction technologies. Furthermore, achieving RAOs could be expedited if this technology were supplemented with other dissolved phase GWOU technologies. It is possible for this alternative to be protective of the ecological receptors that may be exposed to contaminated groundwater discharging to the surface water. However, for this protection to be permanent, the technology will require continuous long-term operation in the target area, because without DNAPL source removal the plumes will regenerate over time.

Compliance with ARARs

Potential chemical-specific ARARs

Chemical contamination. The aquifers are known to contain chemical contaminants in the form of metals and organics. The federal and state water quality requirements include standards that would be applicable ARARs. The regulations that apply are found in 40 *CFR* 141 (National Primary Drinking Water Standards); 40 *CFR* 143 (Secondary Drinking Water Standards); 401 KAR 5:029 (General Provisions); and 401 KAR 5:031 (Surface Water Standards). These standards are summarized in Table 4.17 and include state general standards, domestic water supply standards, and standards applicable to warm water aquatic habitat. These are applicable based upon the classification of the designation for surface water use associated with the area (Ohio River, River Mile 940.7 to River Mile 943.3), as specified in 401 KAR 5:026. All potentially applicable chemical ARARs for COCs have been included in the table for completeness. Those standards that must be achieved in order to meet the applicable requirements are the lowest of the applicable standards, which in most cases are the MCLs.

Radiological contamination. The GWOU is known to be contaminated with radionuclides such as ^{99}Tc, radon, uranium, and uranium daughter products. The DOE's Order on Radiation Protection of the Public and Environment, DOE Order 5400.5, as codified at 10 *CFR* 835, is TBC information for cleanup of radionuclides at DOE sites. The order requires that remediation activities must not result in radiation exposures to members of the general public greater than an EDE of 100 mrem/year from all exposure pathways. Exposure to the general public also must be ALARA (DOE 1990).

DOE Order 5400.5 also contains reference values, known as DCGs, for operational DOE facilities. Based on the DCGs, radionuclide concentrations in air and drinking water must not exceed an EDE of 10 mrem/year and 4 mrem/year, respectively, to the total body or any organ.

The NRC also has set criteria for decommissioning standards at nuclear facilities in 10 *CFR* 20 Subpart E. These rules require that residual radioactivity at nuclear sites meet a total EDE of 25 mrem/year for unrestricted release. In addition to the NRC standards, EPA has issued guidance for cleanup levels at CERCLA sites with radioactive contamination. EPA has disagreed with the protectiveness specified within the NRC standard and has specified that a 15 mrem/year EDE be used as the risk level that is protective of human health and the environment. EPA also has codified exposure limits for environmental radiation protection standards for nuclear power operations in 40 *CFR* 190. These requirements apply to

Table 4.17. Summary of Potential ARARs for Dissolved Phase Plume Area – Ozonation Technology

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
Chemical-Specific ARARs			
National Primary Drinking Water Standards	40 *CFR* 141	Provides chemical-specific numeric standards for toxic pollutants expressed as MCLs and MCLGs.	These requirements are relevant and appropriate due to the nature of the contaminants found within the groundwater.
National Secondary Drinking Water Standards	40 *CFR* 143	Provides secondary MCLs for public water systems.	These requirements are TBCs, as they have been established as guidelines for the states and are not federally enforceable.
Kentucky Surface Standards including • Warm Water Aquatic Habitat Criteria • Kentucky Domestic Water Supply • Kentucky General Standards • Kentucky Outstanding State Resource Waters	401 KAR 5:031 and 5:026	Provides chemical-specific numeric standards for pollutants discharged or found in surface waters. Provides chemical-specific numeric standards for pollutants in domestic water supplies.	These standards are applicable to the segment of the Ohio River into which Little Bayou Creek discharges. The requirements found in these standards are applicable due to the groundwater to surface water interface to Little Bayou Creek and subsequently to the Ohio River. Note: CWA Water Quality Criteria are not relevant and appropriate because Kentucky has promulgated these state standards that Kentucky has determined to be appropriate for state waters.
Radiation Exposure of the General Public at DOE Facilities	DOE Order 5400.5	Specifies that the general public must not receive an effective dose equivalent of >100 mrem/year from all exposure pathways. In addition, all releases of radioactive materials resulting in doses to the general public must meet the ALARA criteria.	This requirement is TBC information.
Decommissioning Standards at Nuclear Facilities	10 *CFR* 20, Subpart E	Specifies a residual activity at nuclear facilities for unrestricted releases of 25 mrem/year.	These standards are considered to be applicable to the GWOU.
Environmental Radiation Protection Standards for Nuclear Power Operations	40 *CFR* 190, Subpart B	Requires that the annual dose equivalent to the public must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment from uranium fuel cycle operations and radiation from these operations.	These standards are considered to be relevant and appropriate and are equivalent to the NRC standards.
Location-Specific ARARs			
Protection of Wetlands	10 *CFR* Section 1022; Executive Order 11990; 40 *CFR* 230.10 33; *CFR* 330.5	Activities must avoid or minimize impacts to wetlands to preserve and enhance their natural and beneficial value. If wetland resources are not avoided, measures must be taken to address ecologically sensitive areas and mitigate adverse effects. Such measures may include, minimum grading requirements, runoff controls, and design and construction considerations. Allows minor discharges of dredge and fill material, or other minor activities for which there is no practicable alternative, provided that the pertinent requirements of the NWP system are met.	These requirements are applicable due to the presence of wetlands but will be met through avoidance of wetlands during construction and implementation of alternatives.

Table 4.17. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
Endangered Species Act	16 U.S.C. 1531 et seq. Section 7(a)(2)	Actions that jeopardize the existence of listed species or result in the destruction or adverse modification of critical habitat must be avoided or reasonable and prudent mitigation measures taken.	Action that is likely to jeopardize fish, wildlife, or plant species or destroy or adversely modify critical habitat-applicable.
Migratory Bird Treaty Act	16 U.S.C. 703-711 Executive Order 13186	Federal Agencies are encouraged (until requirements are established under a formal MOU) to do the following: • avoid or minimize, to the extent practicable, adverse impacts on migratory bird resources when conducting agency actions; • restore and enhance the habitats of migratory birds, as practicable; • prevent or abate the pollution or detrimental alteration of the environment for the benefit of migratory birds, as practicable; • ensure that environmental analysis of federal actions required by the NEPA or other established environmental review processes evaluate the effects of actions and agency plans of migratory birds, with emphasis on species of concern; and • identify where unintentional take will likely result from agency actions and develop standards and/or practices to minimize such unintentional take.	Action that is likely to impact migratory birds, habitats, and resources-applicable.
		Action-Specific ARARs	
Fugitive Dust Emissions during site preparation and construction activities.	401 KAR 63:010	Precautions must be taken to prevent particulate matter from becoming airborne. Such precautions must be incorporated into the planning and design of activities and include actions such as • wetting or adding chemicals to control dust from construction activities; • using materials such as asphalt or concrete (or other suitable chemicals/fixing agents) on roads or material stockpiles to prevent fugitive emissions; and • using covers on trucks when transporting materials to and from the construction site(s). The requirement specifies that for on-site construction activities, no visible emissions may occur at the PGDP fenceline. Similar points of compliance shall be identified for construction activities that occur outside the fence.	These requirements are applicable and will be met through the use of appropriate dust-control practices identified during alternative design phase.
Toxic Emissions	401 KAR 63:022	The regulations require that a determination of toxic emissions be made in order to assess the applicability of required controls. Calculations of the significant emission levels are compared to the allowable emission limits specified in Appendix A of 401 KAR 63:022. If emission levels are exceeded, the best available control technologies must be incorporated into equipment/process design.	These requirements are considered to be applicable and shall be complied with through calculation of significant emission levels for toxic materials and application of best available control technology as necessary during the design of the alternative.

Table 4.17. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
Monitoring Well Installation	401 KAR 6:310	Monitoring wells (including extraction wells) must be constructed in a manner to maintain existing protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole. In addition, abandoned wells must be plugged and abandoned in accordance with the requirements specified.	These requirements are considered to be applicable. Compliance with well design and protection standards shall be achieved through the use of approved well design and materials of construction. While in service, wells shall be secured as required. Abandoned wells shall be plugged and abandoned as required.
		Chemical-Specific ARARs	
Hazardous Waste Management	40 *CFR* 260 through 264 and 268; 401 KAR 31 through 34, 36, and 37	All wastes or environmental media containing wastes must be characterized to determine whether the waste is also a hazardous waste in accordance with 40 *CFR* 262.11 and 401 KAR 32:010. If it is determined that a waste is hazardous or that environmental media contain a hazardous waste that is subject to the RCRA regulation, the substantive requirements of 40 *CFR* 262 through 268 are applicable. These standards include design and operation of storage and accumulation areas, waste handling and shipment, and treatment technologies or numeric standards applicable to wastes prior to disposal.	These requirements are applicable and will be complied with through characterization of wastes and environmental media generated as a result of implementation of the alternative. Waste management will be predicated upon the characterization and will comply with all substantive requirements associated with hazardous waste management if identified as such.

ALARA = as low as reasonably achievable
ARAR = applicable or relevant and appropriate requirement
CFR = *Code of Federal Regulations*
CWA = Clean Water Act
DOE = U.S. Department of Energy
GWOU = groundwater operable unit
KAR = Kentucky Administrative Regulations
MCL = maximum contaminant level
MCLG = maximum containment level goal
NRC = U.S. Nuclear Regulatory Commission
NWP = Nationwide Permit
PGDP = Paducah Gaseous Diffusion Plant
RCRA = Resource Conservation and Recovery Act
TBC = to be considered

operations involved in the uranium fuel cycle and include enrichment operations. Subpart B of these requirements specifies that the annual dose equivalent to the public not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughter products excepted, to the general environment from uranium fuel cycle operations and the radiation from these operations. These requirements would be considered relevant and appropriate because release to the groundwater would not be planned.

The Commonwealth of Kentucky is an NRC Agreement State and has promulgated regulations for radiation protection of the public. The Kentucky radiation protection standard for individual members of the public is 0.1 rem (100 mrem) EDE per year or less (902 KAR 100:019 Section 10), which is equivalent to the DOE radiation protection standard found in DOE Order 5400.5.

Due to the differing view and values among NRC, EPA, and DOE total EDE for members of the general public, EPA and DOE have agreed not to finalize their respective standards until an agreement can be reached. In the interim, DOE Order 5400.5 is identified as TBC information and the NRC standard is identified as relevant and appropriate. Therefore, the radiation protection standard identified within the NRC regulations in 10 *CFR* 20 Subpart E, requiring an EDE of 25 mrem/year or less, shall be used as the exposure limit for the general public.

Chemical-specific ARAR summary. The chemical-specific ARARs associated with the implementation of this alternative are outlined in Table 4.17. Implementation of this alternative would not result in immediate attainment of the chemical-specific ARARs associated with the off-site groundwater plumes. Attainment of the identified ARARs would be met in the future as implementation progresses. Although TBC information, the radiological exposure standards included in DOE Order 5400.5 shall be achieved and will be confirmed through monitoring. Continued monitoring of the groundwater will be used during the five-year reviews to ensure the identified goals are met and that concentrations of COCs continue to decrease.

Potential location-specific ARARs

Wetlands. Wetlands have been identified within the area where construction activities will occur, certain jurisdictional wetlands have been identified in on-site drainage ditches within the plant boundary. In order to comply with these applicable requirements, wetlands shall be avoided.

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, 40 *CFR* 6.302(a), 40 *CFR* 6 Appendix A, and 10 *CFR* 1022]. These applicable requirements include avoiding construction in wetlands, avoiding (to the extent practicable) long-term 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. Although not anticipated, if this alternative results in impacts to wetlands that cannot be avoided, the substantive requirements of the NWP 38 (33 *CFR* 330) will be met.

Off-site operations shall not impact wetlands, and all treatment will be conducted either *in situ* or in units already in operation.

Endangered Species and Migratory Birds. Actions taken by federal agencies are prohibited from impacting T&E species or adversely modifying critical habitat (50 *CFR* 17.94) in accordance with the Endangered Species Act [16 USCA 1531 *et seq.* Section (7)(a)(2)]. These requirements are potential ARARs in the event T&E species or their habitats are found at or near areas where remedial action is to occur. An ecological resource investigation inside the PGDP security fence did not detect any T&E species or their preferred habitats (CDM Federal 1994). The USFWS has not designated critical habitats for any species within the DOE property. However, outside the PGDP fence on the DOE property, potential habitats for federally listed T&E species were reviewed, and Indiana bat habitat was evaluated during the COE (1994) environmental investigation. The COE study determined that total potential bat habitat consisted of 20% of the 994-ha (2,456-acre) study area. Remedial activities must be evaluated to ensure that such actions do not adversely impact areas identified as critical habitat for any identified endangered species.

In addition, Executive Order 13186 directs federal agencies to enter into an MOU with the USFWS to further the purposes of the Migratory Bird Treaty Act (16 U.S.C. 703-711). Until such time as the MOU between DOE and the USFWS is finalized, federal agencies are encouraged immediately to begin implementing the conservation measures set forth in the Executive Order. The requirements of the Executive Order are applicable and must be considered during planning and design of the remedial action.

Potential action-specific ARARs

Monitoring well/injection installation requirements. This alternative includes the installation of additional monitoring wells and injection wells. Installation of these wells would have to be conducted in a manner to maintain existing natural protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole (401 KAR 6:310 Section 13). These requirements also mandate the construction materials required for well construction, well design criteria, well completion activities, and well abandonment methodologies. These requirements are considered applicable to design and installation of monitoring, injection, and extraction wells associated with the implementation of this alternative.

Fugitive dust emissions. Construction activities may result in the production of particulate airborne pollutants (dust). The Kentucky Air Quality standards found in 401 KAR 63:010 include requirements governing fugitive dust emissions. These standards require that dust-suppression measures be undertaken, including activities such as use of water or chemicals to control emissions, placement of asphalt or concrete, and stockpiling of soils. The standards also require that visible dust generated from the implementation of the remedial alternative not be discharged beyond the property boundary of the site. For the purpose of compliance with these requirements, the site boundary is interpreted to mean the DOE site boundary or the immediate boundary of construction activities that occur on non-DOE property. Trucks transporting material outside the property boundary, where materials could become airborne, must be covered. These requirements are considered to be applicable to the implementation of this alternative and will be complied with through careful planning to ensure that excavated materials are sufficiently wetted or protected to control dust generation.

Radionuclide emission standards. Airborne emissions of radionuclides may occur as a result of on-site construction activities. Although the potential is low for such emissions to occur, the regulations in 40 *CFR* 61.92 would be applicable, requiring that the emissions not exceed amounts that would cause an EDE to the public of 10 mrem/year. In order to determine whether the alternative complies with this applicable requirement, computer modeling using the CAP-88 or other EPA-approved models must be undertaken. If the modeling demonstrates that the radionuclide emission is in excess of 1% of the 10 mrem/year standard, emission rates must be measured, as required by 40 *CFR* 61.93. This ARAR shall be complied with by planning activities in such a manner as to control fugitive emissions from construction and treatment activities.

Toxic emission standards. Although toxic emissions are not expected as a result of construction activities or with the pumping of the groundwater to the on-site water treatment facility, these emission requirements would be applicable if such an emission does occur. Due to organic concentrations found in the groundwater and potentially within the subsurface soils, there is a low potential for such emissions to occur. The regulations at 401 KAR 63:022 require that emissions be evaluated to determine whether they are significant for each specific toxic air pollutant. If analysis indicates that the toxic emission requirements are triggered, the regulations specify that no source may exceed the allowable emission limit specified in Appendix A of 401 KAR 63:022. If applicable, these rules would require application of the best available control technology to limit toxic emissions. If calculations indicate that the emission rates specified within the rule are not exceeded, then the calculation package may be used to demonstrate compliance with these requirements. Activities that must be considered include collection and treatment of contaminated groundwater.

Stormwater discharge. Construction activities will be subject to the substantive requirements associated with the KPDES permit that requires the use of BMPs and sediment/erosion controls to control transport of sediment in stormwater runoff. These requirements are considered to be applicable.

Waste management requirements. Secondary wastes may be generated during the implementation of this alternative in the form of potentially contaminated environmental media. All wastes generated shall be subject to the hazardous waste determination requirements of 40 *CFR* 262 and 401 KAR 32:010. Soils shall be assessed to determine whether they contain a hazardous waste. If it is determined that any wastes are, in fact, hazardous wastes, the materials must be managed in accordance with the substantive requirements found in 40 *CFR* 262 through 40 *CFR* 268 (401 KAR 32 through 37). These standards include storage requirements, transportation requirements, and disposal requirements. Specific requirements applicable to each waste stream must be identified after characterization of the material is complete. These requirements shall be complied with through the development of a WMP during the design phase of implementation. If materials are identified as RCRA hazardous wastes, these requirements are applicable.

Action-specific ARAR summary. This alternative will trigger action-specific ARARs with regard to the treatment of the contaminated groundwater. In addition, the requirements of RCRA may be applicable if hazardous waste is generated. This alternative will comply with these requirements during the planning phase to include compliant waste handling, storage, and disposition components.

A summary of the ARARs for the implementation of this alternative is presented in Table 4.17.

Compliance with ARARs summary. Implementation of this alternative would not achieve compliance with the MCL for TCE. In addition this technology does not address contamination from metals or radionuclides present within the soils or groundwater. Because this alternative does not immediately meet the stated MCLs, an ARAR waiver or agreed schedule of compliance would have to be sought as part of the ROD and PRAP.

To comply with the identified chemical-specific ARARs, an ARAR waiver will be required due to the time frames required to meet the specified concentrations within the GWOU at the point of compliance and points of exposure.

As discussed, no potential location-specific ARARs have been identified within the area in which remedial action will occur. However, to ensure that jurisdictional wetlands are not impacted, all construction activities associated with the installation of the monitoring wells and injection wells will be reviewed as a safeguard. The protection of wetlands is not considered a location-specific ARAR at this time because jurisdictional wetlands have not been identified within the areas impacted by the implementation of this alternative.

Construction and implementation of the alternative may trigger several action-specific ARARs, such as the requirements associated with well installation and abandonment, fugitive dust emissions, radionuclide emissions, and toxic emissions. The requirements associated with the installation and abandonment of groundwater wells will be met though the use of well designs and materials of construction, as specified at 401 KAR 6:310 Section 13. All well installation and abandonment practices incorporated into the approved remedial design shall comply with the substantive requirements of 401 KAR 6:310.

The treatment of groundwater will require the injection of materials into the subsurface. During the remedial design assessment, all materials used in the construction will be reviewed to ensure that materials that could further impact water quality are not used or are limited in use.

The construction activities associated with this alternative may require that BMPs for sedimentation/ erosion controls be established. Sedimentation control is required if the area to be disturbed during construction exceeds regulatory limits. Regardless of the size of the construction area(s), sedimentation controls will be TBC information. This requirement will be complied with through the use of sediment fences or other appropriate means. The remedial design shall incorporate the specific controls necessary to ensure that the construction site(s) do not allow sedimentation and/or erosion of disturbed areas to comply with this requirement during implementation of this alternative.

Fugitive dust emissions that may occur during construction activities will be controlled as required by 401 KAR 63:010. BMPs, such as the wetting or covering of potential sources of fugitive dust, will be incorporated into the remedial design. The specific actions to be developed shall control potential emission sources to ensure that dust emissions do not migrate from the immediate area where construction activities occur. It is anticipated that, in most cases, the moisture content in the soil will be sufficient to control dust emissions during well installation. However, practices such as wetting of disturbed soils, collection of soils, or reseeding activities shall be considered and incorporated into the remedial design as necessary to ensure compliance with these requirements. Radionuclide emissions at construction sites also must be considered during the implementation phase. In order to ensure that the emission standard of 10 mrem/year EDE to the public is met, concentrations of radionuclides in soils and groundwater must be evaluated. If the potential for such emissions are identified, modeling using the CAP-88 or other EPA-approved method must be undertaken during the design phase of the alternative. It is anticipated that the primary conveyance of airborne radionuclides will be in particulate form. Therefore control of fugitive dust emissions also will result in compliance with the emission standards applicable to radionuclides. If radiological contamination from plant activities is found in soils where construction activities are planned, the soil will be protected or containerized to prevent airborne migration. Measures necessary to prevent airborne emissions or radionuclides shall be evaluated and incorporated, as appropriate, into the remedial design in order to comply with these requirements during implementation of this alternative.

Emissions of toxins, such as volatile organics, must also be evaluated before implementation. Although the potential for exceedance of toxic air emissions is considered to be low, an evaluation of the potential for such emissions must be undertaken during the remedial design. Potential emissions must be evaluated for each toxin present in the plumes (i.e., TCE, vinyl chloride, etc.) to determine whether the contaminant levels found in the subsurface could result in airborne emissions in excess of the allowable limits specified in Appendix A of 401 KAR 63:022. Compliance with the emissions standards shall be achieved for this alternative through the evaluation process or the application of best available control technology where emissions are calculated to exceed allowable levels. It is anticipated that through the use of the ozonation system there will no air emissions at all. However, the potential does exist that vapors may migrate from the injections wells during the operation. Appropriate emission control equipment will be incorporated into the treatment system as necessary. The specifications for this equipment shall be identified during the remedial design based upon the initial evaluation. This requirement will be complied with during implementation of the alternative.

Secondary wastes generated from the *in situ* treatment of groundwater will result in the generation of wastes that will trigger the characterization requirements associated with the RCRA regulation. The implementing regulations found at 40 *CFR* 262 and 401 KAR 32:010 require that generators of solid wastes (or contaminated environmental media) must determine whether the waste also is a hazardous waste. If the materials generated from the implementation of this alternative are found to be hazardous wastes, the materials shall be containerized and managed as such. The requirements mandate that hazardous wastes must be properly labeled and stored in areas that comply with the technical standards for storage of hazardous waste in containers. These standards shall be complied with by testing of secondary wastes generated during groundwater treatment. If any of these materials are found to be hazardous waste regulated under RCRA, appropriate storage areas shall be constructed and maintained. All hazardous waste generated during the implementation of this alternative that is required to be shipped for off-site disposal shall use the EPA Identification Number for the PGDP. Hazardous wastes shall be shipped to facilities permitted to treat, store, or dispose of the hazardous waste(s) being shipped, if on-site treatment or disposal is not allowable. These activities shall be incorporated into the remedial design for this alternative in order to comply with these requirements.

Secondary wastes generated during the implementation of this alternative also may be subject to regulation under TSCA (as PCB remediation waste) and DOE Order 435.1 (as LLW). Characterization of these materials will be required to determine whether specific wastes are regulated under these requirements. If it is determined that the waste generated is a PCB or LLW, appropriate management standards will be incorporated into the remedial design. Existing information will be used where practicable to determine the regulatory status of all waste to be generated before implementation. This alternative will comply with all TSCA and LLW requirements.

Long-term Effectiveness and Permanence. Dissolved Phase Plume Ozonation Technology offers a relatively high level of long-term control for VOCs and ^{99}Tc located in areas of RGA treatment. The implementation of this technology alone in the RGA will provide little to no control over Primary and Source Area target contaminants located in the UCRS or the RGA. The only exception would the potential for collateral reductions in VOC concentrations when the dissolved phase target is adjacent to a Secondary Source area. It also should be understood that without the removal of the DNAPL source zones, the plumes would regenerate over time.

Magnitude of residual risk. Residual risk in the RGA will remain in place after implementation of an Ozonation Technology. The technology will require assistance from other technologies in either the UCRS or RGA to meet the MCLs at the point of compliance, thereby preventing the regeneration of the dissolved phase plumes. This alternative will reduce VOCs in the dissolved phase plume areas by *in situ* use of ozone to react with and destroy the VOC. ^{99}Tc will be captured on an ion exchange media as contaminated groundwater circulates through the injection wells. The technology will have no impact on contaminants present in the UCRS or the RGA source areas unless those areas are targeted for the treatment.

Following treatment of the selected RGA areas, residual COCs would contribute to long-term risks. However, the five-year reviews, mandated by CERCLA [40 *CFR* §300.430(f)(4)(ii)], would be an effective means to demonstrate that contaminant levels were reduced from the technologies implementation and additional exposure pathways have not developed.

Adequacy and reliability of controls. The reliability for operation and control of Ozonation Technology would be moderate. The components that make up the treatment systems such as injection wells, compressors, ozone generators, and down-hole pumps are common industrial items that have been used for many years successfully. However, a limiting factor in the reliability of the ozonation process is ensuring that the VOCs and ozone come into contact with one another as well as with the ^{99}Tc and ion exchange media. The contact of the contaminants and the treatment media is largely controlled by the subsurface conditions of the RGA. The RGA has high permeability; therefore, this limitation is not expected. Another limiting factor is the presence of large amounts of organic material being present in the treatment zone. The ozone will react with VOCs as well as any other organic compounds present. If large quantities of organics are present, the ozone is spent on reacting with these extraneous organic compounds and not reacting with the contaminants. Computer modeling would be used to design the site-specific location, injection-well layouts, and ozone concentrations to ensure appropriately sized treatment zones and that contaminants are not migrated to noncontamination areas due to the injection process and that contaminants are destroyed. It also should be understood that the technology must operate continuously to ensure that complete coverage of the contaminant plume occurs. Should extended interruptions of electrical power or other vital systems occur, the potential would exist for COCs to escape from the treatment system area. Long-term groundwater monitoring will be required to monitor the extended effectiveness of the treatment following its completion.

Environmental impacts and mitigative measures. The following paragraphs summarize potential long-term impacts to resources and mitigative measures to offset these impacts. The depth-of-impact analysis is proportional to the degree of expected impact.

Land use. Long-term, land use impacts would be few for the implementation of this alternative. The long-term impacts will be related to the placement and use of injection and monitoring wells and access roads used in the operation. If designed to target the entire off-site plume, there could be several hundred injection wells used in the operation. The areas of use will include the WKWMA, DOE, and TVA, as wells as a number of private land parcels. The total acreage impacted cannot be determined without first identifying the target areas and determining whether linear injection or blanket type injection is to be used. However, it is expected that less than one-fourth of an acre per injection well, not including service roads, will be impacted in the long term. A LUCIP would be developed as necessary per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomics. The presence of contaminants in the groundwater will prevent its use and may limit economic development opportunities until the groundwater is brought back to beneficial use. However, no long-term effects to socioeconomics would result from the implementation of this technology. There would be minimal change to the number of permanent jobs within the PGDP area as a result of implementing this technology.

Air quality and noise. No long-term effects to air quality and ambient noise levels would result from implementation of this alternative. The ozonation technologies will not result in an air emission that must be treated.

Vegetation. There will be long-term impacts to vegetation as a result of this alternative. The alternative will require the installation of injection wells, monitoring wells, and associated access roads on DOE, WKWMA, and TVA land, as well as on private property. The long-term impacts will be the removal of vegetation for the placement of the facilities. The amount of vegetation destroyed has not been determined, as the total target or installation patterns have not been determined. However, the system can be designed to minimize the vegetation destruction by locating access roads and wells to minimize vegetation impact. Some reclamation will be possible after construction is complete.

Wildlife. There will be limited long-term effects to wildlife resulting from implementing this alternative. The long-term impacts will be the removal of trees that will result in destruction of wildlife habitat. There is, however, considerable habitat available in adjacent areas for the displaced mammals, birds, etc. The amount of habitat destruction has not been estimated because the total target area and injection patterns have not been defined. However, the system can be designed to minimize the removal of habitat by locating access roads and wells to minimize impact. Some habitat reclamation will be possible after construction is complete.

Construction in creeks and tributaries may occur as a result of implementing this technology. However, the system design and the use of directional drilling can be used to minimize the impacts to the creeks and tributaries. However, it is likely that access roads will have to cross creeks and tributaries.

Threatened and endangered species. Long-term impacts to T&E species are expected to occur. Indiana bat habitat, as mapped by Bryan (COE 1993), indicates that potential habitat occurs in the dissolved phase plume areas, particularly at the near the terminus of the dissolved phase Northwest Plume. The actual target areas for implementation of the ozonation technology have not been determined and, therefore, the impacts to habitat cannot be determined. However, the placement of wells and access road can be strategically placed to minimize impacts. Technologies such as directional drilling also can be used. After a detailed design of the injection well field, possible impacts to Indiana bat potential habitat will need to be evaluated.

Cultural resources. No long-term effects to cultural resources are anticipated for this alternative.

Groundwater. As a result of implementing an Ozonation Technology in the Dissolved Phase Plume Areas, VOC and ^{99}Tc contamination in the RGA either is reduced or eliminated. No aesthetic changes in the quality of the groundwater should occur as result of injecting ozone into the groundwater. Groundwater monitoring systems will be used to monitor contaminant levels and for the migration of contaminants to noncontaminated areas due to the injection process. The implementation of this alternative would not require the pumping of groundwater to the surface for treatment. All treatment is performed *in situ*.

Surface water. No adverse impacts to streams are expected to result from implementing an Ozonation Technology in a Dissolved Phase Plume Area (RGA). There will be no increases in water discharge volumes to outfalls as a result of this alternative. The alternative may result in the reduction or elimination of contaminants being discharged to the Little Bayou Creek. However, if the DNAPL source areas are not removed at the PGDP, it will be necessary to repeat the action, since the plumes will regenerate over time and reimpact the Little Bayou Creek.

Floodplains. It is not expected that work will impact floodplains in the long term.

Wetlands. It is expected that only limited impacts to wetlands will result from implementing an Ozonation Technology in the Dissolved Phase Plume Area. These impacts will be the result from construction of wells and access roads. The wetlands in the area near to PGDP occur due to surface flow into poorly drained soils and not from recharge from the RGA. These wetlands are isolated and relatively small; therefore, measures can be taken to avoid impacts to the subsurface fragipan that would damage the wetland integrity. The exception to this would be the area of Little Bayou Creek near the TVA Shawnee Steam Plant that does receive recharge from the RGA. These wetlands are relatively extensive. The only mitigating measure would be to design the ozonation system to miss wetland areas of concern to the extent possible.

Soils and prime farmland. Prime farmland would be impacted by the implementation of this alternative. The impacts would be the use of the land for the construction of injection and monitoring wells as well as the associated access roads. If the entire off-site plume area is targeted, there could be several hundred injection wells constructed to be used in such an operation. The areas of use will include the WKWMA, DOE, and TVA, as wells as a number of private land parcels. Prime farmland exists north of the PGDP and DOE property. The NRCS has identified prime farmland as the Calloway, Waverly, and Grenada soil series in the area between the PGDP and the TVA Shawnee Steam Plant. The total acreage impacted cannot be determined without first identifying the target areas and determining the number and distribution of injection wells. However, it is expected that less than one-fourth of an acre per injection well, not including access roads will be impacted. A LUCIP would be developed as necessary per the requirements of the PGDP LUCAP (DOE 2000).

Transportation. No long-term direct, indirect, or cumulative effects to transportation are anticipated from implementing this alternative.

Cumulative Impacts. Cumulative impacts are defined as the incremental impact of an action when added to other past, present, and reasonable foreseeable future actions, regardless of what agency or person undertakes other such actions. Cumulative impacts resulting from this alternative will be identified at a later time during development of site-specific GWOU decision documents.

Reduction of Mobility, Toxicity, or Volume Through Treatment. Technology would be used to destroy VOC contaminants contained in the Dissolved Phase Plume Areas in the RGA. The process is by *in situ* destruction. It is expected that nearly 100% of the VOC contaminants in the target area are expected to be destroyed by the ozone. It also is expected that nearly 100% of the ^{99}Tc contamination will be removed from the groundwater through the use of an ion exchange media. However unless the source of the contamination is removed, the plume will regenerate for 7,000 years.

The implementation of an Ozonation Technology would reduce the long-term volume and toxicity of VOCs and ^{99}Tc present in the RGA through the destruction VOCs or capture of ^{99}Tc. The implementation of this technology is not expected to alter the chemical and physical soil properties of the RGA and, as such, may should not prevent subsequent implementation of an additional technology, should it be determined that additional treatment is needed for the target areas.

The type and characteristics of residual subsurface contamination would be similar to that of the contaminants prior to treatment. Residual contaminants would pose a risk, although contaminant quantities would be considerably reduced following treatment. Since the treatment of VOCs occurs *in situ*, there will be no residual contaminant to be disposed of from any surface or *ex situ* treatment. However spent ion exchange media will require proper a disposal. Ozonation Technology will meet the statutory preference for treatment as a principal element of the remedial action under CERCLA.

Short-Term Effectiveness. The short-term effectiveness of implementing an Ozonation Technology in the Dissolved Phase Plume Area of the RGA was evaluated relative to its effect on community protection, worker protection, environmental impact, and the time until RAOs are achieved. Environmental impact was further evaluated for NEPA values. This information is presented in the following subsections.

Community protection. The potential for adverse impacts to the community from the implementation of this alternative is minimal. The likely target areas will the dissolved phase portions of the groundwater plumes, which lie between PGDP and the Ohio River. The areas specifically contain property of the WKWMA, TVA, DOE, and also parcels of privately held land. The potential impacts identified include a release of ozone during injection and inadvertent surface release of ozone during injection. The target area for the injected ozone in a Secondary Source Areas is the RGA that lies at a depth of greater than 50 ft. The injection of the ozone will be through tubing or pipe. Due to the depth, the ozone is likely not to surface as a result of the injection process. The Little Bayou creek, into which the RGA discharges near the Ohio River, may be in the target area. For that reason, special design precautions will be used to insure that the ozone spends prior to flowing into the stretch of Little Bayou Creek near the TVA Steam Plant. Also, engineering controls, including appropriate packaging and handling mechanisms, will be used prevent a spill of ozone that could impact the community. Restrictions will be used to limit the access of persons that may be in the area during construction and injection operations. This will include warning signs, temporary control fencing, and periodic security patrols. Also, environmental monitoring would be conducted during the construction of monitoring wells where COCs may be present. Following completion of the construction activities, only temporary periodic access will be required for sampling of the monitoring wells used to check the long-term effectiveness of the action on the RGA.

Transportation of ion exchange resin from manufacturing facilities to PGDP will be required periodically. Proper packaging and other required safety features would be used to limit releases as a result of accidents when shipping the resin materials.

Worker protection. During the implementation of an Ozonation Technology, workers could be exposed to COCs during short periods of time. Potential exposure could result from direct contact with contaminated soil and/or groundwater during construction of the injection wells. The workers also will be exposed to ozone, a hazardous substance, during the injection operations. Appropriate handling procedures, injection equipment, and PPE would be utilized to minimize the potential for worker exposure or injury while handling the ozone production equipment. However, short-term risks are not expected to exceed acceptable limits. Health and safety requirements and PGDP procedures would further control the exposures.

Environmental impacts and mitigative measures. The following paragraphs summarize potential short-term impacts to resources and mitigative measures to offset any potential impacts. The depth of impact analysis and mitigative measures are correlated to the degree to which a resource may be impacted.

Land use. The areas expected to be targeted for implementation of an Ozonation Technology in the Dissolved Phase Plume Area lies between PGDP and the Ohio River. The expected land to be impacted includes land of WKWMA, DOE, TVA, and, potentially, parcels of private land. The short-term impacts will be related to the construction and use of injection and monitoring wells and access roads used in the operation. If the entire off-site plume areas are targeted, there could be several hundred injection wells used in such an operation. The total acreage impacted cannot be determined without first identifying the target areas and injection well density. However, it is expected that approximately one-fourth of an acre per injection well, not including access roads, will be impacted. The impacted area, in the short term, likely will be slightly larger than in the long term. This is due to the need to get support vehicles to the locations to install the injections wells and monitoring wells. Once the wells are installed, less equipment will necessary to support the injection operations. A LUCIP would be developed as necessary per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomics. This alternative would not be expected to change the short-term economic conditions in the nearby area. There would be a moderate increase in temporary jobs related to the construction of injection wells and injection operations.

Air quality and noise. Heavy equipment traffic and operation associated with construction of the injection wells would result in a minimal increase in dust and vehicular emission levels. The use of BMPs during construction would reduce short-term direct impacts to air quality from dust. Noise associated with construction activities would occur in the immediate vicinity of the work locations, which may be near private residences for the Northeast Plume. The noise levels would increase during construction and will diminish during the actual ozone injection operations. There would be no planned air emissions as a result of implementing an ozonation technology.

Vegetation. There will be moderate impacts to vegetation as a result of this alternative. The alternative will require the installation of injection wells, monitoring wells, and associated access roads on DOE, WKWMA, and TVA land, as well as on private property. The impacts will be the removal of vegetation for the placement of the facilities. The amount of vegetation destroyed has not been determined, as the total target or installation patterns have not been determined. However, the system can be designed to minimize the vegetation destruction by locating access roads and wells to minimize vegetation impact. Some reclamation will be possible after construction is complete.

Wildlife. There will be moderate effects to wildlife resulting from implementing this alternative. The impacts will be the destruction of wildlife habitat through vegetation removal. There is, however, considerable habitat available in adjacent areas for the displaced mammals, birds, etc. The amount of habitat destruction has not been estimated because the total target area and injection patterns have not been defined. However, the system can be designed to minimize the removal of habitat by locating access roads and wells to minimize impact. Some habitat reclamation will be possible after construction is complete.

Construction in creeks and tributaries may occur as a result of implementing this technology. However, the system design and the use of directional drilling can be used to minimize the impacts to the creeks and tributaries. However, it is likely that access roads will have to cross creeks and tributaries.

Threatened and endangered species. Immediate impacts to T&E species are likely to occur. Indiana bat habitat, as mapped by Bryan (COE 1993), indicates that potential habitat occurs in the dissolved phase plume areas, particularly near the terminus of the dissolved phase Northwest Plume. The actual target areas for implementation of the ozonation technology have not been determined and, therefore, the impacts to habitat cannot be determined. However, the placement of wells and access road can be strategically planned to minimize impacts. Technologies such as directional drilling also can be used. After a detailed design of the injection well pattern, impacts to Indiana bat potential habitat will need to be evaluated.

Cultural resources. No short-term effects to cultural resources are anticipated for this alternative.

Groundwater. As a result of implementing an Ozonation Technology in the Dissolved Phase Plume Areas, VOC, and ^{99}Tc contamination in the RGA either is reduced or eliminated. No aesthetic changes in the quality of the groundwater should occur as result of injecting ozone into the groundwater. Groundwater monitoring systems will be used to monitor contaminant levels and for the migration of contaminants to noncontaminated areas due to the injection process. The implementation of this alternative would not require the pumping of groundwater to the surface for treatment. All treatment is performed *in situ*.

Surface water. No adverse impacts to streams are expected to result from implementing an Ozonation Technology in a Dissolved Phase Plume Area (RGA). There will be no increases in water discharge volumes to outfalls as a result of this alternative. The alternative may result in the reduction or elimination of contaminants being discharged to the Little Bayou Creek. However, if the DNAPL source areas are not removed at the PGDP, it will be necessary to repeat the action, since the plumes will regenerate over time and reimpact the Little Bayou Creek.

Floodplains. It is expected that work may occur in the floodplain of the Ohio River in the short-term. However, it is not expected that impacts will occur as a result implementing this alternative. No modifications to floodplains such as realignment, trenching, or relocating will occur.

Wetlands. It is expected that only limited impacts to wetlands will result from implementing an Ozonation Technology in the Dissolved Phase Plume Area. These impacts will be the result from construction of wells and access roads. The wetlands in the area near to PGDP occur due to surface flow into poorly drained soils and not from recharge from the RGA. These wetlands are relatively small and isolated; therefore, measures can be taken to avoid them and not impact the subsurface fragipan, which would damage the wetland integrity. The exception to this would be the area of Little Bayou Creek near the TVA Shawnee Steam Plant that does receive recharge from the RGA. The wetlands in this area are relatively extensive, and the only mitigating measure would be to design the ozonation system to miss wetland areas of concern to the extent possible.

Soils and prime farmland. Prime farmland would be impacted by the implementation of this alternative. The impacts would be the use of the land for the construction of injection and monitoring wells as well as the associated access roads. If the entire off-site plume area is targeted, there could be several hundred injection wells constructed. The areas of use will include the WKWMA, DOE, and TVA, as wells as a number of private land parcels. Prime farmland exists north of the PGDP and DOE property. The NRCS has identified prime farmland as the Calloway, Waverly, and Grenada soil series in the area between the PGDP and the TVA Shawnee Steam Plant. The total acreage impacted cannot be determined without first identifying the target areas and determining the number and distribution on injection wells. However, it is expected that less than one-fourth of an acre per injection well, not including access roads, will be impacted. A LUCIP would be developed, as necessary, per the requirements of the PGDP LUCAP (DOE 2000).

Transportation. No short-term direct, indirect, or cumulative effects to transportation are anticipated from implementing this alternative. It will, however, be necessary to transport waste soils and development water during construction and start up operations. The appropriate precautions and controls and packaging will be used to protect against spill during the transportation of these items.

Cumulative Impacts. Cumulative impacts are defined as the incremental impact of an action when added to other past, present, and reasonable foreseeable future actions, regardless of what agency or person undertakes other such actions. Cumulative impacts resulting from this alternative will have to be identified at a later time during development of site-specific GWOU decision documents.

Time until action is complete. Implementation of this alternative will not result in achievement of the GWOU RAOs specified or groundwater MCLs upgradient of the installation. RAOs and MCLs could be achieved in the immediate vicinity and downgradient of the installation within 15 years. Without the reduction of DNAPL sources, the plumes will continue to regenerate from source areas for approximately 7,000 years and the ozonation operation would need to operated full-time during this period. It will be necessary to implement source reduction actions to shorten the completion time.

Implementability. The implementability of Ozonation Technologies in the Dissolved Phase Plume Area of the RGA was evaluated based upon its technical feasibility, administrative feasibility, and the availability of services and materials. This information is summarized in the following subsections.

Technical feasibility. Implementation of Ozonation Technologies is technically feasible. These technologies, although innovative, have been implemented at other hazardous waste sites, and the necessary equipment should be readily obtained. Ozonation uses standard commercially available equipment. The technology is available from a limited number of vendors. Implementation difficulties may arise due to design the injection systems around sensitive areas. Sensitive areas include wetlands, Indiana bat habitat, and creeks. A monitoring network will be necessary to evaluate the effectiveness of the treatment operations.

Administrative feasibility. This alternative is administratively feasible. All activities would be conducted in accordance with substantive federal, state, and local requirements. Waivers of ARARs are anticipated to be necessary to implement these actions.

Availability of material and services. The services and materials necessary to implement this alternative are readily available. The potential exception would be personnel/vendors necessary to implement the Ozonation Technology. The equipment is standard industrial equipment used in other fields such as wastewater treatment. However, the number of vendors experienced at implementing ozonation in the environmental remediation arena is limited.

The construction of this alternative will result in the generation of waste soil cuttings and drilling and development water from the construction of injection and monitoring wells. Additionally, the construction will generate construction debris during the building of any required injection facilities. Appropriate disposal, treatment, and discharge options are available for the expected waste streams.

It is expected that an ARAR waiver will be required for this alternative since MCLs will not be attained in a timely manner.

Cost. Table 4.18 summarizes the preliminary unit cost estimates for implementation of an Ozonation Technology in a Dissolved Phase Plume Area of the RGA. These preliminary unit cost estimates are based upon FS-level scoping and are intended to aid with selection of a preferred alternative. The estimates have an expected accuracy of -30 to +50% for the proposed scope of action (EPA 1988a). The capital cost estimate represents those expenditures required to implement this remedial alternative. The O&M cost estimates represent expenditures required to maintain the remedy after the initial phase of remedial action is completed. The total contingency cost presented includes direct, indirect, and all O&M associated contingency costs. The total cost includes all capital costs, direct and indirect with O&M and associated reports, plus 25% contingency costs, for a 30-year term of comparison. All estimates have been escalated using DOE-approved annual rates and a schedule for the various activities based on similar project experience. Present worth values also are included using a discount factor of 5% (EPA 1988b). (Additional information regarding the preliminary cost estimates is presented in Appendix C7.)

Table 4.18. Preliminary unit cost estimates for Dissolved Phase Plume Area – Ozonation Technology

Total capital costs/acre-foot	$31,321
Total operation and maintenance costs	$31,575
Overhead	$44,684
Total contingency	$26,895
Total cost	**$134,477**
Total cost (present worth)	**$75,065**

Note: preliminary cost estimates are per acre-foot, escalated and presented in dollars.

State/Commonwealth Acceptance. Commonwealth of Kentucky acceptance or nonacceptance of this alternative will be addressed in the ROD if it is selected as the preferred alternative.

Community Acceptance. Following a formal public comment period on the PRAP for the GWOU, comments from the community will be addressed formally in a responsiveness summary, which will be presented in the ROD.

Evaluation summary of Dissolved Phase Plume Area – Ozonation Technology

This alternative consists of implementing an Ozonation Technology in a Dissolved Phase Plume Area of the RGA to remove VOC contaminants and ^{99}Tc present in the RGA in the targeted area. Monitoring of the action, and conducting five-year reviews as required by CERCLA also is included. Monitoring COC migration will prevent or minimize exposure to contaminated groundwater, and it also allows the effectiveness of the remedial actions to be evaluated. Although the Dissolved Phase Area concentration in the RGA would be reduced following the implementation, the residual contamination and risks would remain. These residual risks in the RGA from Primary and Secondary Source Areas still will be present and prevent the use of the groundwater for an estimated 7,000 years. It would necessary to conduct source area reductions and supplemental dissolved phase plume actions to reduce the time the groundwater would be unusable.

Implementation of this alternative alone will not be protective of human health and the environment. It must be combined with actions in the source areas. The Ozonation Alternative can be implemented in compliance with ARARs. Long-term effectiveness could be achieved to an acceptable degree (100% mass removal within the Dissolved Phase Areas of the RGA in less than 15 years of implementation). However, because of the nature of the soil and groundwater contamination associated with the GWOU, it will take much longer or other actions to remediate permanently. Residual contamination will remain in the groundwater, with TCE levels exceeding the MCL for approximately 7,000 years. The volume and toxicity of the VOCs and ^{99}Tc would be reduced by *in situ* destruction and capture, respectively. Limited short-term risks to workers would exist during the construction and operation phase of the alternative. The alternative is technically and administratively feasible to implement. The unit cost of this alternative, which is intended to address only the Dissolved Phase Areas of the RGA in the GWOU at the PGDP, is quite significant. Input from the Commonwealth of Kentucky and the community has not yet been received but will be added to later versions of this FS report and the corresponding ROD once the respective comment periods have been completed.

4.2.4.3 Dissolved Phase Plume Area – Permeable Treatment Zone Technology

Description of Dissolved Phase Plume Area – Permeable Treatment Zone Technology

Permeable Treatment Zone Technology Alternative for the Dissolved Phase Plume Area would include using reactive media zones to remove migrating contaminants in the RGA aquifer from the three plumes present at the PGDP. The specific action may be from capturing only the portions of the plumes that contain higher concentrations of contaminant or the placement of zones across the entire plumes at specifically targeted locations. The treatment zones would use iron or other reactive media to destruct TCE or other VOCs and to capture ^{99}Tc in the zone. A graphical description of the technology is shown in Fig. 4.9 (snapshot figure) The use of the PTZ to provide groundwater contamination treatment has become more commonplace in the last decade. The best description of the many applications to date can be found on the Internet at http://www.rtdf.org/public/permbar/pbrsumms/default.cfm. This site contains the site descriptions of 37 locations where the technology has been used. Continued groundwater monitoring both onsite and offsite will be used to monitor COC migration. A CERCLA five-year review program will continue during the life of this activity to meet the requirements of CERCLA.

This alternative provides no aggressive reduction of Primary or Secondary Source Area contaminant volume. In the absence of a source-area action, on-site groundwater TCE levels can be expected to remain above the MCL of 5 μg/L for approximately 7,000 years. The highest COC levels, resulting from the dissolution of the RGA DNAPL zone, will persist for approximately 1,000 years. Thereafter, the influence of dissolution from the UCRS DNAPL zones dominates. These trends influence the expected TCE levels downgradient of the PTZ at the PGDP perimeter. For this alternative, as long as the RGA and UCRS DNAPL persists, off-site groundwater TCE levels will remain above the 5 μg/L MCL. After approximately 1,000 years, the PTZ will be able to reduce TCE levels in groundwater migrating offsite to below 5 μg/L and off-site groundwater quality will return to beneficial use approximately 60 years thereafter.

Environmental Media Monitoring. The existing groundwater-monitoring program will be continued to monitor the movement of the COCs within the RGA. The monitoring program will integrate existing PGDP monitoring wells, where possible, with additional monitoring wells to be installed, as needed, following a review of the existing program. Different objectives such as the flow gradients along the axis of the newly created PTZs may require additional monitoring points in order to determine the effectiveness of the PTZs in reducing contamination levels.

CERCLA Five-Year Review. The CERCLA Five-Year Review process will be used to monitor the effectiveness of the alternative and to identify any needed changes.

Assessment of Dissolved Phase Plume – Permeable Treatment Zone Technology

A detailed analysis of the performance of Permeable Treatment Zone Technology for the Dissolve Phase Plume Area against the nine CERCLA criteria is outlined in detail below.

Overall Protection of Human Health and the Environment. Implementation of this alternative would use PTZs to prevent the off-site migration of the contaminated groundwater from the DOE property to downgradient areas. The technology will be effective at removing TCE and VOC contaminants by destruction.

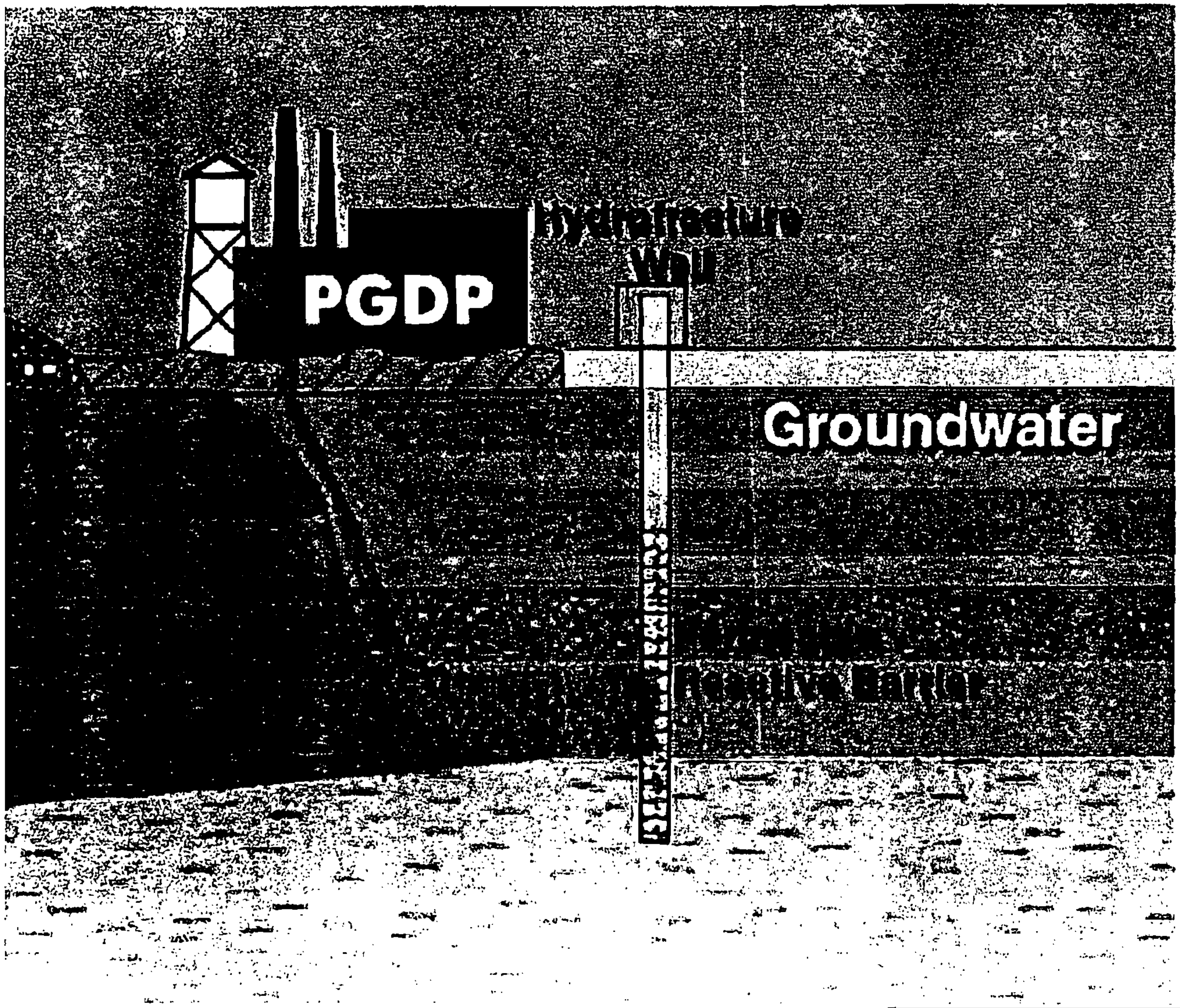


Fig. 4.9. Dissolved phase plume area - permeable treatment zone technology.

U. S. DEPARTMENT OF ENERGY
DOE OAK RIDGE OPERATIONS
PADUCAH GASEOUS DIFFUSION PLANT

BECHTEL JACOBS COMPANY, LLC
MANAGED FOR THE US DEPARTMENT OF ENERGY UNDER
US GOVERNMENT CONTRACT DE-AC-05-98OR22700
Oak Ridge, Tennessee • Paducah, Kentucky • Portsmouth, Ohio

Science Applications
International Corporation
P.O. Box 2502
Oak Ridge, Tennessee 37831

FIGURE No. FS4-9
DATE 05-25-01

It also will capture ^{99}Tc and adsorb it to the reactive media. Although this alternative will reduce dissolved phase contaminant levels in the migrating groundwater, it will not alone satisfy the RAOs for the GWOU. However, it will support achieving those RAOs when implemented in concert with Primary and Secondary Source reduction technologies. The continuation of the groundwater-monitoring program will provide indirect protection for human health and the environment by minimizing the potential exposure to contaminated groundwater through early identification and avoidance. Should major changes occur in the groundwater hydrological cycle, modifications can be made to the PTZ structure by addition of new zones. This will allow for continued treatment of the contamination if changes occur in the currently defined groundwater system.

Groundwater modeling of the groundwater flow in the RGA provides data to support COC reduction over time after implementation of a PTZ Technology to prevent further COC migration to off-site areas. Modeling indicates that in approximately 60-100 years, after removal of RGA DNAPL, the TCE contaminant concentrations in the off-site plumes will decrease to the required MCLs.

The implementation of a PTZ Technology does provide for a reduction in groundwater contamination levels through destructive chemical dehalogenation of the chlorinated solvents. This chemical reaction in the PTZ media is shown in Fig. 4.10, as described by researchers. ^{99}Tc will be retained in the PTZ by chemical precipitation and chemisorbtion. Figure 4.11 shows the current groundwater system for technetium. Since the PTZ will drastically increase the pH of the groundwater flowing through it, the technetium will be removed by the noted phenomena as the pH moves toward the bottom of this graph and more to the right (due to increases in the pH in the PTZ).

PTZ Technology will destroy the volatile chlorinated organic COCs in the plume by chemical reduction and dehalogenation and reduce ^{99}Tc by chemisorbtion. Reactive media used in the construction of the PTZ will produce dehalogenation of the chlorinated solvents; chemical precipitation of the technetium in the zone will cause the end products to be trapped and fixed as they flow through the treatment zone.

Compliance with ARARs

Potential chemical-specific ARARs

Chemical contamination. The aquifers are known to contain chemical contaminants in the form of metals and organics. The federal and state water quality requirements include standards that would be applicable ARARs. The regulations that apply are found in 40 *CFR* 141 (National Primary Drinking Water Standards) and 40 *CFR* 143 (Secondary Drinking Water Standards), 401 KAR 5:029 (General Provisions) and 401 KAR 5:031 (Surface Water Standards). These standards, summarized in Table 4.19 include general state standards, domestic water supply standards, and standards applicable to warm water aquatic habitat. These are applicable based upon the classification of the designation for surface water use associated with the area (Ohio River, River Mile 940.7 to River Mile 943.3) as specified in 401 KAR 5:026. All potentially applicable chemical ARARs for COCs have been included in the table for completeness. Those standards that must be achieved in order to meet the applicable requirements are the lowest of the applicable standards, which in most cases are the MCLs.

Radiological contamination. The OU is known to be contaminated with radionuclides such as ^{99}Tc, radon, uranium, and uranium daughter products. DOE's Order on Radiation Protection of the Public and Environment, DOE Order 5400.5, as codified at 10 *CFR* 835, is TBC information for cleanup of radionuclides at DOE sites. The order requires that remediation activities must not result in radiation exposures to members of the general public, greater than an EDE of 100 mrem/year from all exposure pathways. Exposure to the general public also must be ALARA (DOE 1990).

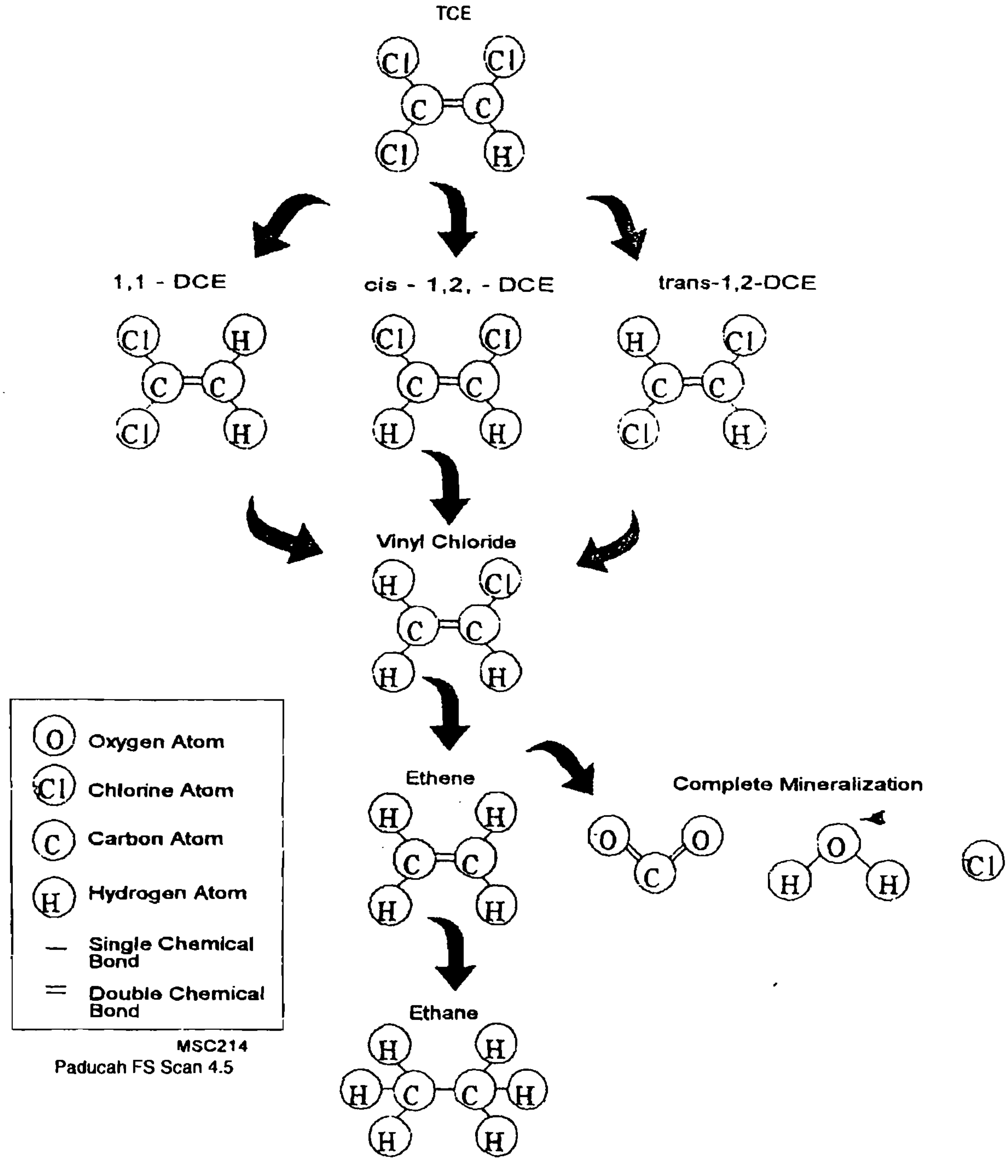


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Fig. 4.10. Reductive dechlorination pathway of TCE.

FIGURE No. FS4-10
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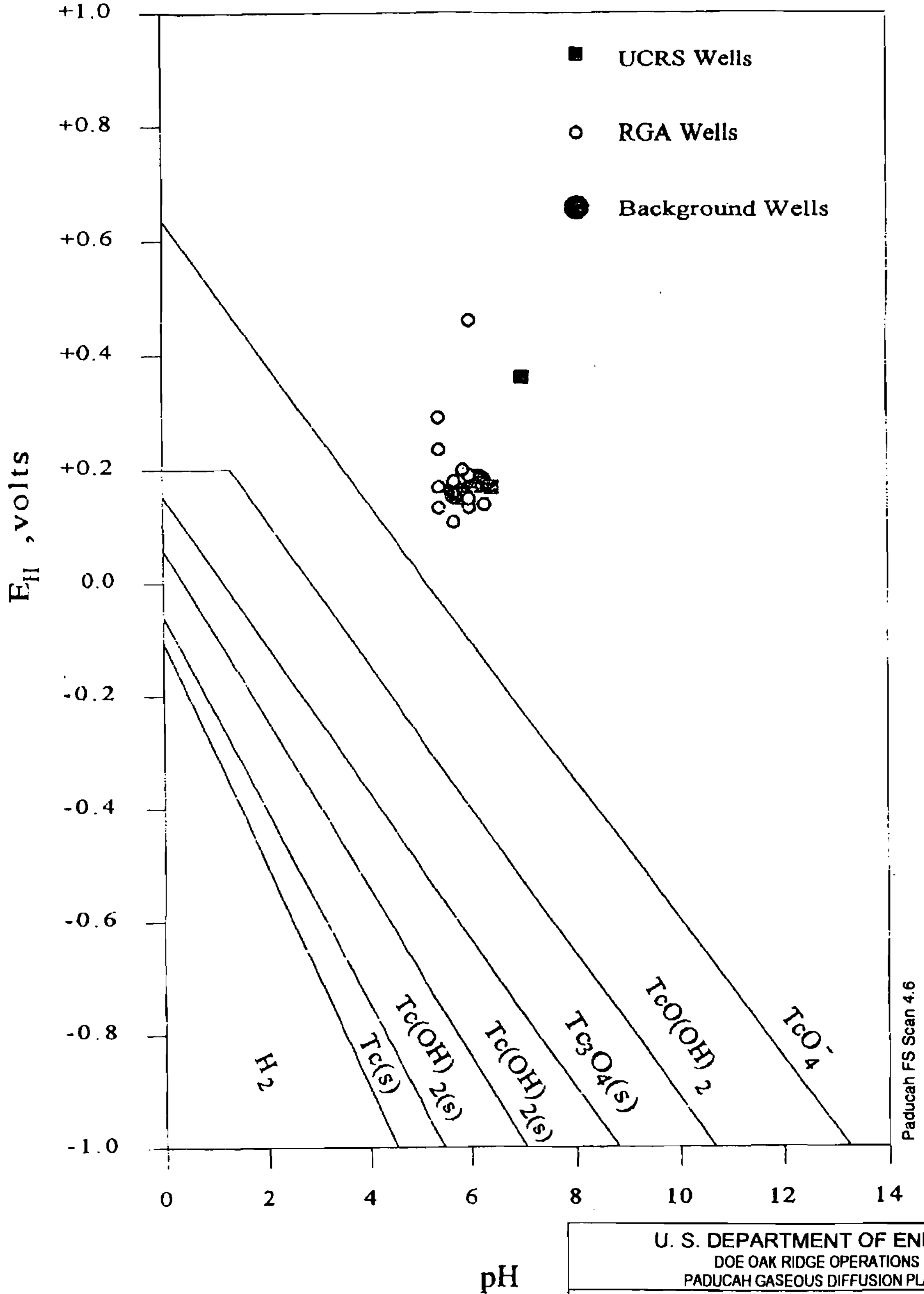

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Fig. 4.11. Potential pH stability diagram for Tc-99.

FIGURE No. FS4-11
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Table 4.19. Summary of Potential ARARs for Dissolved Phase Plume – Permeable Treatment Zone Technology

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Chemical-Specific ARARs	
National Primary Drinking Water Standards	40 *CFR* 141	Provides chemical-specific numeric standards for toxic pollutants expressed as MCLs and MCLGs.	These requirements are relevant and appropriate due to the nature of the contaminants found within the groundwater.
National Secondary Drinking Water Standards	40 *CFR* 143	Provides secondary MCLs for public water systems.	These requirements are TBCs, as they have been established as guidelines for the states and are not federally enforceable.
Kentucky Surface Standards including • Warm Water Aquatic Habitat Criteria • Kentucky Domestic Water Supply • Kentucky General Standards • Kentucky Outstanding State Resource Waters	401 KAR 5:031 and 5:026	Provides chemical-specific numeric standards for pollutants discharged or found in surface waters. Provides chemical-specific numeric standards for pollutants in domestic water supplies.	These standards are applicable to the segment of the Ohio River into which the Little Bayou Creek discharges. The requirements found in these standards are applicable due to the groundwater to surface water interface to Little Bayou Creek and, subsequently, to the Ohio River. Note: CWA Water Quality Criteria are not relevant and appropriate because Kentucky has promulgated these state standards that Kentucky has determined to be appropriate for waters of the State.
Radiation Exposure of the General Public at DOE Facilities	DOE Order 5400.5	Specifies that the general public must not received an effective dose equivalent of >100 mrem/year from all exposure pathways. In addition, all releases of radioactive materials resulting in doses to the general public must meet the ALARA criteria.	This requirement is TBC information.
Decommissioning Standards at Nuclear Facilities	10 *CFR* 20, Subpart E	Specifies a residual activity at nuclear facilities for unrestricted release of 25 mrem/year.	These standards are considered to be applicable to the GWOU.
Environmental Radiation Protection Standards for Nuclear Power Operations	40 *CFR* 190, Subpart B	Requires that the annual dose equivalent to the public must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon, and its daughter products excepted, to the general environment from uranium fuel cycle operations and the radiation from these operations.	These standards are considered to be relevant and appropriate and are equivalent to the NRC standards.

Table 4.19. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Location-Specific ARARs	
Protection of Wetlands	10 *CFR* Section 1022 Executive Order 11990 40 *CFR* 230.10 33 *CFR* 330.5	Activities must avoid or minimize impacts to wetlands to preserve and enhance their natural and beneficial value. If wetland resources are not avoided, measures must be taken to address ecologically sensitive areas and mitigate adverse effects. Such measures may include, minimum grading requirements, runoff controls, design, and construction considerations. Allows minor discharges of dredge and fill material, or other minor activities for which there are no practicable alternatives, provided that the pertinent requirements of the NWP system are met.	These requirements are applicable due to the presence of wetlands, but will be met though avoidance of wetlands during construction and implementation of alternatives.
Endangered Species Act	16 U.S.C. 1531 et seq. Section 7(a)(2)	Actions that jeopardize the existence of listed species or result in the destruction of adverse modification of critical habitat must be avoided or reasonable and prudent mitigation measures taken.	Action that is likely to jeopardize fish, wildlife, or plant species or destroy or adversely modify critical habitat-applicable.
Migratory Bird Treaty Act	16 U.S.C. 703-711 Executive Order 13186	Federal Agencies are encouraged (until requirements are established under a formal MOU) to do the following: • avoid or minimize, to the extent practicable, adverse impacts on migratory bird resources when conducting agency actions; • restore and enhance the habitats of migratory birds, as practicable; • prevent or abate the pollution or detrimental alteration of the environment for the benefit of migratory birds, as practicable; • ensure that environmental analysis of federal actions required by the NEPA or other established environmental review processes evaluate the effects of actions and agency plans of migratory birds, with emphasis on species of concern; and • identify where unintentional take will likely result from agency actions and develop standards and/or practices to minimize such unintentional take.	Action that is likely to impact migratory birds, habitats, and resources-applicable.
		Action-Specific ARARs	
Fugitive Dust Emissions during site preparation and construction activities.	401 KAR 63:010	Precautions must be taken to prevent particulate matter from becoming airborne. Such precautions must be incorporated into the planning and design of activities and include actions such as the following: • wetting or adding chemicals to control dust from construction activities; • using materials such as asphalt or concrete (or other suitable chemicals/fixing agents) on roads or material stockpiles to prevent fugitive emissions; • using covers on trucks when transporting materials to and from the construction site(s).	These requirements are applicable and will be met through the use of appropriate dust control practices identified during alternative design phase.

Table 4.19. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
Fugitive Dust Emissions (continued)		The requirement specifies that for on-site construction activities, no visible emissions may occur at the PGDP fenceline. Similar points of compliance shall be identified for construction activities that occur outside the fence.	
Toxic Emissions	401 KAR 63:022	The regulations require that a determination of toxic emissions be made in order to assess the applicability of required controls. Calculations of the significant emission levels are compared to the allowable emission limits specified in Appendix A of 63:022. If emission levels are exceeded, best available control technologies must be incorporated into equipment/process design.	These requirements are considered to be applicable and shall be complied with through calculation of significant emission levels for toxic materials and application of best available control technology, as necessary, during the design of the alternative.
Monitoring Well Installation	401 KAR 6:310	Monitoring wells (including extraction/injection wells) must be constructed in a manner to maintain existing protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole. In addition, abandoned wells must be plugged and abandoned in accordance with the requirements specified.	These requirements are considered to be applicable. Compliance with well design and protection standards shall be achieved through the use of approved well design and materials of construction. While in service, wells shall be secured as required. Abandoned wells shall be plugged and abandoned as required.
		Chemical-Specific ARARs	
Discharge of Stormwater and Treated Groundwater	40 *CFR* 122 401 KAR 5:055	Stormwater discharges from construction activities onsite are subject to the requirements of the substantive requirements of the KPDES permit. This requires that BMPs to control stormwater runoff and sedimentation be employed. Although off-plant construction activities within the contaminated area are not subject to the permit, these requirements should be considered relevant and appropriate and be incorporated into any off-site construction activities. Discharge of treated groundwater will be conducted in compliance with the KPDES program and the CWA.	These requirements are considered applicable for all on-site construction or treatment activities where a discharge of stormwater or treated groundwater occurs. For off-site construction activities, these requirements are considered relevant and appropriate and will be adhered to. Compliance with these ARARs shall be achieved by application of required controls during the design phase of the alternative.

ALARA = as low as reasonably achievable
ARAR = applicable or relevant and appropriate requirement
BMP = best management practice
CFR = *Code of Federal Regulations*
CWA = Clean Water Act
DOE = U.S. Department of Energy
GWOU = groundwater operable unit
KAR = Kentucky Administrative Regulation
KPDES = Kentucky Pollutant Discharge Elimination System
MCL = maximum contaminant level
MCLG = maximum contaminant level goal
NRC = U.S. Nuclear Regulatory Commission
NWP = Nationwide Permit
PGDP = Paducah Gaseous Diffusion Plant
TBC = to be considered

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The DOE Order 5400.5 also contains reference values, known as DCGs, for operational DOE facilities. Based on the DCGs, radionuclide concentrations in air and drinking water must not exceed an EDE of 10 mrem/year and 4 mrem/year, respectively, to the total body or any organ.

The NRC also has set criteria for decommissioning standards at nuclear facilities at 10 *CFR* 20 Subpart E. These rules require that residual radioactivity at nuclear sites meet a total EDE of 25 mrem/year for unrestricted release. In addition to the NRC standards, EPA has issued guidance for cleanup levels at CERCLA sites with radioactive contamination. EPA has disagreed with the protectiveness specified within the NRC standard and has specified that a 15 mrem/year EDE be used as the risk level that is protective of human health and the environment. EPA also has codified exposure limits for environmental radiation protection standards for nuclear power operations at 40 *CFR* 190. These requirements apply to operations involved in uranium fuel cycle and include enrichment operations. Subpart B of these requirements specify that the annual dose equivalent to the public not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughter products excepted, to the general environment from uranium fuel cycle operations and to radiation from these operations. These requirements would be considered relevant and appropriate since the release to the groundwater would not be planned.

The Commonwealth of Kentucky is an NRC Agreement State and has promulgated regulations for radiation protection of the public. The Kentucky radiation protection standard for individual members of the public is 0.1 rem (100 mrem) EDE per year or less (902 KAR 100:019 Section 10), which is equivalent to the DOE radiation protection standard found in DOE Order 5400.5.

Due to the differing views and values among NRC, EPA, and DOE total EDE for members of the general public, EPA and DOE have agreed not to finalize their respective standards until an agreement can be reached. In the interim, DOE Order 5400.5 is identified as TBC information, and the NRC standard is identified as relevant and appropriate. Therefore, the radiation protection standard identified within the NRC regulations at 10 *CFR* 20 Subpart E requiring an EDE of 25 mrem/year or less shall be used as the exposure limit for the general public.

Chemical-specific ARAR summary. The chemical-specific ARARs associated with the implementation of this alternative are outlined in Table 4.19. Implementation of this alternative would not result in immediate attainment of the chemical-specific ARARs associated with the off-site groundwater plumes for uses in the immediate vicinity of the PGDP property. Attainment of the identified ARARs would be met in approximately 1,000 years as implementation progresses. Implementation of this alternative should result in compliance with the requirements applicable to warm water aquatic habitats, as the installation of the PTZ will intercept potential COCs before discharge to Little Bayou Creek. Continued monitoring of the groundwater will be used during the five-year reviews to ensure the identified goals are met and that concentrations of COCs continue to decrease.

Potential Location-Specific ARARs

Wetlands. Wetlands have been identified within the area where construction activities will occur, certain jurisdictional wetlands have been identified in on-site drainage ditches within the plant boundary. In order to comply with these applicable requirements, wetlands shall be avoided.

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, 40 *CFR* 6.302(a), 40 *CFR* 6 Appendix A, 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 discharging 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. Although not anticipated, if this alternative results in impacts to wetlands that cannot be avoided, the substantive requirements of NWP 38 (33 *CFR* 330) will be met.

Implementation of this alternative is not anticipated to impact wetlands during the construction phase. Compliance with these applicable requirements shall be attained to the greatest extent possible through careful planning during the location of the specific areas for installation. All treatment will be conducted *in situ* and is not anticipated to discharge to wetlands, thereby complying with the requirement of no degradation.

Endangered Species and Migratory Birds. Actions taken by federal agencies are prohibited from impacting T&E species or adversely modifying critical habitat (50 CFR 17.94) in accordance with the Endangered Species Act (16 USCA 1531 et seq. Section (7)(a)(2)). These requirements are potential ARARs in the event T&E species or their habitats are found at or near areas where remedial action is to occur. An ecological resource investigation inside the PGDP security fence did not detect any T&E species or their preferred habitats (CDM Federal 1994). The USFWS has not designated critical habitat for any species within the DOE property. However, outside the PGDP fence on the DOE property, potential habitats for federally listed T&E species were reviewed, and Indiana bat habitat was evaluated during the COE (1994) environmental investigation. The COE study determined that total potential bat habitat consisted of 20% of the 994-ha (2,456-acre) study area. Remedial activities must be evaluated to ensure that such actions do not adversely impact areas identified as critical habitat for any identified endangered species.

In addition, Executive Order 13186 directs federal agencies to enter into an MOU with the USFWS to further the purposes of the Migratory Bird Treaty Act (16 U.S.C. 703-711). Until such time as the MOU between DOE and the USFWS is finalized, federal agencies are encouraged immediately to begin implementing the conservation measures set forth in the Executive Order. The requirements of the Executive Order are applicable and must be considered during planning and design of the remedial action.

Potential action-specific ARARs

Monitoring well installation requirements. This alternative includes the installation of additional monitoring and injection wells. Installation of these wells would have to be conducted in a manner to maintain existing natural protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole (401 KAR 6:310 Section 13). These requirements also mandate the construction materials required for well construction, well design criteria, well completion activities, and well abandonment methodologies. These requirements are considered applicable to design and installation of monitoring and injection wells associated with the implementation of this alternative.

Fugitive dust emissions. Construction activities onsite and offsite may result in the production of particulate airborne pollutants (dust). The Kentucky Air Quality standards found in 401 KAR 63:010 include requirements governing fugitive dust emissions. These standards require that dust suppression measures be undertaken, including activities such as use of water or chemicals to control emissions, placement of asphalt or concrete, and stockpiling of soils. The standards also require that visible dust generated from the implementation of the remedial alternative not be discharged beyond the property boundary of the site. Trucks transporting material outside the property boundary, where materials could become airborne, must be covered. These requirements are considered to be applicable to the implementation of this alternative and will be complied with through careful planning to ensure that excavated materials are sufficiently wetted or protected to control dust generation. Specific activities that could result in the generation of fugitive dust that must be considered during the design phase include construction, well installation, and excavation/disposal of contaminated soils. For off-site construction activities, the point of compliance for airborne dust emissions must be identified in addition to the application of material handling practices necessary to control such emissions.

Radionuclide emission standards. Airborne emissions of radionuclides may occur as a result of on-site construction activities. Although the potential is low for such emissions to occur, the regulations at 40 *CFR* 61.92 would be applicable, requiring that the emissions not exceed amounts that would cause an EDE to the public of 10 mrem/year. To determine whether the alternative complied with this applicable requirement, computer modeling using the CAP-88 or other EPA-approved models must be undertaken. If the modeling demonstrates the radionuclide emission to be in excess of 1% of the 10 mrem/year standard, emission rates must be measured, as required by 40 *CFR* 61.93. This ARAR shall be complied with by planning activities in such a manner as to control fugitive emissions from construction and excavation activities.

Toxic emission standards. Although toxic emissions are not expected as a result of construction activities or with the pumping of the groundwater to the on-site water treatment facility, these emission requirements would be applicable in the event that such emissions do occur. Because of organic concentrations found in the groundwater and potentially within the subsurface soils at depth, there is a low potential for such emissions to occur. The regulations at 401 KAR 63:022 require that the emissions be evaluated to determine whether they are significant for each specific toxic air pollutant. If analysis indicates that the toxic emission requirements are triggered, the regulations specify that no source may exceed the allowable emission limit specified in Appendix A of 401 KAR 63:022. If applicable, these rules would require the application of the best available control technology to limit toxic emissions. If calculations indicate that the emission rates specified within the rule are not exceeded, then the calculation package may be used to demonstrate compliance with these requirements. Activities that must be considered include excavation and treatment of contaminated groundwater.

Stormwater discharge. Both on-site and off-site construction activities will be subject to the substantive requirements associated with the KPDES permit that requires the use of BMPs and sediment/erosion controls to control transport of sediment in stormwater runoff for construction activities. BMPs shall be developed during the planning and design phase of the implementation of the alternative. These shall include erosion control and sedimentation features such as silt fences and grading, as necessary, in order to comply with this ARAR.

Action-specific ARARs summary. Fugitive emission requirements for dust shall be complied with through the application of appropriate engineering and material management controls such as wetting or covering of materials during construction. Specific actions shall be developed during the planning phase of alternative implementation. In addition, points of compliance for fugitive dust emissions shall be established.

Emissions associated with radionuclides and toxic materials are not expected but will be addressed through appropriate engineering estimates and required modeling to ensure that receptors are not put at risk during the construction phase. If such emissions are identified, emission controls shall be incorporated into the construction methods employed during the planning and design phase of alternative implementation.

As discussed above, compliance with stormwater runoff and sediment control requirements shall be complied with as applicable or relevant and appropriate standards. BMPs shall be developed during the planning and design phase to ensure that stormwater discharge requirements are met.

A summary of the ARARs for the implementation of Dissolved Phase Plume – Permeable Treatment Technology are presented in Table 4.19.

Compliance with ARARs summary. Implementation of this alternative would not achieve immediate compliance with the MCL for TCE. Compliance at the fenceline has been calculated to occur in approximately 1,000 years. Compliance with the MCL at the DOE property boundary is calculated to occur in approximately 1,000 years and at Little Bayou Creek in approximately 40 years. Because this alternative does not immediately meet the stated MCLs, an ARAR waiver or agreed schedule of compliance would have to be sought as part of the ROD and PRAP.

In order to comply with the identified chemical-specific ARARs, an ARAR waiver will be required due to the time frames required to meet the specified concentrations within the GWOU at the point of compliance and points of exposure.

As discussed, no potential location-specific ARARs have been identified within the area where remedial action will occur. However, to ensure that jurisdictional wetlands are not impacted, all construction activities associated with the installation of the PTZs in this alternative will be reviewed as a safeguard. The protection of wetlands is not considered a location-specific ARAR at this time because jurisdictional wetlands have not been identified within the areas impacted by the implementation of this alternative.

Construction and implementation of the alternative may trigger several action-specific ARARs such as the requirements associated with well installation and abandonment, construction of the PTZs, fugitive dust emissions, radionuclide emissions, and toxic emissions. The requirements associated with the installation and abandonment of groundwater wells will be met through the use of well designs and materials of construction as specified at 401 KAR 6:310 Section 13. All well installation and abandonment practices incorporated into the approved remedial design shall comply with the substantive requirements of 401 KAR 6:310.

Construction of the PTZs will require the injection of materials into the subsurface. During the remedial design assessment, all materials used in the construction will be reviewed to ensure that materials that could further impact water quality are not used or are limited in use. The construction activities associated with this alternative may require that BMPs for sedimentation/erosion controls be established. Sedimentation control is required if the area to be disturbed during construction exceeds regulatory triggers. Regardless of the size, sedimentation controls will be a TBC if the areal extent of the area disturbed during construction does not require sedimentation control. This requirement will be complied with through the use of sediment fences or other appropriate means. The remedial design shall incorporate the specific controls necessary to ensure that the construction site(s) do not allow sedimentation and or erosion of disturbed areas in order to comply with this requirement during implementation of this alternative.

Fugitive dust emissions that may occur during construction activities will be controlled as required by 401 KAR 63:010. BMPs, such as wetting or covering of potential sources of fugitive dust, will be incorporated into the remedial design. The specific actions to be developed shall control potential emission sources to ensure that dust emissions do not migrate from the immediate area where construction activities occur. It is anticipated that, in most cases, the moisture content in the soil will be sufficient to control dust emissions during well and PTZ installation. However, practices such as wetting of disturbed soils, collection of soils, or reseeding activities shall be considered and incorporated into the remedial design as necessary to ensure compliance with these requirements. Radionuclide emissions at construction sites also must be considered during the implementation phase. In order to ensure that the emission standard of 10 mrem/year EDE to the public is met, concentrations of radionuclides in soils and groundwater must be evaluated. If the potential for such emissions is identified, modeling using the CAP-88 or other EPA-approved methods must be undertaken during the design phase of the alternative. It is anticipated that the primary conveyance of airborne radionuclides will be in particulate form; therefore, control of fugitive dust emissions will also result in compliance with the emission standards applicable to radionuclides. If radiological contamination from plant activities is found in soils where construction activities are planned, the soil will be protected or containerized to prevent airborne migration. Measures necessary to prevent airborne emissions or radionuclides shall be evaluated and incorporated, as appropriate, into the remedial design in order to comply with these requirements during implementation of this alternative.

Emissions of toxics, such as volatile organics, must also be evaluated before implementation. Although the potential for exceedance of toxic air emissions is considered to be low, an evaluation of the potential for such emissions must be undertaken during the remedial design. Potential emissions must be evaluated for each toxic present in the plumes (i.e., TCE, vinyl chloride, etc.) to determine whether the contaminant levels found in the subsurface could result in airborne emissions in excess of the allowable limits specified in Appendix A of 401 KAR 63:022. Compliance with the emissions standards shall be achieved for this alternative through the evaluation process or the application of best available control technology where emissions are calculated to exceed allowable levels. Emission control equipment will be incorporated into implementation activities during the remedial design, as necessary, based upon the initial evaluation. This requirement will be complied with during implementation of the alternative.

Long-Term Effectiveness and Permanence. This evaluation addresses the results of the alternative in terms of risk remaining at the site after completion of the action and the effects of the required long-term control. A discussion of the magnitude of the residual risks at the site and the adequacy and reliability of the controls is presented in the following section.

Magnitude of residual risks. Permeable Treatment Zone Technology is designed to remediate contaminated groundwater by providing *in situ* treatment. In the near term, following the start up of a PTZ remedial action that contains all three PGDP groundwater plumes, the residual risk will remain consistent with the risk before taking the action. Following start up and continued long-term operation of the remedy, the residual risk will decrease with the concentration levels as they decrease in the RGA. This will result in lower eventual risk for the potential groundwater users in the area. Groundwater modeling results for the COC concentrations in the RGA indicate that a 60-year operation of the PTZ system after removal of the RGA DNAPL eventually will result in the reduction of the TCE concentrations in the RGA to MCLs.

The residual risk for the potential groundwater user located upgradient of the PTZ will remain for an undetermined period of time. This is due largely to the nonaqueous-phase concentrations of TCE in the primary and secondary source areas. The source areas for the TCE contamination have concentrations that indicate that TCE may be in a nonaqueous phase. Nonaqueous-phase COCs may remain in an area, dissolving slowly into migrating groundwater, for an extended period of time. As long as the TCE and ^{99}Tc concentrations remain high in the source areas, the residual risks will remain high in those source areas and other downgradient areas in advance of the PTZ. Should the PTZ cease effectiveness, the plumes will regenerate due to the presence of the Primary and Secondary Source Areas.

Five-year reviews, mandated by CERCLA [40 *CFR* §300.430(f)(4)(ii)], will be required to demonstrate the integrity and effectiveness of the controls and confirm that additional exposure pathways have not developed.

Adequacy and reliability of controls. The PTZ Technology will provide adequate controls of the plumes migrating from the facility to the downgradient receptors through the use of routine groundwater monitoring and the treatment provided by the PTZs. The use of PTZs to treat groundwater contamination is an evolving science. It has been proven to have applications at a number of sites, like PGDP, for the removal of chlorinated solvents. Since chlorinated solvents are destroyed by dehalogenation, they can be reduced to be less hazardous by products of the reactions, which can be allowed to migrate in the groundwater environment. Other more hazardous potential by-products of the reaction, however, are less acceptable in the groundwater for their potential risk effects on the groundwater receptors. Some of these by-products are more amenable to natural degradation than TCE. Natural degradation in the current environment of the RGA is not acceptable for natural degradation of TCE (Clausen 1997) but could potentially be for other by-products, such as vinyl chloride.

The PTZ system for treatment of the groundwater contamination will accumulate ^{99}Tc in the media during operation. Retention of the technetium in these media will be tested during the upcoming treatability study for the PTZ demonstration to be conducted in Summer 2001.

Future maintenance of the PTZs can be maintained through agreements with service providers. Intrusive activities that could damage or destroy the PTZs will be prevented by access agreements. It is expected that long-term maintenance of the PTZ will be infrequent and limited in scope to replacement of media. The PTZ Treatability Study implementation and the information developed from it will support the determination as to the extent of maintenance required.

Environmental impacts and mitigative measures. The following text provides a description of potential long-term impacts to resources and mitigative measures to offset any potential impacts. The depth of the impact analysis and mitigation measures is correlated to the degree to which a resource might be impacted.

Land use. Implementation of this alternative would result in any changes to the current land use around the PGDP. Following construction of the alternative, the bulk of the land disturbed during the construction activities will return to its prior use. Only a few acres will remain with monitoring and associated access roads. A LUCIP will be developed, as necessary, per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomic. The socioeconomic conditions of the PGDP and surrounding area would not be expected to change as a result of the implementation of this alternative. Existing socioeconomic structure will remain after implementation of this system of PTZs. The long-term employment in the area will not be changed because of the installation of the PTZ. However, the presence of contaminants in the groundwater will prevent its use and may limit economic development opportunities until the groundwater is brought back to beneficial use.

Air quality and noise. Long-term impacts are not expected to air quality with the PTZ Technology. In fact, air quality, as compared to existing operating systems, will be improved with the installation of a completely nonpolluting *in situ* PTZ system.

Long-term increases in noise are not expected as the result of this alternative.

Vegetation. Construction activities associated with the installation of the PTZs and monitoring network may take up to 1 year. There will be impacts to vegetation in the long term. The level of impacts is dependent on the selected location of the construction. If the zone is near the PGDP, the level of long-term impacts to vegetation will be very minimal. If the selected areas are nearer the extreme far end of the plumes, the impacts to vegetation will be larger. The impacts will be in the form of loss of trees. During the construction period, numerous activities that will impact trees and, therefore, disrupt the habitat for birds, mammals, reptiles, and other animals. Revegetation around the construction areas will be mitigated by engineering controls such as reseeding. However, once the system is installed, there will be no surface evidence of the operation of the system. The only mild operating influence would be the monitoring well system used to monitor the operation of the PTZ. At intervals, technicians may visit the monitoring wells in the area to collect samples to assess the operating effectiveness of the PTZ system.

Wildlife. As mentioned above, the construction activities at the PTZ locations might disrupt some of the wildlife in the area. However, these activities will take only a short period of time during the year of the construction phase for any given area. Activities during the remainder of the life of the project should include monitoring well visits to take required samples at monthly or quarterly intervals, as dictated by the sampling and analysis plan. No other activities in the area of the PTZ installation will interrupt the wildlife functions that currently take place there.

Threatened and endangered species. It is expected that impacts to the habitat of the Indiana Bat may occur in some instances of implementing of this alternative. If the implementation is near the existing plant, the impacts will be none to minimal since much of the area is clear already. If the implementation is nearer the Ohio River or in the area of the Little Bayou Creek, the impacts may be larger. This is due to presence of more potential habitat in that area. The habitat, as mapped by Bryan (COE 1993), indicates that increased density of potential habitat occurs at the extreme ends of the Northwest Dissolved Phase Plume. However, since the actual location or locations for implementation have not been determined, the actual impact cannot be determined. After detail design of the alternative, it will be necessary to perform a reanalysis of impacts. No impacts are anticipated for this alternative.

Cultural resources. No long-term effects are anticipated for this alternative.

Groundwater. Activities associated with this alternative are designed to intercept and treat the contaminated groundwater migrating from the PGDP through the use of PTZs. The PTZs will treat the contamination currently moving from the PGDP to potential receptors outside the DOE property. This will eventually remove the risk currently associated with the off-site groundwater. The VOCs are destructed, while the ^{99}Tc is captured on the reactive media making up the zone. A groundwater-monitoring program will track and monitor the presence of the groundwater contaminants during the treatment period.

Surface water. Permeable Treatment Zone Technology has no detrimental effect on the surface water near PGDP, but it might have a positive impact, depending upon the implementation area. A seasonal surface water connection with the shallow groundwater occurs along a stretch of the Little Bayou Creek northeast of the PGDP (Fryar 2000). The installation of a PTZ upgradient of the creek will intercept and treat this groundwater in the RGA before it can impact the Little Bayou Creek. This would remove potential COCs that could be intercepted by Little Bayou Creek before discharge into the Ohio River. Modeling predicts that such an impact potentially could occur in 15 years or less.

Floodplains. This alternative should have no impact on the floodplains, since it should not be installed within the floodplains.

Wetlands. The installation of this alternative may have only minimal impact on wetlands. The wetlands in the area of the PGDP occur due to surface water flow into poorly drained soils without adequate recharge into the RGA. Since the implementation of this alternative occurs in a linear fashion, there are limitations to moving the alignment of the zone to prevent impacts to wetlands in the area of concern. Directional drilling, if necessary, can be used to prevent impacts on small scale wetlands. During construction activities, every effort will be made to avoid wetlands during the installation of the injected PTZ. Any damaged areas will be repaired or replaced as part of the construction activities.

Soils and prime farmland. There will be long-term impacts in implementing this alternative. Minor impacts will occur during construction. Impacts will be mitigated using standard DOE construction practices, which place erosion and drainage control at construction areas. Spills of contaminated water will be controlled by engineering practices for spill containment. The impacts will be in the form of monitoring wells and associated access road. The amount of impact to land cannot be determined until a remedial design is completed, which will allow the length of the PTZs to be determined.

Transportation. No long-term direct or indirect effects are anticipated for this alternative. The implementation of this alternative will result in the transportation of iron media, soil samples, groundwater samples, and a small amount of drilling and injection wastes. Standard engineering practices will be used to ship these materials safely. All regulatory shipping regulations will be used for the shipment of LLW materials.

Cumulative impacts. Cumulative impacts are defined as the incremental impacts of an action when added to other past, present, and reasonable, future foreseeable actions, regardless of what agency or person undertakes such actions. No notable cumulative impacts result from the implementation of this action.

Reduction of Toxicity, Mobility, or Volume through Treatment. The statutory preference is to select a remedial action that employs treatment to reduce the toxicity, mobility, or volume of hazardous substances. This criterion addresses the anticipated performance of the technologies that may be employed to achieve treatment goals. The treatment processes proposed in this alternative includes the injection or installation of PTZs into the RGA in order to treat the contaminated groundwater by reducing the chlorinated solvents and removing the ^{99}Tc.

The locations and lengths of the PTZ installations have not been selected at this time. As the contaminated groundwater flows through these treatment zones, the TCE will react with the media to be reductively dehalogenated to harmless products such as salts, gases, and water, and the technetium is either co-precipitated or sorbed and physically captured in the media by physical filtration. The University of Kentucky currently is studying this mechanism to more closely define the actual mechanisms that occur in the emplacement. However, if PTZs near the existing PGDP security fence are installed to remove both TCE and ^{99}Tc and treat the entire Northwest, Northeast, and Southwest Plumes, during the 30 years of the active treatment, approximately 50 billion gal (based on current groundwater data) of contaminated groundwater will flow through these treatment systems. The reduction of source zone volume is limited to that obtained through dissolution of the DNAPL under the same conditions as the No Action alternative. Accordingly, these zones, if installed, would remove only 20,000 L, 3% of the total volume present, within the first 30 years of implementation. Additional zones could also be installed out in the existing Northwest, Northeast, and Southwest Plumes. These PTZs, if utilized, could treat the untreated plume COCs, which are currently migrating off-site in the high concentration zones. They could be constructed to allow for the possible movement of current plumes of contamination in a wider field of interception. In any amount and locale of implementation, the PTZs will function in a similar manner to remove the COCs from the aquifer. A second set of zones also will provide some redundancy if the first set does not meet treatment goals. Also, another possibility is to install an additional PTZ immediately upgradient of the Little Bayou Creek, where it will intercept the plume before potential exposure in the Little Bayou Creek.

It is expected that the treatment zones will be designed to reduce the COC levels in the aquifer system to MCLs. However, due to the limited rate of migration in the aquifer and the fact that the flushing of COCs from the aquifer media in a natural system may take several pore volumes, it may take additional time for the aquifer COC concentrations to be reduced to MCLs. However, the treatment goals of the PTZ will be to treat the COCs to MCLs in the PTZ.

Experiments are being conducted in the treatability study to determine the dynamics of the technetium reactions in the media. The currently anticipated rate of precipitation and filtration in the media should provide for the capacity of the media to allow for stabilization in the PTZ during its useful life and far into the next century. However, a more accurate estimate of the stabilization mechanisms and the rate at which the ^{99}Tc is taken up and held will need to be documented after completion of the treatability studies.

Following installation of the PTZs, no further residuals from the implementation are anticipated. Drilling and construction wastes will be created during the installation of the PTZs. It is currently anticipated that the media will remain in the aquifer at the end of its useful life. It will, however, still contain the stabilized ^{99}Tc in the matrix of the media in the aquifer following the treatment phase of the system. The installation of the PTZ technology is essentially irreversible due to the placement of the reactive media at depth. It would be virtually impossible to remove the media under normal construction means.

The PTZ Technology, as mentioned above, reacts to capture only the ^{99}Tc contaminant. To that end, the ^{99}Tc will be a treatment residual located at depth in the RGA and located on the reactive media. It is not known at this time, the length of time the ^{99}Tc will remain absorbed to the reactive media. Since the VOCs are destructed *in situ*, the PTZ Technology qualifies for the statutory preference for treatment of contaminants under CERCLA.

Short-Term Effectiveness. This criterion involves evaluating alternative for community protection, worker protection, environmental impacts, and the time until remedial response actions are achieved. A discussion of each is provided in the following paragraphs.

Community protection. The potential for adverse impacts to the community from the implementation of this alternative is minimal. It is expected that implementation locations will be selected to minimize impacts to the community especially in the Northeast Plume where private land is present above the plume. The other plumes have little private land in their respective areas. The land is predominantly owned by DOE, TVA, and the WKWMA.

Worker protection. PTZ Technology has the potential for worker exposure to contaminated soil and groundwater during installation. Potential exposures include dermal exposure and inhalation of dusts. Procedures and PPE will minimize the potential for exposure.

Potential environmental impacts and mitigating measures. Short-term environmental impacts are assessed and include an evaluation of sensitive resources, socioeconomic, cultural resources, cumulative impacts and other activities in the area.

Land use. There would be limited impacts to land use in the short term. During implementation, areas for would be used for access road, monitoring well installations, and injection wells. Following completion of the construction, the area of the injection wells would be returned to its original use. However, the monitoring wells and access roads would remain in place. A LUCIP would be developed, as necessary, per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomic. The socioeconomic conditions of the PGDP area would not change with implementation of the PTZ Technology. There would be a limited number of temporary construction jobs that result from its installation.

Air quality and noise. During implementation of PTZ technology, local dust suppression procedures and practices will be used for the drilling and injection phase of the construction.

Noise levels would be increased during construction, but are not expected to be above those noise levels that occur during normal plant maintenance and operations. Ambient noise levels in the area of the PGDP would not change from present conditions; thus, no noise impacts would occur.

Vegetation. There would be adverse impacts to vegetation as a result of this alternative due to construction of additional off-site injection and monitoring wells. The location selected for the placement of the PTZ will actually determine the level of impacts. If the selected area is near the current PGDP, the limits will be minimal since these areas are relatively clear of trees. If the selected area is nearer the Ohio River or Little Bayou Creek, the impacts will be larger due to the heavy vegetation in those areas. Methods to mitigate the loss of the trees will include the use of direction drilling as possible and the use of limited vegetation reduction during construction. All necessary rehabilitation practices also will be used to revegetate the areas at the completion of construction.

Wildlife. As mentioned above, the construction activities at the PTZ locations might disrupt some of the vegetation in the construction area; therefore the wildlife in the area also will be impacted. However, these activities will only take a short period of time during the year of the construction phase for any given area. Activities during the remainder of the life of the project should include monitoring well visits to take required samples at monthly or quarterly intervals as dictated by the sample and analysis plan. No other activities in the area of the PTZ installation will interrupt the wildlife functions, which currently take place there. The mitigative measures discussed in the *Vegetation* section also will be implemented, as feasible, to control impacts to wildlife.

Threatened and endangered species. It is expected that impacts to the habitat of the Indiana Bat may occur in some instances of implementing of this alternative. If the implementation is near the existing plant, the impacts will be none to minimal since much of the area is clear already. If the implementation is nearer the Ohio River, or in the area of the Little Bayou Creek, the impacts may be larger. This is due to presence of more potential habitat in that area. The habitat, as mapped by Bryan (COE 1993), indicates that increased density of potential habitat occurs at the extreme ends of the Northwest Dissolved Phase Plume. However, since the actual locations for implementation have not been determined, the actual impacts cannot be determined. However, after detail design of the alternative, it will be necessary to perform a reanalysis of impacts. No impacts are anticipated for this alternative.

Cultural resources. No adverse impacts to cultural resources were identified for this alternative.

Groundwater. Implementation of PTZ Technology is not expected to have any adverse impact on groundwater hydrology and ambient flow conditions. However, positive improvements in the reduction in COC concentrations from the installation of the PTZ should be apparent in less than 6 months following installation.

There are four potential failure areas that may impact the PTZ. These include incomplete breakdown of the TCE, desorbing of ^{99}Tc and fouling of the zone, or improperly matching the surrounding permeabilities. The incomplete breakdown of the TCE due to insufficient residence time in the zone could result in the release of breakdown products such as vinyl chloride, which then would result in its presenting a risk. The ^{99}Tc will be absorbed in the zone. However, it is not destroyed and, as such, may be released as some point in the future. Also, since the zone is constructed by putting non-native material into the subsurface, if the permeabilities are not matched sufficiently, the zone could result in preventing flow of groundwater through it and migrating the location of the contaminant plume. Biological action by bacteria can foul the zone and impact the flow of groundwater through the zone, also resulting in the relocation of the contaminant plume. Thus, the potential adverse impacts of the PTZ in the alternative could be the failure of the system to completely remove TCE from migrating groundwater, recontaminating with degradation product, or relocation of the contaminant plume. This would result in the recontamination of dissolved-phase plumes with other compounds or contaminating previously uncontaminated groundwater. The treatability testing of the PTZ technologies should indicate the potential of these failures before completing the implementation of this alternative.

Surface water. No short-term adverse impacts are expected for surface water from implementing this remedy. However, if the PTZ is selected for installation near the Little Bayou Creek and the TVA Shawnee Steam Plant, improvements in the surface water resulting from the influence on Little Bayou Creek should be measurable after as little as 15 months of installation.

Floodplains. PTZ Technology would not have an adverse effect on floodplains. The action should not take place in any floodplain of any stream at PGDP.

Wetlands. The installation of this alternative may have only minimal impact on wetlands. The wetlands in the area of the PGDP occur due to surface water flow into poorly drained soils without adequate recharge into the RGA. Since the implementation of this alternative occurs in a linear fashion, there are limitations to moving the alignment of the zone to prevent impacts to wetlands in the area of concern. Directional drilling, if necessary, can be used to prevent impacts on small-scale wetlands. During construction activities, every effort will be made to avoid wetlands during the installation of the injected PTZ. Any damaged areas will be repaired or replaced as part of the construction activities.

Soils and prime farmland. There will be short-term impacts in implementing this alternative. Minor impacts will occur during construction. Impacts will be mitigated using standard DOE construction practices, which place erosion and drainage control at construction areas. Spills of contaminated water will be controlled by engineering practices for spill containment. The impacts will be in the form of monitoring wells and injection wells and associated access road. The amount of impact to land cannot be determined until a remedial design is completed, which will allow the length of the PTZs to be determined.

Transportation. No long-term direct or indirect effects are anticipated for this alternative. The implementation of this alternative will result in the transportation of iron media, soil samples, groundwater samples, and a small amount of drilling and injection wastes. Standard engineering practices will be used to ship these materials safely. All regulatory shipping regulations will be used for the shipment of LLW materials.

Cumulative impacts. Cumulative impacts are defined as the incremental impacts of an action when added to other past, present, and reasonable, future foreseeable actions, regardless of what agency or person undertakes such actions. No notable cumulative impacts result from the implementation of this action.

Time until remedial response objectives are achieved. The use of groundwater downgradient without the presence of the PTZs may require 7,000 years to reach acceptable concentrations. Recent modeling indicates that approximately 60 years of attenuation will be necessary after the placement of the PTZs before downgradient groundwater, including that groundwater that may be discharging into Little Bayou Creek, may be used with the protection of the sitewide treatment system (Barber 1999). However, implementation of this alternative will not result in the achievement of the specified GWOU RAOs or the MCLs upgradient of the PTZ technology without the implementation of additional groundwater alternatives to remove the Primary and Secondary Sources.

Implementability. Activities to be conducted under this alternative include continuation of the existing environmental monitoring activities to track COC migration and placement of PTZ Technology to remediate migrating contaminated groundwater.

Technical feasibility. Implementation of Dissolved Phase Plume – Permeable Treatment Zone Technology is technically feasible. Similar PTZs have been installed in at least five other sites in a similar manner. More than 37 PTZs have been constructed in the last decade. For more information on the existing installations, refer to www.rtdf.org. However, one of the goals for the demonstration project being conducted in 2000 and 2001 is determining the constructability of such a PTZ in the actual conditions of the Southwest Plume area. There are, however, only a limited number of vendors that are currently experienced in the installation of the PTZ Technology. The PTZ Technology also is incompatible with some other technologies such as oxidation. The PTZ Technology results in a strongly reducing environment. As such if an oxidant is placed in the PTZ, there will a reaction and the actions will offset one another, damaging the capacity to remove contaminants.

Administrative feasibility. The currently anticipated treatability study for the Southwest Plume will assure administrative feasibility and availability of services and materials for the PTZ at the PGDP site. It is anticipated that an ARAR waiver will be required for this alternative since MCLs will not be attained in a timely manner.

Cost. Table 4.20 summarizes the preliminary unit cost estimate for a PTZ Technology Alternative. These preliminary unit cost estimates are based upon FS-level scoping and are intended to aid in selection of a preferred alternative. The estimates have an expected accuracy of -30 to +50% for the proposed scope of action (EPA 1988a). The capital cost estimate represents those expenditures required to implement this remedial alternative. The O&M cost estimates represent expenditures required to maintain the remedy after the initial phase of remedial action is completed. The total contingency cost presented includes direct, indirect, and all O&M associated contingency costs. The total cost includes all capital costs, direct and indirect with O&M and associated reports, plus 25% contingency costs, for a 30-year term of comparison. All estimates have been escalated using DOE-approved annual rates and a schedule for the various activities based on similar project experience. Present worth values also are included using a discount factor of 5% (EPA 1988b). (Additional information regarding the preliminary cost estimates is presented in Appendix C.)

Table 4.20. Preliminary unit cost estimate for Dissolved Phase Plume Area – Permeable Treatment Zone Technology

Total unit capital costs (per acre-foot)	$58,328
Total operation and maintenance costs	$22,763
Overhead	$63,122
Total contingency	$36,053
Total cost	**$180,269**
Total cost (present worth)	**$124,285**

Note: preliminary cost estimates are per acre-foot, escalated and presented in thousands of dollars. The per acre-foot cost is equivalent to two 600' × 50' × 0.5' panels.

State/Commonwealth Acceptance. Commonwealth of Kentucky acceptance or nonacceptance of this alternative will be addressed in the ROD should PTZ Technology for treatment of Off-site Dissolved Phase Plume be the preferred alternative.

Community Acceptance. Following a formal public comment period on the PRAP for the GWOU, comments from the community will be addressed formally in a responsiveness summary, which will be presented in the ROD.

Evaluation summary of Dissolved Phase Plume Area – Permeable Treatment Zone Technology

Permeable Treatment Zone Technology would provide treatment for the existing plumes as they migrate. This will minimize the potential exposure of residents or visitors to potential groundwater contamination beyond the location of the PTZ Technology. Since the source areas upgradient of the PTZ Technology will remain a continuing source of contamination, which will require monitoring and treatment by the PTZs, risks will remain in the source areas for long periods of time. This will require the maintenance of the PTZs for treatment of the contamination for long periods of time. Extended monitoring and maintenance will be required to provide protection from this alternative.

The PTZ Technology is technically and administratively feasible. It also will result in the *in situ* destruction of VOCs and the capturing of ^{99}Tc on the reactive media. The capital cost of implementing the PTZ Technology is large. The use of the PTZ Technology near the area of interaction of the Northwest Plume and Little Bayou Creek could protect against the release of contaminants to the surface water. Input from the Commonwealth of Kentucky and the general public has not been obtained yet.

4.2.4.4 Dissolved Phase Plume Area – Oxidation Technology

The following subsections contain a description of Dissolved Phase Plume Area – Oxidation Technology Alternative and the detailed analysis.

Description of Dissolved Phase Plume Area – Oxidation Technology

This alternative would consist of implementing an Oxidation Technology in portions of or over the entire RGA dissolved phase plume areas located in both the PGDP On-site Secure Area and the Off-site Unsecure Area. Unlike the Secondary Source Area technologies evaluated above, the Oxidation Technology in this alternative would be designed to remove only dissolved phase contaminant concentrations. In this technology, a series of injection wells would be drilled into the RGA in the target areas. The injection wells could be installed in a linear pattern transecting the plume migration route, or they could be installed a blanket type fashion in which wells would be spaced periodically across the entire plume area. The injection wells then would be used to inject into the zone of interest, the RGA, an oxidizing compound such as potassium permanganate or sodium permanganate. The oxidizing compound then would react with the VOCs, or TCE DNAPL, and they would be destroyed from the reaction with the oxidant. Using the linear pattern, the oxidant would travel with the groundwater and oxidize the contaminants. The linear patterns would be spaced such that the oxidant would not spend, or become ineffective, before reaching the next downgradient injection pattern. Using the "blanket" installation, the wells would be spaced in the remedial design to allow the oxidant to be injected over the entire target area thereby oxidizing the entire area of concern. The ^{99}Tc contamination would not be remediated by the oxidation technology. The use of this alternative will be performed *in situ* and will not require any *ex situ* treatment of produced water or release of air emissions. It will, however, require, as discussed above, the placement of injection wells and injection equipment to effect the introduction of oxidant into the RGA.

Figure 4.12 contains a "snapshot" that graphically summarizes what is involved in the application of Oxidation Technology to the Dissolved Phase Plume Area.

The dissolved phase contaminant reduction efforts of implementing this technology in the dissolved phase plume areas will have only minimal impact on returning the groundwater to beneficial use. This is due the fact that without the removal of primary and secondary sources located beneath the PGDP plant areas, the plumes will regenerate over time due to the presence of dissolving DNAPL concentrations of TCE. Due to the presence of the sources, the groundwater will not be returned to beneficial use for approximately 7,000 years. Oxidation Technologies will not remove ^{99}Tc as part of the operation. This is due to the ^{99}Tc element not being destroyed as a result of oxidation. Additional measures will be required to remove the ^{99}Tc from the Off-site Plume Areas.

The existing groundwater monitoring program, which is being implemented under a separate action, would be continued to monitor the movement of COCs within the RGA. The monitoring program will integrate existing PGDP monitoring wells, where possible, with additional monitoring wells to be installed as needed following a review of the existing program.

Five-Year Reviews. This remedial alternative would result in residual "contaminants remaining at the PGDP site above levels that allow for unlimited use and unrestricted exposure"; therefore, this remedial action would be reviewed "no less often than every five years" in accordance with 40 *CFR* 300.430 (f)(4)(ii).

4.2.4.4.2 Assessment of Dissolved Phase Plume Area – Oxidation Technology

The detailed analysis of this alternative using the CERCLA criteria is presented in the following subsections.

Overall Protection of Human Health and the Environment. Dissolved Phase Plume Area Oxidation Technology includes the *in situ* treatment of dissolved phase concentrations of VOCs in the RGA. Although this technology is applicable to the reduction of Secondary Source Area concentrations, this detailed analysis is only for dissolved phase areas of the plumes. The technology would reduce VOC contamination

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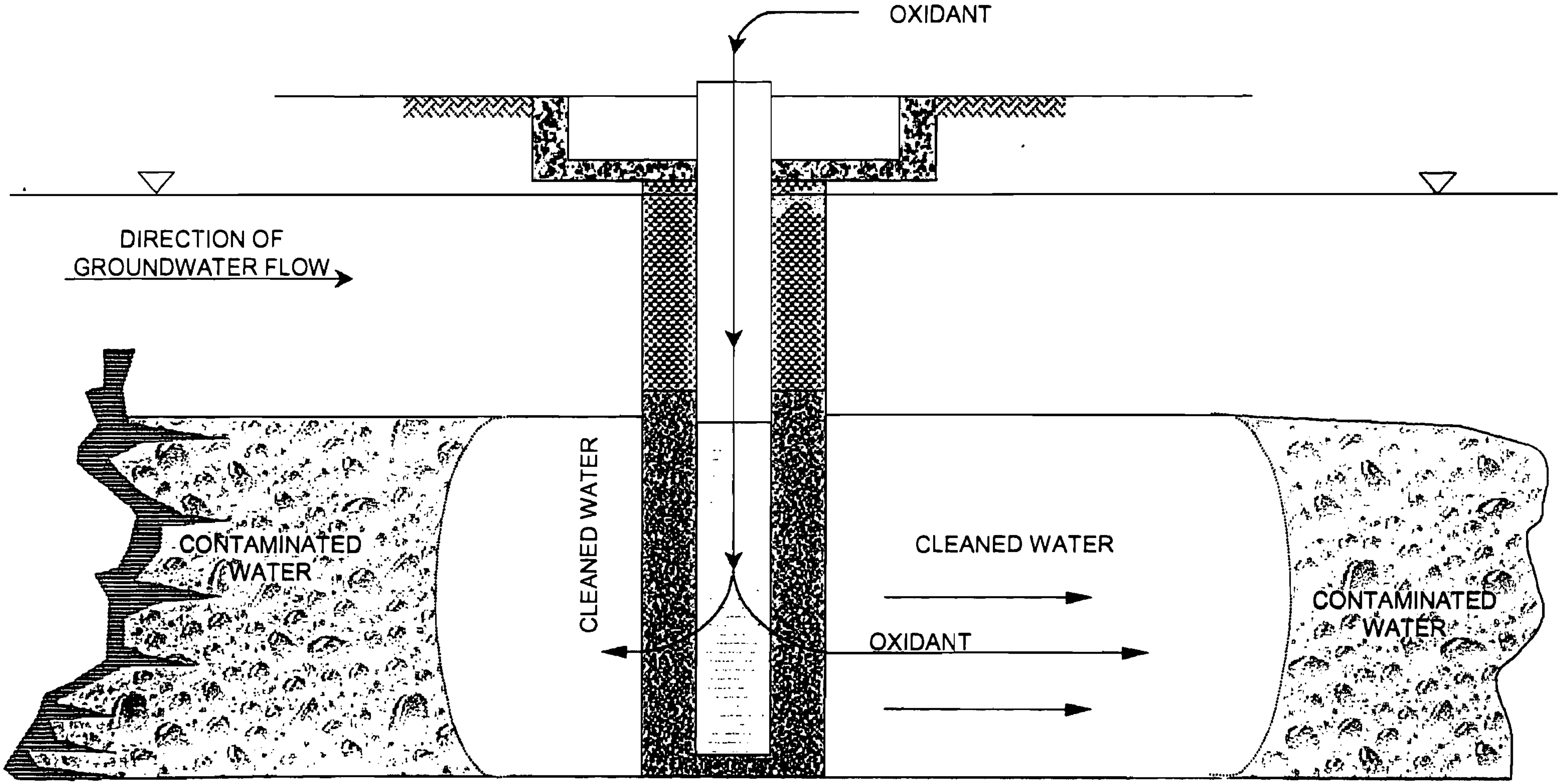


U. S. DEPARTMENT OF ENERGY
DOE OAK RIDGE OPERATIONS
PADUCAH GASEOUS DIFFUSION PLANT

BECHTEL JACOBS COMPANY, LLC
MANAGED FOR THE US DEPARTMENT OF ENERGY UNDER
US GOVERNMENT CONTRACT DE-AC-05-98OR22700
Oak Ridge, Tennessee • Paducah, Kentucky • Portsmouth, Ohio

Science Applications
International Corporation
P.O. Box 2502
Oak Ridge, Tenness 831

Fig. 4.12. Dissolved phase plume area - oxidant technology.

FIGUF FS4-12
DATE 05-25-01

in the RGA only. It is not expected that oxidation have any impact on the ^{99}Tc contamination present in the treatment area. The ^{99}Tc present in the RGA is chemically oxidized to it highest potential state of TcO_4. However, should the oxidant encounter ^{99}Tc in a reduced state, the oxidant may increase dissolved levels of ^{99}Tc in the groundwater. This alternative alone will not satisfy the RAOs for the GWOU. It will support achieving the RAOs, when implemented in concert with other source reduction and dissolved phase GWOU technologies. It is possible for this alternative to be protective of the ecological receptors that may be exposed to contaminated groundwater discharging to the surface water. This is possible due to the low levels of ^{99}Tc present in the groundwater in the areas of the Little Bayou Creek. However, for this to be permanent when implemented alone, the technology will require repeat applications in the target area; without DNAPL source removal, the plumes will regenerate over time.

Compliance with ARARs. An alternative must meet this threshold criterion to be eligible for selection. The following discussion summarizes the potential ARARs and TBC Guidance for use of Oxidation Technology.

Potential chemical-specific ARARs. The potential chemical-specific ARARs for this alternative are summarized in the following paragraphs.

Chemical contamination. The aquifers are known to contain chemical contaminants in the form of metals and organics. The federal and state water quality requirements include standards that would be applicable ARARs. The regulations that apply are found in 40 *CFR* 141 (National Primary Drinking Water Standards); 40 *CFR* 143 (Secondary Drinking Water Standards); 401 KAR 5:029 (General Provisions); and 401 KAR 5:031 (Surface Water Standards). These standards, summarized in Table 4.22, include general state standards, domestic water supply standards, and standards applicable to warm water aquatic habitat. These are applicable based upon the classification of the designation for surface water use associated with the area (Ohio River, River Mile 940.7 to River Mile 943.3) as specified in 401 KAR 5:026. All potentially applicable chemical ARARs for COCs have been included in the table for completeness. Those standards that must be achieved in order to meet the applicable requirements are the lowest of the applicable standards, which in most cases are the MCLs.

Radiological contamination. The OU is known to be contaminated with radionuclides such as ^{99}Tc, radon, uranium, and uranium daughter products. DOE's Order on Radiation Protection of the Public and Environment, DOE Order 5400.5, is TBC information for cleanup of radionuclides at DOE sites. The order requires that remediation activities must not result in radiation exposures to members of the general public greater than an EDE of 100 mrem/year from all exposure pathways. Exposure to the general public also must be ALARA (DOE 1990).

The DOE Order 5400.5 also contains reference values, known as DCGs, for operational DOE facilities. Based on the DCGs, radionuclide concentrations in air and drinking water must not exceed an EDE of 10 mrem/year and 4 mrem/year, respectively to the total body or any organ.

The NRC also has set criteria for decommissioning standards at nuclear facilities at 10 *CFR* 20 Subpart E. These rules require that residual radioactivity at nuclear sites meet a total EDE of 25 mrem/year for unrestricted release. In addition to the NRC standards, EPA has issued guidance for cleanup levels at CERCLA sites with radioactive contamination. EPA has disagreed with the protectiveness specified within the NRC standard and has specified that a 15 mrem/year EDE be used as the risk level that is protective of human health and the environment. EPA also has codified exposure limits for environmental radiation protection standards for nuclear power operations at 40 *CFR* 190. These requirements apply to operations involved in uranium fuel cycle and include enrichment operations. Subpart B of these requirements specifies that the annual dose equivalent to the public must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughter products excepted, to the general environment from uranium fuel cycle operations and to radiation from these operations. These requirements would be considered relevant and appropriate because the release to the groundwater would not be planned.

The Commonwealth of Kentucky is an NRC Agreement State and has promulgated regulations for radiation protection of the public. The Kentucky radiation protection standard for individual members of the public is 0.1 rem (100 mrem) EDE per year or less (902 KAR 100:019 Section 10), which is equivalent to the DOE radiation protection standard found in DOE Order 5400.5.

Due to the differing views and values among NRC, EPA, and DOE total EDE for members of the general public, EPA and DOE have agreed not to finalize their respective standards until an agreement can be reached. In the interim, DOE Order 5400.5 is identified as TBC information and the NRC standard is identified as relevant and appropriate. Therefore, the radiation protection standard identified within the NRC regulations at 10 *CFR* 20 Subpart E requiring an EDE of 25 mrem/year or less shall be used as the exposure limit for the general public.

Chemical-specific ARAR summary. The chemical-specific ARARs associated with the implementation of this alternative are outlined in Table 4.21. Implementation of this alternative would not result in immediate attainment of the chemical-specific ARARs associated with the off-site groundwater plumes. Attainment of the identified ARARs would be met in the future as implementation progresses. Continued monitoring of the groundwater will be used during the five-year reviews to ensure the identified goals are met and that concentrations of COCs continue to decrease.

Potential location-specific ARARs. The potential location-specific ARARs for Alternative 3 are summarized in the following paragraphs.

Wetlands. Wetlands have been identified within the area where construction activities will occur, and certain jurisdictional wetlands have been identified in on-site drainage ditches within the plant boundary. In order to comply with these applicable requirements wetlands shall be avoided.

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, 40 *CFR* 6.302(a), 40 *CFR* 6 Appendix A, and 10 *CFR* 1022). These applicable requirements include avoiding construction in wetlands, avoiding (to the extent practicable) long-term 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. Although not anticipated, if this alternate results in impacts to wetlands that cannot be avoided, the substantive requirements of the NWP 38 (33 *CFR* 330) will be met.

Off-site operations are expected to impact wetlands, and all treatment will be conducted either *in situ* or in units already in operation. To the extent possible, wetlands will be avoided through the use of selected drilling sites and directional drilling.

Endangered Species and Migratory Birds. Actions taken by federal agencies are prohibited from impacting T&E species or adversely modifying critical habitat (50 CFR 17.94) in accordance with the Endangered Species Act (16 USCA 1531 *et seq.* Section (7)(a)(2)). These requirements are potential ARARs in the event T&E species or their habitats are found at or near areas where remedial action is to occur. An ecological resource investigation inside the PGDP security fence did not detect any T&E species or their preferred habitats (CDM Federal 1994). The USFWS has not designated critical habitat for any species within the DOE property. However, outside the PGDP fence on the DOE property, potential habitats for

Table 4.21. Summary of potential ARARs for Dissolved Phase Plume Oxidation Technology

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Chemical-Specific ARARs	
National Primary Drinking Water Standards	40 *CFR* 141	Provides chemical-specific numeric standards for toxic pollutants expressed as MCLs and MCLGs.	These requirements are relevant and appropriate due to the nature of the contaminants found within the groundwater.
National Secondary Drinking Water Standards	40 *CFR* 143	Provides secondary MCLs for public water systems.	These requirements are TBCs, as they have been established as guidelines for the states and are not federally enforceable.
Kentucky Surface Standards including • Warm Water Aquatic Habitat Criteria • Kentucky Domestic Water Supply • Kentucky General Standards • Kentucky Outstanding State Resource Waters	401 KAR 5:031 and 5:026	Provides chemical-specific numeric standards for pollutants discharged or found in surface waters. Provides chemical-specific numeric standards for pollutants in domestic water supplies.	These standards are applicable to the segment of the Ohio River into which the Little Bayou Creek discharges. The requirements found in these standards are applicable due to the groundwater to surface water interface to Little Bayou Creek and subsequently to the Ohio River. Note: CWA Water Quality Criteria are not relevant and appropriate because Kentucky has promulgated these state standards that Kentucky has determined to be appropriate for waters of the Commonwealth.
Radiation Exposure of the General Public at DOE Facilities	DOE Order 5400.5	Specifies that the general public must not receive an effective dose equivalent of >100 mrem/year from all exposure pathways. In addition, all release of radioactive materials resulting in doses to the general public must meet the ALARA criteria.	This requirement is TBC information.
Decommissioning Standards at Nuclear Facilities	10 *CFR* 20, Subpart E	Specifies a residual activity at nuclear facilities for unrestricted release of 25 mrem/year.	These standards are considered to be applicable to the GWOU.
Environmental Radiation Protection Standards for Nuclear Power Operations	40 *CFR* 190, Subpart B	Requires that the annual dose equivalent to the public must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment from uranium fuel cycle operations and the radiation from these operations.	These standards are considered to be relevant and appropriate and are equivalent to the NRC standards.

Table 4.21. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Location-Specific ARARs	
Protection of Wetlands	10 *CFR* Section 1022, Executive Order 11990 40 *CFR* 230.10 33 *CFR* 330.5	Activities must avoid or minimize impacts to wetlands to preserve and enhance their natural and beneficial value. If wetland resources are not avoided, measures must be taken to address ecologically sensitive areas and mitigate adverse effects. Such measures may include, minimum grading requirements, runoff controls, design, and construction considerations. Allows minor discharge of dredge and fill material, or other minor activities for which there are no practicable alternatives, provided that the pertinent requirements of the NWP system are met.	These requirements are applicable due to the presence of wetlands, but will be met though avoidance of wetlands during construction and implementation of alternatives.
Endangered Species Act	16 U.S.C. 1531 et seq. Section 7(a)(2)	Actions that jeopardize the existence of listed species or result in the destruction or adverse modification of critical habitat must be avoided or reasonable and prudent mitigation measures taken.	Action that is likely to jeopardize fish, wildlife, or plant species or destroy or adversely modify critical habitat-applicable.
Migratory Bird Treaty Act	16 U.S.C. 703-711 Executive Order 13186	Federal Agencies are encouraged (until requirements are established under a formal MOU) to do the following: • avoid or minimize, to the extent practicable, adverse impacts on migratory bird resources when conducting agency actions; • restore and enhance the habitats of migratory birds, as practicable; • prevent or abate the pollution or detrimental alteration of the environment for the benefit of migratory birds, as practicable; • ensure that environmental analysis of federal actions required by the NEPA or other established environmental review processes evaluate the effects of actions and agency plans on migratory birds, with emphasis on species of concern; and • identify where unintentional take will likely result from agency actions, and develop standards and/or practices to minimize such unintentional take.	Action that is likely to impact migratory birds, habitats, and resources-applicable.

Table 4.21. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
Action-Specific ARARs			
Fugitive Dust Emissions during site preparation and construction activities.	401 KAR 63:010	Precautions must be taken to prevent particulate matter from becoming airborne. Such precautions must be incorporated into the planning and design of activities and include actions such as • wetting or adding chemicals to control dust from construction activities; • using materials such as asphalt or concrete (or other suitable chemicals/fixing agents) on roads or material stockpiles to prevent fugitive emissions; and • using covers on trucks when transporting materials to and from the construction site(s). The requirement specifies that for on-site construction activities, no visible emissions may occur at the PGDP fenceline. Similar points of compliance shall be identified for construction activities that occur outside the fence.	These requirements are applicable and will be met through the use of appropriate dust control practices identified during alternative design phase.
Toxic Emissions	401 KAR 63:022	The regulations require that a determination of toxic emissions be made in order to assess the applicability of required controls. Calculations of the significant emission levels are compared to the allowable emission limits specified in Appendix A of 63:022. If emission levels are exceeded, best available control technologies must be incorporated into equipment/process design.	These requirements are considered to be applicable and shall be complied with through calculation of significant emission levels for toxic materials and application of best available control technology as necessary during the design of the alternative.
Monitoring Well Installation	401 KAR 6:310	Monitoring wells (including extraction wells) must be constructed in a manner to maintain existing protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole. In addition, abandoned wells must be plugged and abandoned in accordance with the requirements specified.	These requirements are considered to be applicable. Compliance with well design and protection standards shall be achieved through the use of approved well design and materials of construction. While in service, wells shall be secured as required. Abandoned wells shall be plugged and abandoned as required.
Discharge of Stormwater	40 *CFR* 122, 401 KAR 5:055	Stormwater discharges from construction activities on-site are subject to the requirements of the KPDES permit. This requires that BMPs to control stormwater runoff and sedimentation be employed. Although off-plant construction activities within the contaminated area are not subject to the permit, these requirements should be considered relevant and appropriate and be incorporated into any off-site construction activities.	These requirements are considered applicable for all on-site construction or treatment activities where a discharge of stormwater or treated groundwater occurs. For off-site construction activities, these requirements are considered relevant and appropriate and will be adhered to. Compliance with these ARARs shall be achieved by application of required controls during the design phase of the alternative.

Table 4.21. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
Hazardous Waste Management	40 *CFR* 260 through 268; 401 KAR 32 through 37	All wastes or environmental media containing wastes must be characterized to determine whether the waste also is a hazardous waste in accordance with 40 *CFR* 262.11 and 401 KAR 32:010. If it is determined that a waste is a hazardous waste or that environmental media contain a hazardous waste subject to the RCRA regulation, the substantive requirements of 40 *CFR* 262 through 268 are applicable. These standards include design and operation of storage and accumulation areas, waste handling and shipment, and treatment technologies or numeric standards applicable to wastes before disposal.	These requirements are applicable and will be complied with through characterization of wastes and environmental media generated as a result of implementation of the alternative. Waste management will be predicated upon the characterization and comply with all substantive requirements associated with hazardous waste management, if identified as such.
PCB Waste Management	40 *CFR* 761	TSCA requirements for the management of PCB wastes or items containing >50 ppm PCBs or from a source of 50 ppm or greater. Requirements include • management of waste and material; • characterization of PCB-containing materials; • labeling and storage for disposal; • manifest completion for shipment off-site; • decontamination of affected equipment or items; and • disposal of PCB wastes. These requirements will be complied with if PCBs are found at concentrations requiring compliance.	These requirements are applicable if PCBs are found or result from items or equipment regulated under 40 *CFR* 761. Activities necessary to comply with these ARARs shall be incorporated into the planning phase of the alternative implementation.

ALARA = as low as reasonably achievable
ARAR = applicable or relevant and appropriate requirement
BMP = best management practice
CFR = *Code of Federal Regulations*
CWA = Clean Water Act
DOE = U.S. Department of Energy
GWOU = groundwater operable unit
KAR = Kentucky Administrative Regulation
KPDES = Kentucky Pollutant Discharge Elimination System
MCLGs = maximum containment level goals
MCLs = maximum contaminant level
NRC = Nuclear Regulatory Commission
NWP = Nationwide Permit
PCB = polychlorinated biphenyls
PGDP = Paducah Gaseous Diffusion Plant
TBC = to be considered
TSCA = Toxic Substances Control Act

federally listed T&E species were reviewed and Indiana bat habitat was evaluated during the COE (1994) environmental investigation. The COE study determined that total potential bat habitat consisted of 20% of the 994-ha (2,456-acre) study area. Remedial activities must be evaluated to ensure that such actions do not adversely impact areas identified as critical habitat for any identified endangered species.

In addition, Executive Order 13186 directs federal agencies to enter into an MOU with the USFWS to further the purposes of the Migratory Bird Treaty Act (16 U.S.C. 703-711). Until such time as the MOU between DOE and the USFWS is finalized, Federal agencies are encouraged immediately to begin implementing the conservation measures set forth in the Executive Order. The requirements of the Executive Order are applicable and must be considered during planning and design of the remedial action.

Potential action-specific ARARs. The potential action-specific ARARs for the Dissolved Phase Plume Oxidation Technology alternative are summarized in the following paragraphs.

Monitoring and injection well installation requirements. This alternative includes the installation of additional monitoring and injection wells. Installation of these wells would have to be conducted in a manner to maintain existing natural protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole (401 KAR 6:310 Section 13). These requirements also mandate the construction materials required for well construction, well design criteria, well completion activities, and well abandonment methodologies. These requirements are considered applicable to design and installation of monitoring and extraction wells associated with the implementation of this alternative.

Fugitive dust emissions. Construction activities for well installation may result in the production of particulate airborne pollutants (dust). The Kentucky Air Quality standards found in 401 KAR 63:010 include requirements governing fugitive dust emissions. These standards require that dust-suppression measures be undertaken that include activities such as use of water or chemicals to control emissions, placement of asphalt or concrete, and stockpiling of soils. The standards also require that visible dust generated from the implementation of the remedial alternative not be discharged beyond the property boundary of the site or the construction location. These requirements are considered to be applicable to the implementation of this alternative and will be complied with through the planning to ensure that construction activities incorporate appropriate controls (e.g., wetting, covering, etc.) to control dust generation. Specific activities that could result in the generation of fugitive dust must be considered during the design phase include construction and well installation.

Radionuclide emission standards. Airborne emissions of radionuclides may occur as a result of construction activities. Although this potential is low for such emissions to occur, the regulations at 40 *CFR* 61.92 would require that the emissions not exceed amounts that would cause an EDE to the public of 10 mrem/year. In order to determine whether the alternative complied with this applicable requirement, computer modeling using the CAP-88 or other EPA-approved models must be undertaken. If the modeling demonstrates the radionuclide emission to be in excess of 1% of the 10 mrem/year standard, emission rates must be measured, as required by 40 *CFR* 61.93. This ARAR shall be complied with by planning activities in such a manner as to control fugitive emissions from construction activities.

Toxic emission standards. Although toxic emissions are not expected as a result of construction activities or with the *in situ* treatment of the groundwater, these emission requirements would be applicable if such emissions do occur. Due to organic concentrations found in the groundwater and potentially within the subsurface soils at depth, there is a low potential for such emissions to occur. The regulations at 401 KAR 63:022 require that the emissions be evaluated to determine whether they are significant for each specific toxic air pollutant. If analysis indicates the toxic emission requirements are triggered, the regulations specify that no source may exceed the allowable emission limit specified in Appendix A of 401 KAR 63:022. If applicable, these rules would require the application of best available control technology to limit toxic emissions. If calculations indicate that the emission rates specified within the rule are not exceeded, the calculation package may be used to demonstrate compliance with these requirements.

Stormwater discharge. Construction/well installation activities will be subject to the substantive requirements associated with the KPDES permit that requires the use of BMPs and sediment/erosion controls to control transport of sediment in stormwater runoff. In addition, groundwater produced from monitoring well development operations will be treated in a wastewater treatment unit where discharge will be subject to the substantive requirements of the KPDES program. These requirements are considered to be applicable.

Waste management requirements. Hazardous materials and wastes may be generated during the implementation of this alternative. It is anticipated that these wastes will be low-level radioactive wastes and, therefore, subject to the DOE Order 435.1 requirements that apply to the management of all radioactive wastes generated at DOE facilities. This requirement is TBC rather than applicable or relevant and appropriate, because it is a DOE Order rather than a federal or state regulation or standard.

The potential exists that some of the wastes generated from well installation may be RCRA hazardous wastes as defined in 40 *CFR* 261 of the federal program. All wastes generated shall be subject to the hazardous waste determination requirements of 40 *CFR* 262 and 401 KAR 32:010. If it is determined that any wastes are, in fact, hazardous wastes, the materials must be managed in accordance with the substantive requirements found in 40 *CFR* 262 through 40 *CFR* 268 (401 KAR 32 through 37). These standards include storage requirements, transportation requirements, and disposal requirements. Specific requirements applicable to each waste stream must be identified after characterization of the material is complete. These requirements shall be complied with through the development of a WMP during the design phase of implementation. If materials are identified as RCRA hazardous waste, these requirements are applicable.

Although considered unlikely, the potential exists that wastes generated from the implementation of this alternative may contain PCBs regulated under the Toxic Substances Control Act (TSCA). These regulations would be applicable to this alternative if PCB concentrations were found in soil or water that exceeded 50 ppm or PCBs were found and attributable to a source whose concentration exceeded 50 ppm PCBs. The substantive requirements for management of PCB wastes found in 40 *CFR* 761 would be applicable and include standards for storage, shipment, and equipment decontamination. These requirements shall be complied with through the development of a WMP during the design phase of implementation. If materials are identified as TSCA PCB regulated material these requirements are applicable.

Action-specific ARAR summary. This alternative will trigger action-specific ARARs with regard to the installation of wells and the handling of the potentially contaminated soils from well installation. All wells installed must be conducted in a manner to maintain existing natural protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole (401 KAR 6:310 Section 13). Generated wastes must meet the requirements for compliance with the RCRA requirements for wastes generated as a result of implementation. In addition, the requirements of TSCA may be applicable if PCB-containing materials are identified. This alternative will comply with these requirements during the planning phase to include compliant waste handling, storage, and disposition components. The proposed alternative will comply with the substantive requirements of both the CWA and RCRA because the treatment and discharge of treated effluent, in compliance with the CWA, meets both requirements, and because such treatment is allowed under RCRA. If wastes from treatment of well development groundwater or excavation of soils is determined to be hazardous wastes under RCRA, the substantive requirements for storage, management and disposal of hazardous wastes shall be incorporated into the alternative during the planning phase. Activities that may be required for RCRA and TSCA compliance include use of appropriate containers, labeling of containers, appropriate storage area design and operation (secondary containment or storage for less than 90 days in a compliant accumulation area), and transportation of wastes.

A summary of the ARARs for the implementation of this alternative are presented in Table 4.21.

Compliance with ARARs summary. Implementation of this alternative would not achieve compliance with the MCL for TCE. Compliance at the fenceline has been calculated to occur in approximately 7,000 years. Compliance with the MCL at the DOE property boundary is calculated to occur in approximately 7,000 years. With continuous application of oxidants to prevent the plumes from regenerating, MCLs can be achieved in 15 years. The MCLs applicable to antimony, chromium (action level), and alpha-emitting radionuclides would be exceeded at the point of compliance (plant fenceline) and points of exposure (DOE property boundary, Ohio River) if contaminants were allowed to continue to migrate offsite from source areas, according to the modeling used in the development of this FS. As stated in the risk assessment, the metals and radionuclides, other than ^{99}Tc, based upon historic observations are far less mobile than current modeling indicates. Based on the time frames illustrated in the model required for migration to the point of compliance and the historical observations associated with migration of metals and radionuclides at the PGDP, exceedance of the associated MCLs is considered unlikely.

In order to comply with the identified chemical-specific ARARs, an ARAR waiver will be required due to the time frames required to meet the specified concentrations within the GWOU at the point of compliance and points of exposure.

As discussed, no potential location-specific ARARs have been identified within the area where remedial action will occur. However, to ensure that jurisdictional wetlands are not impacted, all construction activities associated with this alternative will be reviewed as a safeguard. The protection of wetlands is considered a location-specific ARAR at this time, because jurisdictional wetlands have been identified within the areas of implementation of this alternative.

Construction and implementation of the alternative may trigger several action-specific ARARs such as the requirements associated with well installation and abandonment, fugitive-dust emissions, radionuclide emissions, toxic emissions, and discharge of stormwater and treated well-development groundwater. The requirements associated with the installation and abandonment of wells will be met though use of well designs and materials of construction as specified at 401 KAR 6:310 Section 13. All well installations and abandonment practices incorporated into the approved Remedial Design shall comply with the substantive requirements of 401 KAR 6:310.

Fugitive dust emissions that may occur during construction activities will be controlled as required by 401 KAR 63:010. BMPs such as wetting or covering of potential sources of fugitive dust will be incorporated into the remedial design. The specific actions to be developed shall control potential emission sources to ensure that dust emissions do not migrate from the immediate area where construction activities occur. It is anticipated that, in most cases, the moisture content in the soil will be sufficient to control dust emissions during well installation. However, practices such as the wetting of disturbed soils, collection of soils, or reseeding activities shall be considered and incorporated into the remedial design, as necessary, to ensure compliance with these requirements. Radionuclide emissions at construction sites also must be considered during the implementation phase. In order to ensure that the emission standard of 10 mrem/year EDE to the public is met, concentrations of radionuclides in soils and groundwater must be evaluated. If the potential for such emissions is identified, modeling using the CAP-88 or other EPA-approved methods must be undertaken during the design phase of the alternative. It is anticipated that the primary conveyance of airborne radionuclides will be in particulate form; therefore, control of fugitive dust emissions will also result in compliance with the emission standards applicable to radionuclides. If radiological contamination from plant activities is found in soils where construction activities are planned, the soil will be protected or containerized to prevent airborne migration. Measures necessary to prevent airborne emissions or radionuclides shall be evaluated and incorporated, as appropriate, into the remedial design in order to comply with these requirements during implementation of this alternative.

Emissions of toxins such as volatile organics also must be evaluated before implementation. Although the potential for exceedance of toxic air emissions is considered to be low, an evaluation of the potential for such emissions must be undertaken during the remedial design. Potential emissions must be evaluated for each toxin present in the plumes (i.e., TCE, vinyl chloride, etc.) to determine whether the contaminant levels found in the subsurface could result in airborne emissions in excess of the allowable limits specified in Appendix A of 401 KAR 63:022. Compliance with the emissions standards shall be achieved for this alternative through the evaluation process or the application of the best available control technology where emissions are calculated to exceed allowable levels. Emission control equipment will be incorporated into implementation activities during the remedial design, as necessary, based upon the initial evaluation. This requirement will be complied with during implementation of the alternative.

The construction activities associated with this alternative will require that BMPs for sedimentation/ erosion controls be established. This requirement will be complied with through the use of sediment fences or other appropriate means. The remedial design shall incorporate the specific controls necessary to ensure that the construction sites do not allow sedimentation and/or erosion of disturbed areas in order to comply with this requirement during implementation of this alternative.

Wastes including secondary wastes generated from the installation of wells will trigger the characterization requirements associated with RCRA. The implementing regulations found at 40 *CFR* 262 and 401 KAR 32:010 require that generators of solid wastes (or contaminated environmental media) must determine whether the waste also is a hazardous waste. If the materials generated from the implementation of this alternative are found to be hazardous wastes, the materials shall be containerized and managed as such. The requirements mandate that hazardous wastes must be properly labeled and stored in areas that comply with the technical standards for storage of hazardous waste in containers. These standards shall be complied with through testing of soils during drilling and waste management activities. If the soils are found to be hazardous, appropriate storage areas shall be constructed and maintained. All hazardous waste generated during the implementation of this alternative shall be shipped for off-site disposal using the EPA Identification Number for the PGDP. Hazardous wastes shall be shipped to facilities permitted to treat, store, or dispose of the hazardous waste(s) being shipped. These activities shall be incorporated into the remedial design for this alternative in order to comply with these requirements.

Wastes including secondary wastes generated during the implementation of this alternative also may be subject to regulation under TSCA as PCB remediation waste and DOE Order 435.1 as LLW. Characterization of these materials will be required in order to determine whether specific wastes are regulated under these requirements. If it is determined that the waste generated is a PCB or LLW, appropriate management standards will be incorporated into the Remedial Design. Existing information will be used where practicable to determine the regulatory status of all waste to be generated before implementation.

Long-Term Effectiveness and Permanence. Dissolved Phase Plume Oxidation Technology offers a relatively high level of long-term control for VOCs contaminants located in areas of the RGA that may be subject to treatment. There would no positive impact to ^{99}Tc concentrations located in the treated areas since ^{99}Tc cannot be destroyed by oxidation. The implementation of this technology only in the RGA will provide little to no control over Primary and Source Area target contaminants located in the UCRS or the RGA. The only exception would the potential for collateral reductions in VOC concentrations when the dissolved phase target AOC is in close proximity of a Secondary Source area. It also should be understood that without the removal of the DNAPL source zones, the plumes will regenerate over time.

Magnitude of residual risk. Residual risk in the RGA will remain in place after implementation of an Oxidation Technology. The technology will require assistance from other technologies, either in the UCRS or RGA, to meet the MCLs at the point of compliance, thereby preventing the regeneration of the dissolved phase plumes. This alternative will reduce VOCs in the dissolved phase plume areas by *in situ* oxidation using an oxidant to react with the contamination. The technology will have no impact on contaminants present in the UCRS or the RGA source areas, unless those areas are targeted for the treatment.

Following treatment of the selected RGA areas, residual COCs would contribute to long-term risks. However, the five-year reviews, mandated by CERCLA [40 *CFR* §300.430(f)(4)(ii)], would be an effective means to demonstrate that contaminant levels were reduced from the technologies implementation, and additional exposure pathways have not developed.

Adequacy and reliability of controls. The reliability for operation and control of Oxidation Technology would be moderate. The components that make up the treatment systems such as an oxidant, injection wells, metering pumps, etc., are common industrial items that have been used for many years successfully. However, a limiting factor in the reliability of the oxidation process is ensuring that the contaminants and oxidants come into contact with one another to allow the reaction to occur. The contact of the two compounds is largely controlled by the subsurface conditions of the RGA and whether liquids can be injected into the areas. The RGA has high permeability; therefore, this limitation is not expected to be encountered. However, variation in the permeabilities from one location to another also will limit the oxidant and the contaminants from reacting. Overtime, the oxidant will migrate into these tighter areas under natural migration just as the TCE.

Another limiting factor is the presence of large amounts of organic material being present in the treatment zone. The oxidant will react with any other organic compounds present as well as with VOCs. If large quantities of organics are present, the oxidant is spent on reacting with these extraneous organic compounds and not reacting with the contaminants. Computer modeling would be used to design the site-specific location, injection well layouts, and oxidant concentrations to ensure appropriately sized treatment zones and that contaminants are not migrated to non-contamination areas due to the injection process and that contaminants are oxidized. It also should be understood that multiple applications of the technology may be warranted to ensure complete coverage of the contaminant plume occurs. However, should extended interruptions of electrical power, fuel, or other vital systems occur, the potential would exist for COCs to escape from the treatment system area. Long-term groundwater monitoring will be required to monitor the extended effectiveness of the treatment following its completion.

Environmental impacts and mitigative measures. The following paragraphs summarize potential long-term impacts to resources and mitigative measures to offset any potential impacts. The depth of impact analysis and mitigative measures is correlated to the degree to which a resource may be impacted.

Land use. Long-term land use impacts would be low for the implementation of this alternative. The long-term impacts will be related to the placement and use of injection and monitoring wells and access roads used in the operation. If it chosen to target the entire off-site plume areas, there could be several hundred injection wells used in such an operation. The areas of use will include the WKWMA, DOE, and TVA, as wells as a number of parcels of privately owned land. The total acreage impacted cannot be determined without first identifying the target areas and determining whether linear injection or blanket type injection is used. However, it is expected that less than one-fourth of an acre per injection well will be impacted in the long term. A LUCIP would be developed as necessary per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomics. The presence of contaminants in the groundwater will prevent its use and may limit economic development opportunities until the groundwater is brought back to beneficial use. However, no long-term effects to socioeconomics would result from the implementation of this technology. There would be few changes to permanent jobs within the PGDP area as a result of implementing this technology.

Air quality and noise. No long-term effects to air quality and ambient noise levels would result from implementation of this alternative. The oxidation technologies will not result in an air emission that must be treated.

Vegetation. There will be long-term impacts to vegetation as a result of this alternative. The alternative will require the installation of injection wells, monitoring wells and associated access roads on DOE, WKWMA, and TVA land as well as on private property. The long-term impacts will be the removal of trees for the placement of the facilities. This will result in disruption of habitat of birds, mammals, and reptiles inhabiting the immediate area. There is however, considerable habitat available in contiguous areas for the displaced mammals, birds, etc. The quantities of trees that would require moving has not been determined, as the total target areas have not been identified nor has the means of designing the injection method (i.e., linear or blanket). However, the system can be designed to minimize the removal of trees by aligning the access road to miss trees as feasible. Also, well installations can be performed by minimizing the removal of trees rather than clearing an area for each injection and monitoring well. The areas can be vegetatively restored to grasses following construction.

Wildlife. There will be limited long-term effects to wildlife resulting from implementing this alternative. The long-term impacts will be the removal of trees that will result in disruption of habitat of birds, mammals, and reptiles inhabiting the immediate area. There is however, considerable habitat available in contiguous area for the displaced mammals, birds, etc. The quantities of trees that would require moving has not been determined as the total target areas have not been identified nor has the means of designing the injection method (i.e., linear or blanket). However, the system can be designed to minimize the removal of habitat and trees by aligning access road to miss trees as feasible. Also, well installations can be performed by minimizing the removal of trees rather than clearing an area for each injection and monitoring well. The areas can be vegetatively restored to grasses following construction.

Construction in creeks and tributaries may occur as a result of implementing this technology. However, since the creeks and tributaries are somewhat narrow, the design of the system and the use of directional drilling can be used to minimize the impacts to the creeks and tributaries. However, it is likely that access roads will have to cross creeks and tributaries in the implementation.

Threatened and endangered species. Long-term impacts to T&E species are expected to occur. The Indiana bat, which regionally has suitable habitat, is expected be impacted by this alternative. The habitat, as mapped by Bryan (COE 1993), indicates that increased density of potential habitat occurs at the extreme ends of the dissolved phase Northwest Plume. The actual target areas for implementation of the oxidation technology have not been determined and, therefore, the impacts to habitat cannot be determined. However, The placement of wells and access roads can be strategically placed to minimize impacts. Technologies such as directional drilling also can be used. However, after a detailed design of the injection well field, a reanalysis of potential impacts to Indiana bat habitats will need to be completed.

Cultural resources. No long-term effects to cultural resources are anticipated for this alternative.

Groundwater. As a result of implementing an Oxidation Technology in the Dissolved Phase Plume Areas, potential RGA VOC contamination either is reduced or eliminated. As a result of the use of injecting an oxidant into the groundwater, an aesthetic change in the quality of the groundwater may occur due to the precipitation and migration of manganese dioxide. The manganese dioxide also may precipitate in large enough particles that would prevent its migration. In this instance the precipitation would result in potentially reducing the permeability of the formation and limiting water production. A positive aspect of the precipitation is the softening of the water due to removal of dissolved manganese. There will no reduction in ^{99}Tc contaminant levels. If ^{99}Tc contaminant in non-fully oxidized state is encountered by the oxidant, the dissolved phase ^{99}Tc concentrations may increase. This is not expected to occur; however, since the ^{99}Tc in the RGA is already fully oxidized. Groundwater monitoring systems will be used to monitor contaminant levels and for the migration of contaminants to noncontaminated areas due to the injection process. The implementation of this alternative would not require the production of groundwater to the surface for treatment. All treatment is performed *in situ* following the injection of the oxidant.

Surface water. No adverse impacts to streams are expected to result from implementing an Oxidation Technology in a Dissolved Phase Plume Area (RGA). No adverse impacts to wetlands are expected to occur either. There will be no increases in water discharge volumes to outfalls as a result of this alternative. The alternative may result in the reduction or elimination of contaminants being discharged to the Little Bayou Creek. However, if the DNAPL source areas are not removed at the PGDP, it will be necessary to repeat the action, since the plumes will regenerate over time and reimpact the Little Bayou Creek.

Floodplains. It is not expected that work will impact floodplains in the long-term.

Wetlands. It is expected that only limited impacts to wetlands will result from implementing an Oxidation Technology in the Dissolved Phase Plume Area. These impacts will be the result from construction of wells and access roads. The wetlands in the area near to PGDP occur due to surface flow into poorly drained soils, not from recharge from the RGA. Therefore measures, including directional drilling, can be taken not to impact the subsurface fragipan and destroy the wetland integrity. The exception to this would be the area of Little Bayou Creek near the TVA plant that does receive recharge from the RGA. The only mitigating measure would be to design the oxidation system to miss wetland AOCs to the extent possible.

Soils and prime farmland. Prime farmland would be impacted by the implementation of this alternative. The impacts would be the use of the land for the construction of injection and monitoring wells, as well as the associated access roads. If it is chosen to target the entire off-site plume areas, there could be several hundred injection wells used in such an operation. The areas of use will include the WKWMA, DOE, and TVA, as well as a number of parcels of privately owned land. Prime farmland exists north of the PGDP and DOE property. The NRCS has identified prime farmland as the Calloway, Waverly, and Grenada soil series in the area between the PGDP and the TVA Shawnee Steam Plant. The total acreage impacted cannot be determined without first identifying the target areas and determining whether linear injection or blanket type injection is used. However, it is expected that less than one-fourth of an acre per injection well will be impacted in the long term. However, this area can be expected be slightly larger during construction due to the need to get support vehicles into the area. Once construction is complete, vehicles use will be minimal during the injection operations. How much of this acreage would be located on the soils cannot be determined at this time, since the target areas have not be identified and the well locations designed. A LUCIP would be developed, as necessary, per the requirements of the PGDP LUCAP (DOE 2000).

Transportation. No long-term direct, indirect, or cumulative effects to transportation are anticipated from implementing this alternative.

Cumulative Impacts. Cumulative impacts are defined as the incremental impacts of an action when added to other past, present, and reasonable foreseeable future actions, regardless of what agency or person undertakes other such actions. Cumulative impacts resulting from this alternative will have to be identified at a later time during development of site-specific GWOU decision documents.

Reduction of Mobility, Toxicity, or Volume Through Treatment. Oxidation Technology would be used to destroy VOC contaminants contained in the Dissolved Phase Plume Areas in the RGA. The process is by *in situ* destruction. It is expected that 60%–90% of the VOC contaminants in the target area could be expected to be destroyed by the oxidant. The Oxidant Technologies will not have an effect on the ^{99}Tc contaminant levels in the treatment area.

The implementation of an Oxidation Technology would reduce the long-term volume and toxicity of VOCs present in the RGA through the destruction of those contaminants. The implementation of this technology is expected to alter the chemical and physical soil properties of the RGA and as such may prevent subsequent implementation of an additional technology should it be determined that additional treatment is needed for the target areas. One identified physical alteration is the precipitation of manganese dioxide in the formation.

The type and characteristics of residual subsurface contamination would be similar to that of the contaminants prior to treatment. Residual contaminants would pose a risk, although contaminant quantities would be considerably reduced following treatment. Since the treatment occurs *in situ*, there will be no residual contaminants to be disposed of from any surface or *ex situ* treatment. The technology will, however, not remove the ^{99}Tc contamination if it is present in the plume. [Since ^{99}Tc may be present and there will be some residual VOC contamination in the RGA and if the source areas are not also removed, the groundwater will remain unusable for an extended period of time.] Oxidation Technology will meet the statutory preference for treatment as a principal element of the remedial action under CERCLA.

Short-Term Effectiveness. The short-term effectiveness of implementing an Oxidation Technology in the Dissolved Phase Plume Area of the RGA was evaluated relative to its effect on community protection, worker protection, environmental impact, and the time until RAOs are achieved. Environmental impact was further evaluated for NEPA values. This information is presented in the following subsections.

Community protection. The potential for adverse impacts to the community from the implementation of this alternative is minimal. The likely target areas will be the dissolved phase portions of the groundwater plumes that lie between PGDP and the Ohio River. The areas specifically contain property of the WKWMA, TVA, DOE, and also parcels of privately held land. The potential impacts identified include spill of the oxidant during injection and inadvertent surface release of oxidant during injection. The target area for the injected oxidant in a Secondary Source Areas is the RGA that lies at a depth of greater than 50 ft. The injection of the oxidant will be through tubing or pipe. Due to the depth, the oxidant is likely not to surface as a result of the injection process. The Little Bayou creek, into which the RGA discharges near the Ohio River, may be in the target area. For that reason, special design precautions will be used to insure that the oxidant spends prior to flowing into the stretch of Little Bayou Creek near the TVA Steam Plant. Also, engineering controls, including appropriate packaging and handling mechanisms, will be used prevent a spill of oxidant that could impact the community. Restrictions will be used to limit the access of persons that may be in the area during construction and injection operations. This will include warning signs, temporary control fencing, and periodic security patrols. Also, environmental monitoring would be conducted during the construction of monitoring wells where COCs may be present. Following completion of the construction activities, only temporary periodic access will be required for sampling of the monitoring wells used to check the long-term effectiveness of the action on the RGA.

Transportation of oxidant will be required periodically from manufacturing facilities to PGDP. Proper packaging and other required safety features would be used to limit releases as a result of accidents when shipping the oxidant materials.

Worker protection. During the implementation of an Oxidation Technology, workers could be exposed to COCs during short periods of time. Potential exposure could result from direct contact with contaminated soil and/or groundwater during construction of the injection wells. The workers also will be exposed to oxidant, a hazardous substance, during the injection operations. Appropriate handling procedures, injection equipment, and PPE would be utilized to minimize the potential for worker exposure or injury while handling the oxidant. However, short-term risks are not expected to exceed acceptable limits. Health and safety requirements and PGDP procedures would further control the exposures.

Environmental impacts and mitigative measures. The following paragraphs summarize potential short-term impacts to resources and mitigative measures to offset any potential impacts. The depth of impact analysis and mitigative measures is correlated to the degree to which a resource may be impacted.

Land use. The areas expected to be targeted for implementation of an Oxidation Technology in the Dissolved Phase Plume Area lies between PGDP and the Ohio River. The expected land to be impacted includes land of WKWMA, DOE, TVA, and potentially multiple parcels of privately held property. The short-term impacts will be related to the construction and placement and use of injection and monitoring wells and access roads used in the operation. If it is chosen to target the entire off-site plume areas, there could be several hundred injection wells used in such an operation. The total acreage impacted cannot be determined without first identifying the target areas and determining whether linear injection or blanket type injection is used. However, it is expected that less than one-fourth of an acre per injection well will be impacted in the long term. The impacted area in the short term likely will be slightly larger. This is due to the need to get support vehicles to the locations to install the injections wells and monitoring wells. Once the wells are installed, few pieces of equipment will necessary to support the injection operations. A LUCIP would be developed, as necessary, per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomics. This alternative would not be expected to change the short-term economic conditions in the nearby area. There would be a minimal increase in temporary jobs related to the construction of injection wells and injection operations.

Air quality and noise. Heavy equipment traffic and operation associated with construction of the injection wells would provide a minimal increase of dust and vehicular emission levels. The use of BMPs during construction would reduce short-term direct impacts to air quality from dust. Noise associated with construction activities would occur in the immediate vicinity of the work locations, which may be near private residences for the Northeast Plume. The increased noise levels would be during construction and will diminish during the actual oxidant injection operations. There would be no air emissions as a result of implementing an oxidation technology.

Vegetation. There will be short-term impacts to vegetation as a result of this alternative. The alternative will require the installation of injection wells, monitoring wells and associated access roads on DOE, WKWMA, and TVA land, as well as to private property. The long-term impacts will be the removal of trees for the placement of the injection facilities. This will result in disruption of habitat of birds, mammals, and reptiles inhabiting the immediate area. There is however, considerable habitat available in contiguous areas for the displaced mammals, birds, etc. The quantities of trees that would require moving have not been determined, as the total target areas have not been identified, nor has the means for designing the injection method (i.e., linear or blanket). However, the system can be designed to minimize the removal of trees by aligning the access road to miss trees as feasible. Also, well installations can be performed by minimizing the removal of trees rather than clearing an area for each injection and monitoring well. The areas can be vegetatively restored to grasses following construction.

Construction in creeks and tributaries may occur as a result of implementing this technology. However, since the creeks and tributaries are somewhat narrow, the design of the system and the use of directional drilling can be used to minimize the impacts to the creeks and tributaries. However, it is likely that access roads will have to cross creeks and tributaries in the implementation.

Threatened and endangered species. Short-term impacts to T&E species are expected to occur. The Indiana bat, which regionally has suitable habitat, is expected to be impacted by this alternative. The habitat, as mapped by Bryan (COE 1993), indicates that increased density of potential habitat occurs at the extreme ends of the dissolved phase Northwest Plume. The actual target areas for implementation of the oxidation technology have not been determined and, therefore, the impacts to habitat cannot be determined. However, the placement of wells and access roads can be strategically placed to minimize impacts. Technologies such as directional drilling also can be used. However, after a detailed design of the injection well field, a reanalysis of possible impacts to potential Indiana bat habitat will need to be completed.

Cultural resources. No short-term effects to cultural resources are anticipated for this alternative.

Groundwater. As a result of implementing an Oxidation Technology in the Dissolved Phase Plume Areas, potential RGA VOC contamination either is reduced or eliminated. As a result of the use of injecting an oxidant into the groundwater, an aesthetic change in the quality of the groundwater may occur due to the precipitation of manganese dioxide. The manganese dioxide precipitation may not change the water aesthetically if the precipitant is sufficiently large that it doesn't migrate. The precipitation also will result in the softening of the water due to the removal of dissolved manganese. There will no reduction in ^{99}Tc contaminant levels. If ^{99}Tc contaminant in non-fully oxidized state is encountered by the oxidant, the dissolved phase ^{99}Tc concentrations may increase. However, this is not expected to occur; since the ^{99}Tc in the RGA is already fully oxidized. Groundwater monitoring systems will be used to monitor contaminant levels and for the migration of contaminants to noncontaminated areas due to the injection process. The implementation of this alternative would not require the production of groundwater to the surface for treatment. All treatment is performed *in situ* following the injection of the oxidant.

Surface water. No adverse impacts to streams are expected to result from implementing an Oxidation Technology in a Dissolved Phase Plume Area (RGA). No adverse impacts to wetlands are expected to occur either. There will be no increases in water discharge volumes to outfalls as a result of this alternative. The alternative may result in the reduction or elimination of contaminants being discharged to the Little Bayou Creek. However, if the DNAPL source areas are not removed at the PGDP, it will be necessary to repeat the action, since the plumes will regenerate over time and reimpact the Little Bayou Creek.

Floodplains. It is expected that work may occur in the floodplain of the Ohio River in the short-term. However, it is not expected that impacts will occur as a result implementing this alternative. No modifications such as re-alignment, trenching, relocating of floodplains will occur.

Wetlands. It is expected that only limited impacts to wetlands will result from implementing an Oxidation Technology in the Dissolved Phase Plume Area. These impacts will be the result from construction of wells and access roads. The wetlands in the area near to PGDP occur due to surface flow into poorly drained soils, not from recharge from the RGA. Therefore measures, including directional drilling, can be taken to not impact the subsurface fragipan and destroy the wetland integrity. The exception to this would be the area of Little Bayou Creek near the TVA plant that does receive recharge from the RGA. The only mitigating measure would be to design the oxidation system to miss wetland AOCs to the extent possible.

Soils and prime farmland. Prime farmland would be impacted by the implementation of this alternative. The impacts would be the use of the land for the construction of injection and monitoring wells, as well as the associated access roads. If it is chosen to target the entire off-site plume areas, there could be several hundred injection wells used in such an operation. The areas of use will include the WKWMA, DOE, and TVA, as well as a number of parcels of privately owned land. Prime farmland exists north of the PGDP and DOE property. The NRCS has identified prime farmland as the Calloway, Waverly, and Grenada soil series in the area between the PGDP and the TVA Shawnee Steam Plant. The total acreage impacted cannot be determined without first identifying the target areas and determining whether linear injection or blanket type injection is used. However, it is expected that less than one-fourth of an acre per injection well will be impacted in the long term. However, this area can be expected be slightly larger during construction due to the need to get support vehicles into the area. Once construction is complete, there will be only minimal vehicles used during the injection operations. How much of this acreage would be located on the soils cannot be determined at this time since the target areas have not be identified and the well locations designed. A LUCIP would be developed, as necessary, per the requirements of the PGDP LUCAP (DOE 2000).

Transportation. No short-term direct, indirect, or cumulative effects to transportation are anticipated from implementing this alternative. It will, however, be necessary to transport waste soils and development water during construction and oxidants during operations. The appropriate precautions and controls and packaging will be used to protect against spill during the transportation of these items.

Cumulative Impacts. Cumulative impacts are defined as the incremental impacts of an action when added to other past, present, and reasonable foreseeable future actions, regardless of what agency or person undertakes other such actions. Cumulative impacts resulting from this alternative will have to be identified at a later time during development of site-specific GWOU decision documents.

Time until action is complete. Implementation of this alternative will not result in achievement of the GWOU RAOs specified or groundwater MCLs. Approximately 7,000 years will be required before groundwater may be used following the application of an Oxidant Technology only in the Dissolved Phase Plume Areas of the RGA. Without the reduction of DNAPL sources, the plumes will regenerate over time. Also, ^{99}Tc levels will not be reduced as a result of the implementation of an oxidation technology in the Dissolved Phase Areas. It will be necessary to implement other source reduction and dissolved phased technologies in conjunction with Oxidation Technologies in the Secondary Source Areas to reduce the time the groundwater will remain unusable.

Implementability. The implementability of Oxidation Technologies in the Secondary Source Areas of the RGA was evaluated based upon its technical feasibility, administrative feasibility, and the availability of services and materials. This information is summarized in the following subsections.

Technical feasibility. Implementation of Oxidation Technologies is technically feasible. These technologies, although innovative, have been implemented at other hazardous waste sites, and the necessary equipment can be readily obtained. Oxidation uses standard commercially available equipment. The technology is available from a limited number of vendors. Implementation difficulties may arise due to designing the injection systems around sensitive areas in the target areas. Some of these items may include wetlands, Indiana bat habitat, and creeks. A monitoring network will be necessary to monitoring the effectiveness of the treatment operations.

Administrative feasibility. This alternative is administratively feasible. All activities would be conducted in accordance with substantive federal, state, and local requirements. Waivers of ARARs are expected to be necessary to implement these actions, since MCLs will not be achieved in a reasonable time frame.

Availability of material and services. The services and materials necessary to implement this alternative are readily available. The potential exception would be personnel/vendors necessary to implement the Oxidation Technology. The equipment is standard industrial equipment used in other fields such as wastewater treatment. However, the number of vendors experienced at implementing oxidation in the environmental remediation arena is limited.

The construction of this alternative will result in the generation of waste soil cuttings and drilling and development water from the construction of injection and monitoring wells. Additionally, the construction will generate construction debris during the building of any required injection facilities. All of these materials either will be treated, as necessary, and released, as in the development water, or disposed of appropriately.

Cost. Table 4.22 summarizes the preliminary unit cost estimates for implementation of an Oxidation Technology in a Dissolved Phase Plume Area of the RGA. These preliminary unit cost estimates are based upon FS-level scoping and are intended to aid with selection of a preferred alternative. The estimates have an expected accuracy of -30 to +50% for the proposed scope of action (EPA 1988a). The capital cost estimate represents those expenditures required to implement this remedial alternative. The O&M cost estimates represent expenditures required to maintain the remedy after the initial phase of remedial action is completed. The total contingency cost presented includes direct, indirect, and all O&M associated contingency costs. The total cost includes all capital costs, direct and indirect with O&M and associated reports, plus 25% contingency costs, for a 30-year term of comparison. All estimates have been escalated using DOE-approved annual rates and a schedule for the various activities based on similar project experience. Present worth values also are included using a discount factor of 5% (EPA 1988b). (Additional information regarding the preliminary cost estimates is presented in Appendix C7.)

Table 4.22. Preliminary unit cost estimates for Dissolved Phase Plume Area – Oxidation Technology

Total capital costs/acre-feet	$60,340
Total operation and maintenance costs	$35,509
Overhead	$71,831
Total contingency	$41,920
Total cost	**$209,601**
Total cost (present worth)	**$157,636**

Note: preliminary cost estimates are per acre-foot, escalated and presented in dollars.

State/Commonwealth Acceptance. Commonwealth of Kentucky acceptance or nonacceptance of this alternative will be addressed in the ROD should Alternative 3 be selected as the preferred alternative.

Community Acceptance. Following a formal public comment period on the PRAP for the GWOU, comments from the community will be addressed formally in a responsiveness summary, which will be presented in the ROD.

Evaluation summary of Dissolved Phased Plume Area - Oxidation Technology

This alternative consists of implementing an Oxidation Technology in a Dissolved Phase Plume Area of the RGA to remove VOC contaminants present in the RGA in the targeted area, monitoring of the action, and conducting five-year reviews as required by CERCLA. Monitoring COC migration allows the potential for exposure to contaminated groundwater to be prevented or minimized through early warning of migration to other areas, and it also allows the effectiveness of the remedial actions to be evaluated. Although the Dissolved Phase Area concentration in the RGA would be reduced following the implementation, the residual contamination and risks would remain. These residual risks in the RGA from Primary and Secondary Source Areas still will be present and prevent the use of the groundwater for an estimated 7,000 years. The oxidation technology will not remove ^{99}Tc contamination. It would be necessary also to conduct source area reductions and dissolved phased plume actions for ^{99}Tc contamination to reduce the time the groundwater would be unusable.

Implementation of this alternative alone will not be protective of human health and the environment. It must be combined with other source area and dissolved phase plume actions. Oxidation Alternatives can be implemented in compliance with ARARs. Long-term effectiveness could be achieved to an acceptable degree (60%-90% mass removal within the Dissolved Phase Areas of the RGA within 15 years of implementation). However, because of the nature of the soil and groundwater contamination associated with the GWOU, it will take several years and other actions to remediate completely. Residual contamination will remain in the groundwater, with TCE levels exceeding the MCL for approximately 7,000 years. The volume and toxicity of the VOC COCs would be reduced by *in situ* destruction. Limited short-term risks to workers would exist during the construction and operation phase of the alternative. The alternative is technically and administratively feasible to implement. The unit cost of this alternative, which is intended to address only the Dissolved Phase Areas of the RGA in the GWOU at the PGDP is quite significant. Input from the Commonwealth of Kentucky and the community has not yet been received but will be added to later versions of this FS report and the corresponding ROD once the respective comment periods have been completed.

4.2.4.5 Dissolved Phase Plume Area – Bioremediation Technology

The following subsections contain a description of Dissolved Phase Plume Area – Bioremediation Technology and the detailed analysis.

Description of Dissolved Phase Plume Area – Bioremediation Technology

This alternative consists of implementing a Bioremediation Technology in portions of, or over the entire, RGA dissolved phase plume areas located both in the PGDP On-site Secure Area and the Off-site Unsecure Area. The purpose of the alternative would be to remove TCE and other VOC dissolved phase contaminants from areas of the RGA. In this technology, a series of injection wells would be drilled into the RGA in the target areas. The injection wells could be installed in a linear pattern transecting the plume migration route, or they could be installed in a blanket-type fashion in which wells would be spaced periodically across the entire plume area. The injection wells would be used to inject a nutrient solution (such as lactate or methane) into the RGA that would promote the bacterial activity and, in turn, destroy the contaminant.

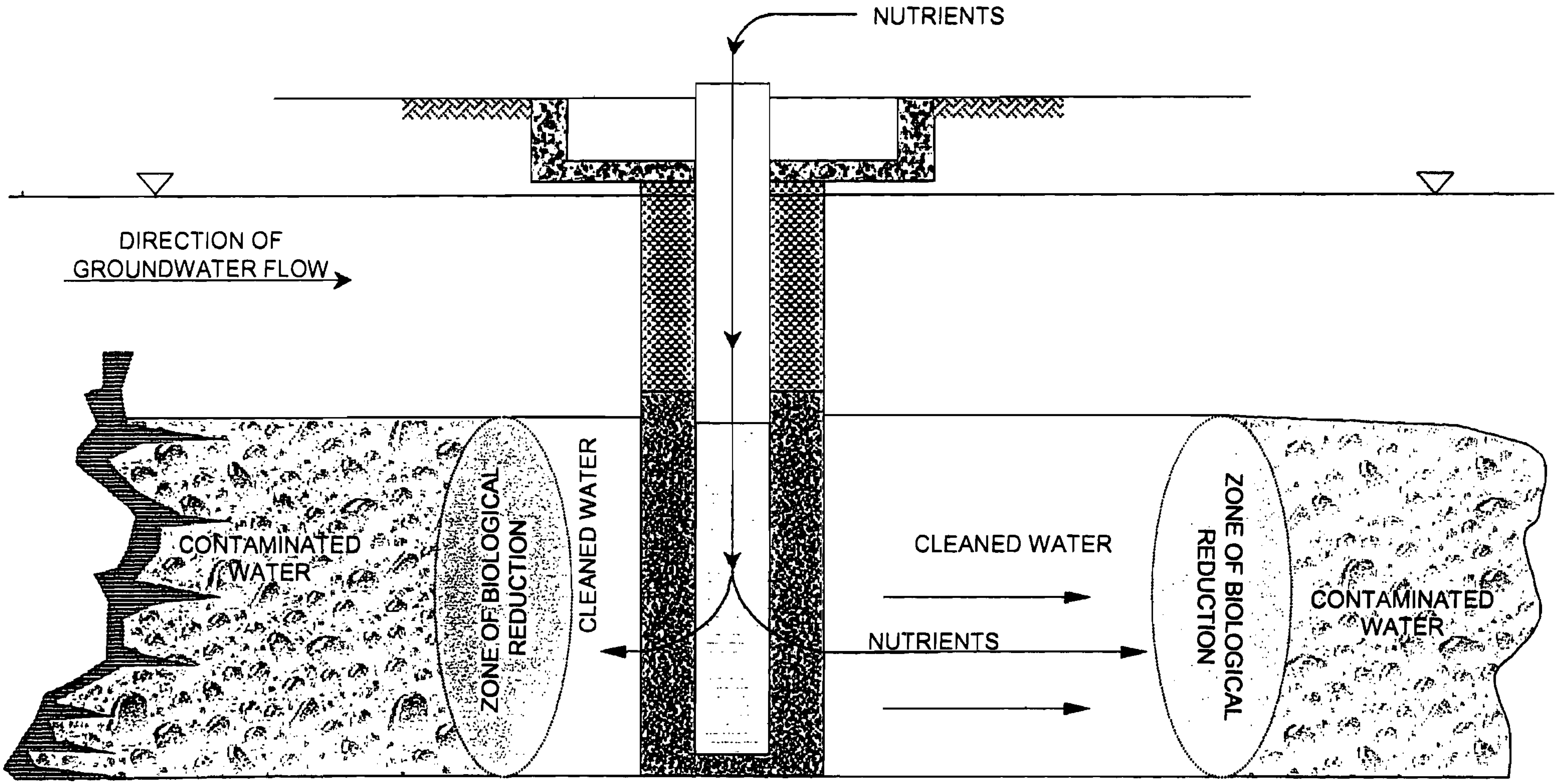
Two approaches can be used in bioremediation. In one form of bioremediation, the contaminant is consumed by the anaerobic bacteria that are present in the subsurface. In this approach, the potential exists for the production of toxic degradation compounds to be formed. This method of bioremediation is found to be the fastest, since the contaminants are consumed directly by the bacteria as an energy source. In the anaerobic approach, large volumes of lactate will be required to be introduced into the RGA to convert the subsurface environment from an aerobic to an anaerobic environment. The RGA, in its natural state, can have oxygen contents up to 8 ppm. The aerobic bacteria would flourish in the presence of the lactate and consume the oxygen in the aquifer. Once the oxygen is depleted, the aerobic bacteria population would decrease, leaving the aquifer in an anaerobic state. The anaerobic bacteria then proliferate and consume the contaminants.

The other means of bioremediation is to use another indigenous bacteria present in the subsurface to destroy the contaminants as a secondary food source to the bacteria. This process requires the introduction of an energy source (primary food source) to the subsurface to promote the activity of methanogenic bacteria. As the bacteria consume the primary food source, they also consume the contaminants that are secondary foods to them. The methanogenic bacteria in this method are, to some degree, impacted by the destruction of the contaminant. As the contaminant is consumed, an epoxide is developed, which is toxic to the bacteria. This results in the limitation of the remediation due to the loss of the bacteria.

In both methods, once the nutrients no longer are available, either injected or naturally, the bacterial activity will decrease to pre-remedial, or natural, levels. Delivery of the nutrients to the areas is critical. Using the linear pattern, the nutrients would travel with the groundwater and cause the bacteria to flourish in the areas of the nutrient flow. The linear patterns would be spaced such that the nutrients would not dissipate before reaching the next downgradient injection pattern. Using the "blanket" installation, the wells would be spaced to allow the nutrients to be injected over the entire target area, thereby proliferating the native bacteria and removing the contaminants from the entire area of concern.

The ^{99}Tc contamination would not be reduced by the bioremediation technology. The use of this alternative will be performed *in situ* and will not require any *ex-situ* treatment of produced water or release of air emissions. However, as discussed above, it will require the placement of injection wells and injection equipment to effect the introduction of the nutrient solution into the RGA.

Figure 4.13 contains a "snapshot" that graphically summarizes what is involved in the application of Bioremediation Technology to the Dissolved Phase Plume Area.



U. S. DEPARTMENT OF ENERGY
DOE OAK RIDGE OPERATIONS
PADUCAH GASEOUS DIFFUSION PLANT

BECHTEL JACOBS COMPANY, LLC
MANAGED FOR THE US DEPARTMENT OF ENERGY UNDER
US GOVERNMENT CONTRACT DE-AC-05-98OR22700
Oak Ridge, Tennessee • Paducah, Kentucky • Portsmouth, Ohio

Science Applications
International Corporation
P.O. Box 2502
Oak Ridge, Tennes 831

FIGUF FS4-13
DATE 05-25-01

Fig. 4.13. Dissolved phase area - bioremediation technology.

The dissolved phase contaminant reduction efforts of implementing this technology in the dissolved phase plume areas will have only minimal impact to returning the groundwater to beneficial use. This is due the fact that, without the removal of Primary and Secondary Sources located beneath the PGDP plant areas, the plumes will regenerate over time due to the presence of dissolving DNAPL concentrations of TCE. Due to the technology not effecting removal of the DNAPL TCE contaminants in the UCRS and RGA areas (Primary and Secondary Source Areas), it is anticipated that groundwater will not be returned to the drinking water standard for TCE for approximately 7,000 years. Bioremediation Technologies will not remove ^{99}Tc as part of the operation. Additional measures will be required to remove the ^{99}Tc from the Off-site Plume Areas.

The existing groundwater monitoring program, which is being implemented under a separate action, would be continued to monitor the movement of COCs within the RGA. The monitoring program will integrate existing PGDP monitoring wells, where possible, with additional monitoring wells to be installed as needed following a review of the existing program.

Five-Year Reviews. This remedial alternative would result in residual "contaminants remaining at the PGDP site above levels that allow for unlimited use and unrestricted exposure"; therefore, this remedial action would be reviewed "no less often than every five years" in accordance with 40 *CFR* 300.430 (f)(4)(ii).

Assessment of Dissolved Phase Plume Area – Bioremediation Technology

The detailed analysis of this alternative using the CERCLA criteria is presented in the following subsections.

Overall Protection of Human Health and the Environment. Dissolved Phase Plume Area bioremediation Technology includes the *in situ* treatment of dissolved phase concentrations of VOCs in the RGA. The technology would reduce VOC contamination in the RGA only and, as implemented, only in the VOC dissolved phase portions of the plumes. It is not expected that bioremediation would have any impact on the ^{99}Tc contamination present in the treatment area. This alternative alone will not satisfy the RAOs for the GWOU. It will support achieving the RAOs when implemented in concert with other source reduction and dissolved phase GWOU technologies. It is possible for this alternative to be protective of the ecological receptors that may be exposed to contaminated groundwater discharging to the surface water. However, for this to be permanent when implemented alone, the technology will require repeat applications in the target area, because without DNAPL source removal, the plumes will regenerate over time.

Compliance with ARARs

Potential chemical-specific ARARs

Chemical contamination. The aquifers are known to contain chemical contaminants in the form of metals and organics. The federal and state water quality requirements include standards that would be applicable ARARs. The regulations that apply are found in 40 *CFR* 141 (National Primary Drinking Water Standards) and 40 *CFR* 143 (Secondary Drinking Water Standards), 401 KAR 5:029 (General Provisions) and 401 KAR 5:031 (Surface Water Standards). These standards are summarized in Table 4.23 and include state general standards, domestic water supply standards, and standards applicable to warm water aquatic habitat. These are applicable based upon the classification of the designation for surface water use associated with the area (Ohio River, River Mile 940.7 to River Mile 943.3) as specified in 401 KAR 5:026. All potentially applicable chemical ARARs for COCs have been included in the table for completeness. Those standards that must be achieved in order to meet the applicable requirements are the lowest of the applicable standards, which in most cases are the MCLs.

Table 4.23. Summary of potential ARARs for Dissolved Phase Plume – Bioremediation Technology

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Chemical-Specific ARARs	
National Primary Drinking Water Standards	40 *CFR* 141	Provides chemical-specific numeric standards for toxic pollutants expressed as MCLs and MCLGs.	These requirements are relevant and appropriate due to the nature of the contaminants found within the groundwater.
National Secondary Drinking Water Standards	40 *CFR* 143	Provides secondary MCLs for public water systems.	These requirements are TBCs, as they have been established as guidelines for the states and are not federally enforceable.
Kentucky Surface Standards including • Warm Water Aquatic Habitat Criteria • Kentucky Domestic Water Supply • Kentucky General Standards • Kentucky Outstanding State Resource Waters	401 KAR 5:031 and 5:026	Provides chemical-specific numeric standards for pollutants discharged or found in surface waters. Provides chemical-specific numeric standards for pollutants in domestic water supplies.	These standards are applicable to the segment of the Ohio River into which the Little Bayou Creek discharges. The requirements found in these standards are applicable due to the groundwater to surface water interface to Little Bayou Creek and, subsequently, to the Ohio River. Note: CWA Water Quality Criteria are not relevant and appropriate because Kentucky has promulgated these state standards that Kentucky has determined to be appropriate for state waters.
Radiation Exposure of the General Public at DOE Facilities	DOE Order 5400.5	Specifies that the general public must not receive an effective dose equivalent of >100 mrem/year from all exposure pathways. In addition, all releases of radioactive materials resulting in doses to the general public must meet the ALARA criteria.	This requirement is TBC information.
Decommissioning Standards at Nuclear Facilities	10 *CFR* 20, Subpart E	Specifies a residual activity at nuclear facilities for unrestricted release of 25 mrem/year.	These standards are considered to be applicable to the GWOU.
Environmental Radiation Protection Standards for Nuclear Power Operations	40 *CFR* 190, Subpart B	Requires that the annual dose equivalent to the public must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment from uranium fuel cycle operations, and radiation from these operations.	These standards are considered to be relevant and appropriate and are equivalent to the NRC standards.

Table 4.23. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Location-Specific ARARs	
Protection of Wetlands	10 *CFR* Section 1022; Executive Order 11990; 40 *CFR* 230.10; 33 *CFR* 330.5	Activities must avoid or minimize impacts to wetlands to preserve and enhance their natural and beneficial value. If wetland resources are not avoided, measures must be taken to address ecologically sensitive areas and mitigate adverse effects. Such measures may include, minimum grading requirements, runoff controls, design and construction considerations. Allows minor discharges of dredge and fill material, or other minor activities for which there is no practicable alternative, provided that the pertinent requirements of the NWP system are met.	These requirements are applicable due to the presence of wetlands, but will be met though avoidance of wetlands during construction and implementation of alternatives.
Endangered Species Act	16 U.S.C. 1531 et seq. Section 7(a)(2)	Actions that jeopardize the existence of listed species or result in the destruction of adverse modification of critical habitat must be avoided or reasonable and prudent mitigation measures taken.	Action that is likely to jeopardize fish, wildlife, or plant species or destroy or adversely modify critical habitat-applicable.
Migratory Bird Treaty Act	16 U.S.C. 703-711; Executive Order 13186	Federal Agencies are encouraged (until requirements are established under a formal MOU) to do the following: • avoid or minimize, to the extent practicable, adverse impacts on migratory bird resources when conducting agency actions; • restore and enhance the habitats of migratory birds, as practicable; • prevent or abate the pollution or detrimental alteration of the environment for the benefit of migratory birds, as practicable; • ensure that environmental analysis of federal actions required by the NEPA or other established environmental review processes evaluate the effects of actions and agency plans of migratory birds, with emphasis on species of concern; and • identify where unintentional take likely will result from agency actions and develop standards and/or practices to minimize such unintentional take.	Action that is likely to impact migratory birds, habitats, and resources-applicable.

Table 4.23. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
		Action-Specific ARARs	
Fugitive Dust Emissions during site preparation and construction activities.	401 KAR 63:010	Precautions must be taken to prevent particulate matter from becoming airborne. Such precautions must be incorporated into the planning and design of activities and include actions such as • Wetting or adding chemicals to control dust from construction activities; • Using materials such as asphalt or concrete (or other suitable chemicals/fixing agents) on roads or material stockpiles to prevent fugitive emissions; and • Using covers on trucks when transporting materials to and from the construction site(s). The requirement specifies that for on-site construction activities, no visible emissions may occur at the PGDP fenceline. Similar points of compliance shall be identified for construction activities that occur outside the fence.	These requirements are applicable and will be met through the use of appropriate dust-control practices identified during alternative design phase.
Toxic Emissions	401 KAR 63:022	The regulations require that a determination of toxic emissions be made in order to assess the applicability of required controls. Calculations of the significant emission levels are compared to the allowable emission limits specified in Appendix A of 401 KAR 63:022. If emission levels are exceeded, best available control technologies must be incorporated into equipment/process design.	These requirements are considered to be applicable and shall be complied with through calculation of significant emission levels for toxic materials and application of best available control technology as necessary during the design of the alternative.
Monitoring Well Installation	401 KAR 6:310	Monitoring wells (including extraction wells) must be constructed in a manner to maintain existing protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole. In addition, wells with no further use must be plugged and abandoned in accordance with the requirements specified.	These requirements are considered to be applicable. Compliance with well design and protection standards shall be achieved through the use of approved well design and materials of construction. While in service, wells shall be secured as required. Wells with no further use shall be plugged and abandoned as required.
Discharge of Stormwater and Treated Well Completion Water	40 *CFR* 122; 401 KAR 5:055	Stormwater discharges from construction activities on-site are subject to the requirements of the KPDES permit. This requires that BMPs to control stormwater runoff and sedimentation be employed. Although off-plant construction activities within the contaminated area are not subject to the permit, these requirements should be considered relevant and appropriate and be incorporated into any off-site construction activities. Discharge of treated groundwater will be conducted in compliance with the substantive requirements of the KPDES program and CWA.	These requirements are considered applicable for all on-site construction or treatment activities where a discharge of stormwater or treated groundwater occurs. For off-site construction activities, these requirements are considered relevant and appropriate and will be adhered to. Compliance with these ARARs shall be achieved by application of required controls during the design phase of the alternative.

Table 4.23. (continued)

Standards, Requirement, Criteria, or Limitation	Citation	Description of Requirement	Comments
Hazardous Waste Management	40 *CFR* 260 through 264 and 268; 401 KAR 31 through 34, 36, and 37	All wastes or environmental media containing wastes must be characterized to determine whether the waste also is a hazardous waste in accordance with 40 *CFR* 262.11 and 401 KAR 32:010. If it is determined that a waste is hazardous or that environmental media contain a hazardous waste that is subject to the RCRA regulation, the substantive requirements of 40 *CFR* 262 through 268 are applicable. These standards include design and operation of storage and accumulation areas, waste handling and shipment, and treatment technologies or numeric standards applicable to wastes prior to disposal.	These requirements are applicable and will be complied with through characterization of wastes and environmental media generated as a result of implementation of the alternative. Waste management will be predicated upon the characterization and comply with all substantive requirements associated with hazardous waste management, if identified as such.
PCB Waste Management	40 *CFR* 761	TSCA requirements for the management of PCB wastes or items containing >50 ppm PCBs or from a source of 50 ppm or greater. Requirements include the following: • waste and material management; • characterization of PCB-containing materials; • labeling and storage for disposal; • manifest completion for shipment offsite; • decontamination of affected equipment or items; and • disposal of PCB wastes. These requirements will be complied with in the event that PCBs are found at concentrations requiring compliance.	These requirements are applicable if PCBs are found or result from items or equipment regulated under 40 *CFR* 761. Activities necessary to comply with these ARARs shall be incorporated into the planning phase of the alternative implementation.

ALARA = as low as reasonably achievable
ARAR = applicable or relevant and appropriate requirement
BMP = best management practice
CFR = *Code of Federal Regulations*
CWA = Clean Water Act
DOE = U.S. Department of Energy
GWOU = groundwater operable unit
KAR = Kentucky Administrative Regulations
KPDES = Kentucky Pollutant Discharge Elimination System
MCL = maximum contaminant level
MCLG = maximum containment level goal
NRC = U.S. Nuclear Regulatory Commission
NWP = Nationwide Permit
PCB = polychlorinated biphenyl
PGDP = Paducah Gaseous Diffusion Plant
RCRA = Resource Conservation and Recovery Act
TBC = to be considered
TSCA = Toxic Substances Control Act

Radiological contamination. The GWOU is known to be contaminated with radionuclides such as ^{99}Tc, radon, uranium, and uranium daughter products. DOE's Order on Radiation Protection of the Public and Environment, DOE Order 5400.5, as codified at 10 *CFR* 835, is TBC information for cleanup of radionuclides at DOE sites. The order requires that remediation activities must not result in radiation exposures to members of the general public greater than an EDE of 100 mrem/year from all exposure pathways. Exposure to the general public also must be ALARA (DOE 1990).

DOE Order 5400.5 also contains reference values, known as DCGs, for operational DOE facilities. Based on the DCGs, radionuclide concentrations in air and drinking water must not exceed an EDE of 10 mrem/year and 4 mrem/year, respectively, to the total body or any organ.

The NRC also has set criteria for decommissioning standards at nuclear facilities in 10 *CFR* 20 Subpart E. These rules require that residual radioactivity at nuclear sites meet a total EDE of 25 mrem/year for unrestricted release. In addition to the NRC standards, EPA has issued guidance for cleanup levels at CERCLA sites with radioactive contamination. EPA has disagreed with the protectiveness specified within the NRC standard and has specified that a 15 mrem/year EDE be used as the risk level that is protective of human health and the environment. EPA also has codified exposure limits for environmental radiation protection standards for nuclear power operations in 40 *CFR* 190. These requirements apply to operations involved in uranium fuel cycle and include enrichment operations. Subpart B of these requirements specifies that the annual dose equivalent to the public not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as the result of exposures to planned discharges of radioactive materials, radon and its daughter products excepted, to the general environment from uranium fuel cycle operations and to radiation from these operations. These requirements would be considered relevant and appropriate since release to the groundwater would not be planned.

The Commonwealth of Kentucky is an NRC Agreement State and has promulgated regulations for radiation protection of the public. The Kentucky radiation protection standard for individual members of the public is 0.1 rem (100 mrem) EDE per year or less (902 KAR 100:019 Section 10), which is equivalent to the DOE radiation protection standard found in DOE Order 5400.5. Due to the differing view and values among DOE, EPA, and the NRC total EDE for members of the general public, DOE and EPA have agreed not to finalize their respective standards until an agreement can be reached. In the interim, DOE Order 5400.5 is identified as TBC information and the NRC standard is identified as relevant and appropriate. Therefore, the radiation protection standard identified within the NRC regulations in 10 *CFR* 20 Subpart E, requiring an EDE of 25 mrem/year or less, shall be used as the exposure limit for the general public.

Chemical-specific ARAR summary. The chemical-specific ARARs associated with the implementation of this alternative are outlined in Table 4.23. Implementation of this alternative would not result in immediate attainment of the chemical-specific ARARs associated with the off-site groundwater plumes. Attainment of the identified ARARs would be met in the future as implementation progresses. Although TBC information, the radiological exposure standards included in DOE Order 5400.5 shall be achieved and will be confirmed through monitoring. Continued monitoring of the groundwater will be used during the five-year reviews to ensure that the identified goals are met and that concentrations of COCs continue to decrease. As this alternative will effectively treat metals or radionuclides, only concentrations of organics will be decreased.

Potential location-specific ARARs

Wetlands. Wetlands have been identified within the area where well construction activities are anticipated to occur, certain jurisdictional wetlands have been identified within the area. In order to comply with these applicable requirements, wetlands shall be avoided to the extent practicable.

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, 40 *CFR* 6.302(a), 40 *CFR* 6 Appendix A, 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. Although not anticipated, if this alternative results in impacts to wetlands that cannot be avoided, the substantive requirements of the NWP 38 (33 *CFR* 330) will be met.

Off-site operations shall avoid impacts to wetlands, and all treatment will be conducted either *in situ* or in units already in operation.

Endangered Species and Migratory Birds. Actions taken by federal agencies are prohibited from impacting T&E species or adversely modifying critical habitat (50 CFR 17.94) in accordance with the Endangered Species Act (16 USCA 1531 et *seq.* Section (7)(a)(2)). These requirements are potential ARARs in the event T&E species or their habitats are found at or near areas where remedial action is to occur. An ecological resource investigation inside the PGDP security fence did not detect any T&E species or their preferred habitats (CDM Federal 1994). The USFWS has not designated critical habitat for any species within the DOE property. However, outside the PGDP fence on the DOE property, potential habitats for federally listed T&E species were reviewed, and Indiana bat habitat was evaluated during the COE (1994) environmental investigation. The COE study determined that total potential bat habitat consisted of 20% of the 994-ha (2,456-acre) study area. Remedial activities must be evaluated to ensure that such actions do not adversely impact areas identified as critical habitat for any identified endangered species.

In addition, Executive Order 13186 directs federal agencies to enter into an MOU with the USFWS to further the purposes of the Migratory Bird Treaty Act (16 U.S.C. 703-711). Until such time as the MOU between DOE and the USFWS is finalized, Federal agencies are encouraged immediately to begin implementing the conservation measures set forth in the Executive Order. The requirements of the Executive Order are applicable and must be considered during planning and design of the remedial action.

Potential action-specific ARARs

Monitoring well installation requirements. This alternative includes the installation of additional monitoring wells. Installation of these wells would have to be conducted in a manner to maintain existing natural protection against the introduction of pollutants into aquifers and to prevent the entry of pollutants through the borehole (401 KAR 6:310 Section 13). These requirements also mandate the construction materials required for well construction, well design criteria, well completion activities, and well abandonment methodologies. These requirements are considered applicable to design and installation of monitoring and extraction wells associated with the implementation of this alternative.

Fugitive dust emissions. Construction activities onsite may result in the production of particulate airborne pollutants (dust). The Kentucky Air Quality standards found in 401 KAR 63:010 include requirements governing fugitive dust emissions. These standards require that dust-suppression measures be undertaken, including activities such as use of water or chemicals to control emissions, placement of asphalt or concrete, and stockpiling of soils. The standards also require that visible dust generated from the implementation of the remedial alternative not be discharged beyond the property boundary of the site. For the purpose of compliance with these requirements, the site boundary is interpreted to mean the DOE site boundary or the immediate boundary of construction activities that occur on non-DOE property. These requirements are considered to be applicable to the implementation of Alternative 6 and will be complied with through careful planning to ensure that excavated materials are sufficiently wetted or protected to control dust generation. The only activity that could result in the generation of fugitive dust that must be considered during the design phase is the installation/construction of additional wells.

Radionuclide emission standards. Airborne emissions of radionuclides may occur as a result of on-site construction activities. Although the potential is low for such emissions to occur, the regulations in 40 *CFR* 61.92 would be applicable, requiring that the emissions not exceed amounts that would cause an EDE to the public of 10 mrem/year. In order to determine whether the alternative complies with this applicable requirement, computer modeling using the CAP-88 or other EPA-approved models must be undertaken. If the modeling demonstrates that the radionuclide emission is in excess of 1% of the 10 mrem/year standard, emission rates must be measured as required by 40 *CFR* 61.93. This ARAR shall be complied with by planning activities in such a manner as to control fugitive emissions from installation of monitoring wells.

Toxic emission standards. Although toxic emissions are not expected as a result of construction activities or with the pumping of the groundwater to the on-site water treatment facility, these emission requirements would be applicable if such an emission does occur. Due to organic concentrations found in the groundwater and potentially within the subsurface soils, there is a low potential for such emissions to occur. The regulations at 401 KAR 63:022 require that emissions be evaluated to determine whether they are significant for each specific toxic air pollutant. If analysis indicates the toxic emission requirements are triggered, the regulations specify that no source may exceed the allowable emission limit specified in Appendix A of 401 KAR 63:022. If applicable, these rules would require application of the best available control technology to limit toxic emissions. If calculations indicate that the emission rates specified within the rule are not exceeded, the calculation package may be used to demonstrate compliance with these requirements. Activities that must be considered include installation and construction of monitoring wells.

Stormwater discharge and KPDES requirements for groundwater treatment. Construction activities will be subject to the substantive requirements associated with the KPDES permit that requires the use of BMPs and sediment/erosion controls to control transport of sediment in stormwater runoff. These requirements are considered to be applicable.

Waste management requirements. Wastes and contaminated environmental media shall be generated during the implementation of this alternative in the form of soils and water from the installation and completion of wells. It is anticipated that at least a portion of these wastes will be low-level radioactive wastes and, therefore, subject to DOE Order 435.1 requirements that apply to the management of all radioactive wastes generated at DOE facilities. This requirement is TBC rather than applicable or relevant and appropriate because it is a DOE Order rather than a federal or state regulation or standard.

The potential also exists for some or all of the wastes or soils generated from treatment to be RCRA hazardous wastes as defined in 40 *CFR* 261 of the federal program. All wastes or soils generated shall be subject to the hazardous waste determination requirements of 40 *CFR* 262 and 401 KAR 32:010. Soils shall be assessed to determine whether they contain a hazardous waste. If it is determined that any wastes are, in fact, hazardous wastes, or if soils are determined to contain hazardous wastes, the materials must be managed in accordance with the substantive requirements found in 40 *CFR* 262 through 40 *CFR* 268 (401 KAR 32 through 37). These standards include storage requirements, transportation requirements, and disposal requirements. Specific requirements applicable to each waste stream must be identified after characterization of the material is complete. These requirements shall be complied with through the development of a WMP during the design phase of implementation. If materials are identified as RCRA-hazardous wastes, these requirements are applicable.

Although considered unlikely, the potential exists for materials (wastes and/or soils) generated from the implementation of this alternative to contain PCBs regulated under TSCA. These regulations would be applicable to this alternative if PCB concentrations were found in soil or water that exceeded 50 ppm or PCBs were found and attributable to a source where concentration exceeded 50 ppm PCBs. The substantive requirements for management of PCB wastes found in 40 *CFR* 761 would be applicable and include standards for storage, shipment, and equipment decontamination. These requirements shall be complied with through the development of a WMP during the design phase of implementation. If materials are identified as TSCA PCB-regulated material, these requirements are applicable.

Action-specific ARAR summary. This alternative will trigger action-specific ARARs with regard to the control of storm water runoff and waste management during well installation. The requirements of the KPDES program associated with the discharge of well completion water/decontamination fluid and the applicability of the RCRA requirements for wastes generated as a result of implementation. In addition, the requirements of TSCA may be applicable if PCB-containing materials are identified. This alternative will comply with these requirements during the planning phase to include compliant waste handling, storage, and disposition components. The proposed alternative will comply with substantive requirements of both the CWA and RCRA as the treatment and discharge of treated effluent in compliance with the CWA meets both requirements and is allowed under RCRA. If wastes from treatment or soils from well installation are determined to be hazardous wastes under RCRA, the substantive requirements for storage, management, and disposal of hazardous wastes shall be incorporated into the alternative during the planning phase. Activities that may be required for RCRA and TSCA compliance include: use of appropriate containers, labeling of containers, appropriate storage area design and operation (secondary containment or storage for less than 90 days in a compliant accumulation area); and transportation of wastes.

A summary of the ARARs for the implementation of this Dissolved Phase Plume – Bioremediation Technology alternative is presented in Table 4.23.

Compliance with ARARs summary. Implementation of this alternative would not achieve compliance with the MCL for TCE and would not lessen any metals or radionuclide concentrations present in groundwater. Because this alternative does not immediately meet the stated MCLs, an ARAR waiver or agreed schedule of compliance would have to be sought as part of the ROD and PRAP.

In order to comply with the identified chemical-specific ARARs, an ARAR waiver will be required due to the time frames required to meet the specified concentrations within the GWOU at the point of compliance and points of exposure.

As discussed, no potential location-specific ARARs have been identified within the area where remedial action will occur. However, to ensure that jurisdictional wetlands are not impacted, all construction activities associated with the installation of the monitoring wells will be reviewed as a safeguard. The protection of wetlands is not considered a location-specific ARAR at this time because jurisdictional wetlands have not been identified within the areas impacted by the implementation of this alternative.

Construction and implementation of the alternative may trigger several action-specific ARARs, such as the requirements associated with well installation and abandonment, construction of the PTZs, fugitive dust emissions, radionuclide emissions, and toxic emissions. The requirements associated with the installation and abandonment of groundwater wells will be met though the use of well designs and materials of construction as specified in 401 KAR 6:310 Section 13. All well installation and abandonment practices incorporated into the approved remedial design shall comply with the substantive requirements of 401 KAR 6:310.

Construction of the monitoring wells and the *in situ* treatment of groundwater will require the injection of materials into the subsurface. During the remedial design assessment, all materials used in construction will be reviewed to ensure that materials that could further impact water quality are not used or are limited in use. The construction activities associated with this alternative may require that BMPs for sedimentation/erosion controls be established. Sedimentation control is required if the area to be disturbed during construction exceeds regulatory limits. Regardless of the size of the construction area(s), sedimentation controls are TBC. This requirement will be complied with through use of sediment fences or other appropriate means. The remedial design shall incorporate the specific controls necessary to ensure that the construction site(s) do not allow sedimentation and or erosion of disturbed areas in order to comply with this requirement during implementation of this alternative.

Fugitive dust emissions that may occur during construction activities will be controlled as required by 401 KAR 63:010. BMPs such as wetting or covering of potential sources of fugitive dust will be incorporated into the remedial design. The specific actions to be developed shall control potential emission sources to ensure that dust emissions do not migrate from the immediate area where construction activities occur. It is anticipated that, in most cases, the moisture content in the soil will be sufficient to control dust emissions during well installation. However, practices such as wetting of disturbed soils, collection of soils, or reseeding activities shall be considered and incorporated into the remedial design, as necessary, to ensure compliance with these requirements. Radionuclide emissions at construction sites also must be considered during the implementation phase. In order to ensure that the emission standard of 10 mrem/year EDE to the public is met, concentrations of radionuclides in soils and groundwater must be evaluated. If the potential for such emissions is identified, modeling using the CAP-88 or other EPA-approved methods must be undertaken during the design phase of the alternative. It is anticipated that the primary conveyance of airborne radionuclides will be in particulate form; therefore, control of fugitive dust emissions also will result in compliance with the emission standards applicable to radionuclides. If radiological contamination from plant activities is found in soils where construction activities are planned, the soil will be protected or containerized to prevent airborne migration. Measures necessary to prevent airborne emissions or radionuclides shall be evaluated and incorporated as appropriate into the remedial design to comply with these requirements during implementation of this alternative.

Emissions of toxins, such as volatile organics, must also be evaluated before implementation. Although the potential for exceedance of toxic air emissions is considered to be low, an evaluation of the potential for such emissions must be undertaken during the remedial design. Potential emissions must be evaluated for each toxin present in the plumes (i.e., TCE, vinyl chloride, etc.) to determine whether the contaminant levels found in the subsurface could result in airborne emissions in excess of the allowable limits specified in Appendix A of 401 KAR 63:022. Compliance with the emissions standards shall be achieved for this alternative through the evaluation process or the application of the best available control technology in which emissions are calculated to exceed allowable levels. It is anticipated that through the use of a dual phase extraction system, all air emission standards will be met. Appropriate emission control equipment will be incorporated into the treatment system utilized. The specifications for this equipment shall be identified during the remedial design based upon the initial evaluation. This requirement will be complied with during implementation of the alternative.

The construction activities associated with this alternative may require that BMPs for sedimentation/ erosion controls be established if the areal extent of the disturbed area exceeds regulatory trigger levels. These requirements will be complied with through the use of sediment fences or other appropriate means. The control of sedimentation and runoff is TBC if the areal extent of the construction does not exceed the 5 acres specified within the rules. The remedial design shall incorporate the specific controls necessary to ensure that the construction site(s) do not allow sedimentation and or erosion of disturbed areas in order to comply with this requirement during implementation of this alternative.

Installation of wells may result in the generation of wastes and secondary wastes that will trigger the characterization requirements associated with the RCRA. Implementing regulations found at 40 *CFR* 262 and 401 KAR 32:010 require that generators of solid wastes (or contaminated environmental media) must determine whether the waste also is a hazardous waste. If the materials generated from the implementation of this alternative are found to be hazardous wastes, the materials shall be containerized and managed as such. The requirements mandate that hazardous wastes must be properly labeled and stored in areas that comply with the technical standards for storage of hazardous waste in containers. These standards shall be complied with through testing of soils before excavation activities. If the soils are found to be hazardous, appropriate storage areas shall be constructed and maintained. All hazardous waste generated during the implementation of this alternative shall be shipped for off-site disposal using the EPA Identification Number for the PGDP. Hazardous wastes shall be shipped to facilities permitted to treat, store, or dispose of the hazardous waste(s) being shipped. These activities shall be incorporated into the remedial design for this alternative in order to comply with these requirements.

Secondary wastes generated during the implementation of this alternative also may be subject to regulation under TSCA as PCB-remediation waste and DOE Order 435.1 as LLW. Characterization of these materials will be required to determine whether specific wastes are regulated under these requirements. If it is determined that the waste generated is a PCB or LLW, appropriate management standards will be incorporated into the remedial design. Existing information will be used where practicable to determine the regulatory status of all waste to be generated before implementation.

Long-Term Effectiveness and Permanence. Dissolved Phase Plume Bioremediation Technology offers a relatively high level of long-term control for dissolved phased VOC contaminants located in areas of the RGA that may be subject to treatment. There would no impact to ^{99}Tc concentrations located in the treated areas, since ^{99}Tc will not be destroyed by bioremediation. The implementation of this technology only in the RGA will provide no control over Primary or Secondary Source Area target contaminants located in the UCRS or the RGA. The only exception would the potential for collateral reductions in VOC concentrations when the dissolved phase target area of concern is in close proximity to a Secondary Source area. However, due to the high concentrations of the dissolved contaminants in the source areas, the contaminants become toxic to the bacteria and prevent the removal of the DNAPL. It also should be understood that without the removal of the DNAPL source zones, the plumes will regenerate over time.

Magnitude of residual risk. Residual risk in the RGA will remain in place after implementation of a Bioremediation Technology. The technology will require assistance from other technologies either in the UCRS or RGA to meet the MCLs at the point of compliance, thereby preventing the regeneration of the dissolved phase plumes. This alternative will reduce VOCs in the dissolved phase plume areas by *in situ* bioremediation using nutrients to increase bacterial action on the contaminants. The technology will have no impact on ^{99}Tc contamination present in the RGA source areas unless those areas are targeted for the treatment by a remedial measure that is effective against ^{99}Tc.

Following treatment of the selected RGA areas, residual COCs, especially in the source zone areas, would contribute to long-term risks. However, the five-year reviews, mandated by CERCLA [40 *CFR* §300.430(f)(4)(ii)], would be an effective means to demonstrate that contaminant levels were reduced from the technologies implementation, and additional exposure pathways have not developed.

Adequacy and reliability of controls. The reliability for operation and control of Bioremediation Technology would be moderate. Bioremediation is a mature technology. The components that make up the treatment systems such as a nutrient solution, injection wells, metering pumps, etc., are common industrial items that have been used for many years successfully. The technology has been implemented successfully in a number of aquifers. However, a technical concern does exist with the chemistry of the RGA. The aquifer has a high saturation of oxygen, up to about 8 ppm, which is not conducive to anaerobic bioremediation. The bacteria that would be active in destruction of the TCE in the RGA, with this level of dissolved oxygen and under natural conditions, are aerobic type bacteria. It will be necessary to introduce lactate or a similar nutrient source into the subsurface to deplete the aquifer of oxygen so that aerobic bacteria die off as a result of no oxygen. It is estimated that up to 4 million pounds of lactate solution may be needed to complete this process.

The methanogenic destruction of the VOCs will require the introduction of methane or a similar substance for the bacteria to use as an energy source, or primary food will be required. As part of the consumption of the methane, the bacteria also consume the VOCs or TCE. However, as a result of the consumption of the TCE, the bacteria produce epoxides as part of the biological process. The development of an epoxide, in some instances, has led to the destruction of the implementing bacteria, which then causes the process to be self-limiting.

Additionally, it will likely be necessary to use computer modeling to design the site-specific location, injection well layouts, and nutrient solution concentrations to ensure appropriately sized treatment zones and that contaminants are not migrated, missed, or by-passed in the operation. Long-term groundwater monitoring will be required to monitor the extended effectiveness of the treatment following its completion.

Environmental impacts and mitigative measures. The following paragraphs summarize potential long-term impacts to resources and mitigative measures to offset any potential impacts. The depth of impact analysis and mitigative measures is correlated to the degree to which a resource may be impacted.

Land use. Long-term land use impacts would be low for the implementation of this alternative. The long-term impacts will be related to the placement and use of injection and monitoring wells and access roads used in the operation. If it is chosen to target the entire off-site plume areas, there could be several hundred injection wells used in such an operation. The areas of use will include DOE, TVA, and the WKWMA, as wells as a number of parcels of privately owned land. The total acreage impacted cannot be determined without first identifying the target areas and determining whether linear injection or blanket-type injection is to be used. However, it is expected that less than one-fourth of an acre per injection well will be impacted in the long term. This would not include the area occupied by the access road, since the length of the road cannot be determined without knowing the well locations. A LUCIP would be developed as necessary per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomics. The presence of contaminants in the groundwater will prevent its use and may limit economic development opportunities until the groundwater is brought back to beneficial use. However, no long-term effects to socioeconomics would result from the implementation of this technology. There would be few changes to permanent jobs within the PGDP area as a result of implementing this technology.

Air quality and noise. No long-term effects to air quality and ambient noise levels would result from implementation of this alternative. The bioremediation technologies will not result in an air emission that must be treated.

Vegetation. There will be long-term impacts to vegetation as a result of this alternative. The alternative will require the installation of injection wells, monitoring wells, and associated access roads on DOE, TVA, and WKWMA land as well as private property. The long-term impacts will be the removal of trees for the placement of the facilities. This will disrupt the habitats of birds, mammals, and reptiles inhabiting the immediate area. There is, however, considerable habitat available in contiguous area for the displaced mammals, birds, etc. The quantities of trees that would require moving has not been determined, as the total target areas have not been identified or the means to designing the injection method (i.e., linear or blanket). However, the system can be designed to minimize the removal of trees by aligning the access road to miss trees as feasible. Also, well installations can be performed by minimizing the removal of trees rather than clearing an area for each injection and monitoring well. The areas can be vegetatively restored to grasses following construction.

Wildlife. There will be limited long-term effects to wildlife resulting from implementing this alternative. The long-term impacts will be the removal of trees that will result in disruption of habitats of birds, mammals, and reptiles inhabiting the immediate area. There is, however, considerable habitat available in contiguous area for the displaced mammals, birds, etc. The quantities of trees that would require moving has not been determined, as the total target areas have not been identified or the means to designing the injection method (i.e., linear or blanket). However, the system can be designed to minimize the removal of habitat and trees by aligning the access road to miss trees as feasible. Also well installations can be performed by minimizing the removal of trees rather than clearing an area for each injection and monitoring well. The areas can be vegetatively restored to grasses following construction allowing some wildlife to reintroduce into the area.

Construction in creeks and tributaries may occur as a result of implementing this technology. However, since the creeks and tributaries are somewhat narrow, the design of the system and the use of directional drilling can be used to minimize the impacts to the creeks and tributaries. However, it is likely that access roads will have to cross creeks and tributaries in the implementation.

Threatened and endangered species. Long-term impacts to T&E species are expected to occur. The Indiana bat, which regionally has suitable habitat, is expected to be impacted by this alternative. The habitat as mapped by Bryan (COE 1993), indicates that increased density of potential habitat occurs at the extreme ends of the dissolved phase Northwest Plume. The actual target areas for implementation of the bioremediation technology have not been determined and, therefore, the impacts to habitat cannot be determined. However, the placement of wells and access road can be strategically placed to minimize impacts. Technologies such as directional drilling also can be used. However, after a detailed design of the injection well field, a reanalysis of potential impacts to potential habitat for the Indiana bat will need to be completed.

Cultural resources. No long-term effects to cultural resources are anticipated for this alternative.

Groundwater. As a result of implementing a Bioremediation Technology in the Dissolved Phase Plume Areas, potential RGA VOC contamination either is reduced or eliminated. As a result of injecting a nutrient solution into the groundwater, there will be increased biological activity in the aquifer. Once the VOCs have been consumed by the bacteria, the increased biological activity will dissipate over time, due to the lack of nutrients. No long-term degradation of groundwater is expected. There will no reduction in ^{99}Tc contaminant levels. Groundwater monitoring systems will be used to monitor contaminant levels and the progress of the remediation. The implementation of this alternative would not require the production of groundwater to the surface for treatment. All treatment is performed *in situ,* following the injection of the nutrient solution.

Surface water. No adverse impacts to streams are expected to result from implementing a Bioremediation Technology in a Dissolved Phase Plume Area (RGA). There may be limited impacts to wetlands, as discussed below. There will be no increases in water discharge volumes to outfalls as a result of this alternative. The alternative may result in the reduction or elimination of contaminants being discharged to the Little Bayou Creek. However, if the DNAPL source areas are not removed at the PGDP, it will be necessary to repeat the action since the plumes will regenerate over time and reimpact the Little Bayou Creek.

Floodplains. It is not expected that work will impact floodplains in the long term.

Wetlands. It is expected that only limited impacts to wetlands will result from implementing a Bioremediation Technology in the Dissolved Phase Plume Area. These impacts will be the result from construction of wells and access roads. The wetlands in the area near PGDP occur due to surface flow into poorly drained soils and not from recharge from the RGA. Therefore, measures, including directional drilling, can be taken not to impact the subsurface fragipan and destroy the wetland integrity. The exception to this would be the area of Little Bayou Creek near the TVA Shawnee Steam Plant that does receive recharge from the RGA. The only mitigating measure would be to design the bioremediation system to miss wetland areas of concern to the extent possible.

Soils and prime farmland. Prime farmland would be impacted by the implementation of this alternative. The impacts would be the use of the land for the construction of injection and monitoring wells as well as the associated access roads. If it is chosen to target the entire off-site plume areas, there could be several hundred injection wells used in such an operation. The areas of use will include DOE, TVA, and the WKWMA as wells as a number of parcels of privately owned land. Prime farmland exists north of the PGDP and DOE property. The NRCS has identified prime farmland as the Calloway, Waverly, and Grenada soil series in the area between the PGDP and the TVA Shawnee Steam Plant. The total acreage impacted cannot be determined without first identifying the target areas and determining whether linear injection or blanket-type injection is to be used. However, it is expected that less than one-fourth of an acre per injection well will be impacted in the long term. This area can be expected to be slightly larger during construction due to the need to get support vehicles into the area. Once construction is complete, there will be only minimal vehicles used during the injection operations. How much of this acreage would be located on the prime farmland soils cannot be determined at this time, since the target areas have not been identified and the well locations designed. A LUCIP would be developed, as necessary, per the requirements of the PGDP LUCAP (DOE 2000).

Transportation. No long-term direct, indirect, or cumulative effects to transportation are anticipated from implementing this alternative.

Cumulative Impacts. Cumulative impacts are defined as the incremental impact of an action when added to other past, present, and reasonable foreseeable future actions, regardless of what agency or person undertakes other such actions. Cumulative impacts resulting from this alternative will have to be identified at a later time during development of site-specific GWOU decision documents.

Reduction of Mobility, Toxicity, or Volume Through Treatment. Bioremediation Technology would be used to destroy VOC contaminants contained in the Dissolved Phase Plume Areas in the RGA. The process is by *in situ* destruction. It is expected that 90% of the VOC contaminants in the target area could be expected to be destructed by bioremediation. A limited factor in bioremediation is that once contaminant concentrations get to a level whereby insufficient nutrients exists to sustain the bacteria, the remediation stops. It is expected that this critical contaminant level may be in the 100 ppb range, which is above the 5 ppb MCL for TCE. If methanogenic bacteria are used, the limiting factor is that epoxides are produced that may result in the destruction of the implementing bacteria, which may drive the remediation to be limited. The Bioremediation Technologies will not have an effect on the ^{99}Tc contaminant levels. The destruction of the contaminants by the bacteria results in the release of gases and chlorides. The gases and the injected methane, if used, will migrate to the vadose zone and eventually to the atmosphere. The concentrations will not present a hazard upon release.

The implementation of a Bioremediation Technology would reduce the long-term volume and toxicity of VOCs present in the RGA through the destruction of those contaminants. The implementation of this technology is not expected to alter the physical soil properties of the RGA and, as such, should not prevent the implementation of an additional technology should it be determined that additional treatment is needed for the target areas. However, bioremediation by anaerobic bacteria can, in some instances, result in the production of TCE degradation products that may be more toxic than the original TCE. Although the presence of the degradation products may not preclude the implementation of additional technologies, it may, to some degree, limit the number of technologies available.

The type and characteristics of residual subsurface contamination would be similar to that of the contaminants prior to treatment. If the bioremediation is implemented without the removal of the source zone areas at PGDP, residual contaminants would exist in the RGA following treatment and would pose a risk. However, contaminant quantities would be considerably reduced following treatment in the target areas. Since the treatment occurs *in situ*, there will be no residual contaminants to be disposed of from any surface or *ex situ* treatment. The technology will, however, not remove the ^{99}Tc contamination if it is present in the plume. Since ^{99}Tc may be present and there will be some residual VOC contamination in the RGA, and if the source areas are not also removed, the groundwater will remain unusable for an extended period of time. Bioremediation Technology will meet the statutory preference for treatment as a principal element of the remedial action under CERCLA.

Short-Term Effectiveness. The short-term effectiveness of implementing a Bioremediation Technology in the Dissolved Phase Plume Area of the RGA was evaluated relative to its effect on community protection, worker protection, environmental impact, and the time until RAOs are achieved. Environmental impact was further evaluated for NEPA values. This information is presented in the following subsections.

Community protection. The potential for adverse impacts to the community from the implementation of this alternative is minimal. The likely target areas will be the dissolved phase portions of the groundwater plumes that lie between PGDP and the Ohio River. The areas specifically contain property of DOE, TVA, the WKWMA, and also a parcel of privately held land.

Worker protection. During the implementation of a Bioremediation Technology, workers could be exposed to COCs during short periods of time. Potential exposure could result from direct contact with contaminated soil and/or groundwater during construction of the injection wells. The workers also will be exposed to the nutrient solutions during the injection operations. Although the nutrient solutions are non-toxic, appropriate handling procedures, injection equipment procedures, and PPE would be utilized to minimize the potential for worker exposure or injury while handling the nutrient. Short-term risks are not expected to exceed acceptable limits. Health and safety requirements and PGDP procedures would further control the exposures.

Environmental impacts and mitigative measures. The following paragraphs summarize potential short-term impacts to resources and mitigative measures to offset any potential impacts. The depth of impact analysis and mitigative measures is correlated to the degree to which a resource may be impacted.

Land use. The areas expected to be targeted for implementation of a Bioremediation Technology in the Dissolved Phase Plume Area lies between PGDP and the Ohio River. The expected land to be impacted includes land of DOE, EPA, WKWMA, and potentially multiple parcels of privately held property. The short-term impacts will be related to the construction and placement and use of injection and monitoring wells and access roads used in the operation. If it is chosen to target the entire off-site plume areas, there could be several hundred injection wells used in such an operation. The total acreage impacted cannot be determined without first identifying the target areas and determining whether linear injection or blanket-type injection is to be used. However, it is expected that less than one-fourth of an acre per injection well will be impacted in the long term. The impacted area in the short term likely will be slightly larger. This is due to the need to get support vehicles to the locations to install the injections wells and monitoring wells. Once the wells are installed, less equipment will be necessary to support the injection operations. A LUCIP would be developed, as necessary, per the requirements of the PGDP LUCAP (DOE 2000).

Socioeconomics. This alternative would not be expected to change the short–term economic conditions in the nearby area. There would be a minimal increase in temporary jobs related to the construction of injection wells and injection operations.

Air quality and noise. Heavy equipment traffic and operation associated with construction of the injection wells would provide a minimal increase in dust and vehicular emission levels. The use of BMPs during construction would reduce short-term direct impacts to air quality from dust. Noise associated with construction activities would occur in the immediate vicinity of the work locations, which may be near private residences for the Northeast Plume. The noise levels would be increased during construction and will diminish during the actual nutrient injection operations. There would be no air emissions as a result of implementing a Bioremediation Technology.

Vegetation. There will be short-term impacts to vegetation as a result of this alternative. The alternative will require the installation of injection wells, monitoring wells, and associated access roads on DOE, WKWMA, and TVA land as well as private property. The short-term impacts will be the removal of trees for the placement of the injection facilities. This will result in disruption of habitats of birds, mammals, and reptiles inhabiting the immediate area. There is, however, considerable habitat available in contiguous area for the displaced mammals, birds, etc. The quantities of trees that would require moving has not been determined, as the total target areas have not been identified and neither has the means to designing the injection method (i.e., linear or blanket). However, the system can be designed to minimize the removal of trees by aligning the access road to miss trees as feasible. Also, well installations can be performed by minimizing the removal of trees rather than clearing an area for each injection and monitoring well. The areas can be vegetatively restored to grasses following construction.

Construction in creeks and tributaries may occur as a result of implementing this technology. However, since the creeks and tributaries are somewhat narrow, the design of the system and the use of directional drilling can be used to minimize the impacts to the creeks and tributaries. However, it is likely that access roads will have to cross creeks and tributaries in the implementation.

Wildlife. There will be moderate short-term effects to wildlife resulting from implementing this alternative. The long-term impacts will be the removal of trees that will result in disruption of habitat of birds, mammals and reptiles inhabiting the immediate area. There is however, considerable habitat available in contiguous area for the displaced mammals, birds, etc. The quantities of trees that would require moving has not been determined as the total target areas have not been identified and the means to designing the injection method (i.e., linear or blanket). However, the system can be designed to minimize the removal of habitat and trees by aligning access road to miss trees as feasible. Also well installations can be performed by minimizing the removal of trees rather than clearing an area for each injection and monitoring well. The areas can be vegetatively restored to grasses following construction, allowing some wildlife to reintroduce into the area.

Construction in creeks and tributaries may occur as a result of implementing this technology. However, since the creeks and tributaries are somewhat narrow, the design of the system and the use of directional drilling can be used to minimize the impacts to the creeks and tributaries and, thereby, minimizing the impacts to wildlife. However, it is likely that access roads will have to cross creeks and tributaries in the implementation.

Threatened and endangered species. Short-term impacts to T&E species are expected to occur. The Indiana bat, which regionally has suitable habitat, is expected to be impacted by this alternative. The habitat, as mapped by Bryan (COE 1993), indicates that increased density of potential habitat occurs at the extreme ends of the dissolved phase Northwest Plume. The actual target areas for implementation of the bioremediation technology have not been determined and, therefore, the impacts to habitat cannot be determined. However, the placement of wells and access road can be strategically placed to minimize impacts. Technologies such as directional drilling also can be used. However, after a detailed design of the injection well field, a reanalysis of potential impacts to potential habitats for the Indiana bat will need to be completed.

Cultural resources. No short-term effects to cultural resources are anticipated for this alternative.

Groundwater. As a result of implementing a Bioremediation Technology in the Dissolved Phase Plume Areas, potential RGA VOC contamination either is reduced or eliminated. As a result of the use of injecting a nutrient, there will be increased biological activity in the aquifer. The increased biological activity will diminish to pre-treatment levels once the nutrient injections stop and the VOC contaminant food supply dissipates. It is not expected that other adverse impacts to groundwater will occur as a result of this alternative. Groundwater monitoring systems will be used to monitor contaminant levels and the effects of the technology. The implementation of this alternative would not require the production of groundwater to the surface for treatment. All treatment is performed *in situ* following the injection of the nutrient solution.

Surface water. No adverse impacts to streams are expected to result from implementing a Bioremediation Technology in a Dissolved Phase Plume Area (RGA). No adverse impacts to wetlands are expected to occur either. There will be no increases in water discharge volumes to outfalls as a result of this alternative. The alternative may result in the reduction or elimination of contaminants being discharged to the Little Bayou Creek. However, if the DNAPL source areas are not removed at the PGDP, it will be necessary to repeat the action, since the plumes will regenerate over time and reimpact the Little Bayou Creek.

Floodplains. It is expected that work may occur in the floodplain of the Ohio River in the short term. However, it is not expected that impacts will occur as a result of implementing this alternative. No modifications such as realignment, trenching, or relocating of floodplains will occur.

Wetlands. It is expected that only limited impacts to wetlands will result from implementing a Bioremediation Technology in the Dissolved Phase Plume Area. These impacts will be the result of construction of wells and access roads. The wetlands in the area near PGDP occur due to surface flow into poorly drained soils and not from recharge from the RGA. Therefore, measures, including directional drilling, can be taken not to impact the subsurface fragipan and destroy the wetland integrity. The exception to this would be the area of Little Bayou Creek near the TVA Shawnee Steam Plant that does receive recharge from the RGA. The only mitigating measure would be to design the bioremediation system to miss wetland areas of concern to the extent possible.

Soils and prime farmland. Prime farmland would be impacted by the implementation of this alternative. The impacts would be the use of the land for the construction of injection and monitoring wells, as well as for the associated access roads. If it is chosen to target the entire off-site plume areas, there could be several hundred injection wells used in such an operation. The areas of use will include DOE, TVA, and the WKWMA, as wells as a number of parcels of privately owned land. Prime farmland exists north of the PGDP and DOE property. The NRCS has identified prime farmland as the Calloway, Waverly, and Grenada soil series in the area between the PGDP and the TVA Shawnee Steam Plant. The total acreage impacted cannot be determined without first identifying the target areas and determining whether linear injection or blanket-type injection is to be used. However, it is expected that less than one-fourth of an acre per injection well will be impacted in the long term. This area can be expected to be slightly larger during construction due to the need to get support vehicles into the area. Once construction is complete, there will be only minimal vehicles used during the injection operations. How much of this acreage would be located on the soils cannot be determined at this time, since the target areas have not been identified or the well locations designed. A LUCIP would be developed, as necessary, per the requirements of the PGDP LUCAP (DOE 2000).

Transportation. No short-term direct, indirect, or cumulative effects to transportation are anticipated from implementing this alternative. It will, however, be necessary to transport waste soils and development water during construction and nutrient solutions during operations. The appropriate precautions and controls and packaging will be used to protect against spill during the transportation of these items.

Cumulative Impacts. Cumulative impacts are defined as the incremental impacts of an action when added to other past, present, and reasonable foreseeable future actions, regardless of what agency or person undertakes other such actions. Cumulative impacts resulting from this alternative will have to be identified at a later time during development of site-specific GWOU decision documents.

Time until action is complete. Implementation of this alternative will not result in achievement of the GWOU RAOs specified or groundwater MCLs. Approximately 7,000 years will be required before groundwater may be used following the application of a Bioremediation Technology in the Dissolved Phase Plume Areas of the RGA. Without the reduction of DNAPL sources, the plumes will regenerate over time. Also, ^{99}Tc levels will not be reduced as a result of the implementation of a Bioremediation Technology in the Dissolved Phase Areas. It will be necessary to implement source reduction and other dissolved phased technologies in conjunction with Bioremediation Technologies to reduce the time the groundwater will remain unusable.

Implementability. The implementability of Bioremediation Technologies in the Dissolved Phase Plume Area was evaluated based upon its technical feasibility, administrative feasibility, and the availability of services and materials. This information is summarized in the following subsections.

Technical feasibility. Implementation of Bioremediation Technologies is technically feasible. These technologies have been implemented at other hazardous waste sites successfully, and the necessary equipment may be readily obtained. Bioremediation uses standard commercially available equipment and materials. The technology can be implemented by multiple vendors. However, a technical concern does exist with the chemistry of the RGA. The aquifer has a high saturation of oxygen, which generally is about 8 ppm. The bacteria that would be active in destruction of the TCE in the RGA with this level of dissolved oxygen and under natural conditions are methanogenic or aerobic. The use of the aerobic bacteria in the destruction of the contaminants will require the injection of a nutrient source to provide an energy source or primary food for the bacteria to consume. The bacteria also will consume the contaminant as they are consuming the methane. However, the methanogenic bacteria will produce epoxides in this operation, which can be toxic to the bacteria which then results in the death of the methanogenic bacteria. This further results in the termination of the process due to lack of methanogenic bacteria.

The oxygen level of up to 8 ppm in the RGA is not the best suited for the bacterial anaerobic destruction of the TCE. The anaerobic destruction of TCE can produce undesirable degradation products. However, sufficient lactate injection will cause an increase in anaerobic bacteria, which will deplete the oxygen supply. Once the oxygen supply is depleted, the aerobic bacteria cease activity and anaerobic degradation bacteria begin activity. It is estimated that approximately 4 million pounds of 60% lactate solution may be required for injection over the activities operation. Implementation difficulties also may arise due to design the injection systems around sensitive areas in the target areas. Some of these items may include wetlands, Indiana bat Habitat, and creeks. A monitoring network will be necessary to monitoring the effectiveness of the treatment operations.

Administrative feasibility. This alternative is administratively feasible. All activities would be conducted in accordance with substantive federal, state, and local requirements. Waivers of ARARs are anticipated to be necessary to implement these actions, since MCLs will not be attained in a timely manner.

Availability of material and services. The services and materials necessary to implement this alternative are readily available. There are multiple vendors available that are experienced in bioremediation implementation. The equipment is standard, industrial equipment used in other fields such as wastewater treatment.

The construction of this alternative will result in the generation of waste soil cuttings and drilling and development water from the construction of injection and monitoring wells. Additionally, the construction will generate construction debris during the building of any required injection facilities. All of these materials will either be treated as necessary and released, as in the development water, or disposed of appropriately.

Cost. Table 4.24 summarizes the preliminary unit cost estimates for implementation of a Bioremediation Technology in a Dissolved Phase Plume Area of the RGA. These preliminary unit cost estimates are based upon FS-level scoping and are intended to aid with selection of a preferred alternative. The estimates have an expected accuracy of -30 to +50% for the proposed scope of action (EPA 1988a). The capital cost estimate represents those expenditures required to implement this remedial alternative. The O&M cost estimates represent expenditures required to maintain the remedy after the initial phase of remedial action is completed. The total contingency cost presented includes direct, indirect, and all O&M associated contingency costs. The total cost includes all capital costs, direct and indirect with O&M and associated reports, plus 25% contingency costs, for a 30-year term of comparison. All estimates have been escalated using DOE-approved annual rates and a schedule for the various activities based on similar project experience. Present worth values also are included using a discount factor of 5% (EPA 1988b). (Additional information regarding the preliminary cost estimates is presented in Appendix C7.)

Table 4.24. Preliminary unit cost estimates for Dissolved Phase Plume Area – Bioremediation Technology

Total capital costs/acre-foot	$49,043
Total operation and maintenance costs	$66,952
Overhead	$81,920
Total contingency	$50,507
Total cost	**$248,424**
Total cost (present worth)	**$205,154**

Note: preliminary cost estimates are per acre-foot, escalated and presented in dollars.

State/Commonwealth Acceptance. Commonwealth of Kentucky acceptance or nonacceptance of this alternative will be addressed in the ROD should this alternative be selected as the preferred alternative.

Community Acceptance. Following a formal public comment period on the PRAP for the GWOU, comments from the community will be addressed formally in a responsiveness summary, which will be presented in the ROD.

Evaluation summary of Dissolved Phased Plume Area - Bioremediation Technology

This alternative consists of implementing a Bioremediation Technology in a Dissolved Phase Plume Area of the RGA to remove VOC contaminants present in the RGA in the targeted area, monitoring of the action, and conducting five-year reviews as required by CERCLA. Monitoring COC migration allows the potential for exposure to contaminated groundwater to be prevented or minimized, and it also allows the effectiveness of the remedial actions to be evaluated. Although the Dissolved Phase Area concentration in the RGA would be reduced following the implementation, the residual contamination and risks would remain, especially at the Primary and Secondary Source Areas. These residual risks in the RGA from Primary and Secondary Source Areas still will be present and prevent the use of the groundwater for an estimated 7,000 years. The bioremediation technology will not remove ^{99}Tc contamination. It also would be necessary to conduct source area reductions and dissolved phased plume actions for ^{99}Tc contamination to reduce the time the groundwater would be unusable.

Implementation of this alternative alone will not be protective of human health and the environment. It must be combined with source area and dissolved phase plume actions. Bioremediation Alternatives can be implemented in compliance with ARARs. Long-term effectiveness could be achieved to an acceptable degree 90% mass removal within the Dissolved Phase Areas of the RGA within 15 years of implementation. However, because of the nature of the soil and groundwater contamination associated with the GWOU, it will take several years and other actions to remediate completely. Residual contamination will remain in the groundwater, with TCE levels exceeding the MCL for approximately

7,000 years. The volume and toxicity of the VOCs COCs would be reduced by *in situ* destruction. Limited short-term risks to workers would exist during the construction and operation phase of the alternative. The alternative is technically and administratively feasible to implement. The unit cost of this alternative, which is intended to address only the Dissolved Phase Areas of the RGA in the GWOU at the PGDP, is quite significant. Input from the Commonwealth of Kentucky and the community has not yet been received, but these will be added to later versions of this FS report and the corresponding ROD once the respective comment periods have been completed.

4.3 COMPARATIVE ANALYSIS OF ALTERNATIVES

Table 4.25 contains a summary of the detailed evaluations for each alternative. This table serves as a comparative analysis of the twelve alternatives.

By far, the largest of the DNAPL zones at the PGDP is located at the southeast corner of the C-400 Building. For each of the FS alternatives, the main C-400 DNAPL source zone is the limiting case for the time required for sufficient source zone mass removal to diminish risk to a groundwater user. None of the technologies when implemented alone provide for meeting the GWOU RAOs in a timely manner. It is required to implement multiple technologies in concert to reduce the time the groundwater is unusable. The Primary Source Area Technologies provide the greatest removal of contaminants and reduction of time until groundwater becomes of beneficial use (1,000 years). The Secondary Source Area Technologies and Dissolved Phase Plume Technologies provide the longest time until groundwater becomes beneficial (7,000 years). This is due to the Primary Source Areas low dissolution rate. If, however, the Dissolved Phase Area Technologies are implemented to effect a containment of contaminant migration from the PGDP, which requires continuous operation, the groundwater can become useable outside these zones in approximately 15 years.

The Primary and Secondary Source Area technologies that provide the addition of energy to the subsurface (Direct Heating, Steam Extraction) to volatilize the VOCs are expected to be most effective at removing the DNAPL concentrations since they use air or vapor as a carrier to remove the volatile contaminant. However, these technologies will have limited effectiveness on the reduction of ^{99}Tc since ^{99}Tc reductions are driven by removal of groundwater. Whereas, the Pump-and-Treat Technologies will provide the greatest reductions in ^{99}Tc, they will be effected by the limited dissolution of TCE into the groundwater. Excavation Technologies provide the greatest removal efficiencies but will limited by depth of contaminants and influx of groundwater when excavating below the groundwater table.

Table 4.26 presents the expected TCE volume reduction for each of the alternatives during the first 30 years of implementation.

Table 4.25. Comparative Analysis Table

Criteria	No Action	Primary Source Areas			Secondary Source Areas		
Description	No Action	Vapor Extraction Technology	Direct Heating Technology	Excavation	Steam Extraction Technology	Pump-and-Treat Technology	Oxidation Technology
Overall Protection of Human Health and the Environment							
Human health protection	Does not protect human health	Not protective unless combined with additional measures.	Not protective unless combined with additional measures.	Not protective unless combined with additional measures.	Not protective unless combined with additional measures.	Not protective unless combined with additional measures.	Not protective unless combined with additional measures.
Environmental protection	Discharges from the Northwest Plume into Little Bayou Creek will continue.	Discharges from the Northwest Plume into Little Bayou Creek will continue.	Discharges from the Northwest Plume into Little Bayou Creek will continue.	Discharges from the Northwest Plume into Little Bayou Creek will continue.	Discharges from the Northwest Plume into Little Bayou Creek will continue.	Discharges from the Northwest Plume into Little Bayou Creek will continue.	Discharges from the Northwest Plume into Little Bayou Creek will continue.
Compliance with ARARs							
Chemical-specific	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater or surface water.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater or surface water.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater or surface water.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater or surface water.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater or surface water.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater or surface water.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater or surface water.
Location-specific	No location-specific ARARs were identified for this alternative.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.
Action-specific	No action-specific ARARs were identified for this alternative.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.
Other criteria and guidance	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.
Long-Term Effectiveness and Permanence							
Magnitude of residual risk	Residual risks remain high during the first 30 years; residual risks will be reduced in 7,000 years.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the POC.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the POC.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the POC.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the POC.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the POC.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the POC.
Adequacy and reliability of controls	No implementation of controls preventing exposure to potential receptors.	Adequate and reliable.	Adequate and reliable.	Adequate and very reliable where applicable. Reliability decreases where infrastructure impedes implementation.	Adequate and reliable.	Adequate and reliable.	Adequate and moderately reliable.
Need for 5-year review	Required	Required	Required	Required	Required	Required	Required

Table 4.25. (continued)

Criteria	No Action	Primary Source Areas			Secondary Source Areas		
Description	No Action	Vapor Extraction Technology	Direct Heating Technology	Excavation	Steam Extraction Technology	Pump-and-Treat Technology	Oxidation Technology
Environmental impacts and mitigative measures	No action would allow current rates of contamination to continue.	Minimal environmental impacts and mitigative measures.	Minimal environmental impacts and mitigative measures.	Minimal overall environmental impacts and mitigative measures. However, local impacts will be significant.	Minimal environmental impacts and mitigative measures.	Minimal environmental impacts and mitigative measures.	Minimal environmental impacts and mitigative measures.
Reduction of Toxicity, Mobility, or Volume through Treatment							
Treatment processes used	None	Vapor extraction; ion exchange and air stripper with cat/ox system.	Direct heating with ion exchange and air stripper with cat/ox system.	Excavation with *ex situ* thermal treatment of soil.	Steam extraction; ion exchange and air stripper with cat/ox system.	Pump-and-treat; ion exchange and air stripper with cat/ox system.	*In situ* oxidation
Amount destroyed or treated	None	TCE and VOCs will be treated. Moderately effective on DNAPL. Minimal ^{99}Tc will be captured.	TCE and VOCs will be treated. Highly effective on DNAPL. Minimal ^{99}Tc will be captured.	All contaminated soils will be removed. TCE and other VOCs will be treated. Highly effective on DNAPL if within excavation zone.	TCE and VOCs will be treated. Highly effective on DNAPL. ^{99}Tc will be captured.	TCE and VOCs will be treated. Minimally effective on DNAPL. Minimal ^{99}Tc will be captured.	TCE and VOCs will be treated. Moderately to highly effective on DNAPL. Not effective on ^{99}Tc.
Degree of reduction of toxicity, mobility, or volume	No reduction in toxicity, mobility, and volume.	High reduction in VOC toxicity and volume of sources. Minimal reduction in ^{99}Tc volume.	High reduction in VOC toxicity and volume of sources. Minimal reduction in ^{99}Tc volume.	High reduction in VOC toxicity and volume of VOC and ^{99}Tc sources within the zone of excavation.	High reduction in VOC toxicity and volume of sources. Moderate reductions in ^{99}Tc volume.	Low volume of VOC contaminants recovered. High reduction in toxicity of VOCs recovered. Large reductions in ^{99}Tc volume.	High reduction in VOC toxicity. No impact on ^{99}Tc.
Irreversibility of treatment	Not applicable.	Reversible.	Irreversible.	Irreversible.	Reversible.	Reversible.	Irreversible.
Type/quantity of residuals remaining after treatment	Not applicable.	Treatment residuals include ^{99}Tc contaminated ion-exchange resin and salt from off-gas treatment.	Treatment residuals include ^{99}Tc contaminated ion-exchange resin and salt from off-gas treatment.	Treatment residuals include ^{99}Tc contaminated ion-exchange resin and salt from off-gas treatment.	Treatment residuals include ^{99}Tc contaminated ion-exchange resin and salt from off-gas treatment.	Treatment residuals include ^{99}Tc contaminated ion-exchange resin and salt from off-gas treatment.	None.
Statutory preference for treatment	Not applicable.	Satisfied for VOCs.	Satisfied for VOCs.	Satisfied for VOCs.	Satisfied for VOCs.	Satisfied for VOCs.	Satisfied for VOCs.
Short-term Effectiveness							
Community protection	No increase in risk to community as no action is taken.	No negative impacts to the community are anticipated.	No negative impacts to the community are anticipated.	No negative impacts to the community are anticipated.	No negative impacts to the community are anticipated.	No negative impacts to the community are anticipated.	No negative impacts to the community are anticipated.
Worker protection	No risks to workers as no action is taken.	Minimal risks to workers from handling contaminated groundwater. Risks can be minimized through adherence to health/safety protocols.	Minimal risks to workers from handling contaminated groundwater. Large volumes of electricity are used. Risks can be minimized through adherence to health/safety protocols.	Risks to workers from handling contaminated soils. Risks can be minimized through adherence to health/safety protocols.	Minimal risks to workers from handling contaminated groundwater. Potential exposure to steam under pressure. Risks can be minimized through adherence to health/safety protocols.	Risks to workers from handling contaminated groundwater. Risks can be minimized through adherence to health/safety protocols.	Risks to workers from handling oxidant. Risks can be minimized through adherence to health/ safety protocols.
Environmental impacts and mitigative measures	No action would allow current rates of contamination to continue.	Minimal environmental impacts and mitigative measures.	Minimal environmental impacts and mitigative measures.	Minimal environmental impacts and mitigative measures.	Minimal environmental impacts and mitigative measures.	Increase in discharge to creeks will result.	Minimal environmental impacts and mitigative measures.

Table 4.25. (continued)

Criteria	No Action	Primary Source Areas			Secondary Source Areas		
Description	No Action	Vapor Extraction Technology	Direct Heating Technology	Excavation	Steam Extraction Technology	Pump-and-Treat Technology	Oxidation Technology
Time until action is complete	Time until the groundwater is attenuated is 7,000 years.	Approximately 1,000 years.	Approximately 1,000 years.	Approximately 1,000 years.	Approximately 7,000 years.	Approximately 7,000 years.	Approximately 7,000 years.
Implementability							
Technical feasibility	Feasible to implement.	Feasible to implement.	Feasible to implement.	Feasible to implement above water table and where infrastructure allows.	Feasible to implement.	Feasible to implement.	Feasible to implement.
Administrative feasibility	Feasible to implement. ARARs waiver required.	Feasible to implement. ARARs waiver required.	Feasible to implement. ARARs waiver required.	Feasible to implement. ARARs waiver required.	Feasible to implement. ARARs waiver required.	Feasible to implement. Long-term presence required. ARARs waiver required.	Feasible to implement. ARARs waiver required.
Availability of services and materials	Feasible to implement.	Services and materials are readily available.	Availability of vendors and equipment is limited.	Services and materials are readily available.	Availability of vendors is limited.	Services and materials are readily available.	Availability of vendors is limited.
Unit Cost (Per acre-foot and in dollars)							
Total cost: escalated	$0	$687,648	$694,837	$8,131,025	$2,083,677	$2,318,211	$12,304,300
Total costs: present worth	$0	$554,393	$434,759	$5,930,929	$1,042,276	$1,076,353	$12,218,892
Commonwealth Acceptance							
General	Comments from the Commonwealth of Kentucky will be incorporated into this FS report as appropriate following review of the draft report.						
Community Acceptance							
General	Following a formal public comment period on the PRAP, comments from the community will be addressed in a responsiveness summary, which will be presented in the GWOU ROD documents.						

ARAR = applicable or relevant and appropriate requirement
MCL = maximum contaminant levels
POC = pathway of concern
RAO = remedial action objective
RGA = Regional Gravel Aquifer
TCE = trichloroethene
UCRS = Upper Continental Recharge System
VOC = volatile organic compound
^{99}Tc = technetium-99

Table 4.25a. Comparative Analysis Table

Criteria	Dissolved Phase Areas				
Description	Pump and Treat Technology	Ozonation Technology	Permeable Treatment Zone Technology	Oxidation Technology	Bioremediation Technology
Overall Protection of Human Health and the Environment					
Human health protection	Not protective unless combined with additional measures	Not protective unless combined with additional measures	Not protective unless combined with additional measures	Not protective unless combined with additional measures	Not protective unless combined with additional measures
Environmental protection	May remediate discharges from the Northwest Plume into Little Bayou Creek. Long-term presence will be required.	May remediate discharges from the Northwest Plume into Little Bayou Creek. Long-term presence will be required.	May remediate discharges from the Northwest Plume into Little Bayou Creek. Long-term presence will be required.	May remediate discharges from the Northwest Plume into Little Bayou Creek. Long-term presence will be required.	May remediate discharges from the Northwest Plume into Little Bayou Creek. Long-term presence will be required.
Compliance with ARARs					
Chemical-specific	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater.	Long time frame needed to comply with chemical-specific ARARs associated with contaminated groundwater.
Location-specific	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.	Complies with identified location-specific ARARs by incorporation of requirements into design and pre-construction planning.
Action-specific	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.	Compliance with the identified action-specific ARARs will be achieved through incorporation of the requirements in the design and planning phase of implementation.
Other criteria and guidance	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.	Compliance with identified criteria will be achieved.
Long-Term Effectiveness and Permanence					
Magnitude of residual risk	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the source zones.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the source zones.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the source zones.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the source zones.	Residual risks remain high during the first 30 years; will require additional measures to meet MCLs at the source zones.
Adequacy and reliability of controls	Adequate and reliable	Adequate and reliable	Adequate and reliable	Adequate and reliable.	Adequate and reliable
Need for 5-year review	Required	Required	Required	Required	Required
Environmental impacts and mitigative measures	Moderate environmental impacts and mitigative measures	Low environmental impacts and mitigative measures	Low environmental impacts and mitigative measures	Low environmental impacts and mitigative measures	Low environmental impacts and mitigative measures
Reduction of Toxicity, Mobility, or Volume through Treatment					
Treatment processes used	Pump and treat, ion exchange and air stripper with cat/ox system.	*In situ* ozonation with ion exchange	*In situ* permeable treatment zone	*In situ* oxidation	*In situ* bioremediation
Amount destroyed or treated	TCE and VOCs will be treated. ^{99}Tc will be captured.	TCE and VOCs will be treated. ^{99}Tc will be captured.	TCE and VOCs will be treated. ^{99}Tc will be captured and held within the aquifer.	TCE and VOCs will be treated. ^{99}Tc will not be captured.	TCE and VOCs will be treated to a level of approximately 100 µg/L. ^{99}Tc will not be captured.
Degree of reduction of toxicity, mobility, or volume	High reduction in dissolved phase VOC toxicity and volume. High reduction in dissolved phase ^{99}Tc volume.	High reduction in dissolved phase VOC toxicity and volume. High reduction in dissolved phase ^{99}Tc volume.	High reduction in dissolved phase VOC toxicity and volume. High reduction in dissolved phase ^{99}Tc volume.	High reduction in dissolved phase VOC toxicity and volume.	High reduction in dissolved phase VOC toxicity and volume.

Table 4.25a. (continued)

Criteria	Dissolved Phase Areas				
Description	Pump and Treat Technology	Ozonation Technology	Permeable Treatment Zone Technology	Oxidation Technology	Bioremediation Technology
Irreversibility of treatment	Reversible	Irreversible	Irreversible.	Irreversible.	Reversible
Type/quantity of residuals remaining after treatment	Treatment residuals include ^{99}Tc contaminated ion-exchange resin and salt from off-gas treatment.	Treatment residuals are ^{99}Tc contaminated ion-exchange resin.	Treatment residuals are ^{99}Tc contaminated iron filings.	None	100 μg/L VOCs. Note: residual VOCs may lead to higher risk than original VOCs due to degradation.
Statutory preference for treatment	Satisfied for VOCs	Satisfied for VOCs	Satisfied for VOCs and ^{99}Tc.	Satisfied for VOCs	Satisfied for VOCs
Short-term Effectiveness					
Community protection	Minimal negative impacts to the community are anticipated.	No negative impacts to the community are anticipated.	No negative impacts to the community are anticipated.	Potential negative impacts to the community are anticipated.	No negative impacts to the community are anticipated.
Worker protection	Minimal risks to workers from handling contaminated groundwater. Risks can be minimized through adherence to health/safety protocols.	Minimal risks to workers from handling contaminated groundwater. Risks can be minimized through adherence to health/safety protocols.	Risks to workers from handling contaminated soils. Risks can be minimized through adherence to health/safety protocols.	Minimal risks to workers from handling contaminated groundwater. Potential exposure to oxidant. Risks can be minimized through adherence to health/safety protocols.	Risks to workers from handling contaminated groundwater. Risks can be minimized through adherence to health/safety protocols.
Environmental impacts and mitigative measures	Moderate environmental impact. May eliminate contaminant discharge to Little Bayou Creek. Increase in water discharge to creeks will result.	Moderate environmental impact. May eliminate VOC discharge to Little Bayou Creek.	Moderate environmental impact. May eliminate contaminant discharge to Little Bayou Creek.	Moderate environmental impact. May eliminate VOC discharge to Little Bayou Creek.	Moderate environmental impact. May decrease VOC discharge to Little Bayou Creek.
Time until action is complete	Approximately 7,000 years in source areas. Approximately 100 yrs or less in downgradient areas.	Approximately 7,000 years in source areas. Approximately 100 yrs or less in downgradient areas.	Approximately 7,000 years in source areas. Approximately 100 yrs or less in downgradient areas.	Approximately 7,000 years in source areas. ^{99}Tc levels will not be affected.	Approximately 7,000 years in source areas. ^{99}Tc levels will not be affected.
Implementability					
Technical feasibility	Feasible to implement	Feasible to implement	Feasible to implement	Feasible to implement	Feasible to implement
Administrative feasibility	Feasible to implement. Long-term presence required. ARARs waiver required.	Feasible to implement. Long-term presence required. ARARs waiver required.	Feasible to implement. Long-term presence required. ARARs waiver required.	Feasible to implement. Long-term presence required. ARARs waiver required.	Feasible to implement. Long-term presence required. ARARs waiver required.
Availability of services and materials	Services and materials are readily available.	Services and materials are readily available.	Availability of vendors is limited	Availability of vendors is limited	Services and materials are readily available.
Cost (in thousands of dollars)					
Total cost: escalated	$692,703	$134,477	$180,269	$209,601	$248,424
Total costs: present worth	$361,039	$75,065	$124,285	$157,636	$205,154
Commonwealth Acceptance					
General	Comments from the Commonwealth of Kentucky will be incorporated into this feasibility study report as appropriate following review of the draft report.				
Community Acceptance					
General	Following a formal public comment period on the proposed plan, comments from the community will be addressed in a responsiveness summary, which will be presented in the GWOU Record of Decision documents.				

ARAR = applicable or relevant and appropriate requirement
RAO = remedial action objective
RGA = Regional Gravel Aquifer
TCE = trichloroethene
UCRS = Upper Continental Recharge System
VOC = volatile organic compound
^{99}Tc = technetium-99

Table 4.26. Expected TCE volume reduction within 30 years

Alternative		TCE Volume Reduction	
		UCRS (total of 210,217 liters)	RGA (total of 576,511 liters)
	No Further Action	2% (4,835 liters)	3% (19,025 liters)
Primary Source	Vapor Extraction	75% (157,663 liters)	3% (19,025 liters)
	Direct Heating	95% 199,706 liters)	3% (19,025 liters)
	Excavation	100% (210,217 liters)	3% (19,025 liters)
Secondary Source	Steam Extraction	2% (4,835 liters)	87% (570,746 liters)
	Pump and Treat	2% (4,835 liters)	38% (247,900 liters)
	Oxidation	2% (4,835 liters)	79% (518,860 liters)
Dissolved Phase	Pump and Treat	2% (4,835 liters)	15% (100,029 liters)
	Ozonation	2% (4,835 liters)	15% (100,029 liters)
	Permeable Treatment Zone	2% (4,835 liters)	15% (100,029 liters)
	Oxidation	2% (4,835 liters)	15% (100,029 liters)
	Bioremediation	2% (4,835 liters)	15% (96,724 liters)

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