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FEB 18 2014

PPPO-02-2174764-14

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Ms. Jennifer Tufts
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U.S. Environmental Protection Agency, Region 4
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Dear Mr. Mullins and Ms. Tufts:

TRANSMITTAL OF THE TREATABILITY STUDY WORK PLAN FOR STEAM INJECTION, GROUNDWATER OPERABLE UNIT, AT PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY (DOE/LX/07-1294&D2)

Enclosed for your review and approval is the certified D2 *Treatability Study Work Plan for Steam Injection, Groundwater Operable Unit, at Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-1294&D2 (TSWP). The objective of the treatability study is to gather information on steam mobility in the Regional Gravel Aquifer (RGA) to inform the regulatory decision process for determining the applicability of steam enhanced remediation for Phase IIb. This work plan provides information to guide the design, implementation, and evaluation of the response of the RGA to steam injection.

This D2 document incorporates comments on the D1 version of this document received from the Kentucky Division of Waste Management on November 27, 2013, and from the U.S. Environmental Protection Agency on December 4, 2013. In response to extensive comments on the project Quality Assurance Project Plan (QAPP) (Appendix B of the work plan), and as discussed via teleconference on January 29, 2014, Appendix B has been replaced in its entirety with the site's programmatic QAPP, which was modified to reflect project requirements, as necessary. Additionally this D2 document contains revisions based on feedback received during the comment resolution teleconference held on February 6, 2014. A redlined version of the TSWP and comment response summaries are enclosed to aid in your review.

If you have any questions or require additional information, please contact David Dollins at (270) 441-6819.

Sincerely,

Jennifer Woodard
Federal Facility Agreement Manager
Portsmouth/Paducah Project Office

Enclosures:

1. TSWP—Clean Version
2. TSWP—Redline Version
3. CRS for EPA Comments
4. CRS for KDWM Comments

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CERTIFICATION

Document Identification: ***Treatability Study Work Plan for Steam Injection, Groundwater Operable Unit, at Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-1294&D2**

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

LATA Environmental Services of Kentucky, LLC

Mark J. Duff, Paducah Project Manager

2-18-14
Date Signed

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

U.S. Department of Energy (DOE)

Rachel H. Blumenfeld, Acting Site Lead
Portsmouth/Paducah Project Office

2-18-14
Date Signed

DOE/LX/07-1294&D2
Secondary Document

Treatability Study Work Plan for Steam Injection, Groundwater Operable Unit, at Paducah Gaseous Diffusion Plant, Paducah, Kentucky

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Secondary Document

Treatability Study Work Plan for Steam Injection, Groundwater Operable Unit, at Paducah Gaseous Diffusion Plant Paducah, Kentucky

Issued—February 2014

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

Prepared by
LATA ENVIRONMENTAL SERVICES OF KENTUCKY, LLC
managing the
Environmental Remediation Activities at the
Paducah Gaseous Diffusion Plant
under contract DE-AC30-10CC40020

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ACRONYMS

2-D	two-dimensional
3-D	three-dimensional
ARAR	applicable or relevant and appropriate requirement
bgs	below ground surface
CAB	Citizens Advisory Board
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CSM	conceptual site model
DMIP	data management implementation plan
DNAPL	dense nonaqueous-phase liquid
DOE	U.S. Department of Energy
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
ERH	electrical resistance heating
FFA	Federal Facility Agreement
FS	feasibility study
GWOU	Groundwater Operable Unit
HU	hydrogeologic unit
IRA	interim remedial action
ISMS	Integrated Safety Management System
KDEP	Kentucky Department for Environmental Protection
LCD	Lower Continental Deposits
MIP	membrane interface probe
OREIS	Oak Ridge Environmental Information System
PGDP	Paducah Gaseous Diffusion Plant
POE	point of exposure
PPPO	Portsmouth/Paducah Project Office
QA	quality assurance
QC	quality control
QAPP	quality assurance project plan
RAO	remedial action objective
RDR	remedial design report
RDSI	remedial design support investigation
RGA	Regional Gravel Aquifer
RI	remedial investigation
ROD	record of decision
SOW	statement of work
TSWP	treatability study work plan
UCD	Upper Continental Deposits
UCRS	Upper Continental Recharge System
VOC	volatile organic compound
WAG	waste area grouping
WMC	waste management coordinator
WMP	waste management plan

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EXECUTIVE SUMMARY

The steam injection treatability study will be conducted under the Comprehensive Environmental Response, Compensation, and Liability Act. This study will provide data to assess the feasibility of deploying steam injection with multiphase extraction as a part of the interim remedial action at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant. In April 2013, the U.S. Department of Energy, U.S. Environmental Protection Agency (EPA), and the Kentucky Department for Environmental Protection agreed to scope a treatability study for steam injection. The steam injection treatability study is consistent with the guidance set forth in the EPA's *Guidance for Conducting Treatability Studies under CERCLA* (EPA 1992).

The planned treatability study will include the design, installation, and operation of one steam injection location, with intermediate and deep screened intervals in the Regional Gravel Aquifer (RGA), together with a temperature monitoring array. The steam injection well will be installed to the base of the RGA (~ 100 ft depth). Determination of whether a single extraction well outside the temperature monitoring array will be considered necessary for hydraulic control of contaminant migration will be made at the design stage of the treatability study. The single extraction well would require using the existing water treatment system. Steam injection into the subsurface is controlled by hydrostratigraphic and thermal properties of the target formation. Subsurface temperatures increase in response to steam migration, and groundwater and contaminants are volatilized.

The objective of the treatability study is to gather information on steam mobility in the RGA to inform the regulatory decision process for determining the applicability of steam-enhanced remediation for Phase IIb. The treatability study is designed to observe the movement and distribution of steam and provide data to refine the estimates of permeability, anisotropy/heterogeneity, and local groundwater velocity. The resulting information will be used to model steam injection and multiphase extraction (i.e., well spacing, locations, steam injection rates, and timing) to assess the technical implementability and cost-effectiveness of steam injection. Metrics to assess steam injection as a viable technology will be developed during the treatability study design. Concurrence among the Federal Facility Agreement parties on key performance metrics will be established prior to initiation of treatability study construction.

The treatability study report will document the treatability study set up and operation, field data collection and results, steam injection modeling, and technology evaluation including technical implementability and cost-effectiveness.

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1. INTRODUCTION

This *Treatability Study Work Plan for Steam Injection, Groundwater Operable Unit, at Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (TSWP) presents details for the implementation of a treatability study to evaluate steam injection as a potential technology for the removal of source-based volatile organic compounds (VOC) mass from the middle and lower Regional Gravel Aquifer (RGA) in the southeast treatment area of the C-400 Cleaning Building. This TSWP supports preparation of a detailed design specification and selection of a final remedy for the Phase IIb component of the interim remedial action (IRA) for the C-400 Cleaning Building. The other components of the IRA for the C-400 Cleaning Building are Phases I and IIa. Phase I and Phase IIa utilize electrical resistance heating (ERH) as identified in *Record of Decision for Interim Remedial Action for the Groundwater Operable Unit for the Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (ROD) (DOE 2005). Phase I addressed VOC source mass in the Upper Continental Recharge System (UCRS) and the upper RGA in the east and southwest treatment areas and was completed in 2010. Phase IIa addresses VOC source mass in the UCRS and upper RGA in the southeast treatment area. Phase IIa operations were initiated in July 2013 and are expected to be completed in early 2014. Phase IIb addresses source-based VOC mass in the middle and lower RGA. Information gained from the implementation of Phase I and uncertainty regarding hydrogeological conditions in the middle and lower RGA and VOC source-based mass configuration have complicated the selection of an appropriate remedial action technology for Phase IIb.

The treatability study at the C-400 Building will be conducted under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and will be consistent with the guidance set forth in the U.S. Environmental Protection Agency's (EPA's) *Guidance for Conducting Treatability Studies under CERCLA* (EPA 1992). The study will be consistent with the Federal Facility Agreement (FFA) among the U.S. Department of Energy (DOE), EPA, and the Commonwealth of Kentucky (EPA 1998).

1.1 PURPOSE

The purpose of the steam injection treatability study is to obtain data specific to understanding the behavior of steam injected into the RGA under variable injection scenarios. The treatability study is expected to provide information to inform the regulatory decision process for determining the applicability of steam-enhanced remediation for Phase IIb.

1.2 BACKGROUND

In August 1988, VOCs and radionuclides were detected in residential wells near the DOE's Paducah Gaseous Diffusion Plant (PGDP). Between 1988 and the present, numerous groundwater investigations have been conducted to identify probable source areas. Notably, DOE performed a remedial investigation (RI) of Waste Area Grouping (WAG) 6 in 1997 to assess the nature, extent, and fate of contaminants in the C-400 area (DOE 1999). To address these source areas, the D2 version of the Groundwater Operable Unit (GWOU) Feasibility Study (FS) was issued August 2001 (DOE 2001). This document recognized the presence of three groundwater contaminant plumes resulting from past activities at PGDP. All three of the plumes are located in the RGA. The GWOU FS recognized C-400 as the largest source area of contaminants to the PGDP groundwater plumes and the location of trichloroethene (TCE) dense nonaqueous-phase liquid (DNAPL) source zones in both the UCRS and RGA. Figure 1 depicts the distribution of TCE in groundwater in the RGA for the plant site area near C-400 in 2012 and shows C-400 in relation to the three groundwater plumes. During 2012, concentrations of dissolved-phase TCE were

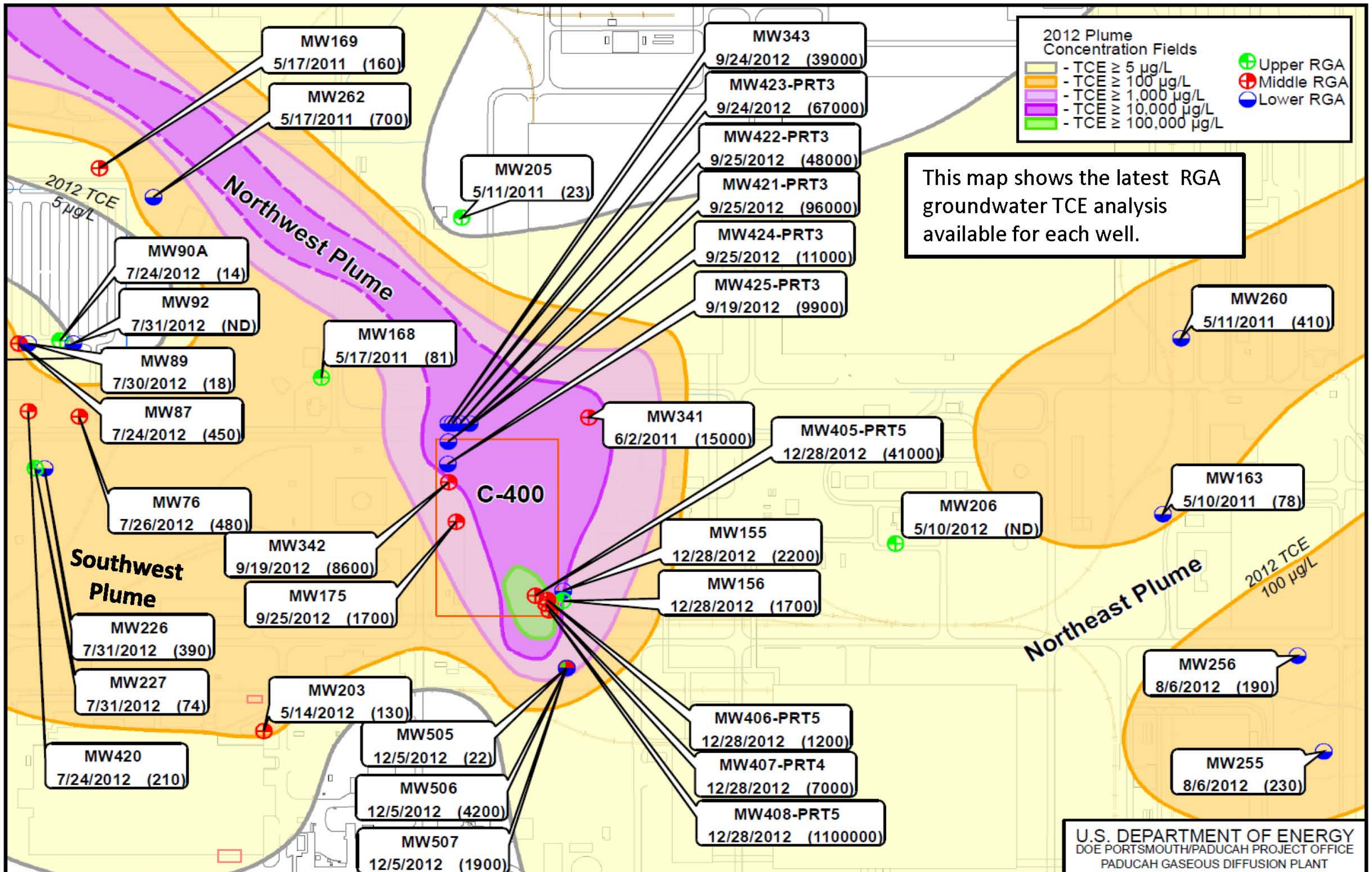

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Figure 1. C-400 in Relation to TCE Groundwater Plumes Mapped for Calendar Year 2012

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stable to declining in several RGA monitoring wells near the south end of C-400. Sharp declines in TCE concentrations were observed in two wells—in MW405, Port 5, TCE concentrations declined between September and December; and in MW156, TCE concentrations declined beginning in June. Also a notable spike in TCE levels was observed in MW408, Port 5 in September when concentrations increased to 1,400,000 µg/L. This value represents the historical maximum for TCE detected in RGA groundwater at PGDP. Concentrations at MW408-PRT5 have shown substantial fluctuation, but no definite trend since monitoring at this location was initiated in 2003. Initial concentrations declined from 1,000,000 µg/L to 69,000 µg/L after completion of the 6-Phase ERH pilot test in early 2003. In mid-2006, TCE concentrations increased again to 1,200,000 µg/L with subsequent concentrations declining to 210,000 µg/L in mid-2007. In 2012, fluctuations showed an increase from 70,000 µg/L in early-2012 to 1,400,000 µg/L in late-2012.

Subsequent technology reviews identified ERH as a promising technology to remediate the TCE DNAPL source zones in both the UCRS and RGA at C-400. Consequently, DOE conducted a six-phase heating treatability study in 2003 (DOE 2004) to assess the constructability and effectiveness of full-scale deployment of ERH. The C-400 ROD (2005) selected implementation of ERH, followed by a remedial design support investigation (RDSI) to further determine the areal and vertical extent of TCE and other VOC contamination at C-400, for the soil and groundwater cleanup under the south end of C-400. The RDSI was performed in 2006 and a remedial design report (RDR) was completed in 2008, containing a conceptual site model of the C-400 TCE sites and with an estimate of the TCE DNAPL mass. Per agreement of the FFA parties, ERH was planned to be deployed in two phases: Phase I (southwest and east treatment areas) and Phase II (southeast treatment area). Phased deployment was considered to provide an opportunity to evaluate heating performance in the UCRS and the RGA, down to the McNairy interface, to assess the radius of containment of hydraulic and vapor recovery systems; and to optimize the aboveground treatment system.

Construction of Phase I began in December 2008 and heating operations began in late March 2010 and continued through October 2010. DOE evaluated attainment of remedial action objectives (RAOs) in mid-2011 for Phase I operations in the east and southwest treatment areas. The RAOs, as established in the C-400 ROD (DOE 2005), were these:

- Prevent exposure to contaminated groundwater by on-site industrial workers through institutional controls (e.g., excavation/penetration permit program);
- Reduce VOC contamination (primarily TCE and its breakdown products) in UCRS soil at the C-400 Cleaning Building area to minimize the migration of these contaminants to RGA groundwater and to off-site points of exposure (POEs); and
- Reduce the extent and mass of the VOC source (primarily TCE and its breakdown products) in the RGA in the C-400 Cleaning Building area to reduce the migration of the VOC contaminants to off-site POEs.

DOE’s evaluation determined that the RAOs were met for the UCRS and upper RGA in these areas. A key performance objective of Phase I was to evaluate the heating performance of ERH throughout the vertical extent of the RGA in the southwest treatment area. A primary finding of Phase I in regard to this performance objective was that ERH was ineffective at reaching target temperatures in the lower RGA.

An Independent Technical Review Team, chartered by DOE, evaluated Phase I performance, numerical simulations, and ERH design concepts for Phase II and determined that ERH (or any other thermally enhanced removal technology) is poorly matched to the RGA conditions in the vicinity of the C-400 Building (DOE 2010). Based on results of Phase I and lessons learned, Phase II was split into two phases (IIa and IIb). Phase IIa employs ERH in the UCRS and upper RGA. Phase IIb addresses the middle and lower RGA. The team recommended identification and implementation of a more appropriate technology for treating the TCE sources located in the RGA to be addressed by the Phase IIb IRA (DOE 2010). Consequently, DOE developed a revised proposed plan for C-400, containing a revised conceptual site model (CSM), in December 2011 (DOE 2011a). The revised proposed plan selected implementation of *in situ* chemical oxidation for the Phase II lower RGA (Phase IIb). The FFA parties agreed to implementation of Phase IIa (heating operations began July 30, 2013); however, comments received from EPA and the Kentucky Department for Environmental Protection (KDEP) on the revised proposed plan expressed concern regarding the effectiveness of *in situ* chemical oxidation in the presence of DNAPL. EPA expressed a preference for steam-enhanced source removal as a preferred alternative, and KDEP suggested that treatability studies should be considered to further evaluate the technical efficacy of steam-enhanced remediation and *in situ* chemical oxidation prior to final remedy selection.

In April 2013, DOE, EPA, and KDEP agreed to scope a treatability study for steam injection in the RGA in the southeast treatment area in order to understand the effectiveness of steam injection with multiphase extraction and the potential for full-scale use. During subsequent meetings in April, May, and June 2013, the FFA parties developed data quality objectives (DQOs) to help guide the development of the treatability study. Computer modeling of steam-enhanced remediation within the area of the Phase IIb source zone by TerraTherm, Inc. (July 2012) and by Falta Environmental, LLC, (January 2013) show that the technology may be successful within a range of the expected site conditions.

1.3 TECHNOLOGY AND PROJECT DESCRIPTION

Steam injection with multiphase extraction is the engineered combination of steam injection and vapor extraction for subsurface remediation. This technology significantly enhances the removal rate of volatile and semivolatile source contaminants from the subsurface, both above and below the water table. The process works as steam injected into the subsurface sweeps a target volume, mobilizing and volatilizing the contaminant present in all compartments—separate phase DNAPL, sorbed, and dissolved. As steam moves through the subsurface, it condenses and releases energy, heating the surrounding soil. Based on historical performance at sites contaminated with TCE, source areas that are heated to temperatures approaching the boiling point of water are treated effectively. The process is less effective for areas that do not achieve target temperatures. Thus, the distribution pattern of the steam and associated heat are important factors in understanding performance and designing a treatment system.

One of the benefits of steam injection is that the process can be implemented with standard, established engineering methods. Subsurface temperatures required for treatment of compounds such as TCE are easily attainable over broad treatment areas with standard equipment. Steam generated in boilers can be delivered through insulated steam piping or hoses pressure controlled and delivered to individual wellheads. Well placements are designed through thermal modeling using standard techniques from heat transfer, hydrogeological, and mass transport studies.

Because the use of heat to remove TCE and related contaminants from the subsurface has been demonstrated successfully at numerous locations, including in the UCRS at C-400 during a previous six-phase heating treatability study (DOE 2004) and during the Phase I remedial action, the effectiveness of steam injection with multiphase extraction in an appropriate geologic setting is not the primary concern of this treatability study. Instead, the effort will focus on refining and understanding the behavior of steam in the challenging hydrogeologic conditions in the RGA—a thick sand and gravel aquifer, with high permeability, low to moderate anisotropy, and moderate to high groundwater velocity.

Data collected during Phase I suggested that the buoyancy of the injected steam in this setting will impact the distribution of the steam and the ability to achieve target temperatures in the lower portions of the aquifer. The treatability study is intended to assess whether/how injected steam can heat the full thickness of the RGA, to the base of the RGA, to an effective distance from the injection wells, and to obtain data to support Phase IIb decisions.

The treatability study will include the design, installation, and operation of one steam injection location with an associated temperature monitoring array. The treatability study is designed to understand the behavior of steam when injected into the complex hydrogeology at the C-400 Building, specifically the RGA. Temperature monitoring locations will be constructed to cover the full thickness of the RGA.

The treatability study injection and monitoring array will be constructed near the C-400 Building as shown in Figure 2. The proposed location for the treatability study is on the southern periphery of the Phase IIb treatment area footprint in an area adjacent to the current Phase IIa ERH electrode/wellfield. Work performed previously in this area during drilling for Phase IIa electrode and well installation indicates that installation of the proposed treatability study injection well and temperature monitoring wells can be performed in this area as well. Pretest soil borings will be collected, as described in Section 5, to document the formation characteristics in the vicinity of the treatability study array.

Between 7 and 12 borings are planned for the project: 1 boring for the steam injection well and between 5 and 10 borings for temperature monitoring; and 1 boring for a groundwater extraction well location (pending a determination of the requirement for groundwater extraction and finalization of the treatability study design). The injection well, temperature monitoring points, and extraction wells are expected to be located such that they would be reusable if a full-scale implementation occurs. The need for an extraction well will be determined at the design stage of the treatability study.

The following sections provide a description of the geologic and hydrogeologic setting for the steam injection treatability study in the vicinity of C-400 site.

1.4 GEOLOGY

In the immediate vicinity of PGDP, Coastal Plain deposits unconformably overlie Mississippian carbonate bedrock. The full Coastal Plain stratigraphic sequence to the immediate south of PGDP consists of the following three units (from bottom to top): sands and clays of the Clayton/McNairy Formations; the Porters Creek Clay; and Eocene sand and clay deposits (undivided Jackson, Claiborne, and Wilcox Formations). Continental Deposits unconformably overlie the Coastal Plain deposits, which are, in turn, covered by loess and/or alluvium. Both the loess and alluvium typically are composed of clayey silt. Figure 3 provides a stratigraphic column of the PGDP area.

In the central and northern part of the PGDP site, including the area of the C-400 Cleaning Building, the Coastal Plain sediments are composed exclusively of unconsolidated, interbedded, fine-grained sand, silt and clay of the Upper Cretaceous-aged McNairy Formation. The thickness of the McNairy Formation at C-400 is approximately 250 ft.

A principal geologic feature in the PGDP area is the buried fore slope of the Porters Creek Clay Terrace, a subsurface boundary that trends approximately east to west across the southern portion of the plant. The fore slope of the Porters Creek Clay Terrace represents the southern limit of erosion or scouring of the ancestral Tennessee River. In the area north of the subsurface terrace fore slope, including the C-400 area, Continental Deposits directly overlie the McNairy Formation. Thicker sequences of Continental Deposits, as found underlying most of PGDP, represent valley fill deposits and can be divided informally into a lower unit (gravel facies) and an upper unit (silt facies).

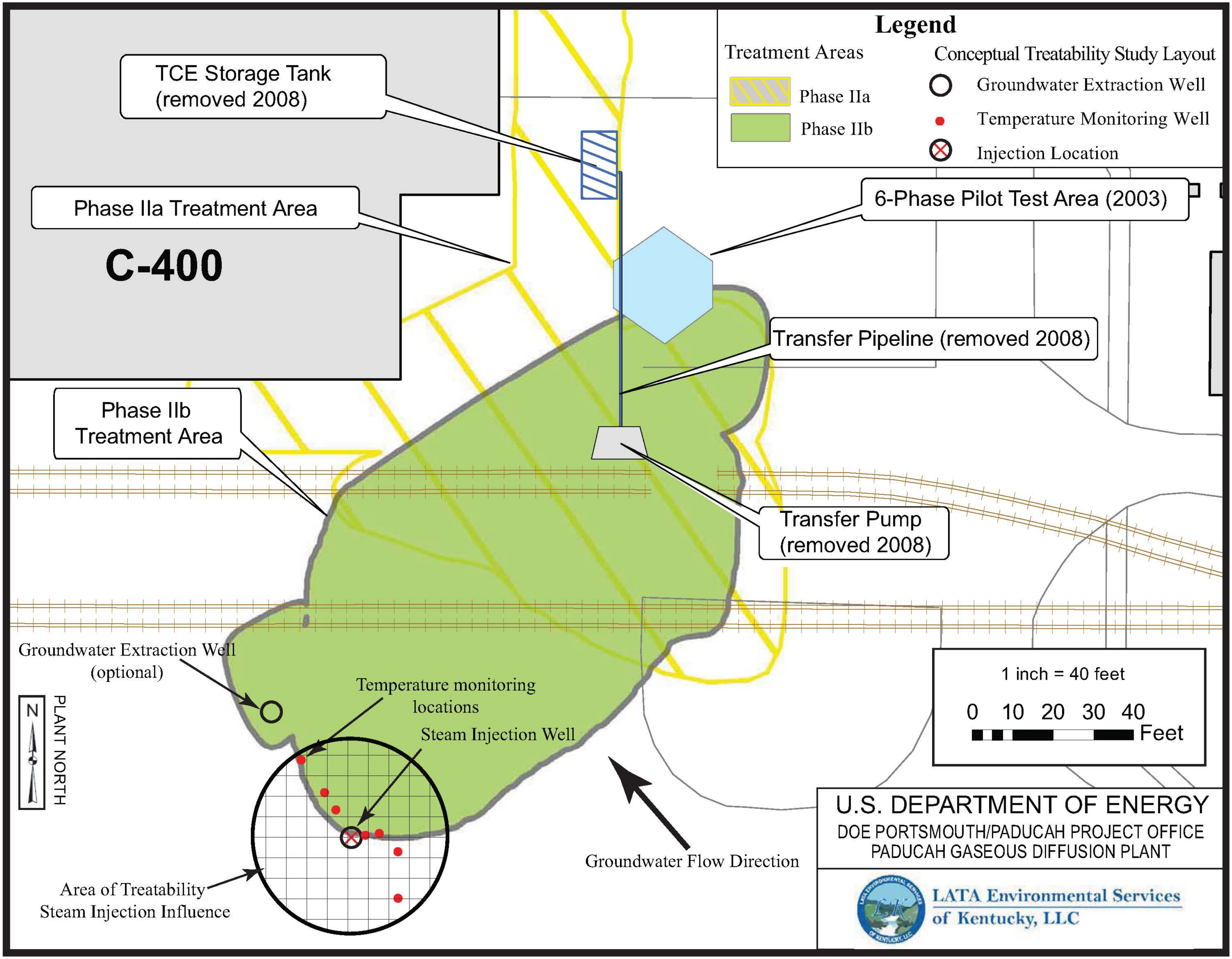

Figure 2. Map of C-400 IIb Target Zone with Conceptual Layout of Treatability Study

SYSTEM	SERIES	FORMATION	THICKNESS (IN FEET)	DESCRIPTION	HYDROGEOLOGIC SYSTEMS
QUATERNARY	PLEISTOCENE AND RECENT	ALLUVIUM	0-40	Brown or gray sand and silty clay or clayey silt with streaks of sand.	Upper Continental Recharge System
	PLEISTOCENE	LOESS	0-43	Brown or yellowish-brown to tan unstratified silty clay.	
	PLEISTOCENE	CONTINENTAL DEPOSITS	3-121	Upper Continental Deposits (Clay Facies) - mottled gray and yellowish brown to brown clayey silt and silty clay, some very fine sand, trace of gravel. Often micaceous.	
TERTIARY	PLIOCENE-MIOCENE (?)			Lower Continental Deposits (Gravel Facies) - reddish-brown clayey, silty and sandy chert gravel and beds of gray sand.	Regional Gravel Aquifer
	EOCENE	JACKSON, CLAIBORNE, AND WILCOX FORMATIONS	0-200+	Red, brown or white fine to coarse grained sand. Beds of white to dark gray clay are distributed at random.	
			0-100+	White to gray sandy clay, clay conglomerates and boulders, scattered clay lenses and lenses of coarse red sand. Black to dark gray lignitic clay, silt or fine grained sand.	McNairy Flow System
	PALEOCENE	PORTERS CREEK CLAY	0-200	Dark gray, slightly to very micaceous clay. Fine grained clayey sand, commonly glauconitic in the upper part. Glauconitic sand and clay at the base.	
		CLAYTON FORMATION	Undetermined	Lithologically similar to underlying McNairy Formation.	
UPPER CRETACEOUS		McNAIRY FORMATION	200-300	Grayish-white to dark gray micaceous clay, often silty, interbedded with light gray to yellowish-brown very fine to medium grained sand with lignite and pyrite. The upper part is interbedded clay and sand, and the lower part is sand.	
		TUSCALOOSA FORMATION	Undetermined	White, well rounded or broken chert gravel with clay.	
MISSISSIPPIAN		MISSISSIPPIAN CARBONATES	500+	Dark gray limestone and interbedded chert, some shale.	

Adapted from Olive 1980.

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Figure 3. Generalized Lithostratigraphic Column of the PGDP Region

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The Lower Continental Deposits (LCD) is a Pliocene (?)[1] to Pleistocene-aged gravel facies consisting of fine-to-coarse chert gravel in a matrix of very fine-to-medium sand and silt.[2] These gravels rest on an erosional surface representing the beginning of the valley fill sequence beneath PGDP. In total, the gravel units commonly average approximately 30-ft thick.

The alluvial gravels and sands of the LCD are overlain by a Late-Tertiary through Quaternary and Holocene section of finer clastic sediments [the Upper Continental Deposits (UCD)].[3] The UCD predominately consists of silt and fine sand with an upper horizon of common sand and gravel units, overlain, in turn, by Pleistocene loess units. These deposits cumulatively range between 30- and 60-ft thick beneath the PGDP site. Previous investigations conducted at PGDP, most recently at the C-746-U Landfill (KRCEE 2006), have identified at least four separate loess units.

Treatability Study Area. The main hydrogeologic units (HUs) in the C-400 area consist of the UCRS, the RGA, and the McNairy Formation. In the study area, the RGA and the first major sand of the upper McNairy Formation are separated by an approximately 9-ft thick lens of McNairy silts, sands, and clays, which act as an aquitard. Approximately 56 ft of silt and clay, with horizons of sand and gravel lenses, covers the RGA.

The treatability study will be located in the southwest corner of the Phase IIb remediation area. Soil boring SB59, sampled in April 2011, provides good characterization of the vicinity of the treatability study. In SB59, the stratigraphic sequence consists of the following (from top to bottom):

- Silt and sandy silt to a depth of 24.1 ft
- Sand and gravel units (2.0- to 4.6-ft thick), separated by fine sands and silts to a depth of 43.1 ft
- Silt to silty sand to a depth of 50.0 ft
- Very fine sand to a depth of 60.0 ft
- Sand and gravel to a depth of 95.6 ft
- Interbedded clay, sand, and silt to the total depth of the boring of 97.0 ft

The uppermost 24.1 ft of soils are disturbed soils and loess; the UCD extends to 60.0 ft depth; and the LCD extends to a depth of 95.6 ft, the contact with the underlying McNairy Formation.

Numerous soil borings and electrical conductivity logs associated with membrane interface probe (MIP) borings define lateral trends of the geologic units on the south end of C-400. With few exceptions, the geologic units are laterally extensive (Figure 4). The geologic unit that will be the subject of the treatability study is the gravel member of the LCD. Based on information from SB59, the gravel member of the LCD consists of sand and gravel from 60 to 95.6 ft. In the C-400 area, the gravel member of the LCD generally consists of poorly sorted chert gravel with discontinuous, thin lenses of fine sand.

The erosional surface that is the top of the McNairy Formation has over 9 ft of relief under the south end of C-400, dipping into a structural bowl in the area of the Phase IIb treatment area (Figure 5). The depth of the base of the LCD/top of the McNairy Formation may have 1 to 2 ft of variability in the area of the treatability study.

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[1] (?) Indicates uncertainty in the age of the geologic unit.
[2] The LCD is stratigraphically equivalent to the Mounds Gravel as designated by the Illinois Geological Survey or the Lafayette Formation (Lafayette gravel) in other parts of the region (Sexton 2006) (Langston and Street 1998).
[3] Equivalent to the Plio-Pleistocene Metropolis Formation as designated by the Illinois Geological Survey.

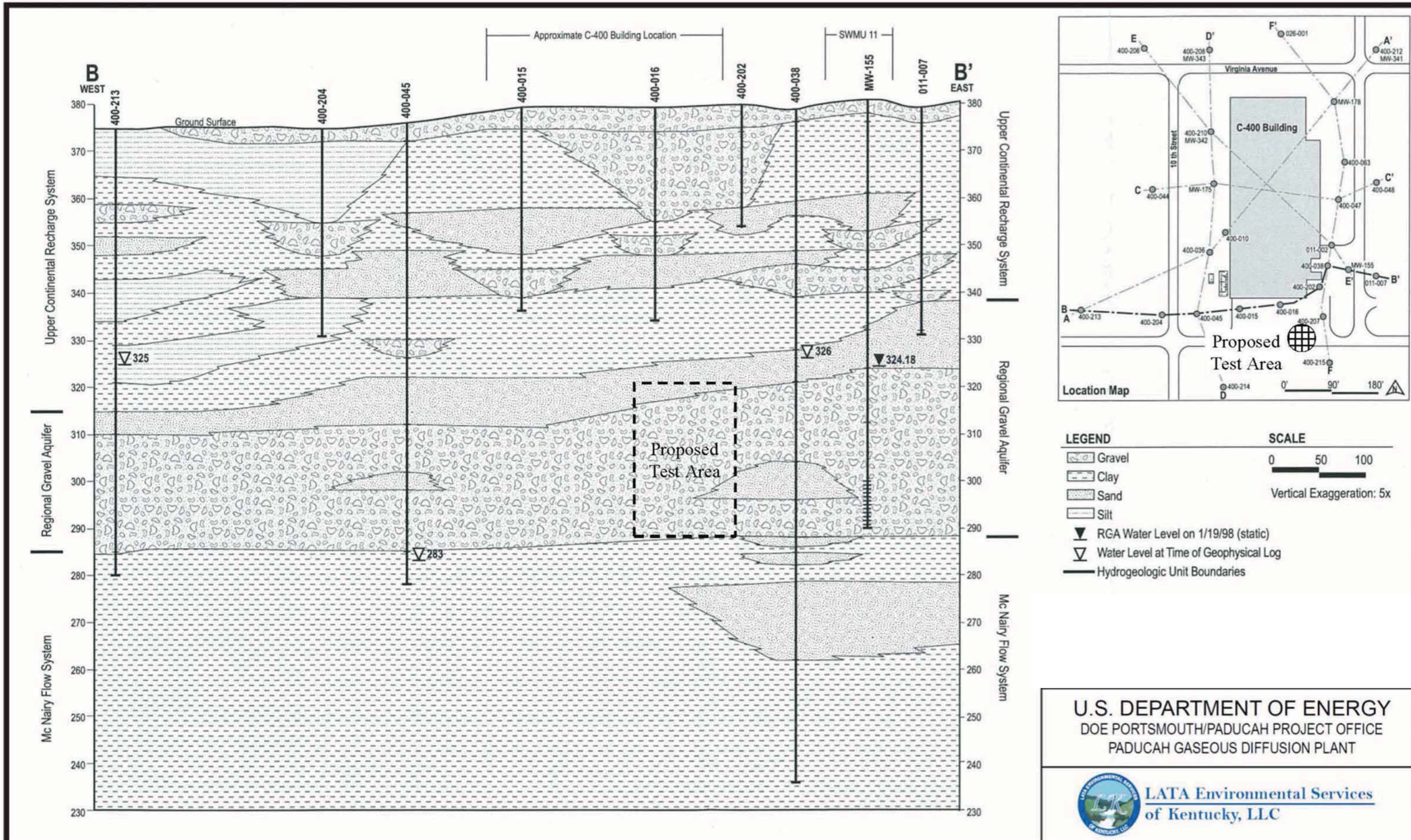

Figure 4. Geologic Cross Section on South Side of C-400 from WAG 6 Remedial Investigation Report

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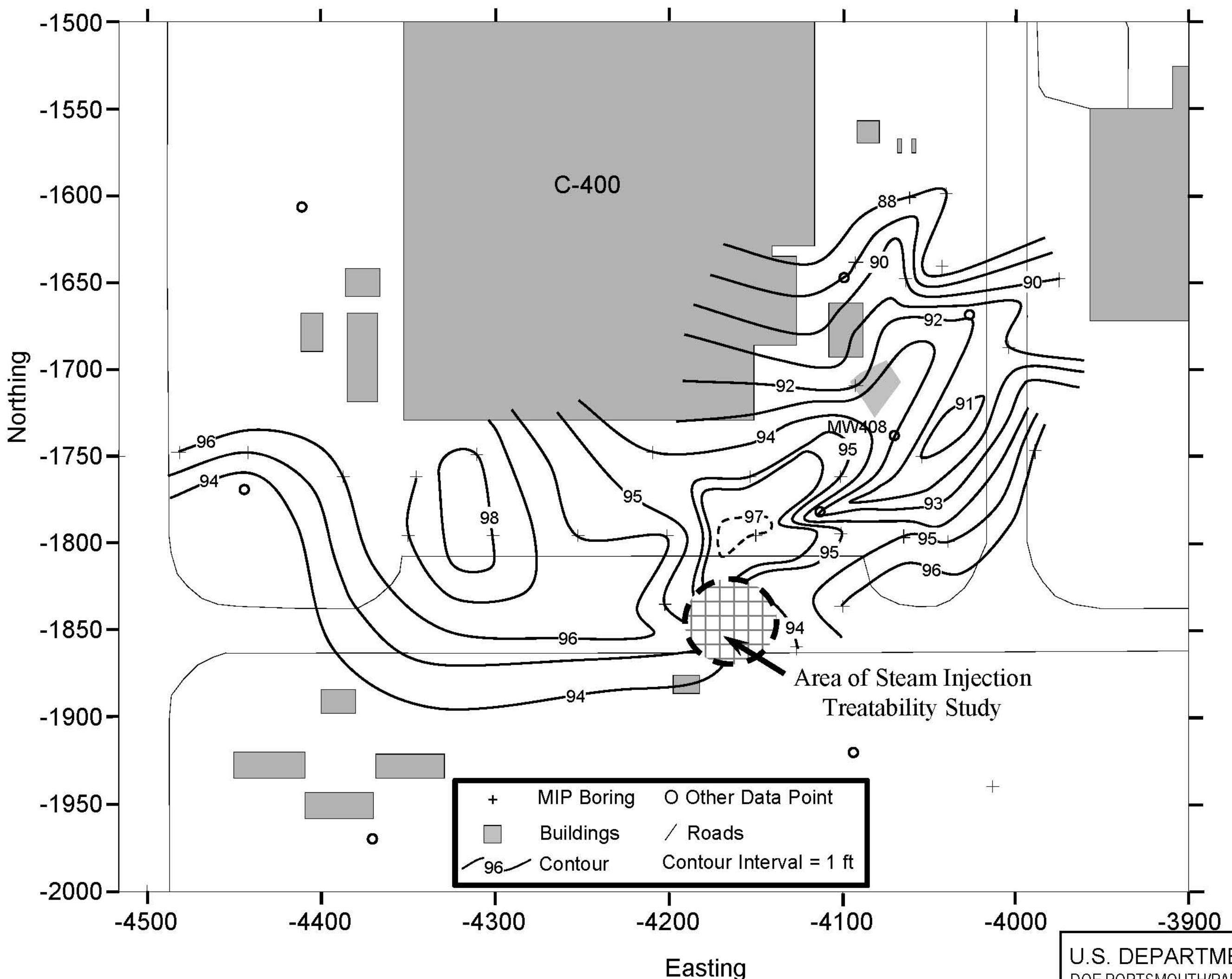

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Figure 5. Depth to the Base of the Continental Deposits/Top of the McNairy Formation (ft below ground surface)

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1.5 HYDROGEOLOGY

The shallow groundwater system at the site, the UCRS, is subdivided into three HUs—HU1, HU2, and HU3—which consist of the loess (HU1) and the underlying UCD (HU2 and HU3) (Figure 6). The shallow sand and gravel interval (HU2) commonly is separated from the underlying RGA by a 7- to 18-ft thick silty or silty sand interval designated the HU3 aquitard. Typically, the HU3 aquitard restricts vertical flow of groundwater from the sands and gravels of the HU2 unit to the gravels of the RGA.

However, in some areas, notably the southeast corner of C-400, the HU3 aquitard is considerably thinner and a lesser barrier to groundwater movement. In the area of C-400, the UCRS is mostly unsaturated. The RGA, the uppermost aquifer in the C-400 area, consists of the lowermost sand interval of the UCD (HU4) and the sand and gravels of the LCD (HU5). Water within the UCRS tends to flow downward to the RGA. The RGA potentiometric surface is encountered at a depth of approximately 56 ft below ground surface (bgs). Groundwater flow in the RGA generally is to the north, eventually discharging into the Ohio River. At the C-400 area, groundwater flow is generally to the northwest as part of the Northwest Plume, although some flow diverges to the east and to the west as part of the Northeast and Southwest Plumes, respectively.

Below the RGA is the McNairy Flow System (HU6), which corresponds to the McNairy Formation. The uppermost portion of the McNairy Flow System typically contains a significant proportion of clay or silty clay. The hydraulic potential (water level) of the shallow McNairy Formation is slightly less than that of the RGA in the C-400 area and dips northward, similar to the RGA. The clayey shallow McNairy functions as an aquitard restricting groundwater flow between the RGA and deeper McNairy Flow System.

Significant Properties. The RGA is the focus of the treatability study. Specific properties of the RGA that impact the treatability study include these:

- Permeability of the formation
- Vertical anisotropy
- Groundwater flow rate and direction

Spatial trends of the groundwater contaminant plumes, PGDP aquifer tests (Figure 7 and Table 1), and groundwater flow model calibration values attest to significant variability in the hydraulic conductivity/permeability of the RGA. Results of the Phase I ERH action in the RGA (Southwest Treatment Area) indicate that the RGA hydraulic conductivity/permeability under the south end of C-400 is intermediate to high.

PGDP currently has no definitive assessment of the vertical anisotropy in the RGA. Lithologic and electrical conductivity logs of the RGA under the southern portion of the C-400 area indicate little vertical variability; consequently, the vertical anisotropy may be low.

In general, groundwater flow in the RGA is estimated to range from 1 to 3 ft/day; however, spatial variability of hydraulic conductivity/permeability and temporal variability in the hydraulic gradient, contribute to uncertainty of the values for groundwater flow velocity on a local scale.

Principal controls on RGA hydraulic gradient are the amount and rate of leakage from PGDP utilities and the stage of the Ohio River, the primary discharge zone of the regional groundwater flow systems (RGA and McNairy). Commonly, RGA hydraulic gradient in the area of PGDP ranges from a few ft vertical/1,000 ft lateral to a few ft vertical/10,000 ft lateral (10^{-3} ft/ft to 10^{-4} ft/ft).

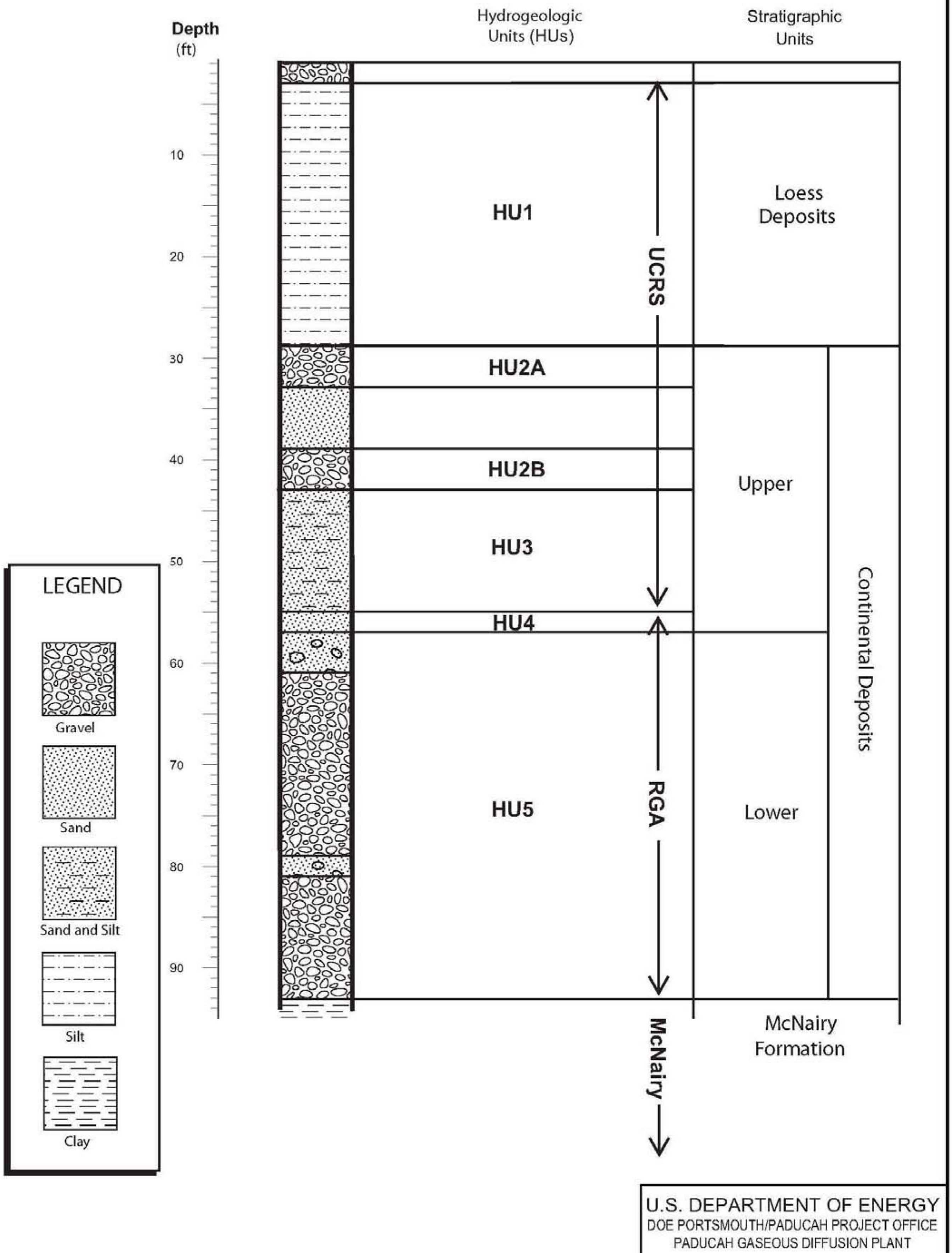

Figure 6. Stratigraphic and Hydrogeologic Units in Soil Boring H-007 of South C-400 Area

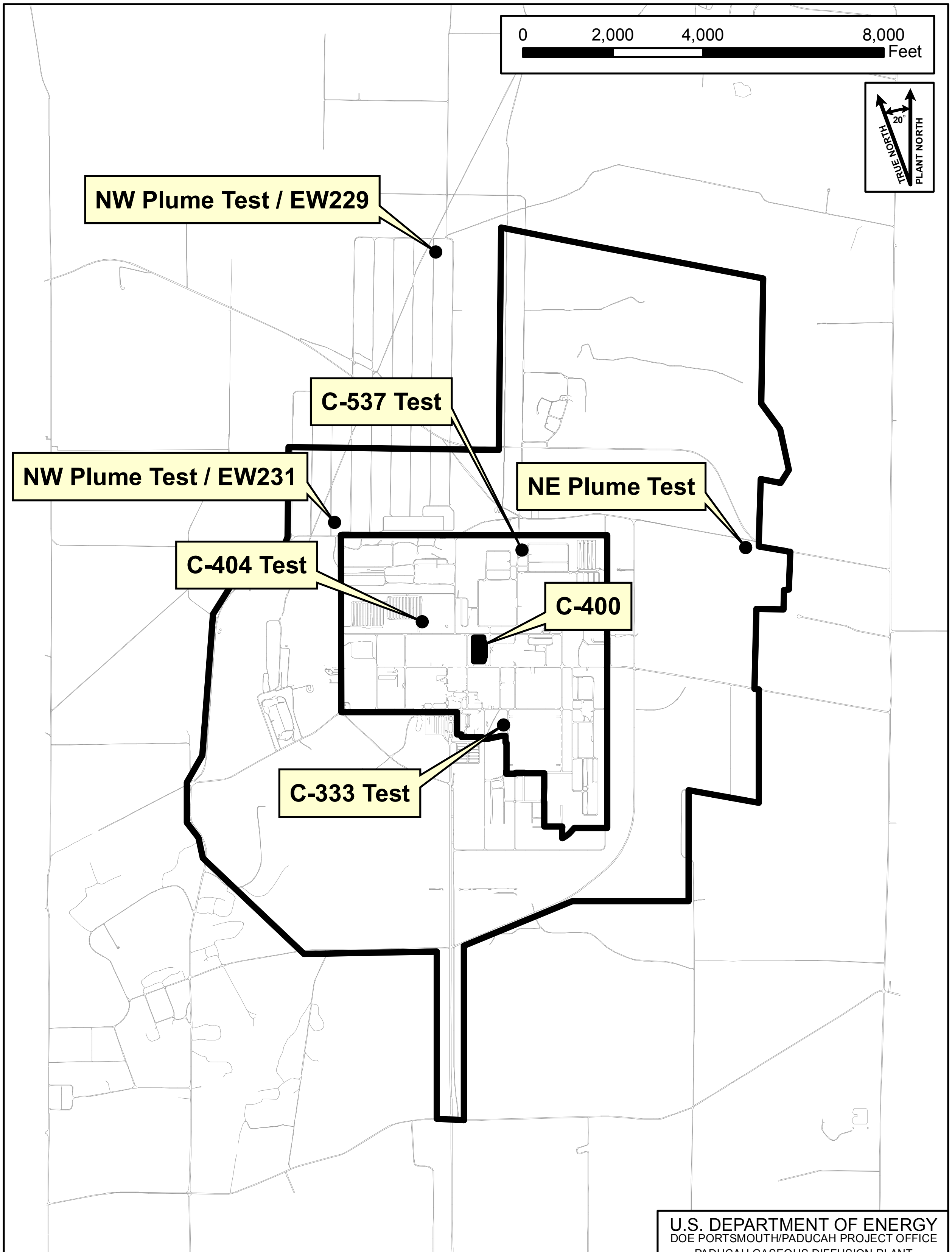

Figure 7. Location of RGA Aquifer Tests at the Paducah Gaseous Diffusion Plant

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Table 1. Hydraulic Conductivity/Permeability (Lateral) Measurements of the RGA from PGDP Aquifer Tests

Test Area and Duration of Test/ Date of Test and Reference Document	Hydraulic Conductivity as cm/sec (ft/day)/ Permeability as cm^2 (darcy)	
	Low	High
C-404 Pumping Test (48 hours pumping in MW79) August and September 1989 (Terran 1990)	1.87×10^{-2} (53)/ 1.91×10^{-7} (19.3)	3.77×10^{-2} (107)/ 3.84×10^{-7} (38.9)
C-537 Pumping Test (72 hours pumping in PW1) June 1991 (CH2M Hill 1992)	3.53×10^{-2} (100)/ 3.60×10^{-7} (36.5)	5.29×10^{-2} (150)/ 5.39×10^{-7} (54.6)
Northeast Plume Containment Wellfield Pumping Tests (46 to 123.5 hours pumping in EW331 and EW332) February 1997 (TN & Associates 1997)	1.87×10^{-1} (529)/ 1.91×10^{-6} (193)	4.28×10^{-1} (1,213)/ 4.36×10^{-6} (442)
C-333 Pumping Test (72 hours pumping in W108) March and April 1992 (Terran 1992)	3.53×10^{-1} (1,000)/ 3.60×10^{-6} (365)	4.23×10^{-1} (1,200)/ 4.31×10^{-6} (437)
Northwest Plume North Containment Wellfield Pumping Test (72 hours pumping in EW229 and EW231) August and September 1995 (LMES 1996)	9.50×10^{-1} (2,686)/ 9.68×10^{-6} (981)	2.01×10^{0} (5,700)/ 2.05×10^{-5} (2,080)

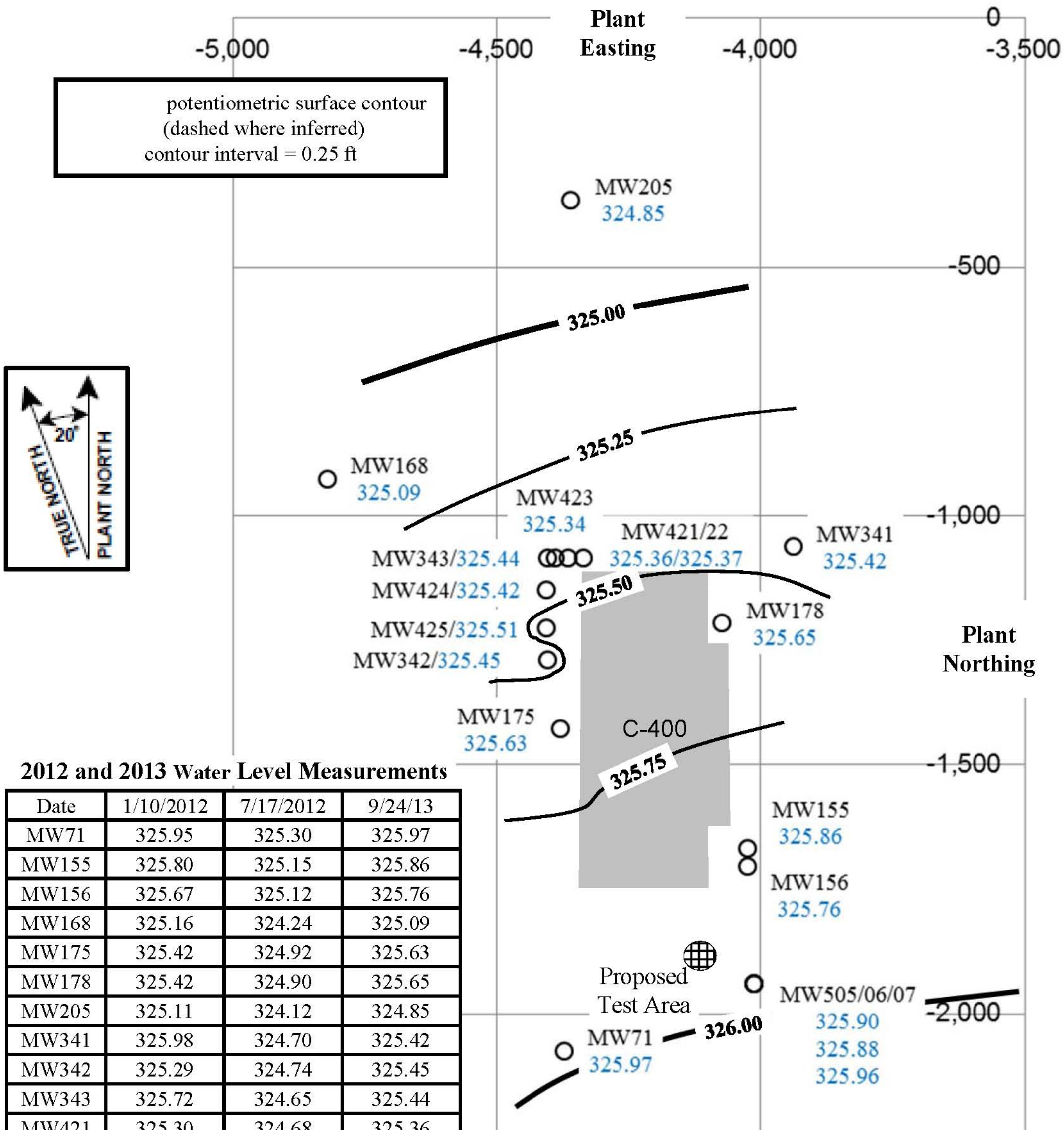
The RGA potentiometric surface in the area of C-400 is relatively flat (Figure 8); thus, minor variability in water level measurements has a significant impact on interpretation of local groundwater flow direction. However, the core of dissolved TCE contamination in the RGA defines the dominant groundwater flow path emanating from the southeast corner of C-400. The axis of the TCE plume consistently is mapped with a trajectory that aligns with the northwest corner of the C-400 Building. Accordingly, groundwater flow in the area of the treatability study is considered to be to the northwest.

Water level measurements in MW156 (southeast C-400) and MW168 (northwest C-400) provide a useful measure of the stability of the groundwater flow direction beneath C-400. Of the 205 dates of water level measurements in either or both wells for the available period of record in Oak Ridge Environmental Information System (OREIS) (November 21, 1991 through December 28, 2012), there are 117 measurements that are comparable (i.e., measurements in both wells on the same day or within 1 day of each other). Water levels are higher in MW156, compared to MW168, in 111 of the measurements. The difference of the measurements is equally distributed between 0.02 and 0.75 ft in most of the data set (97 of the comparable measurements). The distance between MW156 and MW168 is 1,114 ft. Thus, the derived gradient between the 2 wells has varied uniformly between 1.79×10^{-5} and 6.10×10^{-4} ft/ft over the 20-year period of record. This consistency of record is evidence of near-stable groundwater flow rate and direction in the area of C-400.

In the PGDP industrial area, including C-400, leakage from water utilities is anticipated to provide significant recharge to the RGA. Since the conclusion of uranium enrichment operations, beginning in May 2013, the plant water systems have remained operational. Accordingly, the effect of termination of enrichment operations likely has had minimal impact on groundwater flow direction.

1.6 SITE CONCEPTUAL MODEL

This section discusses the evaluation of the CSM, including geologic structure, a refined mass estimate, and the occurrence of DNAPL at the south end of C-400.



2012 and 2013 Water Level Measurements

Date	1/10/2012	7/17/2012	9/24/13
MW71	325.95	325.30	325.97
MW155	325.80	325.15	325.86
MW156	325.67	325.12	325.76
MW168	325.16	324.24	325.09
MW175	325.42	324.92	325.63
MW178	325.42	324.90	325.65
MW205	325.11	324.12	324.85
MW341	325.98	324.70	325.42
MW342	325.29	324.74	325.45
MW343	325.72	324.65	325.44
MW421	325.30	324.68	325.36
MW422	325.30	324.67	325.37
MW423	325.29	324.66	325.34
MW424	325.39	324.74	325.42
MW425	325.38	324.86	325.51
MW505	*	324.90	325.90
MW506	*	324.87	325.88
MW507	*	324.94	325.96

* Not Measured

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Figure 8. Potentiometric Surface of the RGA in the Area of C-400, September 24, 2013

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Key Site Characteristics. Key characteristics of the C-400 CSM include the following:

- The origin of the TCE in the subsurface is postulated to be from TCE pipeline leak(s) and spills at the loading point. The six-phase heating treatability study was implemented in close proximity to the area of the former pipeline leak and recovered an estimated 1,900 gal (≈ 23,000 lb) of TCE from the UCRS and upper RGA. Figure 2 shows the C-400 Cleaning Building, former location of the TCE supply tank, pipeline, loading area, and an outline of the six-phase heating treatability study area.

- The TCE release traveled vertically through the UCRS as DNAPL due to its density and the porous and permeable character of the construction backfill and near surface sediments in this area. When encountering a less permeable lens (e.g., silt), the DNAPL would travel laterally until encountering a discontinuity in that lens and then resume its downward migration. Trails of residual DNAPL would have been left along the migration route.

- Over time, the DNAPL in the UCRS has continued to dissolve into the water phase with subsequent infiltration events (precipitation or plant line losses) resulting in dissolved-phase transport of TCE into the RGA.

- As the DNAPL has dispersed laterally in the finer grained sediments of the upper RGA, fine-grained zones have retained residual DNAPL.

- In the gravelly (more permeable) RGA, the DNAPL has been dispersed in the groundwater and transported vertically as DNAPL; some is present as residual DNAPL in the form of disconnected blobs and ganglia trapped by the capillary forces in the pore spaces (EPA 2009).

- If the DNAPL had sufficient mass for continuous interconnection, it continued traveling vertically through the permeable RGA until it reached a tighter matrix (i.e., McNairy) where it has pooled. In the absence of significant depression in the top of the McNairy, pooling is limited to a thickness of 1.2 inches (McConnell and Numbere 1995).

The current observed concentrations of TCE in the RGA likely result from a continuing release from the UCRS, from DNAPL pooled on capillary boundaries within the RGA, from discrete DNAPL ganglia, and from residual sorbed mass on the soil matrix. Figure 9 provides a conceptualization of the CSM.

Structural Controls on Contaminant Transport. Based on the concept that the DNAPL would travel vertically through a permeable geologic unit and then horizontally when encountering a tighter unit (clay or silt), it is important to refine the hydrogeologic stratigraphy and structure. Through convention, the site has been mapped with six HUs at the site:

- HU1—disturbed soils, surface fill, and loess

- HU2 and HU3 UCRS
  — HU2—sand and gravels separated by fine sands and silts
  — HU3—silt to silty sand, semi-confining aquitard

- HU4 and HU5—RGA
  — HU4—fine-grained sand cap layer of RGA, not laterally continuous
  — HU5—dominant gravel aquifer

- HU6—McNairy Formation: interbedded clay, sand, and silt, basal aquitard

Information on the stratigraphy of the treatability study area is available from 50 borings in the vicinity of the Phase II treatment area [including the WAG 6 RI (in 1997), six-phase heating treatability study (in 2003), C-400 Phase I RDSI (in 2006), and confirmation borings from C-400 Phase I (in 2011)]. Some observations of the structure are as follows:

- The HU layers display variability in thickness and elevation (HU2 through HU6 surfaces).

- The HU4 is thin or absent in some areas, specifically directly below the pipeline loading point. The windows through HU4 provide a direct conduit for the vertical migration of DNAPL from the UCRS into the HU5 aquifer.

- The structural top of HU6 (McNairy) is an erosional surface and displays scour and channel features.

The distribution of the observed and interpolated higher soil TCE levels in context of the geologic model leads to the following observations.

- The current mass is greater below the repaired pipeline. The mass is less dispersed in the UCRS.

- The dissolved TCE footprint is larger in the RGA. The larger area of dissolved contamination in the RGA is presumed to be due to greater dispersion with depth within these more permeable aquifer sediments even though the lateral extent of TCE DNAPL likely is less in the RGA.

Mass Volume Estimate. DOE evaluated the mass volume of the Phase II area based on the analyses of soil samples obtained during the field characterization effort conducted in early 2011 to refine the CSM and support the basis of technology identification and selection. Three approaches were used to assess TCE mass volume for the UCRS and RGA treatment area and determined that a reasonable estimate of the range of TCE mass remaining in the Phase II treatment area is between 600 and 7,000 gal.

The lower end of the range of the estimate, 600 gal (≈ 7,300 lb), is based on interpolation of soil and groundwater sample results collected to date. The higher end of the range of the estimate includes observation of TCE in groundwater and assumptions of potential DNAPL occurrence[4] that are considered to be representative of conditions based on the site conceptual model.

A breakdown of DNAPL mass volume in the UCRS and RGA is as follows:

- For the interval 0 to 60 ft bgs (HU1 through HU4), which is primarily the UCRS, the estimate is 290 to 30,500 lb (24 to 2,500 gal).

- For the interval 60 to 100 ft bgs (HU5), which is the RGA, the estimate is 7,000 to 55,000 lb (576 to 4,500 gal).

The amount of DNAPL mass volume present in the fine sands, silts, and clays of the underlying McNairy Formation has not been estimated. Analyses of dissolved TCE levels in the McNairy Formation at C-400, collected from the deeper soil borings of the WAG 6 RI, generally decline with depth, suggesting DNAPL penetration of the McNairy Formation has been limited.

[4] Samples of TCE DNAPL were collected from MW408, Port 7 (screened in the shallow McNairy Formation at the southeast corner of C-400) in June and September 2003. These samples were collected before the well was completed with an annular seal at the base of the LCD/RGA; the samples are suggestive of the presence of DNAPL at the base of the RGA.

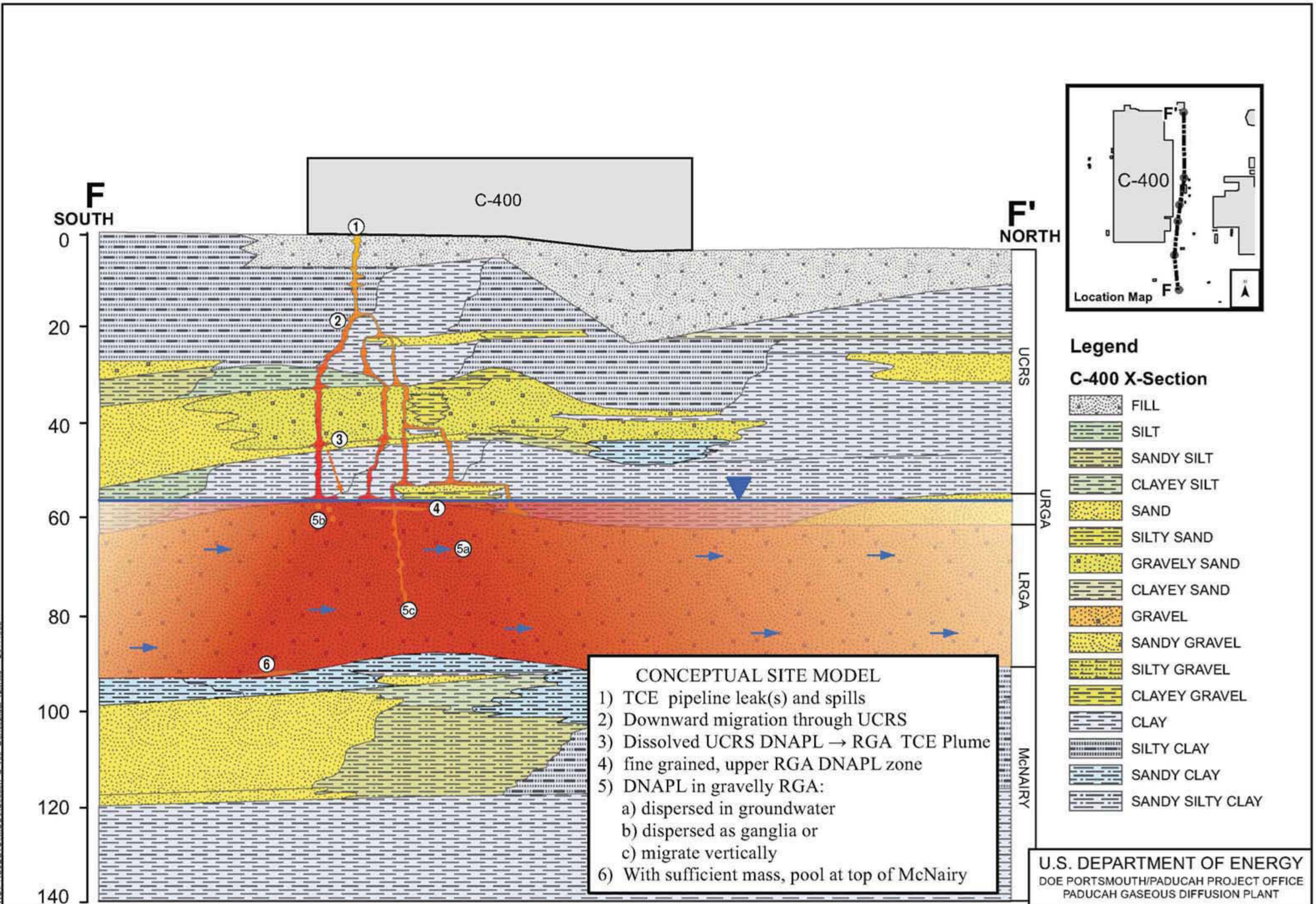

Figure 9. C-400 Conceptual Site Model Cross Section View

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Figure 10 presents the results of depth discrete RGA water samples collected during the 2011 investigation. The range and trends of TCE concentrations are consistent with the CSM and provide support for the assumptions that were used to develop the higher end of the range of the mass volume estimate.

2. DATA QUALITY OBJECTIVES

2.1 DATA QUALITY OBJECTIVES SCOPING PROCESS

In April 2013, DOE's Portsmouth/Paducah Project Office (PPPO) initiated a series of Web-based meetings with EPA and KDEP to scope this steam injection treatability study. A series of meetings were held between mid-April and mid-June 2013 to advance the group's understanding of the treatability study scope, requirements, and options. Scoping discussions were concluded in mid-June and agreements were reached on key scoping concepts and draft DQOs for a treatability study.

2.2 DATA QUALITY OBJECTIVES SCOPING RESULTS

Table 2 presents the DQOs resulting from the collaborative effort between DOE PPPO, EPA and KDEP. The problem statement, "How will steam flow in the RGA in the southeast treatment zone?" formed the premise for DQO development. The primary data required will be engineering parameters associated with steam injection (flow rate, temperature, and pressure) and resulting temperature distribution in the subsurface. The quality objectives for these are relatively straightforward, with key issues relating to design of sufficient coverage and detail.

The results of the treatability study will be used to calibrate modeling simulations to support the assessment of technical implementability and cost-effectiveness. Metrics to assess steam injection as a viable technology will be developed during the treatability study design. Concurrence among the FFA parties on key performance metrics will be established prior to initiation of treatability study construction.

3. TREATABILITY STUDY DESCRIPTION

3.1 CONCEPTUAL DESIGN

The objective of the treatability study is to gather information on steam mobility in the RGA to inform the regulatory decision process for determining the applicability of steam-enhanced remediation for Phase IIb. The treatability study is designed to observe the movement and distribution of steam and provide data to refine the estimates of permeability, anisotropy/heterogeneity, and local groundwater velocity. A complete design will be required that, based on a conceptual layout described below, provides specifications for construction and implementation of the injection and monitoring system (Figure 2). The design being developed in parallel with this TSWP will comply with applicable engineering standards and practices, as well as all Paducah site requirements. The effect of groundwater velocity within the RGA on heating of the target zone was recognized during DQO development as being a critical component of the treatability study evaluation. Analysis of post-injection cooling profiles from temperature monitoring points will provide a determination of groundwater velocity and direction within the RGA. This information will be required for a total energy requirement assessment of any full-scale deployment.

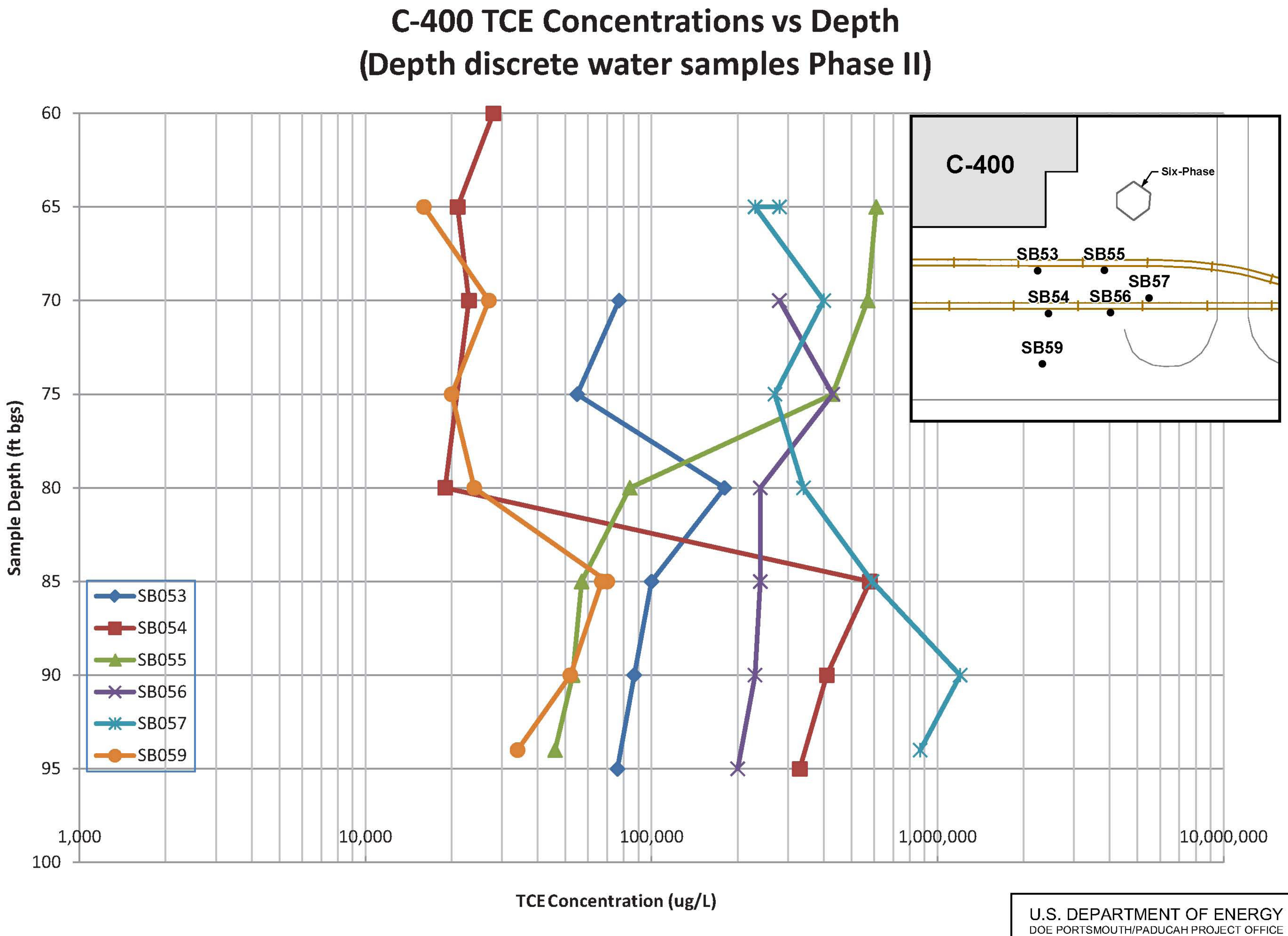

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Figure 10. Depth Discrete TCE Groundwater Samples within the RGA Collected during the Mass Confirmation Filed Effort 2011

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Table 2. Summary of the DQO Process for the C-400 Phase IIb Treatability Study

1: State the Problem	2: Identify the Decision			3: Identify Inputs to the Decision	4: Define the Study Boundaries	5: Develop a Decision Rule	6: Specify Limits on Decision Errors	7: Optimize the Design for Obtaining Data
	Principal Study Questions	**Alternative Actions**	**Decision Statement**					
Problem statement: **How will steam flow in the RGA in the southeast treatment zone?** **Background** Releases of cleaning solvents resulted in a subsurface source zone of TCE and other VOCs at the south end of the C-400 Cleaning Building Area. The *Record of Decision for Interim Remedial Action for the Groundwater Operable Unit for the Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2150&D2/R2, identified a response action for the source area comprised of TCE and other VOCs present in the subsurface at the C-400 Cleaning Building area. The RAOs for the C-400 Cleaning Building source area are as follows: • Prevent exposure to contaminated groundwater by on-site industrial workers through institutional controls (e.g., excavation/penetration permit program); • Reduce VOC contamination (primarily TCE and its breakdown products) in UCRS soil at the C-400 Cleaning Building area to minimize the migration of these contaminants to RGA groundwater and to off-site POEs; and • Reduce the extent and mass of the VOC source (primarily TCE and its breakdown products) in the RGA. The contamination by TCE in the C-400 source zone is present as dissolved TCE in groundwater and as DNAPL. EPA recognizes that DNAPL is a significant technical challenge for both characterization and remediation. DOE anticipates that the interim remedial action may not reduce soil contamination to levels that meet applicable or relevant and appropriate (ARARs) for groundwater by the time treatment is terminated. ERH is the selected response action in the ROD. Phase I deployed ERH in the UCRS at the southwest and east treatment sites and tested the applicability of ERH in the RGA at the southwest treatment site. The results of Phase I are summarized in the technical performance evaluation issued August 2011 (DOE 2011b). The result of the ERH treatability test in the RGA at the southwest treatment site	PSQ-1: Under what conditions can steam be injected into the RGA to develop a technically effective steam front as a basis for preliminary technology design and cost estimation? PSQ-2: How does steam injection using two injection intervals (middle and lower RGA) differ from injection using a single deep injection interval?	No alternative actions were identified.	DS-1: Determine the relationship between steam front development and steam injection pressure/rate over time. DS-2: Based on results for DS-1, how do spacing and injection rate requirements compose a basis for full-scale design and cost concepts?	(1) Previous investigation results (DOE 2011a). (2) Site conceptual model (DOE 2011a). • Collection of soil cores as part of treatability study 3) Information requirements for design of the preferred alternative as follows: • Rate of steam migration in the RGA; • Length of time for steam migration in the RGA; • Heat required to successfully remediate RGA; • Heat required to successfully remediate the RGA in consideration of groundwater velocity impacts; and • Steam injection rate required to successfully heat full thickness of RGA. (4) Define metric(s) for effective steam front development. (5) DOE Headquarters approval is required to commit to the agreed treatability scope.	*Spatial boundaries:* The vertical boundary of the study is the full thickness of the RGA. Location of injection well and monitoring array on upgradient edge of Phase IIb treatment area. Surface and subsurface infrastructure is present in the C-400 source areas. The C-400 building bounds the northwest side of the source area. *Schedule boundaries*: Treatability study operations are anticipated to require approximately 60–90 days. *Operational boundaries:* Field investigations and remedial design are constrained by surface and subsurface infrastructure at the C-400 Building. VOCs are present in the subsurface. The infrastructure geometry will be fixed for the treatability test and therefore optimization can only occur to steam injection scenario design (injection rates/ pressures/duration) rather than geometry of the study. *Administrative boundaries*: The treatability test includes subcontracting for a vendor to provide engineering design, construction, and operation of steam injection, engineering and temperature array monitoring. The vendor also will lead in the evaluation of the data and in providing a design and cost estimate for full-scale.	DR-1: If technically effective steam front propagation in the RGA can be demonstrated then the resulting information can be used to develop design and cost concepts for technology selection. It must be recognized that the conceptual layout presented here for the treatability study is not the optimal layout for full-scale implementation. Superposition of steam from multiple steam injection points will make for a more favorable steam front development at full-scale. Thus, modeling using appropriate models will be necessary to determine the appropriate well spacing and injection rates for full-scale.	Definitive data quality is assumed for temperature monitoring, and standard engineering parameter monitoring (flow rate, pressure, temperature). Screening level data quality is assumed for field data. Subsurface temperature data to be of sufficient quality to be able to determine rate of steam migration from one individual monitoring point to the next both vertically and horizontally. • Multiple temperature monitoring locations (5 to 10) to capture temperature response in RGA across the spatial extent to f the target zone. • Discreet temperature sensors at a maximum vertical spacing of 3 ft. • Horizontal temperature monitoring spacing to include locations that are downgradient, upgradient, and crossgradient locations in regard to groundwater flow direction. • Vertical extent to include full thickness of RGA and extend nominally into McNairy FM, below the RGA, and into the UCRS, above the RGA.	Flexibility in operation of treatability study (injection scenarios) to allow for adaptive management approach. Stopping or realigning treatability study based on results will allow for efficient collection of required data. Communication of the data and discussion with the stakeholders during the operation will be critical to the success of the treatability study. The targeted depth of investigation is the full thickness of the RGA unit in the southeast treatment zone, or approximately 60 to 100 ft bgs. Injection scenarios will include single well injection at the base of the RGA, and two-well injection both at the base and mid-point of the RGA. Parameters, as established in quality assurance project plan (QAPP), for precision, accuracy, representativeness, completeness, and comparability. Groundwater flow direction to be evaluated.

Table 2. Summary of the DQO Process for the C-400 Phase IIb Treatability Study (Continued)

1: State the Problem	2: Identify the Decision			3: Identify Inputs to the Decision	4: Define the Study Boundaries	5: Develop a Decision Rule	6: Specify Limits on Decision Errors	7: Optimize the Design for Obtaining Data
	Principal Study Questions	Alternative Actions	Decision Statement					
indicated that factors including low formation resistivity, high groundwater flow velocity, and low formation anisotropy negatively impacted ERH performance in regard to attainment of target temperatures. Consequently ERH was reevaluated and eliminated as a viable technology for remediation of the RGA. Steam enhanced extraction has been identified as a possible remedial technology for the RGA formation in the southeast treatment zone. In an attempt to understand design specifications and likely remedial outcomes, several modeling efforts have occurred to understand the impact of steam injection into the RGA. The purpose of this modeling is to provide details for design specifications of a steam enhanced extraction system as well as an understanding of schedule and time-frames required for completion of remedial efforts. Critical physical parameters of the RGA, such as horizontal hydraulic conductivity (permeability), vertical anisotropy, and groundwater velocity, in the southeast treatment zone are not well constrained. These uncertainties lead to large variability in the outcomes of modeling efforts, which, in turn, result in large uncertainty in both outcomes and cost estimates for deployment of steam enhanced extraction in the RGA. A treatability test involving steam injection into the RGA in the southeast treatment zone, with sufficient monitoring, is aimed at providing tighter constraints on understanding the movement of injected steam in the RGA, in addition to refining estimates of groundwater velocity, and impacts of groundwater velocity on heating the RGA (DOE 2011b). The objectives of the treatability study are to refine understanding of RGA physical characteristics in the Phase IIb treatment zone with a goal of: • Understanding the response of the RGA to steam injection • Determining the effect of groundwater flow on heating of the RGA				(6) The FFA parties must agree on the criteria for success. Data evaluation will include the following; • Model(s) must be supported by documented verification/ validation (vendor selection submittal); • Model(s) must reproduce field results from the single well injection test; and • Models must be capable of supporting evaluation of full-scale design development and evaluation.	[Vendor involvement is desired prior to finalization of the work plan/design (D2)].			

The approach to determine groundwater flow rate and direction is to use the array of monitoring locations to track relative thermal decay at multiple points both vertically and horizontally. The monitoring array will have locations in the upgradient, downgradient, and crossgradient locations. This analysis assumes that individual thermocouple points (e.g., specific depths and distance from injection well) would cool at approximately the same rate with zero groundwater velocity and that any variation in cooling would be spatially random. Any variation from this will be caused by groundwater movement. If there is a measurable groundwater velocity, the most upgradient thermal monitoring point will cool the quickest; the variation between the rate of cooling of this most upgradient point and the most downgradient thermal monitoring point will provide the rate of groundwater flow. A larger groundwater velocity will create a more predictable (calculable) pattern both spatially and temporally. The calculations will be checked using the thermal modeling provided by the steam injection contractor.

The conceptual steam injection treatability study design includes a single steam injection well with two screen intervals completed at depths corresponding to the middle of the RGA and the bottom of the RGA. The two screen intervals are expected to be approximately 5 ft in length. Aboveground system design will include an adequately sized boiler with steam control, conveyance, and monitoring. The steam injection design will include the ability to inject steam at progressively increasing rates, with a steam boiler capable of injection pressures of 75–100 psig. Steam injection will include two-screen interval and single screen interval injection scenarios (see Figure 11).

The conceptual layout of the treatability study includes multiple temperature monitoring locations at variable distances and directions, from the steam injection well. Each temperature monitoring location will have temperature sensors (e.g., Type K thermocouples or equivalent) spaced vertically across the full thickness of the RGA at approximately 3-ft intervals. The deepest temperature monitoring device will be located within the top 3–6 inches of the McNairy Formation. The second deepest temperature monitoring point will be located at the RGA/McNairy interface, with all subsequent temperature monitoring points spaced at 3-ft intervals. The highest temperature monitoring point should be above the top of the RGA, in the bottom 3 ft of the UCRS.

The importance of understanding temperature profiles at the base of the RGA cannot be underestimated for several reasons: (1) the buoyancy of steam will tend to make the injected steam rise; (2) DNAPL constituents have the tendency to migrate downward until reaching a barrier to continued flow, such as the fine-grained McNairy Formation; and (3) as pointed out in Section 1.4, the top of the McNairy Formation has been interpreted to have erosional channel topography, allowing for particularly important locations where DNAPL may settle. These erosional channels, which may sequester DNAPL at the top of the McNairy Formation, are one of the principal reasons heating must occur to the base of the RGA.

Conceptually, temperature monitoring will occur along a line downgradient away from injection location to a distance of approximately 20 ft. An additional series of temperature monitoring locations will occur in a crossgradient and upgradient direction at variable distances up to approximately 20 ft from injection well.

The closest temperature monitoring location may be as close as 2.5 ft of the steam injection location, with additional locations spaced at varying distances from the injection well (e.g., at 5 ft, at 10 ft, and at 20 ft).

Installation of a groundwater extraction well is under consideration as part of the treatability study design. The basis for groundwater extraction as a component required to meet treatability study objectives is expected to be evaluated as part of design development. If needed, the extraction well likely would be installed at a distance between 30–40 ft from the steam injection location in the downgradient direction with a screen interval that spans the full thickness of the RGA. The extraction well would require design of wellhead monitoring, connections, and piping to an existing water treatment facility.

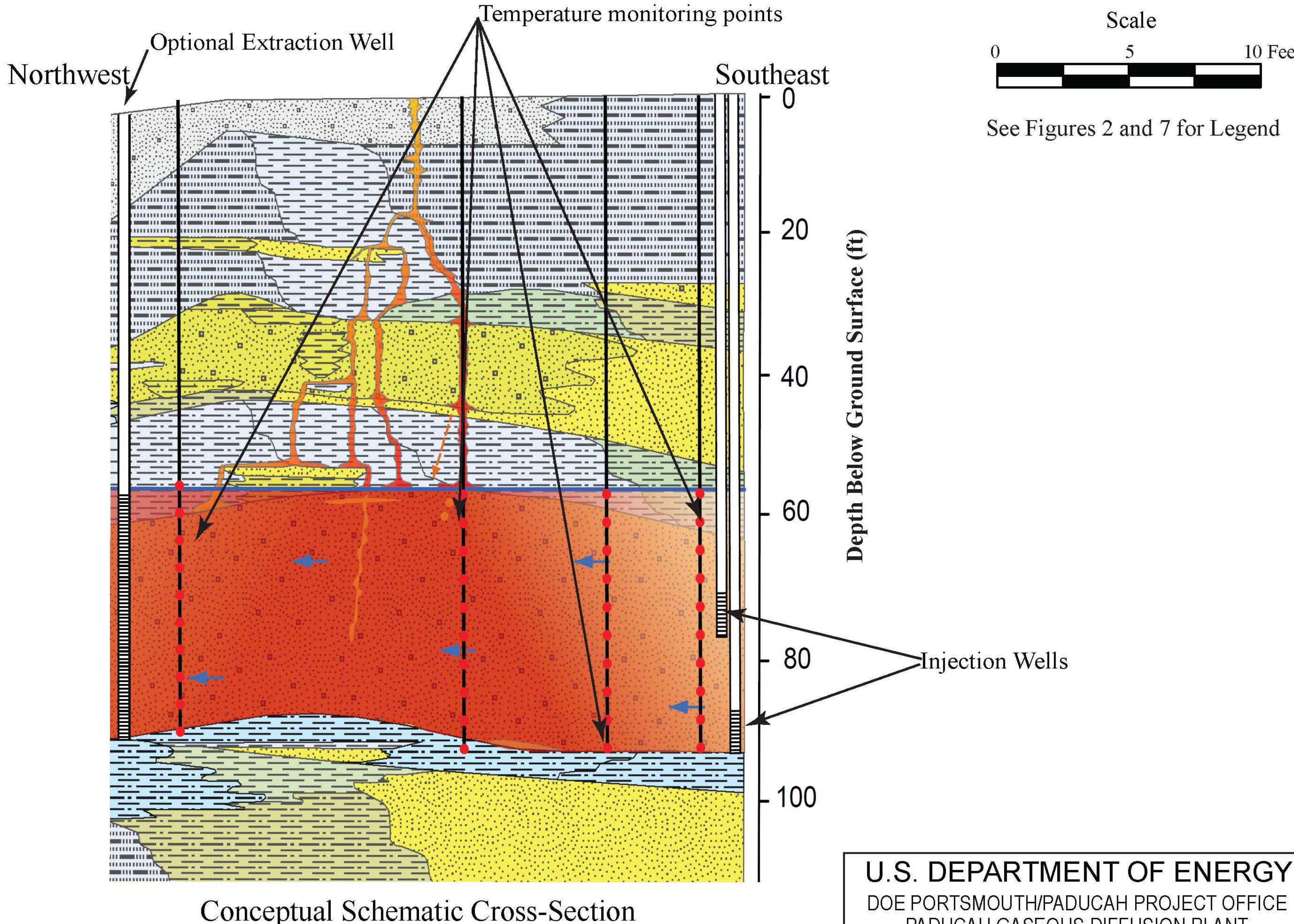

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Figure 11. Cross Section of C-400 Phase IIb Target Zone Location of Treatability Study

3.2 IMPLEMENTATION

Implementation of the steam injection treatability study will require development of an operational strategy that provides a summary of injection scenarios (i.e., low, medium, high injection rates) together with injection and monitoring schedules. The injection scenarios will begin with scenarios using both screen intervals and lowest injection rates and progress to scenarios using the single deep screen interval and higher injection rates.

The operations will require both manual and automated monitoring of aboveground operational parameters (e.g., injection rates, injection pressure, temperature), and automated monitoring of temperature.

The proposed location of the treatability study is the southwest corner of the Phase IIb target zone. Based on review of MIP data and expected groundwater flow direction, the site provides minimal impact to contaminants in the target zone, while at the same time providing a reusable location for injection well and monitoring locations in the event of full-scale deployment.

Depending on the number and range of injection scenarios considered necessary to obtain required data, the treatability operations are expected to occur over 60–90 day period. The operational strategy, developed during the design phase, will provide a matrix of injection scenarios to be tested and the order in which they will be tested. This injection scenario matrix generally will proceed from lower injection rates and pressures to successively higher injection rates and pressures. The design and technical specifications package will address measurements of operational parameters.

The operational goals of the treatability study are not necessarily to achieve full radius of influence for steam injection in each, or even any, scenario, but rather to observe, record, and understand steam flow in the RGA at differing injection rates. The critical period for understanding steam flow in the RGA will be the beginning of each injection scenario when the change of temperatures will clearly indicate rates and directions of steam flow. For this reason, individual scenarios may be required only to occur over several days.

3.3 EQUIPMENT AND MATERIALS

Surface equipment will be specified based on overall mass balance calculations and desired subsurface operational constraints. Steam injection requires certain high-temperature equipment such as specially designed wellheads, steam-tolerant well casing and screen, and temperature-tolerant injection equipment. Much of this equipment is readily available from a variety of commercial vendors, allowing some flexibility in design and economic analysis of full-scale design alternatives (see Figure 12).

In order to install the treatability study steam injection well, a drilling rig capable of drilling a large diameter (8–14 inch diameter) hole to a total depth of 110 ft bgs is required. Temperature monitoring locations will require the drilling of smaller diameter holes to a depth of approximately 110 ft bgs. Other necessary equipment includes common construction equipment such as a crane and forklift.

The following generalized list of equipment and materials are necessary for installation of the steam injection system. A complete list and specifications for equipment is being developed as part of the design.

- Appropriately sized steam boiler with safety/control systems;

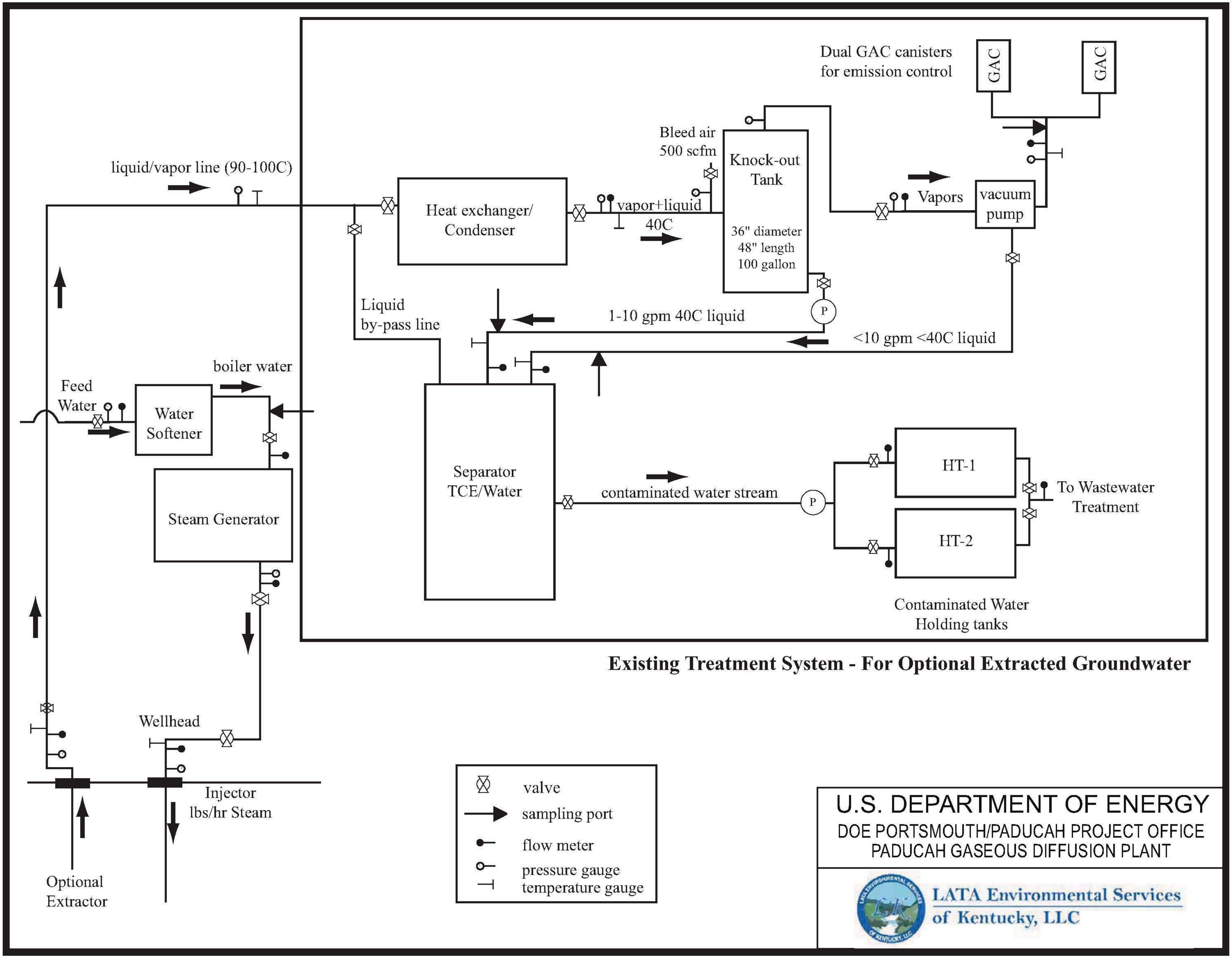

Figure 12. Conceptual Process Flow Diagram for C-400 Phase IIb Treatability Study

- Equipment and infrastructure for providing power (electricity or liquid fuel) to the boiler;
- Steam pipe or hose, steam injection well and temperature monitoring well materials, and wellhead connections;
- Valves/gauges/meters for temperature/pressure/flow monitoring;
- Temperature sensors or thermocouples and wiring (e.g., Type K or equivalent) and signal processor/data storage equipment;
- Construction and operations trailer; and
- Computer(s) and data acquisition software.

Fuel types for the proposed steam generator are limited to fuel oil or electric, because a natural gas line is not available in the vicinity of C-400. An electric steam generator is preferred and should be sufficient given the small amount of steam required for the treatability study. Fuel use and cost effective fuel alternatives will be part of a full-scale design analysis.

3.4 DATA COLLECTION

Treatability study data collection will include spatially distributed formation temperatures, as well as operational data such as steam injection rates, pressures and temperatures. Final treatability study design will include specification details for temperature monitoring points, including the number of locations downgradient, crossgradient, and upgradient of the steam injection location. Data collection will be required throughout injection and relaxation periods at time frames established by the treatability study design.

Collection of operational data will be sufficient to quantify total injected steam, injection rates, pressures, and flow volumes, in order to calculate total energy injected for each injection scenario.

Measurements of temperature with distance and time from the injection well at the beginning of injection will provide the basis for calculating permeability of the RGA to steam injection. Evolution through time of the steam zone will provide estimates of vertical anisotropy of the RGA to steam injection. Both of these formation-specific parameters will provide limits for design configurations of the injection-extraction well layout and specifications for steam injection rates and pressures. The formation parameters together with the steam injection rates and pressures allow for the calculation of the expected length of time required for steam break through between injection and extraction wells, the length of time to heat the full thickness of the RGA, and the amount of energy (steam) required to heat the treatment volume to target temperatures.

After the treatability study steam injection final scenario is turned off, continued temperature monitoring will allow for determination of groundwater flow rates through the target zone. By measuring the differences in cooling of crossgradient temperature monitoring locations with downgradient temperature monitoring locations, a reasonable estimation of groundwater flow rates within the target volume should be achievable.

Monitoring of subsurface temperature before, during, and after steam injection will be required to assess treatability study performance. Operations data are necessary as well for an assessment of the system performance. Measurements of grain size in area soil borings will be used to assess formation vertical anisotropy and support the evaluation of the zone of influence and thermal performance for the steam injection treatability study.

Field measurements will be crucial to the assessment of the treatability study. Issues related to data management and data quality are discussed in Section 5.3, Sampling and Analysis Plan, and Section 5.4, Data Management Plan/Residuals Management. Table 3 summarizes key analyses for the steam injection treatability study.

Table 3. Key Measurements during the Treatability Study

Medium	Property	Type of Measurement	Timing of Measurement	Assessment
Soil	RGA temperature	Field	Baseline, operations, postoperations	Heating efficiency
				Steam injection capability; rate and direction of steam migration
	McNairy Formation temperature	Field	Baseline, operations, postoperations	Heating efficiency
Groundwater*	RGA contaminant level	Laboratory	Pre-Study, operations	Dissolved TCE migration
Steam	Temperature	Field	Operations	Injected energy
	Pressure	Field	Operations	Injection capability

Note: Groundwater measurements contingent on need for extraction well.

4. TECHNOLOGY EVALUATION

4.1 DATA EVALUATION AND MODELING

The results of the treatability study for steam injection will be based upon analysis and interpretation of measurements of subsurface properties and engineering data. In overview, the data must summarize and be sufficient to assess the following:

- Key operating parameters (injection rates, pressures);
- Zone of influence of an individual injection well;
- Anisotropy to steam in the RGA;
- Horizontal permeability to steam;
- Two-well screen injection scenario effects on heating patterns in the RGA, in particular heating at bottom of RGA;
- Single-well injection scenario effects on heating patterns in the RGA, in particular heating at the bottom of the RGA;
- How long steam migration across the full thickness of RGA will take to reach 10 ft, 20 ft, and 30 ft distance from an injection well; and

- Groundwater velocity and calculation of the amount of heat groundwater flow will remove from the target treatment zone.

To reach these goals, the data must be taken from pretest and posttest measurements, in addition to measurements collected during the active operation of the treatability study.

Full-scale implementation of steam injection with multiphase extraction requires an array of injection and extraction wells to provide sufficient spatial coverage of a target zone. This treatability study involves only one injection location; therefore, the results of the treatability study cannot be used directly, without computer simulations, to demonstrate whether a full-scale deployment of the technology will be successful. Three-dimensional (3-D) simulations provide the capability to address the impact of interacting zones of influence from both multiple extraction and injection wells, which cannot be addressed with a two-dimensional (2-D) model.

Without simulating the three dimensional interaction of multiple injection and extraction wells, the effectiveness of steam injection with multiphase extraction in the RGA cannot be properly evaluated (Falta 2013).

In order to prepare simulations of a full-scale deployment, formation parameters (permeability and anisotropy of the RGA to steam injection) need to be understood. The temperature data resulting from each injection scenario will be compared against 2-D simulations using a variety of formation parameters. Any single injection scenario comparison will not yield a unique solution for the formation properties, but the combination of multiple injection scenarios should result in the narrowing to only a few possible values that result in 2-D simulations that match temperature data for all injection scenarios. This is essentially a calibration process for the simulations. As part of this process, a summary of residuals or differences between actual and modeled results will be prepared to confirm that the final formation properties chosen are the best fit to the data.

After determining the best solution for formation properties, a fully 3-D simulation can be constructed. This 3-D simulation will be manipulated to understand the effect of varying injection-extraction well layouts, well-to-well distances, and the impact of groundwater velocity on heating requirements.

The simulation process will follow quality assurance (QA)/quality control QC) documentation, consistent with industry standards for environmental/groundwater model documentation [e.g., ASTM D5718-13 (ASTM 013); ASTM D5880-95 (ASTM 2006)]. QA elements will address software verification and validation; model development and intended use; description of the conceptual model; results of literature searches and other applicable background information; identification of model inputs; and discussion of boundary conditions, model limitations, and uncertainties. A description of the simulation process and attendant QA information will be prepared and provided as an appendix to the treatability study report (see Section 4.4).

4.2 FULL-SCALE DESIGN CONCEPT DEVELOPMENT

The 3-D simulation of steam injection with multiphase extraction at C-400 will provide the basis for a conceptual full-scale design for deployment of the technology. Based on results of this modeling, a final well layout, incorporating optimal injection-extraction well spacing, will be designed. The importance of the well spacing is critical because it will ensure that steam reaches the bottom of the RGA across the entire target zone within a reasonable operational period, and without excessive heat requirements. Engineering specifications that will be derived from the 3-D simulation include the following:

- Number and placement of injection and extraction wells;
- Total energy requirements;
- Boiler requirements (including phasing of equipment to meet variable injection operations);
- Steam conveyance requirements (pipe/hose size, lengths);
- Vapor and groundwater extraction requirements;
- Vapor and groundwater treatment requirements;
- Extraction piping requirements; and
- Operational strategy (injection rates/pressures; injection time frames).

A 3-D model of steam injection with multiphase extraction deployment at C-400 also can be utilized during operations to gauge expected versus actual progress. This could include expected temperature distribution over time, compared with operational temperature monitoring, injection rates, and energy injected/extracted, as well as net expected versus actual injected energy during operations.

4.3 FULL-SCALE COST ESTIMATION

A conceptual cost estimate, following development of a conceptual design for full-scale deployment, including number and placement of wells, as well as preliminary flow estimations for injected steam and extracted fluids, will be prepared. The conceptual cost estimate will incorporate expected operational time frame, preliminary equipment lists, and large item specifications. This preliminary cost estimate will include all elements expected to be required for a successful full-scale deployment of steam injection with multiphase extraction at C-400.

4.4 REPORTS

A summary of treatability study results including modeling and associated QA documentation, full-scale design concepts, and cost estimate information for the conceptual full-scale design will be prepared based on the results of the treatability study.

The primary focus of the treatability study report will be the determination of formation properties through comparison of 2-D simulations of steam injection and steam temperature behavior based on field observations. The resulting refinements in formation properties will be used to simulate full-scale design concepts, and allow evaluation of the technology for remediation of source-based VOCs in the middle and lower RGA at C-400.

The suggested outline for the treatability study report is shown in Figure 13.

5. SUPPORTING PLANS

The plans included in this section govern the general management of fieldwork in support of this treatability study, as well as document the applicable contractor procedures for specific tasks. This section addresses project management and staffing, sampling and analysis, data management, and waste and sample residuals management.

Treatability Study Report Outline

1. Introduction
   1.1 Site description
      1.1.1 Site name and location
      1.1.2 History of operations
      1.1.3 Prior removal and remediation activities
   1.2 Waste stream description
   1.3 Treatment technology description
      1.3.1 Treatment process and scale
      1.3.2 Operating features
   1.4 Previous treatability studies at the site

2. Conclusions and Recommendations
   2.1 Conclusions
   2.2 Recommendations

3. Treatability Study Approach
   3.1 Test objectives and rationale
   3.2 Experimental design and procedures
   3.3 Equipment and materials
   3.4 Data collection and analysis
      3.4.1 Waste stream
      3.4.2 Treatment process
   3.5 Data management
   3.6 Deviations from the work plan

4. Results and Discussion
   4.1 Data analysis and interpretation
      4.1.1 Summary of Field Data
      4.1.2 Two Dimensional modeling
      4.1.3 Three Dimensional modeling
   4.2 Quality assurance/quality control
   4.3 Costs/schedule for performing the treatability study
   4.4 Key contacts

5. References

Appendices

A. Data
B. Standard operation procedures
C. Model development and calibration documentation

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Figure 13. Treatability Study Report Outline C-400 Phase IIb

5.1 PROJECT MANAGEMENT AND STAFFING

This section presents the general management and staffing plan for the treatability study. The organization chart shown in Figure 14 outlines the management structure that will be used for implementing the treatability study. Although not shown in this figure, the DOE project manager provides technical and management oversight. The DOE project manager also serves as the primary interface between the EPA and the Commonwealth of Kentucky. Key roles and their responsibilities for functions shown on the organizational chart are outlined in Table 4.

5.2 PROJECT SCHEDULE

Table 5 contains a schedule for the treatability study activities through completion of the operational phase of the field test and treatability study report. Only the milestones as referenced in the Site Management Plan (DOE 2013a) are enforceable under the FFA (EPA 1998): other dates are included for planning purposes.

5.3 SAMPLING AND ANALYSIS PLAN

The following sections discuss the general sample requirements to assess effectiveness and operation of the steam injection treatability study.[5] Additional details will be provided in the treatability study design package.

5.3.1 Location of the Treatability Study

The steam injection treatability study will be conducted in the southwest corner (upgradient edge) of the Phase IIb target zone, within what appears to be the primary source area for the Northwest Plume. Figure 2 shows the planned location for the treatability study test zone. This location was selected based on site data (specifically, VOC level and soil conductivity trends from MIP profiles) primarily reported in the C-400 VOC source zone RDR (DOE 2008). These data provide the basis for identifying the lateral extent of VOC contamination in the Phase IIb target zone in this area. Additionally, the treatability study design contractor has conducted a site visit and concurred on the proposed location based on its suitability for layout of support equipment, well installation, monitoring, and availability of power.

5.3.2 Sampling Strategy

This section discusses the general sampling strategy to be followed to evaluate the test objective and document the performance goals developed through the DQO process in Section 2. The overall sampling focus for the treatability study is to measure RGA groundwater temperature profiles during and following injection of steam from a central injection well. Initial soil samples will be collected from select soil borings for grain size analyses. Each soil boring will be lithologically logged. Groundwater samples may be collected from an extraction well, pending treatability study design finalization. If required, these samples may be used to assess VOC concentrations preceding (baseline) and during (operational) steam injection. The primary analyte of interest is TCE. Other VOCs of interest are the organic compounds 1,1-dichloroethene (DCE); *cis*-1,2-DCE; *trans*-1,2 DCE; and vinyl chloride (also known as TCE and its degradation products). As indicated in Figure 2, a total of 5 to 10 temperature monitoring locations (downgradient and crossgradient transects and upgradient monitoring) and 1 injection well, and potentially 1 extraction well are planned to be constructed for the project.

[5] This sampling and analysis plan varies from the suggested organization for a treatability study sampling and analysis plan included in *Guidance for Conducting Treatability Studies under CERCLA* (EPA 1992). This sampling and analysis plan incorporates the suggested components as they apply to the CSM and the treatability study DQOs.

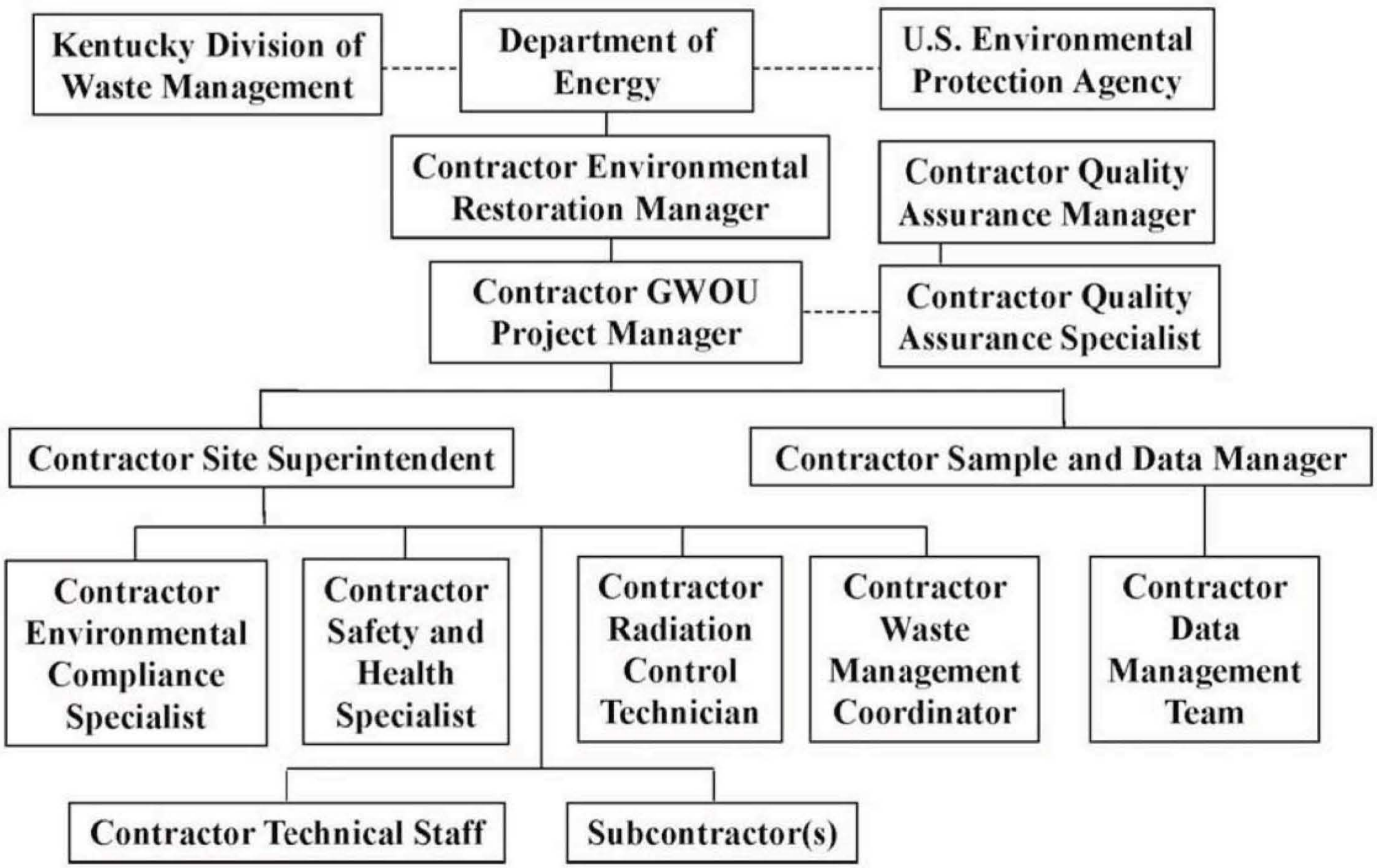

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Figure 14. Organization Chart for the Treatability Study

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Table 4. Roles and Responsibilities

Role	Responsibility
DOE Project Manager	Lead agency. DOE performs oversight of LATA Environmental Services of Kentucky, LLC, and the project. DOE reviews and approves project documents and participates, as needed, in Readiness Reviews. DOE also is responsible for communications with the EPA and state regulatory agencies.
Contractor Project Integration and Operations Manager	Serves as the primary point of contact with DOE to implement sitewide environmental restoration programs. Performs work in accordance with the baseline scope and schedule and directs the day-to-day activities of DOE contractor personnel performing environmental monitoring and restoration activities.
Contractor GWOU Project Manager	Serves as the treatability study primary point of contact and is responsible for the performance, quality, schedule, and budget. Provides overall project direction and execution, implements corrective actions as necessary, verifies compliance with safety and health requirements, and participates in the readiness review. Leads the effort to define the scope of the treatability study. Directs the project team in determining potential sources of existing data, identifying the study area and/or facility to be addressed by the project, and selecting the most effective data collection approach to pursue. May also be the technical contact for subcontracted project support and should ensure that the flow down of data management requirements is defined in a statement of work (SOW).
Contractor QA Manager	Responsible for coordination with the project QA staff to ensure an appropriate level of QA oversight. Schedules audits and surveillances needed to verify compliance with quality commitments and requirements. Has overall responsibility of approving, tracking, and evaluating effectiveness of corrective actions. Receives copies of field changes and approves field changes related to quality. The QA manager is independent of the project.
Contractor QA Specialist	Performs oversight to verify work is completed in accordance with the QAPP and/or the data management and implementation plan (DMIP). Responsible for reviewing project documentation to determine if the project team followed applicable procedures.
Contractor Project Manager	Oversees all field activities and verifies that field operations follow established and approved plans and procedures. Supervises the field team activities and field data collection. Ensures that all field activities are properly recorded and reviewed in the field logbooks and on any necessary data collection forms. Responsibilities include identifying, recording, and reporting project nonconformances or deviations. Interfaces with the GWOU project manager during field activities.
Contractor Safety and Health Specialist	Develops the health and safety plan (see Appendix A) and oversees implementation of Integrated Safety Management System (ISMS) and the overall safety and health of employees, both in the field and the office. Provides direct support to the GWOU project manager concerning the safety and health of project personnel and the general public and impacts to property and the environment. Ensures that each task has the proper safety and health controls in place before work begins, meeting all federal, state, and local regulations.

Table 4. Roles and Responsibilities (Continued)

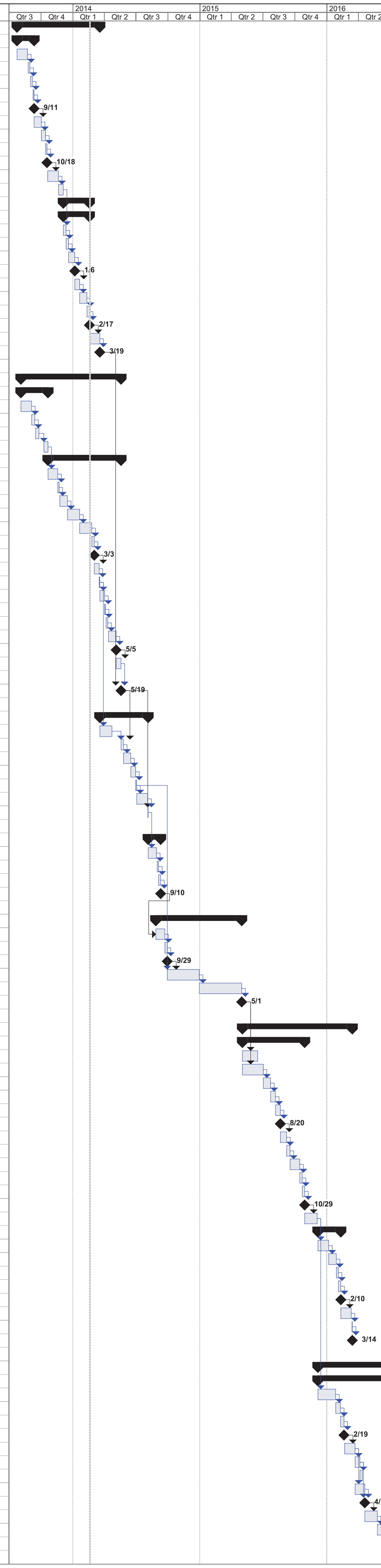
Role	Responsibility
Contractor Environmental Compliance Specialist	Ensure project activities are conducted in compliance with environmental laws and regulations including, but not limited to, National Environmental Policy Act and Clean Air Act, permits, regulatory agreements and documents, DOE Orders and Directives, and company policies and procedures. Review and prepare technical and regulatory documents/reports, National Emission Standards for Hazardous Air Pollutants reports, solid waste management unit notifications and assessment reports, and permit applications/modifications. Conduct regulatory research and reporting, perform field inspections, and support waste minimization and pollution prevention activities. Support implementation of the ISMS and Environmental Management System.
Contractor Radiation Control Technician	Implement the day-to-day programmatic aspects of the Radiation Protection Program. Perform air sampling, radiation surveys, radioactive contamination control and monitoring, access control, posting and labeling, completion and management of records, responding to accidents and emergencies, vehicle and equipment control, instrumentation source check, personnel decontamination, and minor equipment decontamination during the course of surveying. Generate radiological data records and reports.
Contractor Technical Staff	Provides direct support to the site superintendent and GWOU project manager concerning technical aspects of the project during remedial design, construction, and operation.
Contractor Waste Management Coordinator (WMC)	Ensures adherence to the waste management plan (WMP), documents and tracks field-related activities, including waste generation and handling, waste characterization sampling, waste transfer, and waste labeling. The WMC will perform the majority of waste handling field activities.
Contractor Sample and Data Manger	Responsible for the coordination of all sampling activities. Ensures that all quality control sampling requirements are met, chain-of-custody forms are generated properly. Responsible for managing data generated during the remedial design, construction, and operation in accordance with the DMIP.
Contractor Data Management Team	Responsible for entering project information into the project records file and/or database and ensuring that all information has been entered correctly. Ensures that hard copy data records are processed according to data records management requirements. Works with field teams to facilitate data collection and verification and with data users to ensure easy access to the data. Performs data reviews, verification and assessment, as appropriate. Determines project data usability by comparing the data against predefined acceptance criteria and assessing that the data are sufficient for intended use. Ensures that analytical methods, detection limits, minimum detectable activities, laboratory QC requirements, and deliverable requirements are specified in the SOW and that the SOW incorporates necessary deliverables so that data packages from the laboratory will be appropriate for verification and validation. Responsible for contracting any fixed base laboratory utilized during sampling activities. Incorporates any existing data or new project data into the project's hard copy data record file or data base, as appropriate. Ensures that analytical and field data are validated, as required, against a defined set of criteria that includes evaluating associated QC samples to ensure that analyses were preformed within specified control parameters. Performs data reviews, as appropriate [e.g., quality checks; assessing precision, accuracy, representativeness, comparability, completeness, and sensitivity parameter conformance; evaluating adherence to data quality requirements]. Ensures that the project data are properly incorporated into Paducah OREIS.

Table 4. Roles and Responsibilities (Continued)

Role	Responsibility
Subcontractors	A steam remediation specialty subcontractor will be hired to provide equipment and expertise during the design, construction, and operation of the treatability study system. A drilling subcontractor will be hired to install all subsurface borings and assist the steam remediation subcontractor with installation of the treatability study system components.

Table 5. Schedule for Treatability Study Activities

ID	Task Name	Duration	Start	Finish	Predecessors
1	SEE TS Work Plan	157 days	Thu 7/25/13	Wed 3/19/14	
2	Develop D1 SEE TS Work Plan (SEE Vendor not involved in D1)	35 days	Thu 7/25/13	Wed 9/11/13	
3	Develop Draft D1 SEE TS	22 days	Thu 7/25/13	Fri 8/23/13	
4	LATA KY Internal Reviews	5 days	Mon 8/26/13	Fri 8/30/13	3
5	Revise Document	5 days	Mon 9/2/13	Fri 9/6/13	4
6	Final Editing, Concurrence, and Document Production	3 days	Mon 9/9/13	Wed 9/11/13	5
7	Issue D1 WP to DOE for Review	0 days	Wed 9/11/13	Wed 9/11/13	6
8	DOE Review of D1 WP	15 days	Thu 9/12/13	Wed 10/2/13	7
9	Revise WP	8 days	Thu 10/3/13	Mon 10/14/13	8
10	DOE Concurrence on D1 WP	4 days	Tue 10/15/13	Fri 10/18/13	9
11	Issue D1 WP to EPA/KY	0 days	Fri 10/18/13	Fri 10/18/13	10
12	EPA/KY Review of D1 WP (FFA timeframe ~ 90CDs ~ 66WDs)	23 days	Mon 10/21/13	Wed 11/20/13	11
13	EPA/KY Extension of Review of D1 WP	7 days	Thu 11/21/13	Wed 12/4/13	12
14	Develop D2 WP (FFA timeframe ~ 45CDs ~ 32WDs)	43 days	Thu 12/5/13	Mon 2/17/14	
15	Respond to Comments and Develop D2 WP	43 days	Thu 12/5/13	Mon 2/17/14	
16	Develop Draft D2 SEE TS WP	6 days	Thu 12/5/13	Thu 12/12/13	13
17	LATA KY Internal Reviews	5 days	Fri 12/13/13	Thu 12/19/13	16
18	Final Editing, Concurrence, and Document Production	2 days	Fri 12/20/13	Mon 1/6/14	17
19	Issue D2 WP to DOE for Review	0 days	Mon 1/6/14	Mon 1/6/14	18
20	DOE Review of D2 WP	10 days	Tue 1/7/14	Mon 1/20/14	19
21	Revise WP	15 days	Tue 1/21/14	Mon 2/10/14	20
22	DOE Concurrence on D2 WP	5 days	Tue 2/11/14	Mon 2/17/14	21
23	Issue D2 WP to EPA/KY	0 days	Mon 2/17/14	Mon 2/17/14	22
24	EPA/KY Review of D2 WP (FFA timeframe ~ 30CDs ~ 22WDs)	22 days	Tue 2/18/14	Wed 3/19/14	23
25	EPA/KY Concur on D2 WP	0 days	Wed 3/19/14	Wed 3/19/14	24
26					
27	SEE TS Design Development (SEE Vendor Input)	193 days	Mon 8/5/13	Mon 5/19/14	
28	SEE Vendor Subcontracting for TS Design Development	56 days	Mon 8/5/13	Mon 10/21/13	
29	LATA Develop SOW and Quals	23 days	Mon 8/5/13	Wed 9/4/13	
30	LATA Complete RFQ Package and Issue to Bidders	7 days	Thu 9/5/13	Fri 9/13/13	29
31	Bidders Prepare Proposals	8 days	Mon 9/16/13	Wed 9/25/13	30
32	LATA Evaluate Proposals, Select Vendor, and Award	8 days	Thu 10/10/13	Mon 10/21/13	31
33	Develop TS D1 Design	137 days	Tue 10/22/13	Mon 5/19/14	
34	Develop D1 Design and Implementation Details	20 days	Tue 10/22/13	Mon 11/18/13	32
35	LATA Internal Reviews	4 days	Tue 11/19/13	Fri 11/22/13	34
36	LATA/ Vendor Revise Design	13 days	Mon 11/25/13	Mon 12/16/13	35
37	DOE Review of Design	15 days	Tue 12/17/13	Mon 1/20/14	36
38	LATA/ Vendor Revise Design	25 days	Tue 1/21/14	Mon 2/24/14	37
39	DOE Concurrence on D1 Design Report	5 days	Tue 2/25/14	Mon 3/3/14	38
40	Issue D1 TS Design Report to EPA/KY	0 days	Mon 3/3/14	Mon 3/3/14	39
41	EPA/KY Review of D1 Design in Preparation for On-board Reviews	10 days	Tue 3/4/14	Mon 3/17/14	40
42	Web-based/On-board Review of Design by FFA Parties	2 days	Tue 3/18/14	Wed 3/19/14	41
43	Revise Design	10 days	Thu 3/20/14	Wed 4/2/14	42
44	Web-based/On-board Review of Final Design by FFA Parties	2 days	Thu 4/3/14	Fri 4/4/14	43
45	Revise Design	5 days	Mon 4/7/14	Fri 4/11/14	44
46	DOE HQ Briefing and Concurrence on Design	16 days	Mon 4/14/14	Mon 5/5/14	45
47	Transmit D2 TS Design Report to EPA/KY	0 days	Mon 5/5/14	Mon 5/5/14	46
48	EPA/KY Review and Approve D2	10 days	Tue 5/6/14	Mon 5/19/14	47
49					
50	SEE TS WP and Design Approved for Implementation	0 days	Mon 5/19/14	Mon 5/19/14	25,48
51					
52	SEE Vendor Subcontracting for TS Implementation	99 days	Thu 3/20/14	Tue 8/5/14	
53	Develop SOW, Tech Spec, and Other Subcontract Exhibits	25 days	Thu 3/20/14	Wed 4/23/14	42
54	Complete RFP Package and Issue to Bidders	5 days	Tue 5/20/14	Mon 5/26/14	53,50
55	Bidders Prepare Proposals	15 days	Tue 5/27/14	Mon 6/16/14	54
56	LATA Evaluate Proposals and Select Vendor	10 days	Tue 6/17/14	Mon 6/30/14	55
57	LATA Develop and Submit Consent Package	3 days	Tue 7/1/14	Thu 7/3/14	56
58	DOE Review and Approve Consent Package	22 days	Fri 7/4/14	Mon 8/4/14	57
59	LATA Awards Subcontract	1 day	Tue 8/5/14	Tue 8/5/14	58,50
60					
61	Develop TS CFC Drawings and Specifications	26 days	Wed 8/6/14	Wed 9/10/14	
62	Develop Draft Construction Drawings and Specifications	18 days	Wed 8/6/14	Fri 8/29/14	59
63	LATA KY Internal Reviews	4 days	Mon 9/1/14	Thu 9/4/14	62
64	Revise Design Drawings and Specifications	4 days	Fri 9/5/14	Wed 9/10/14	63
65	Issue CFC Package	0 days	Wed 9/10/14	Wed 9/10/14	64
66					
67	SEE Treatability Study	177 days	Thu 8/28/14	Fri 5/1/15	
68	Work Planning and Readiness Assessment	18 days	Thu 8/28/14	Mon 9/22/14	65FS-10 days
69	Internal Field Review	5 days	Tue 9/23/14	Mon 9/29/14	68
70	Construction Start	0 days	Mon 9/29/14	Mon 9/29/14	69
71	Construct and Test TS Systems	66 days	Tue 9/30/14	Tue 12/30/14	57,70
72	Perform TS	88 days	Wed 12/31/14	Fri 5/1/15	71
73	TS Data Collection Complete	0 days	Fri 5/1/15	Fri 5/1/15	72
74					
75	Evaluate Results and Develop TS Report	213 days	Mon 5/4/15	Mon 3/14/16	
76	Develop D1 SEE TS Report (Secondary Document)	129 days	Mon 5/4/15	Thu 10/29/15	
77	Sample Analysis and Data Review	32 days	Mon 5/4/15	Tue 6/16/15	73
78	Numeric Modeling and Draft Text	44 days	Mon 5/4/15	Thu 7/2/15	73
79	LATA KY Internal Reviews	15 days	Fri 7/3/15	Thu 7/23/15	78
80	Revise Document	10 days	Fri 7/24/15	Thu 8/6/15	79
81	Final Editing, Concurrence, and Document Production	10 days	Fri 8/7/15	Thu 8/20/15	80
82	Issue D1 TS Report to DOE for for Review	0 days	Thu 8/20/15	Thu 8/20/15	81
83	DOE Technical Review of D1 TS Report	12 days	Fri 8/21/15	Mon 9/7/15	82
84	Revise TS Report	8 days	Tue 9/8/15	Thu 9/17/15	83
85	DOE HQ Review of TS Report	20 days	Fri 9/18/15	Thu 10/15/15	84
86	Revise TS Report	5 days	Fri 10/16/15	Thu 10/22/15	85
87	DOE Concurrence on D1 TS Report	5 days	Fri 10/23/15	Thu 10/29/15	86
88	Issue D1 TS Report to EPA/KY	0 days	Thu 10/29/15	Thu 10/29/15	87
89	EPA/KY Review of D1 TS Report (FFA timeframe = 90CDs = 66WDs)	23 days	Fri 10/30/15	Fri 12/4/15	88
90	Develop D2 TS Report (FFA timeframe = 45CDs = 32WDs)	38 days	Mon 12/7/15	Wed 2/10/16	
91	Respond to Comments and Develop D2 TS Report	13 days	Mon 12/7/15	Wed 1/6/16	89
92	DOE Review of D2 TS Report	16 days	Thu 1/7/16	Thu 1/28/16	91
93	Revise TS Report	4 days	Fri 1/29/16	Wed 2/3/16	92
94	DOE Concurrence on D2 TS Report	5 days	Thu 2/4/16	Wed 2/10/16	93
95	Issue D2 TS Report to EPA/KY	0 days	Wed 2/10/16	Wed 2/10/16	94
96	EPA/KY Review of D2 TS Report (FFA timeframe = 30CDs = 22WDs)	22 days	Thu 2/11/16	Fri 3/11/16	95
97	EPA/KY Concur on D2 TS Report	1 day	Mon 3/14/16	Mon 3/14/16	96
98	FFA Party Consensus on SEE Results	0 days	Mon 3/14/16	Mon 3/14/16	97
99					
100	Proposed Plan	140 days	Mon 12/7/15	Fri 7/1/16	
101	D1 Proposed Plan	140 days	Mon 12/7/15	Fri 7/1/16	
102	Develop D1 PP	27 days	Mon 12/7/15	Tue 1/26/16	89
103	LATA KY Internal Reviews	10 days	Wed 1/27/16	Tue 2/9/16	102
104	Final Editing, Concurrence, and Document Production	8 days	Wed 2/10/16	Fri 2/19/16	103
105	Issue Draft D1 PP to DOE for Review	0 days	Fri 2/19/16	Fri 2/19/16	104
106	DOE Review of Draft D1 PP	22 days	Mon 2/22/16	Tue 3/22/16	105
107	Revise PP	10 days	Wed 3/23/16	Tue 4/5/16	106
108	DOE Concurrence on D1 PP	5 days	Wed 4/6/16	Tue 4/12/16	107
109	Prepare Remedy Review Package	20 days	Wed 3/23/16	Tue 4/19/16	106
110	Issue D1 PP to DOE HQ for Remedy Review	0 days	Tue 4/19/16	Tue 4/19/16	109,107
111	Remedy Review	26 days	Wed 4/20/16	Wed 5/25/16	110
112	Finalize D1 PP	22 days	Thu 5/26/16	Fri 6/24/16	111
113	DOE Concurrence on D1 WP	5 days	Mon 6/27/16	Fri 7/1/16	112
114	Issue D1 PP to EPA/KY	0 days	Fri 7/1/16	Fri 7/1/16	113



Project: SEE TS Schedule (14-day Mil
Date: Tue 2/18/14

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

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5.3.2.1 Soil and groundwater sampling

Continuous cores will be collected from each well borehole during construction to provide for lithologic descriptions and collection of soil RGA soil samples for grain size analysis. The lithologic descriptions will be referenced to determine the well screen intervals. Samples for grain size analysis will be collected on 2-ft intervals throughout the RGA (both HU4 and HU5 intervals) in the borehole used for the construction of the injection well. Both the lithologic descriptions and the RGA grain size analyses will support an assessment of aquifer vertical anisotropy.

The final decision to install a groundwater extraction well will be addressed in the treatability study design. It is envisioned that the criteria that will be used to evaluate the need for a groundwater extraction well will include the following:

- Is groundwater extraction a critical component for determining steam front behavior in the RGA at C-400?
- Will the effects of steam injection testing warrant hydraulic control beyond the current Northwest Plume extraction system to mitigate mobilization of TCE?
- Is a demonstration of groundwater extraction required to evaluate steam enhanced thermal remediation as a potential remedy for Phase IIb?

If an extraction well is included in the treatability study, groundwater sampling will be performed during baseline and operational periods to characterize VOC trends.

5.3.2.2 Operational sampling

During the operation phase of the treatability study, various engineering parameters will be measured to ensure optimum performance of the overall system and to determine the operating requirements. The parameters to be measured include steam injection rates and pressures, subsurface temperature readings, operating parameters of the system components, and, if applicable (i.e., if an extraction well is used), water extraction rates and contaminant recovery.

5.3.2.3 Waste management sampling

The contractor's WMC will be responsible for sampling the solid and liquid investigation-derived waste as needed. During sampling, all appropriate health and safety concerns will be addressed. Sample materials from different containers will not be mixed, and only containers requiring further characterization will be sampled.

5.3.3 Analytical Requirements

During the treatability study, most analyses will be performed by a fixed-base laboratory contracted through the Sample Management Office. Specific analytical methods and procedures are described in the QAPP contained in Appendix B of this TSWP. This TSWP uses the site's approved programmatic QAPP, *Paducah Gaseous Diffusion Plant Programmatic Quality Assurance Project Plan*, DOE/LX/07-1269&D2/R1, modified, as necessary, for the treatability study (see Appendix B).

Waste characterization sampling will be conducted during the installation and operation of the steam injection system. Waste characterization requirements are discussed in Section 5.4.

5.3.4 Sampling Schedule

The sampling schedule will be determined during the design phase of the treatability study, but will need to capture specific technology related impacts. If an optional groundwater extraction well is included, then a regular schedule of groundwater sampling tied to an operational schedule will be developed and provided prior to implementation.

Data collection associated with steam injection and subsurface temperature monitoring will have specific scenario-related schedules. The subsurface temperature monitoring, in particular, will be designed to collect data at regular, short, intervals beginning before steam injection starts and continuing until several weeks or months after steam injection has been completed. The frequency of temperature data collection should be on the order of several times per hour.

5.3.5 Data Management Implementation Plan

Data management for this treatability study is governed by the DMIP (Section 10) of the current approved version of the *Remedial Action Work Plan of Phase IIa of the Interim Remedial Action for the Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2012).

5.4 WASTE MANAGEMENT PLAN/RESIDUALS MANAGEMENT

Waste management and sample residuals management for this treatability study is governed by the WMP (Section 12) of the current approved version of the *Remedial Action Work Plan of Phase IIa of the Interim Remedial Action for the Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2012). Tables 6 and 7 provide waste generation forecasts for this treatability study for options of without using extraction well and with using the extraction well, respectively.

5.5 ENVIRONMENTAL COMPLIANCE

Environmental compliance for this TSWP is governed by the Environmental Compliance section (Section 11) of the current approved version of the *Remedial Action Work Plan of Phase IIa of the Interim Remedial Action for the Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2012).

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Table 6. Treatability Study Waste Generation Forecast (without Extraction Well Option)

Waste Stream	Volume (ft^3 for solids and gal for liquids)	Container Type	Estimated Number of Containers	Preliminary Waste Category	Characterization Method	Analysis	Expected Disposition	Schedule	Comments
Drill Cuttings from Soil Borings	590	ST-90 box	7	RM	Sampling and analysis	See Section 8.3.2, Tables 10 and 11, in current approved version of the C-400 Phase IIa Remedial Action Work Plan (DOE 2012)	C-746-U Landfill/ RCRA-Permitted Disposal Facility	As needed	NLC determination required for disposal at the C-746-U Landfill
Personal Protective Equipment/Plastic	15	55-gal drum	2	RM	Sampling and analysis	See Section 8.3.2, Tables 10 and 11, in current approved version of the C-400 Phase IIa Remedial Action Work Plan (DOE 2012)	C-746-U Landfill/ RCRA-Permitted Disposal Facility	As needed	NLC determination required for disposal at the C-746-U Landfill
Purge/ Decontamination/ Drilling Water	1,200	1,200-gal poly tank	1	RM or S based on TCE concentration at point of generation	Sampling and analysis	See Section 8.3.2, Table 12, in current approved version of the C-400 Phase IIa Remedial Action Work Plan (DOE 2012)	C-612 Northwest Plume Groundwater System	As needed	Based on TCE concentration at the point of generation

Note: Drill cutting estimate is based on soil borings for injection wells to 75 and 95 ft depths and 10 temperature monitoring wells to 95 ft depth, with a 30% soil swell factor.
NLC = no longer contains
RCRA = Resource Conservation and Recovery Act
RM = Resource Conservation and Recovery Act/mixed
S = solid waste

Table 7. Treatability Study Waste Generation Forecast (with Extraction Well Option)

Waste Stream	Volume (ft^3 for solids and gal for liquids)	Container Type	Estimated Number of Containers	Preliminary Waste Category	Characterization Method	Analysis	Expected Disposition	Schedule	Comments
Drill Cuttings from Soil Borings	650	ST-90 box	8	RM	Sampling and analysis	See Section 8.3.2, Tables 10 and 11, in current approved version of the C-400 Phase IIa Remedial Action Work Plan (DOE 2012)	C-746-U Landfill/ RCRA-Permitted Disposal Facility	As needed	NLC determination required for disposal at the C-746-U Landfill
Personal Protective Equipment/ Plastic	15	55-gal drum	2	RM or S based on TCE concentration at point of generation	Sampling and analysis	See Section 8.3.2, Tables 10 and 11, in current approved version of the C-400 Phase IIa Remedial Action Work Plan (DOE 2012)	C-746-U Landfill/ RCRA-Permitted Disposal Facility	As needed	NLC determination required for disposal at the C-746-U Landfill
Purge/ Decontamination/ Drilling Water	1,500	1,200-gal poly tank	2	RM or S based on TCE concentration at point of generation	Sampling and analysis	See Section 8.3.2, Table 12, in current approved version of the C-400 Phase IIa Remedial Action Work Plan (DOE 2012)	C-612 Northwest Plume Groundwater System	As needed	Based on TCE concentration at the point of generation

Table 7. Treatability Study Waste Generation Forecast (with Extraction Well Option) (Continued)

Waste Stream	Volume (ft^3 for solids and gal for liquids)	Container Type	Estimated Number of Containers	Preliminary Waste Category	Characterization Method	Analysis	Expected Disposition	Schedule	Comments
Extraction Well Production Water	4,320,000	Direct piping to treatment system	Not applicable	RM or S based on TCE concentration at point of generation	Sampling and analysis	See Section 8.3.2, Table 12, in current approved version of the C-400 Phase IIa Remedial Action Work Plan (DOE 2012)	C-400 Remedial Action Groundwater System	As needed	Based on TCE concentration at the point of generation

Note: Drill cutting estimate is based on soil borings for injection wells to 75 and 95 ft depths and 10 temperature monitoring wells to 95 ft depth, with a 30% soil swell factor.
NLC = no longer contains
RM = Resource Conservation and Recovery Act/mixed
S = solid waste

6. COMMUNITY RELATIONS

Current stakeholders for the PGDP site, through the Citizens Advisory Board (CAB), are interested in reducing contaminant source areas that contribute to the groundwater contamination at PGDP. Steam injection with multiphase extraction has been shown at other locations to be capable of dramatically reducing the volume of TCE and any of its degradation products contributing to groundwater contamination. A formal presentation of this technology to the stakeholders is planned.

DOE PPPO has worked to keep the CAB updated on FFA party interaction regarding the need for a treatability study. In May 2013, the CAB provided a recommendation that supports a steam injection treatability study, provided DOE performs a DQO analysis (see Section 2), a cost to benefit analysis at the end of the study, and an alternate path forward, if the study demonstrates that the technology is not viable.

Treatability study information will be included in the appropriate stakeholder-related activities, as described in the *Community Relations Plan under the Federal Facility Agreement at the U.S. Department of Energy Paducah Gaseous Diffusion Plant* (DOE 2013b). These activities include distributing information bulletins, maintaining an information repository, and facilitating public meetings, including meetings for the CAB. In addition, a project-specific fact sheet will be published and distributed. The fact sheet will focus on the treatability study and how it relates to the PGDP remediation strategy.

7. REFERENCES

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APPENDIX A

ENVIRONMENT, SAFETY, AND HEALTH PLAN FOR STEAM INJECTION TREATABILITY STUDY

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ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
AHA	activity hazard assessment
ALARA	as low as reasonably achievable
CFR	*Code of Federal Regulations*
CRZ	Contaminant Reduction Zone
DNAPL	dense nonaqueous-phase liquid
DOE	U.S. Department of Energy
EMS	Environmental Management System
EPA	U.S. Environmental Protection Agency
ER	environmental restoration
ES&H	environment, safety, and health
EZ	Exclusion Zone
FLS	front line supervisor
GWOU	Groundwater Operable Unit
HASP	Health and Safety Plan
ISMS	Integrated Safety Management System
MSDS	material safety data sheet
OSHA	Occupational Safety and Health Act of 1970
PGDP	Paducah Gaseous Diffusion Plant
PID	photoionization detector
PPE	personal protective equipment
PSS	plant shift superintendent
PVC	polyvinyl chloride
PSS	plant shift superintendent
QA	quality assurance
RCT	radiological control technician
RPP	radiation protection plan
RWP	radiological work permit
SHS	safety and health specialist
VC	vinyl chloride
VOC	volatile organic compound
WMC	waste management coordinator

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ENVIRONMENT, SAFETY, AND HEALTH PLAN

This Health and Safety Plan (HASP) has been developed as an overview to discuss the general standards and practices to be used during execution of the steam injection with multiphase extraction treatability study to protect the safety and health of workers and the public. Site-specific hazards and controls will be established for each task and location prior to performing work. These hazards and controls will be documented in the form of a site-specific HASP, activity hazard assessments (AHAs), work control documents, and procedures, or an approved combination thereof. Personnel will be familiar with the hazards, controls, applicable procedures, and work control documents prior to performing work in the affected areas. This work will be performed in accordance with the U.S. Department of Energy's (DOE) Integrated Safety Management System (ISMS) and its environmental compliance and health and safety requirements; these establish a goal of zero-accident performance. Hazard controls will include access restrictions, operator-training requirements, exclusion of nonessential personnel from the work zone, use of engineering/administrative controls and use of personal protective equipment (PPE).

A.1. INTEGRATED SAFETY MANAGEMENT/ ENVIRONMENTAL MANAGEMENT

This treatability study will utilize an ISMS, which integrates the Safety Management System, the Environmental Management System (EMS), and the Quality Management System to ensure personnel and environmental safety and quality are integrated into management and work practices at all levels so that missions are accomplished while protecting the public, the workers, and the environment. The concepts of the ISMS/EMS will be utilized to provide a formal, organized process to ensure the safe performance of work. The ISMS/EMS plan identifies the methodologies that will be used to address previously recognized hazards and how the hazards are mitigated using accepted health and safety practices.

This project will pursue the DOE's goal of zero accident performance through project-specific implementation of ISMS. The core functions and guiding principles of ISMS/EMS will be implemented by complying with 10 *CFR* § 851, *Worker Safety and Health Program*, and incorporating applicable DOE Orders, policies, technical specifications, and guidance. A brief description of the five ISMS/EMS core functions is provided in the following sections.

A.1.1 DEFINE SCOPE OF WORK

Defining and understanding the scope of work is the first critical step in successfully performing any specific activity in a safe manner. Each member of the project team will participate in discussions conducted to understand the scope and contribute to the planning of the work. The project team will conduct a project team planning meeting to discuss the team's general understanding of the scope and the technical and safety issues involved. This meeting is conducted to ensure all parties are in agreement on the scope and general approach to complete the scope.

A.1.2 ANALYZE HAZARDS

In the course of planning the work, the project team will identify hazards associated with the performance of the work. Hazards may be identified and assessed by performing a site visit, reviewing lessons learned, and reviewing project plans or historical data.

A.1.3 DEVELOP AND IMPLEMENT HAZARD CONTROLS

After potential safety hazards and environmental risks are identified, controls necessary to protect workers, the public, and the environment are identified and implemented. These controls are identified in the work planning process that develops how the scope of work will be performed and identifies the applicable standards, requirements, and controls that are needed. Then those processes must be established and implemented in the appropriate work control document, such as procedures, work instructions, and AHAs.

Applicable work control documents/AHAs will be reviewed with the personnel who will perform the work. Participants in this review will sign and date the appropriate documentation to signify that they understand all hazards, controls, and requirements. A copy of the work control documents with appropriate signatures shall be maintained at the work location.

A.1.4 PERFORM WORK WITHIN CONTROLS

Prior to commencing work, the project team will verify that the appropriate work control documents are in place and have been reviewed and approved by authorized personnel. The project team also will ensure that all the requirements and controls have been communicated to the project team. These requirements and controls are communicated through the following applicable methods:

- Training
- Required reading/briefings
- Prejob meetings
- Permits
- Plan-of-the-day/prejob briefings
- AHAs
- Radiological work permits (RWPs)
- Signs and postings

The project team will adhere strictly to the requirements established in approved contractor performance documents and work controls at all times. If a performance document or work control cannot be followed or clearly interpreted, the task will not be performed until a clear and operable document can be provided for the performance of the work.

A.1.5 FEEDBACK AND CONTINUOUS IMPROVEMENT

Feedback and continuous improvement are accomplished through several channels, including ISMS/EMS audits, self-assessments, employee suggestions, lessons learned, and prejob briefings. These actions will be used to solicit worker feedback, as well as to identify, address, and communicate lessons learned using standard corrective action planning and continuous improvement processes.

Project management will encourage employees to submit suggestions freely that offer opportunities for continuous improvement and constructive criticism on the activities. Project management will conduct periodic inspections and meetings with project personnel at the work site to discuss project status, priorities, expectations, safety/environmental issues, and/or concerns as well as other relevant topics.

During field activities, meetings and briefings will provide opportunities for project personnel to communicate the following:

- Lessons learned and any other topics relevant to the work performed;
- How work steps/procedures could be modified to promote a safer working environment;
- How communications could be improved within the project team; and
- Overall issues or concerns they may have regarding how the work was performed.

A.2. FLOWDOWN TO SUBCONTRACTORS

The ISMS/EMS approach to environment, safety, and health (ES&H) ensures that personnel, including subcontractors, are aware of their roles, responsibilities, and authorities for worker/public safety and protection of the environment. All organizations will be responsible for compliance with the prime contractor's Worker Safety and Health Program, ISMS Program, Radiation Protection Program, Environmental Protection Program, and Quality Assurance (QA) Program. In addition, subcontract requirements will flow down to lower-tier subcontractors, as applicable. Personnel will have the appropriate medical qualifications and health and safety training required by appropriate federal regulations, but also will undergo site-specific prejob training, including safety and environmental, to ensure that ES&H issues related to the activities to be performed or specific to the work site are clearly understood. Documentation of training will be available for review prior to starting work.

A.3. SUSPENDING/STOPPING WORK

In accordance with 10 *CFR* § 851.20 and the DOE prime contractor's Worker Safety and Health Program and procedures, employees and subcontractors have suspend/stop work authority. Individuals involved in any aspect of the project have the authority and responsibility to suspend or stop work for any perceived threat to the safety and health of the workers, the public, or to the environment. Concerns shall be brought to the attention of the frontline supervisor (FLS) and safety and health specialist (SHS), will be evaluated by project management personnel, and actions will be taken to rectify or control the situation. In the case of imminent danger or emergency situations, personnel should halt activities immediately and instruct other affected workers to pull back from the hazardous area. The appropriate authority/responders shall be notified immediately in accordance the emergency response plans.

A.4. ISMS/EMS BRIEFINGS

Plan-of-the-day/prejob briefings detailing the specific hazards of the work to be performed and safety precautions and procedures specific for the job shall be conducted by the FLS and/or SHS at the beginning of each shift. During these briefings, work tasks and the associated hazards and mitigating controls will be discussed using approved procedures, work control documents, AHAs, and/or lessons learned as guidance.

Prior to performing work on the site, personnel shall be required to read or be briefed on the DOE prime contractor's Worker Safety and Health Program, applicable AHAs, the work package, and other applicable documents. This shall be documented as required reading, acknowledgement forms, or briefing sheets. Visitors will also be briefed to the applicable plans and potential hazards that they may encounter.

A.5. KEY PROJECT PERSONNEL AND RESPONSIBILITIES

One of the primary underlying principles of a successful project organization is the establishment of clearly defined roles and responsibilities and effective lines of communication among employees and among the prime contractor, subcontractors, and other organizations involved in the project. Ensuring that personnel fully understand their roles and responsibilities and that they have a thorough understanding of the scope of work and other project requirements will provide the foundation for successful and safe completion of the project.

The roles and responsibilities of key field team members are briefly described as follows.

- The contractor manager of projects oversees the implementation of the project's plans and provides the resources for the project.

- The treatability study's project manager oversees the project's plans and work activities while ensuring that operations are conducted in accordance with the DOE prime contractor procedures, regulatory requirements, and Worker Safety and Health Program and is responsible for coordinating and assigning resources needed for the project. The treatability study project manager also performs management audits and inspections.

- The QA specialist provides support and oversight to the project to ensure that work is performed in accordance with the work package and other applicable plans and procedures.

- The FLS coordinates field activities and logistics and provides the communications between the project team and the field team as well as other support groups. The FLS also ensures that on-site personnel comply with the Worker Safety and Health Program, work packages, and applicable procedures.

- The safety and health specialist provides ES&H support and oversight to the project to ensure that work is being performed safely and in accordance with the Worker Safety and Health Program, applicable regulations, 10 *CFR* § 851, DOE Directives, and applicable plans and procedures.

- The radiological control group provides support and guidance to the project and assists the FLS and SHS with implementation of radiological controls and as low as reasonably achievable (ALARA) principles. The radiological control technician (RCT) observes the work area before/during activities for radiological hazards and authorizes entry into and exit from the radiological work area.

- The environmental compliance organization provides environmental support and oversight to the project to ensure that the planning and fieldwork are being performed properly and in accordance with all applicable regulations, DOE Directives, and relevant plans and procedures.

- The waste management coordinator (WMC) provides waste management support to the project to coordinate waste containers and removal of waste from the worksite while complying with the Worker Safety and Health Program, as well as ES&H and work control requirements.

- Field team/subcontractors—Samplers, drillers, operators, maintenance mechanics, electricians, and other site and subcontractor personnel perform work as specified in work packages, adhering to the Worker Safety and Health Program, HASP, RWPs, project procedures, and AHAs. Field team personnel also participate in the identification of the hazards and development of the work controls to be utilized during the work.

A.6. GENERAL PROJECT HAZARDS

A.6.1 OPERATION OF PROJECT VEHICLES AND HEAVY EQUIPMENT

All field personnel operating vehicles and heavy equipment shall have the appropriate training/license for the type of vehicle/equipment being operated, drive responsibly, and comply with posted speed limits. All vehicle/equipment occupants shall use seat belts while in operation and the use of cellular phones or other potentially distracting activities while driving on company business is prohibited. Operators should walk around the vehicle and check for obstacles and material prior to backing up and use spotters as necessary.

Large vehicles and heavy equipment, such as excavators, cranes, and forklifts, have blind spots and the potential for pinch and crush hazards. Heavy equipment shall have a functioning backup alarm or a spotter will be required when the vehicle is backing up in congested areas. The spotter shall not stand directly behind the equipment while backing. Equipment operations will be in accordance with appropriate contractor procedures.

A.6.2 TOOLS AND EQUIPMENT

Tools and equipment shall be inspected visually before each use to ensure that the devices are in good working order. All guards and safety devices (e.g., power tools) shall be in place when the equipment is in use. The individual conducting an inspection should look for signs of wearing (e.g., frayed power cords, loose parts), missing components (e.g., lock pins, guards), and any indication of a potentially unsafe condition. Deficiencies affecting safe operation of project equipment shall cause the equipment to be taken out of service until properly repaired. Field sampling equipment shall be operated only by knowledgeable personnel with appropriate work experience and awareness of the hazards and safe operating procedures of the devices.

A.6.3 MATERIAL AND DRUM HANDLING

Material handling will be accomplished using safe lifting procedures. Vehicles, mechanical lifts, and/or carts will be used whenever possible. Whenever moving or lifting objects, travel paths and actions should be considered prior to initiating the work. Drum-handling activities include the general handling, transport, and opening and closing of drums along with the storage of wastes within the drums.

A.6.4 FIRE SAFETY

Refueling equipment can present a significant fire/explosion hazard if subjected to sparks, static electricity, or other ignition sources. Containers dispensing and receiving flammable/combustible liquids shall be appropriately bonded prior to use. Only safety containers approved by the Factory Mutual Research, Underwriters Laboratories, or the U.S. Department of Transportation will be used to transport and store these liquids. Site personnel are to ensure that the equipment used to transfer the liquids is approved for the material being handled. Safety cans shall be labeled as to their contents and properly secured during transport. When applicable, equipment should be given adequate time to cool down before refueling. During refueling operations, a 20-BC rated fire extinguisher will be within 50 ft of the operation.

Smoking is not allowed in the work area or radiologically controlled areas. Smoking will be allowed in designated areas and cigarette butts properly discarded so as not to create litter or pose a fire risk.

A.6.5 HOUSEKEEPING

Good housekeeping, including routine site cleanup and waste management, shall be practiced at all times to improve the general safety of the site activities. Housekeeping efforts may include eliminating or minimizing slip, trip, and fall hazards. Sanitary trash shall be containerized and disposed of periodically. When not in use, supplies, materials, and ancillary equipment should be stowed properly inside trailers in and away from walk areas.

A.6.6 SLIPS, TRIPS, AND FALLS

Much of the work locations associated with the project will be in construction areas with uneven terrain and possible obstructions that may pose hazards that could cause slips, trips, and/or falls. Care should be taken when working around uneven terrain and obstructions should be avoided as much as possible. If slipping and/or tripping hazards cannot be eliminated completely, obstructions should be marked and/or the area shall be barricaded and posted with the appropriate hazard postings.

A.6.7 INCLEMENT WEATHER

Weather forecasts and conditions shall be monitored for potential inclement weather and lightning. All field activities shall be paused during thunderstorms or high wind conditions. Personnel will secure equipment and materials safely and move to the designated assembly point.

A.6.8 HEAD, EYE, HAND, AND FOOT HAZARDS

Work activities have potential hazards that may result in injuries to the head, eyes, hands, or feet. The use of engineering controls or administrative controls may have limited applications for these hazards. The use of PPE may be necessary to adequately address these hazards. Where these hazards exist, the task-specific AHA and/or work control document will specify the use of appropriate protective equipment, including hard hats, safety eye protection, and/or steel-toe safety footwear.

A.6.9 TEMPERATURE EXTREMES

Heat stress and cold stress are serious hazards to workers during field activities, especially heat stress, when layers of PPE are required for protection from radiological and/or chemical hazards. Personnel will be familiarized on the symptoms of heat and cold stress during training and proper controls implemented, such as work rest regimens, in accordance applicable work controls and procedures.

A.6.10 BIOLOGICAL HAZARDS

Biological hazards that may be present at the site include snakes, insects, ticks, and poisonous plants (e.g., poison ivy, oak, or sumac). Personnel should be aware of the presence of potential hazards and prevent insects and ticks with repellant and avoid hazards as much as possible. Personnel who are or may be hypersensitive to plants and insects stings should report their condition to their supervisor. Some ticks are of a particular concern due to the potential to carry Lyme disease and Southern Tick Associated Rash Illness; therefore, controls will be implemented in the work control and/or AHA.

A.6.11 NOISE

Equipment such as generators, slide hammers, and hand and power tools may produce noise exceeding 85 decibels. Sound levels will be assessed and/or measurements will be taken for specific equipment and activities as necessary and controls/protection will be identified in applicable work control documentation. Personnel shall be trained and hearing tested in accordance with procedures.

A.6.12 STEAM

Pressurized steam for subsurface injection poses special hazards associated with unique equipment, temperature extremes, equipment failures, and noise. In order to ensure that personnel are not injured or equipment is not damaged during pressure system design and operation, all pressure vessels, boilers, and supporting piping systems will meet the DOE contractor pressure system requirements in 10 *CFR* § 851 and PAD-ENG-0042, *Pressure Safety*. Task-specific work documentation will be developed for design, testing, inspection, operation, repair, and maintenance activities on pressurized steam systems and personnel will be trained accordingly.

A.6.13 SPILL CONTAINMENT

The intent of this section of the HASP is to meet the requirements of 29 *CFR* § 1910.120 (b)(4)(ii)(j). The spill containment program shall address all hazardous substance spill scenarios that are likely to occur at the site. In addition, the spill containment program also shall provide procedures to contain and isolate the entire volume of any hazardous substance spilled in the course of a transfer, accident, or on-site release. Response to such an incident is specified in Section A.9.3.

In order to implement successful spill containment during operations, an assessment shall be conducted of the site conditions, current operations, and planned activities. The assessment shall examine carefully all hazardous materials on-site to determine where and how the materials are handled as follows:

- Stored (e.g., location, type of container);
- Handled (e.g., processed, used, transferred); and
- Transported (e.g., mode, routes).

As part of the assessment, each area or activity shall be analyzed for potential accidental releases or spills. Examples of situations that have potential for spill or release are as follows:

- Bulging or corroded containers;
- Transfer line connections (e.g., leaking seals, misaligned connections);
- Metal fatigue of storage tanks;
- Leaking or inoperable valves; and
- Poor housekeeping (e.g., drums improperly staged).

Many potential spills can be avoided through application of proper engineering controls to hazards identified in the assessment. In areas where storage, handling, and transportation activities occur, preplanning to contain the largest volume of material that could be released in the area will minimize worker exposure. The containment measure shall be appropriate to the hazardous material(s) identified and shall be installed in the area or located nearby. The following examples are measures that are most frequently used:

- Salvage containers (e.g., overpack drums);
- Bermed, lined pads;
- Concrete pad and dike;
- Inflatable containment (e.g., "kiddie" pools, bladders); and
- Associated equipment (e.g., pumps, hoses, shovels, hoists).

Spill containment equipment and fixtures shall be maintained and replaced properly, as necessary.

A.6.14 SUSPECTED CHEMICAL AND RADIOLOGICAL HAZARDS

Trichloroethene. Trichloroethene (TCE) is the primary volatile organic compound (VOC) detected in both subsurface soil and groundwater around the C-400 Cleaning Building. This contaminant is a halogenated organic compound used by industry in the past for a variety of purposes. It mainly was used as a degreasing agent at the C-400 Cleaning Building. The U.S. Environmental Protection Agency (EPA) has set the maximum contaminant level for drinking water at 5 ppb and the American Conference of Governmental Industrial Hygienists (ACGIH) has the 8-hour time weighted average at 10 ppm. TCE is a nonflammable, oily, colorless liquid that has a sweet odor and a sweet, burning taste. Historically, TCE was used as a solvent to clean equipment. It is heavier than water and has low solubility (up to one part TCE per thousand parts of water at room temperature). TCE in high concentrations may take on a liquid form commonly referred to as dense nonaqueous-phase liquid (DNAPL) and in the presence of water forms a separate phase from the water. These qualities make TCE a difficult contaminant to remediate. When present in groundwater, TCE tends to settle into a layer at the bottom of the aquifer and then continuously dissolves into the groundwater. This has resulted in varying levels of TCE in the aquifer for years after the release of TCE at Paducah Gaseous Diffusion Plant (PGDP). TCE currently is not used at PGDP.

Breathing small amounts of TCE may cause headaches, lung irritation, dizziness, poor coordination, and difficulty concentrating. Breathing large amounts of TCE may cause impaired heart function, unconsciousness, and death. Breathing it for long periods may cause nerve, kidney, and liver damage.

Drinking large amounts of TCE may cause nausea, liver damage, unconsciousness, impaired heart function, or death. Drinking small amounts of TCE for long periods may cause liver and kidney damage, impaired immune system function, and impaired fetal development in pregnant women, although the extent of some of these effects is not yet clear. Skin contact with TCE for short periods may cause skin rashes. In its 11th Report on Carcinogens, the National Toxicology Program determined that TCE is "reasonably anticipated to be a human carcinogen." The International Agency for Research on Cancer has determined that TCE is a "probable (Group 2A) human carcinogen."

1,2-Dichloroethene, *cis*- and *trans*-. 1,2-Dichloroethene (DCE) exists in two isomeric forms, *cis*-1,2- DCE and *trans*-1,2-DCE. Although not used extensively in industry, 1,2-DCE is used both in the production of other chlorinated solvents and as a solvent. Humans are exposed to 1,2-DCE primarily by inhalation, but exposure also can occur by oral and dermal routes. Information on the toxicity of 1,2-DCE in humans and animals is limited. Studies suggest that the liver is the primary target organ. EPA does not classify 1,2-DCE as a human carcinogen.

Vinyl Chloride. Vinyl chloride (VC) is a degradation product of TCE. It is also a halogenated organic compound and is used in industry as an intermediary of polyvinyl chloride (PVC) and other chlorinated compounds. VC has not been used in the PGDP manufacturing processes. Exposure to VC has been associated with narcosis and anesthesia (at very high concentrations), liver damage, skin disorders, vascular and blood disorders, and abnormalities in central nervous system and lung function. Liver cancer is the most common type of cancer linked with VC, a known human carcinogen. Other cancers related to exposure include those of the lung, brain, blood, and digestive tract.

1,1-DCE. 1,1-DCE is used primarily in the production of PVC copolymers and as an intermediate for synthesis of organic chemicals. Acute exposure to 1,1-DCE has been associated with central nervous system depression, which may progress to unconsciousness. 1,1-DCE is irritating when applied to the skin, and prolonged contact can cause first-degree burns. Direct contact with the eyes may cause conjunctivitis and transient corneal injury. EPA has classified 1,1-DCE as a possible human carcinogen.

Polychlorinated biphenyls. Polychlorinated biphenyls (PCBs) are synthetic organic chemicals comprising 209 individual chlorinated biphenyl compounds (known as congeners). Exposure to each of these compounds is associated with different levels of risk for harmful effects. The potential for overexposure to PCBs is believed to be low for the field activities because the expected amount of PCBs that may be present in the soil and/or water samples is, for the most part, well defined, and the routes of entry are limited for personnel exposure. If PCB levels are unknown and/or expected to be elevated above action limits, personnel will be notified and proper controls put in place in the AHA/work control to protect personnel. Potential radiological hazards associated with work at PGDP come from a few radionuclides including: uranium-234, -235, -238 and technetium-99 (Tc-99). Primarily exposure to Tc-99 is associated with the groundwater

Uranium-234, -235 and -238. Uranium-234, -235, and -238 (collectively) may be the most abundant radionuclides at PGDP and pose a potential for worker exposure when performing invasive work and in radiologically controlled areas. Uranium isotopes undergo radioactive decay by emission of an alpha particle and weak gamma radiation. Workers may be exposed to uranium by inhaling contaminated dust in the air, ingesting contaminated water and food, or if not properly protected through cuts in the skin. Uranium may be harmful to people as a chemical toxin, as well as radioactive substance, and once inside the body is linked to cancer and especially kidney damage.

Tc-99. Tc-99 is a fission product and is a long-lived, low-energy, beta-emitting radionuclide and is one of the major contaminants of concern, especially in the groundwater plume. Tc-99 is a light element that is very mobile and bonds to protein and usually cannot be easily removed, especially from hair. Like most radionuclides, it is harmful if taken internally, although the beta particles it emits are very weak. The potential for personnel exposure is limited and controls are implemented through procedures, work instructions, RWPs, and AHAs.

A potential of exposure to other materials exists as part of site operations. These material descriptions and permissible exposure limits are listed in Table 1.

Table 1. Chemical Exposure and Hazard Information

Substance	Odor	PEL	Route	Symptoms of Exposure	Treatment
Carbon monoxide	Odorless	25 ppm	Inhalation	Headache; nausea, weakness; dizziness; confusion; hallucinations; angina; coma; death	Eye: Immediate medical attention Skin: Immediate medical attention Breath: Respiratory support
Trichloroethene (TCE)	Characteristic aromatic	10 ppm	Inhalation Ingestion Contact	Eye, skin, and mucous membrane irritation; dermatitis; headache, fatigue, dizziness, confusion	Eye: Irrigate immediately Skin: Soap wash immediately Breath: Respiratory support Swallow: Immediate medical attention
1,2-Dichloroethene (1,2-DCE) *(cis-, trans-)*	Acrid, chloroform	200 ppm	Inhalation Ingestion Contact	Eye, skin, and throat irritation; headache, fatigue, central nervous system depression; liver and kidney damage	Eye: Irrigate immediately Skin: Soap wash immediately Breath: Respiratory support Swallow: Immediate medical attention
1,1-Dichloroethene (1,1-DCE)	Mild, sweet, chloroform	5 ppm	Inhalation Ingestion Contact	Eye, skin and throat irritation; dizziness; headache; fatigue; central nervous system depression; liver and kidney damage	Eye: Irrigate immediately Skin: Soap wash immediately Breath: Respiratory support Swallow: Immediate medical attention
Vinyl Chloride (VC)	Pleasant- at high concentration	1 ppm	Inhalation Ingestion Contact	Eye, skin and throat irritation; dizziness; headache; fatigue; central nervous system depression; liver and kidney damage	Eye: Irrigate immediately Skin: Soap wash immediately Breath: Respiratory support Swallow: Immediate medical attention
Compressed Nitrogen (simple asphyxiant)	Gas	N/A	Inhalation Contact	Headache; nausea, weakness; dizziness; confusion; difficulty breathing	Breath: Respiratory support, oxygen, immediate medical attention
Diesel fuel	Oily	100 mg/m^3	Inhalation Ingestion Contact	burning sensation in chest; headache, nausea, weakness, restlessness; incoherence, confusion, drowsiness; diarrhea; dermatitis	Eye: Irrigate immediately Skin: Soap wash immediately Breath: Respiratory support Swallow: Immediate medical attention
Diesel exhaust (carcinogenic)	Varies upon exhaust components	CO 25 ppm	Inhalation	Eye irritation; pulmonary function changes	Breath: Respiratory support
Gasoline (carcinogenic, benzene)	Characteristic aromatic	300 ppm	Inhalation Ingestion Contact	Eye, skin, and mucous membrane irritation; dermatitis; headache, fatigue, dizziness, confusion	Eye: Irrigate immediately Skin: Soap wash immediately Breath: Respiratory support Swallow: Immediate medical attention
Lead	Dust (visual or not), fumes if heated	0.5 mg/m^3	Inhalation Ingestion Contact	Irritated eyes, nose, and throat; weakness, exhaustion); insomnia; paleness; weight loss, malnutrition; constipation, abdominal pain, tremor	Eye: Irrigate immediately Skin: Soap flush promptly Breathing: Respiratory support Swallow: Medical attention immediately
PCB (in soil or stains)	Dust visible Oily stains	0.5 mg/m^3	Inhalation Ingestion Contact	Irritated eyes, nose and throat, dermatitis;	Eye: Irrigate immediately Skin: Soap flush promptly Breathing: Respiratory support

Table 1. Chemical Exposure and Hazard Information (Continued)

Substance	Odor	PEL	Route	Symptoms of Exposure	Treatment
Hydrochloric Acid Sulfuric Acid Nitric acid	Vapors	5 ppm 0.2 mg/m³ 2 ppm	Inhalation Ingestion Contact	Irritated eyes, nose and throat, larynx; cough, choking; dermatitis; skin burns; pulmonary edema	Eye: Irrigate immediately Skin: Soap wash immediately Breath: Respiratory support Swallow: Immediate medical attention
Uranium	Dust visible	0.2 mg/m³	Inhalation Ingestion Contact	Irritated eyes, nose and throat, dermatitis; skin burns; nausea; jaundice	Eye: Irrigate immediately Skin: Soap flush promptly Breathing: Respiratory support Swallow: Medical attention immediately
Technetium-99	N/A	Set by 10 *CFR* § 835	Inhalation Ingestion	Cancer	If contact suspected, notify RADCON immediately
Methanol	Sweet	200 ppm	Inhalation Ingestion Contact	Eye, skin and mucous membrane irritation; headache, fatigue, dizziness, confusion	Eye: Irrigate immediately Skin: Soap wash immediately Breath: Respiratory support Swallow: Immediate medical attention
Silica, crystalline (as respirable dust)	Colorless, odorless solid	0.025 mg/m³	Inhalation Ingestion Contact	Cough; breathing difficulty; wheezing; decreased pulmonary function; progressive respiratory symptoms (silicosis); irritation eyes	Eye: Irrigate immediately Skin: Soap wash daily Breath: Respiratory support Swallow: Immediate medical attention

A.7. SITE CONTROL

A combination of work zones will be utilized to control access, to minimize the number of individuals potentially exposed to site hazards, and to ensure that individuals who enter follow the required procedures. Following is a description of the different types of zones that may be established at the site.

- Exclusion Zone (EZ)—The area where work is being performed and chemical, physical, and/or radiological hazards exist. Entry into this area is controlled and the area clearly marked with barrier tape, rope, or flagging and/or signage. Applicable signage will be posted to adequately communicate hazards and entry requirements. Unauthorized entry into these areas is strictly prohibited.

- Contamination Reduction Zone (CRZ)—The transition area between the EZ and support area. This area will provide a buffer area to reduce the probability that contamination will leave the EZ and reduce the possibility of the support area becoming contaminated by site hazards. The degree of contamination in the CRZ decreases as the distance from the contaminants increases.

- Support Area—The outermost area of the work site. This area is uncontaminated where workers provide operational and administrative support. The support area is clean and will not be entered by contaminated equipment or personnel, except under emergency or evacuation conditions. Normal work clothes are appropriate within this area.

- Construction Zone—The area outside of potential contamination, but encompassing work activities and possible hazards associated with construction activities. Entry into this area is controlled and the area clearly marked with barrier tape, rope, flagging, and/or signage. Applicable signage will be posted to adequately communicate hazards and entry requirements.

The location and size of site control for field activities will be determined by the FLS, SHS, and RCT and communicated to the workers through prejob briefings. Site control may be modified as tasks change and as new information becomes available based on the types of hazards that are found. During the performance of this project, a Radiological Area generally will equate to an EZ (hot zone), a Radiological Buffer Area generally will equate to a CRZ (warm zone), and a Controlled or Clean Area generally will equate to a support zone (cold zone).

A.8. HAZARD COMMUNICATION

OSHA's 29 *CFR* § 1910.1200, "Hazard Communication Standard," states that all employees handling or using hazardous or potentially hazardous materials be advised and informed of the health hazards associated with those materials.

A.8.1 MATERIAL SAFETY DATA SHEET

A material safety data sheet (MSDS) provides specific material identification information; ingredients and hazards; physical data; fire and explosion information; reactivity data; health hazard information; spill, risk, and disposal procedures; special protection information; and special precautions required for materials manufactured for use. It is the manufacturer's responsibility to provide this information to the user for any materials that contain hazardous or potentially hazardous ingredients. Each employee is to be made aware that the MSDSs are available. The project and subcontractors shall maintain copies of all MSDSs for chemicals brought on-site and shall have them readily available.

A.8.2 CHEMICAL INVENTORY

A hazardous material inventory of all chemicals brought on-site will be maintained by the appropriate hazardous material custodian. Prior to bringing hazardous materials on-site, personnel/subcontractors must submit an MSDS and receive approval from the facility manager and chemical safety manager.

It is the responsibility of the user to ensure that all potentially hazardous materials taken to a project site are labeled properly as to the contents of the container and with the appropriate hazard warnings.

A.9. EMERGENCY MANAGEMENT

In the event of an emergency, all site personnel shall follow the requirements and provisions of the PGDP Emergency Management Plan. The PGDP emergency response organization will provide emergency response. The FLS and SHS will be in charge of personnel accountability during emergency activities. All personnel working on-site will be trained to recognize and report emergencies to the safety and health specialist or the FLS. The SHS or FLS will be responsible for notifying the PGDP emergency response organization.

The PGDP emergency response organization will be contacted for emergency response to time-urgent medical emergencies, fires, spills, or other emergencies. The plant shift superintendent (PSS) will coordinate 24-hour emergency response coverage. The requirements of this section will be communicated to site workers. Any new hazards or changes in the plan also will be communicated to site workers.

A.9.1 POTENTIAL EMERGENCIES

Potential emergencies that could be encountered during this project include, but are not limited to, fires, spills, and personnel exposure or injury. An emergency response plan, which contains explicit instructions and information about required emergency actions and procedures, is located in the site-specific HASP and/or in the prime contractor’s facilities.

A.9.2 FIRES

In the event of a fire, the PSS shall be notified immediately. If it is safe to do so, and they are properly trained, on-site personnel may attempt to extinguish an incipient fire with the available fire extinguisher and isolate any nearby flammable materials. If there is any doubt about the safety of extinguishing the fire, all personnel must evacuate to an assembly location and perform a head count to ensure that personnel are accounted for and are safely evacuated. The FLS or designee will provide the fire department with relevant information.

A.9.3 SPILLS

In the event of a spill or leak, the employee making the discovery will vacate the area immediately and notify other personnel and his/her supervisor. The FLS or designee will determine whether the leak is an incidental spill or whether an emergency response is required. If there is a probability that the spill will extend beyond the immediate area, result in an environmental insult, or exceed the capabilities of the on-site personnel, the FLS is to inform the PSS, who will determine whether a response by the PGDP spill response team is warranted. If emergency response crews are mobilized, the FLS or knowledgeable employee will provide the responders with relevant information.

A.9.4 MEDICAL EMERGENCIES

Personnel with current first aid or first responder training will serve as the designated first aid provider. Any event that results in potential employee exposure to bloodborne pathogens will require a post-event evaluation and follow-up consistent with 29 *CFR* § 1910.1030. A person knowledgeable of the location and nature of the injury will meet the emergency response personnel to guide them to the injured person.

The PGDP emergency response organization will be contacted for emergency response to time-urgent medical emergencies, fires, spills, or other emergencies. Site personnel may take workers with injuries that are more severe than can be addressed by first aid, but that do not constitute a medical emergency, to a designated medical facility. The FLS, SHS, and Groundwater Operable Unit (GWOU) project manager must be informed immediately that the worker has been taken to the medical facility and the nature of the injury.

A.9.5 REPORTING AN EMERGENCY

Project personnel will be able to communicate by two-way radio, plant radio, or cellular telephone on-site.

A.9.6 TELEPHONE

The area of the treatability study is located inside the PGDP security perimeter. Inside the PGDP security perimeter, if a plant telephone is accessible, dial 6333 in the case of an emergency. With a cellular phone, dial 270-441-6333. Describe the type and the location of the emergency. Identify who is calling. Identify the number on the phone being used. Tell whether an ambulance is needed. Listen and follow any instructions that are given. Remain on the phone until the Emergency Control Center has hung up.

A.9.7 FIRE ALARM PULL BOXES

Pulling a fire alarm box at PGDP automatically transmits the location of the emergency to the fire department and the Emergency Control Center. The person pulling the alarm should remain at the alarm box, or nearest safe location, and supply any needed information to the emergency responders. Work personnel should note the location of pull boxes in each project area, where applicable.

A.9.8 RADIO

Channel 16 is designated as the emergency channel on the plant radio system. By calling radio call number Alpha 1 and declaring "EMERGENCY TRAFFIC, EMERGENCY TRAFFIC," the PSS is alerted of the emergency. Describe the type and the location of the emergency and who is calling.

A.10. ALARM SIGNALS

A.10.1 PROJECT-SPECIFIC ALARM

A prolonged blast of an air horn or vehicle horn will signal immediate work stoppage and evacuation to a predesignated area.

A.10.2 EVACUATION ALARMS

PGDP facility evacuation alarms are denoted by a steady or continuous sound from the site public address system. In the case of an evacuation alarm, treatability study personnel should proceed to the predetermined assembly station. The assembly station director will provide further instruction.

A.10.3 RADIATION ALARMS

PGDP radiation alarms are denoted by a steady sound from a clarion horn and rotating red beacon lights. Should a radiation alarm sound, project personnel will evacuate the site or area and proceed to the predetermined assembly station. The assembly station director will give further instruction.

A.10.4 TAKE-COVER ALARMS

PGDP take-cover alarms are denoted by an intermittent or wailing siren sound from the site public address system. In the event of a take-cover alarm, site workers will seek immediate protective cover in a strong sheltered part of a building. Evacuate mobile structures to a permanent building or underground shelter.

A.10.5 STANDARD ALERTING TONE

The standard alerting tone at PGDP is a high/low tone from the public address system and is repeated on the plant radio frequencies. During a standard alerting tone, personnel should listen carefully; an emergency announcement will follow.

A.10.6 EVACUATION PROCEDURES

The SHS or FLS will designate the evacuation routes. Every on-site worker should familiarize himself/herself with the evacuation routes. In the event of an evacuation, treatability study personnel should proceed to the predetermined assembly station or designated area and wait for further instructions.

A.10.7 SHELTERING IN PLACE

Certain emergency conditions (e.g., chemical or radioactive material release, tornado warning, fire, security threat) may require that personnel be sheltered in place. Notification of a recommendation of "sheltering in place" is carried out by the PGDP emergency director on the emergency public address system and plant radio frequencies. Requirements for "sheltering in place" follow these steps:

- Go indoors immediately (the treatability study personnel should shelter in the C-100 Administrative Building, if time permits, or in C-400, in the case of immediate need);
- Close all windows and doors;
- Turn off all sources of outdoor air (e.g., fans and air conditioners);
- Shut down equipment and processes, as necessary for safety; and
- Remain indoors and listen for additional information on radios and/or the public address system.

A.10.8 ON-SITE RELOCATION

Certain emergency conditions (e.g., chemical or radioactive material release, tornado warning, fire, security threat) may require that on-site personnel be relocated from their normal workstations and activities to locations more suitable to withstand the threat. Notification of on-site relocation is carried out by the PGDP emergency director on the public address system and plant radio frequencies. Specific instructions about where to relocate will be given with the message.

A.10.9 FACILITY EVACUATION

For evacuations related to emergencies inside PGDP, the PGDP emergency director initiates notification of facility evacuation over the public address system. Assembly stations serve as gathering points for evacuating personnel. In the event of an evacuation alarm, employees will evacuate to the designated assembly point for the area and immediately report to the FLS or the assembly station director. An accounting will be conducted of all personnel who have evacuated. Further instructions and information about the emergency situation will be given to employees by the assembly station director or over the site public address system and plant radio.

A.10.10 EMERGENCY EQUIPMENT

The following items of emergency equipment will be maintained at the work location:

- Hard-wired or cellular telephone and radios;
- First aid kit including bloodborne pathogen PPE;
- ABC-rated fire extinguishers; and
- Basic spill kit suitable to handle small spills.

A.11. HEAT AND COLD STRESS

Common types of stress that affect field personnel are from heat and cold. Heat stress and cold stress may be one of the most serious hazards to workers at hazardous waste sites. In light of this, it is important that all employees understand the signs and symptoms of potential injuries/illnesses associated with working in extreme temperatures.

A.11.1 HEAT STRESS

Heat stress occurs when the body's physiological processes fail to maintain a normal body temperature because of excessive heat. The body reacts to heat stress in a number of different ways. The reactions range from mild (e.g., fatigue, irritability, anxiety, and decreased concentration) to severe (death). Heat-related disorders generally are classified in four basic categories: (1) heat rash, (2) heat cramps, (3) heat exhaustion, and (4) heat stroke.

A.11.2 PREVENTIVE MEASURES

A number of steps can be taken to minimize the potential for heat stress disorders.

- Acclimate employees to working conditions by slowly increasing workloads over extended periods of time. Do not begin site work activities with the most demanding physical expenditures.

- Conduct strenuous activities during cooler portions of the day, such as early morning or early evening, as practicable.

- Provide employees with lots of tempered water and encourage them to drink it throughout the work shift; discourage the use of alcohol during nonworking hours. It is essential that fluids lost through perspiration be replenished. Total water consumption should equal 1 to 2 gal/day.

- Rotate employees wearing impervious clothing during hot periods.

- Provide cooling devices, as appropriate. Mobile showers and/or hose-down facilities, powered air purifying respirators, and ice vests all have proven effective in helping prevent heat stress.

A.11.3 HEAT STRESS MONITORING

For strenuous field activities that are part of ongoing site activities in hot weather, physiological monitoring may be used to monitor the individual's response to heat. Physiological monitoring will be implemented in accordance with PAD-IH-5134, *Temperature Extremes*. The guidelines set forth in the current issue of the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values and Biological Indices shall be used to determine the work/rest regimen for working in environments conducive to heat stress.

A.11.4 COLD STRESS

Persons working outdoors in low temperatures, especially at or below freezing, are subject to cold stress disorders. Exposure to extreme cold for even a short period of time can cause severe injury to the body surfaces and/or profound cooling, which can lead to death. Areas of the body that have high surface-area-to-volume ratios (e.g., fingers, toes, and ears are the most susceptible).

Two basic types of cold disorders exist: (1) localized (e.g., frostbite) and (2) generalized (e.g., hypothermia).

A.11.5 PREVENTIVE MEASURES

A number of steps can be taken to minimize the potential for cold stress.

- Individuals can achieve a certain degree of acclimation when working in cold environments as they can for warm environments. The body will undergo some changes that increase the body's comfort and reduce the risk of cold injury.

- Working in cold environments causes significant water losses through the skin and the lungs as a result of the dryness of the air. Increased fluid intake is essential to prevent dehydration, which affects the flow of blood to the extremities and increases the risk of cold injury. Warm drinks or soups should be readily available.

- The skin should not be continuously exposed to subzero temperatures.

A.11.6 COLD STRESS MONITORING

Air temperature alone is not a sufficient criterion on which to judge the potential for cold-related disorders in a particular environment. Heat loss from convection (air movement at the surface of the skin) is probably the greatest and most deceptive factor in the loss of body heat. For this reason, wind speeds as well as air temperatures need to be considered in the evaluation of the potential for cold stress disorders. The ACGIH Threshold Limit Values and Biological Indices provide additional guidance on cold stress evaluation and the establishment of the work/rest regimen in environments conducive to cold stress.

A.12. EXPOSURE MONITORING

Air monitoring shall be used to identify and quantify airborne levels of hazardous substances and health hazards in order to determine the appropriate level of employee protection needed on-site.

A.12.1 ROUTINE AIR MONITORING REQUIREMENTS

Air monitoring will be performed during the following activities:

- Intrusive activities such as drilling and opening sampling tubes are being done;
- Work begins on a different portion of the site;
- Contaminants other than those previously identified are being handled;
- A different type of operation is initiated; or
- Personnel are opening drums that contain material.

A.12.2 SITE-SPECIFIC AIR MONITORING REQUIREMENTS

Measurements of airborne VOCs, primarily TCE, will be conducted in the work area during intrusive activities by using a photoionization detector (PID) or equivalent instrument. VOC monitoring primarily will be focused on the breathing zones of employees. Air monitoring results will be used to determine the effectiveness and/or need for control measures.

A.12.3 TIME INTEGRATED SAMPLE COLLECTION

Verification sampling will be completed for VOCs and any other identified contaminants of concern. Integrated sampling methodology will be evaluated by the industrial hygiene program supervisor and may be revised during the course of work based on real-time monitoring/sampling results and changing site conditions.

A.13. RADIOLOGICAL PROTECTION

The radiological contaminant of concern is Tc-99. Due to varying levels of Tc-99 some work may be performed under an RWP.

A.13.1 RADIATION PROTECTION PLAN

All workers will operate under the DOE-approved radiation protection plan (RPP) when performing activities where a potential hazard is posed by radiation exposure. The DOE contractor will assess all radiological hazards that may be encountered. This has been accomplished primarily through the preparation of the HASP and the work control process. Based on these evaluation activities, appropriate engineering, administrative, and PPE controls will be selected and implemented. Whenever possible, work will be arranged to avoid (or at least minimize) entry into radiological areas. The radiation safety work practices focus on establishing controls and procedures for conducting work with radioactive material, while maintaining radiation exposures ALARA.

All work associated with radiological issues will be conducted in accordance with the RPP and, as a result, the DOE contractor will provide radiological support for activities with potential radiation exposure. RCTs also may perform surveys and monitoring, identify radiological areas, and implement RWPs. All personnel/subcontractors will implement and maintain any controls identified as a result of these activities.

A.13.2 CONTRACTOR/SUBCONTRACTOR RESPONSIBILITIES

The DOE contractor and subcontractor responsibilities may include the following:

- Provide and erect any radiological barriers, barricades, warning devices, or locks needed to safely control the work site;
- Follow the requirements of the RWPs, including daily briefings, and requirements for signing in on all RWPs;
- Submit bioassay samples and use external dosimeters;
- Notify the GWOU project manager after any employee declares a pregnancy;
- Establish radiation control measures that comply with the requirements specified by radiological personnel supporting the project; and
- Determine required radiological PPE based on appropriate work processes and AHAs.

A.13.3 SITE-SPECIFIC RADIATION SAFETY WORK PRACTICES

The DOE contractor and all subcontractors will implement the following radiation safety work practices when working in radiological areas.

- All personnel will adhere to the action levels and hold points identified in the RWP addressing the potential radiological hazards posed by work activities. Work practices and PPE will be altered according to changing radiological requirements, as prescribed by the RWP and/or the RCT.
- All work activities to be performed will be designed and performed ensuring minimization of material brought into the Radiological Areas. Management, design engineers, and field personnel jointly will identify the materials and equipment needed to perform this work. Only equipment and supplies necessary to accomplish the various tasks to be performed successfully will be taken into the EZ. Work also will be planned and conducted in a manner that minimizes the generation of waste materials. All activities will be designed, before commencement of field activity, to maintain radiation exposures and releases ALARA. Emphasis will be placed on engineering and administrative controls over the use of PPE, when feasible.

- All personnel working in, or subject to, work in the Radiological Areas will read the applicable RWP. The RCT or the SHS also will review the RWP verbally during the initial prework safety briefing. The FLS, the RCT and the SHS will monitor worker compliance continuously with the RWP. The FLS and/or the safety and health specialist will communicate changes to the RWP immediately to all affected personnel, and work practices will be changed accordingly. Radiological controls specified by the RWP, such as PPE and work activity hold points, will be reviewed during preshift briefings.

- Engineering and administrative controls will be utilized to minimize and control the spread of airborne and surface contamination. If airborne contamination is identified, water mist will be used to eliminate or reduce this hazard. The contaminated water will be contained by plastic sheeting covering the work area. Surface contamination, in the form of waste, will be containerized properly throughout the project.

- Personnel will be instructed in the proper use and care of external dosimeters before commencing field activities and periodically during prework tailgate briefings. Personnel will be instructed to wear the dosimeters only during activities posing an occupational ionizing radiation exposure. This will include all field activities. Personnel will be instructed to wear their dosimeters outside of company clothing in the front torso area of the body. They are not to expose the dosimeters to excessive heat or moisture. Dosimeters must be exchanged on a quarterly basis.

- All personnel will participate in the DOE contractor bioassay program. All personnel may be required to submit a baseline bioassay sample before receiving an external dosimeter and participating in any fieldwork. Periodic bioassays also will be submitted in a timely manner, as directed by the radiological control organization. Personnel not complying with these requirements will be subject to removal from the project.

- The FLS and the SHS will conduct a continuous observance of work in progress and of field personnel performance with respect to ALARA. Additional reviews of performance will be discussed during “tailgate” safety meetings with all field personnel.

- Applicable lessons learned will be reviewed with personnel during the project. Work practices will be modified to incorporate lessons learned.

A.13.4 RADIATION SAFETY TRAINING

The DOE contractor and all personnel will observe the radiological training requirements, which require General Employee Training and Radworker II Training for all general employees who will perform hands-on work in radiological areas. The applicability of this training will be determined for each activity. Personnel, including visitors, who are not necessary to the performance of the scope of work and who are not appropriately trained and qualified, will not enter any work areas where radiological exposures may occur. In areas where visitors are essential or otherwise approved to be present, they will be restricted from Contamination Areas, High Contamination Areas, High Radiation Areas, Very High Radiation Areas, or Airborne Radiation Areas. In all other radiological areas, visitors may be present only if escorted by a qualified radiological worker and will perform no hands-on activities.

A.14. HOISTING AND RIGGING PRACTICES

All hoisting and rigging will meet the DOE contractor hoisting and rigging requirements, in PAD-ENG-0012, *Hoisting and Rigging Operations.* Hoisting and rigging equipment will not be modified such that manufacturer's specifications are invalidated. In order to ensure that personnel are not injured or equipment is not damaged during hoisting and rigging operations, the following safe working guidelines will be utilized. These guidelines include those outlined by OSHA and the DOE Hoisting and Rigging Standard, DOE-STD-1090-2011. A competent person will be on-site during all lifting activities.

A.15. DECONTAMINATION

Contamination of personnel, equipment, and/or material can occur from contact with radiological and/or hazardous material. When decontamination is required, appropriate procedures shall be followed to ensure effective decontamination is achieved and to minimize generation of mixed waste.

The overall objectives of decontamination are these:

- To determine and implement the decontamination methods for personnel and equipment that are effective for the specific hazardous/radioactive substance(s) present;
- To ensure the decontamination procedure itself does not pose any additional safety or health hazards;
- To provide pertinent information on the locations and layouts of decontamination stations and equipment;
- To establish procedures for the collection, storage, and disposal of clothing and equipment that has not been completely decontaminated; and
- To provide for periodic evaluation of the effectiveness of decontamination methods.

A.15.1 GENERAL CONSIDERATION

It is assumed that some of contamination concerns from the field activities will be radiological in nature. Disposable PPE and one-time-use items may undergo radiological surveys prior to release for disposal as nonradioactive waste. Reusable equipment may be required to undergo a radiological survey prior to release from a radiological area. If hazardous waste is encountered, ES&H and the radiological control organization will assist project management in determining additional methods of decontamination. If clothing or equipment is contaminated with both radiological and hazardous material, mixed waste may be generated. Special precautions shall be taken to ensure this waste is handled, treated, stored, and disposed of properly.

A.15.2 PERSONNEL DECONTAMINATION METHODS

Personnel decontamination will be conducted in accordance with procedure PAD-RAD-1103, *Personnel and Personal Effects Decontamination*. In the event of a chemical exposure, decontamination will be performed according to the available MSDS or as directed by ES&H industrial safety. After the initial field decontamination, the potentially exposed employee will be transported to the appropriate medical facility for exposure assessment, if deemed necessary by ES&H.

A.15.3 COLLECTION, STORAGE, AND DISPOSAL PROCEDURES

All items (including clothing, equipment, liquids) that cannot be completely decontaminated shall be considered radioactive, hazardous, or mixed waste, as appropriate. Clothing and equipment shall be collected, treated, stored, and disposed of based on the type and level of contamination according to applicable federal, state, and local regulations. Drainage and/or collection systems for contaminated liquids shall be established, and approved containers shall be used. Wash water shall be collected for proper disposal. Waste minimization will be encouraged; however, worker safety and health will take precedence.

A.16. ENVIRONMENTAL MANAGEMENT SYSTEM HAZARDS

Spills and releases to the environment are the most likely EMS hazard to be identified for activities and/or tasks that will be required during the treatability study. Personnel shall use caution when drilling to prevent the spill of drill cuttings and contaminated groundwater on the ground. Care should be taken during handling samples and other hazardous materials/contaminants to prevent spills/releases to the environment and to provide timely response if a spill/release should occur. Spill response is addressed in Section A.9.3, and containment is addressed in Section A.6.13.

Drilling and steam injection pressures introduce a hazard of mobilizing contaminants vertically through the well borehole. The soils overlying the aquifer in the area of the treatability study are not anticipated to contain DNAPL; therefore, there is minimal concern of mobilizing TCE downward into the aquifer in the well borehole. TCE-enriched steam potentially could move upward from the aquifer in the well borehole and contaminate overlying soils or be released to the environment. Proper well construction shall ensure an impermeable annual seal is present around the well that will withstand injection pressures and prevent the escape of steam.

Blowout of aboveground piping and equipment and release of steam present a potential hazardous release to the environment. During the field operation, the treatability study design vendor shall provide work instruction to ensure worker and environmental safety from blowouts and other installation and operation hazards specific to work with pressurized steam.

APPENDIX B

PADUCAH GASEOUS DIFFUSION PLANT
TREATABILITY STUDY WORK PLAN FOR STEAM INJECTION
QUALITY ASSURANCE
PROJECT PLAN

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ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	chain-of-custody
DOE	U.S. Department of Energy
DOECAP	DOE Consolidated Audit Program
DQO	data quality objective
ECD	electron capture detector
EDD	electronic data deliverable
EPA	U.S. Environmental Protection Agency
FFA	Federal Facility Agreement
FID	flame ionization detector
FSP	field sampling plan
GC/MS	gas chromatography/mass spectrometry
GPS	Global Positioning System
ICP-AES	inductively coupled plasma atomic emission spectroscopy
KDEP	Kentucky Department for Environmental Protection
LATA Kentucky	LATA Environmental Services of Kentucky, LLC
LCS	laboratory control sample
MBWA	management by walking around
MS	matrix spike
MSD	matrix spike duplicate
OREIS	Paducah Oak Ridge Environmental Information System
PARCCS	precision, accuracy, representativeness, comparability, completeness, and sensitivity
PGDP	Paducah Gaseous Diffusion Plant
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RI	remedial investigation
SOP	standard operating procedure
TBD	to be determined
UFP	Uniform Federal Policy
VOC	volatile organic compound
WAG	waste area group

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INTRODUCTION

This Treatability Study Work Plan for Steam Injection Quality Assurance Project Plan (QAPP) has been prepared by LATA Environmental Services of Kentucky, LLC, (LATA Kentucky) based on the approved Programmatic QAPP, DOE/LX/07-1269&D2/R1 *Programmatic Quality Assurance Project Plan*, which was based on the *Uniform Federal Policy for Quality Assurance Project Plans* (UFP-QAPP Manual) guidelines for QAPPs (Publication # DoD DTIC ADA 427785).

This QAPP is Appendix B to the *Treatability Study Work Plan for Steam Injection Groundwater Operable Unit, at Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-1294&D2 (TSWP). It describes the project-specific quality assurance (QA) activities that will be conducted to support the treatability study.

This QAPP does the following:

- Refers to the standard operating procedures (SOPs) already developed for the site and in place;
- Identifies laboratory methods that will be required for the treatability study; and
- Incorporates the *Data and Documents Management and Quality Assurance Plan for Paducah Environmental Management and Enrichment Facilities*, DOE/OR/07-1595&D2 (DOE 1998).

The treatability study work plan and the project's design drawings and technical specifications package present the decisions on data quality objectives, type of analyses, number of samples, type of samples, project schedule, etc. This QAPP focuses on geotechnical laboratory analysis of soil grain size and subsurface temperature measurements and potential groundwater volatile organic compound (VOC) analyses (pending inclusion of a groundwater extraction well in the design) during the treatability study.

The final decision to install an extraction well will be addressed in the treatability study design. The QAPP will be revised subsequent to completion of design and procurement, and the QAPP will be provided to the agencies at that time.

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QAPP Worksheet #1
Title Page

Document Title: *Quality Assurance Project Plan for the Treatability Study Work Plan for Steam Injection, Groundwater Operable Unit, at Paducah Gaseous Diffusion Plant, Paducah, Kentucky, Appendix B*

Lead Organization: U.S. Department of Energy **(**DOE)

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Preparation Date (Month/Year): 1/2014

Document Control Number: DOE/LX/07-1294&D2, Appendix B

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LATA Kentucky Sample/Data Management Manager	______________________________ Signature Lisa Crabtree	Date:_______________

QAPP Worksheet #2
QAPP Identifying Information

Site Name/Project Name: Paducah Gaseous Diffusion Plant
Site Location: Paducah, Kentucky
Site Number/Code: KY8-890-008-982
Contractor Name: LATA Kentucky
Contractor Number: DE-AC30-10CC40020
Contract Title: Paducah Gaseous Diffusion Plant Paducah Environmental Remediation Project
Work Assignment Number: N/A

1. Identify guidance used to prepare QAPP:

   Intergovernmental Data Quality Task Force, March 2005. The Uniform Federal Policy for Implementing Environmental Quality Systems, Version 2.0, 126 pages.

   Intergovernmental Data Quality Task Force, March 2005. The Uniform Federal Policy for Quality Assurance Project Plans: Part 1 UFP QAPP Manual, Version 1.0, 177 pages (DTIC ADA 427785 or EPA-505-B-04-900A).

   Intergovernmental Data Quality Task Force, March 2005. The Uniform Federal Policy for Quality Assurance Project Plans: Part 2A UFP QAPP Worksheets, Version 1.0, 44 pages.

   Intergovernmental Data Quality Task Force, March 2005. The Uniform Federal Policy for Quality Assurance Project Plans: Part 2B Quality Assurance/Quality Control Compendium: Minimum QA/QC activities, Version 1.0, 76 pages.

   Paducah Gaseous Diffusion Plant Programmatic Quality Assurance Project Plan, DOE/LX/07-1269&D2/R1

2. Identify regulatory program: Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and *Federal Facility Agreement for the Paducah Gaseous Diffusion Plant*, DOE/OR/07-1707 (FFA)

3. Identify approval entity: DOE, U.S. Environmental Protection Agency (EPA) Region 4, and Kentucky Department for Environmental Protection (KDEP)

4. Indicate whether the QAPP is a generic or a project-specific QAPP (circle one).

5. List dates of scoping sessions that were held: April 2013—DQO session with DOE, EPA, and KDEP

QAPP Worksheet #2 (Continued)
QAPP Identifying Information

6. List dates and titles of QAPP documents written for previous site work, if applicable:

Title:	**Approval Date:**
Data and Documents Management and Quality Assurance Plan for Paducah Environmental Management and Enrichment Facilities, DOE/OR/07-1595&D2 (DOE 1998)	10/5/1998
Paducah Gaseous Diffusion Plant Programmatic Quality Assurance Project Plan, Paducah, Kentucky, DOE/LX/07-1269&D2/R1	5/14/2013

7. List organizational partners (stakeholders) and connection with lead organization:
EPA Region 4 (FFA member), KDEP (FFA member), DOE (Lead Organization), LATA Kentucky (DOE Prime Contractor)

8. List data users: DOE, LATA Kentucky, subcontractors, EPA Region 4, Commonwealth of Kentucky

9. If any required QAPP elements and required information are not applicable to the project, then indicate the omitted QAPP elements and required information on the attached table. Provide an explanation for their exclusion here.

No elements specifically are omitted from this QAPP.

QAPP Worksheet #2 (Continued)
QAPP Identifying Information

NOTE: Information is entered only in the "Crosswalk to Related Documents" if the information is not contained in the QAPP worksheets, as indicated in first two columns. Additionally, if the required QAPP element fulfills other quality requirements, that requirement is noted in the "Crosswalk to Related Documents" column.

Required QAPP Element(s) and Corresponding QAPP Section(s)	Required Information	Worksheet No.	Crosswalk to Related Documents
2.1 Title and Approval Page	• Title and Approval Page	1	
2.2 Document Format and Table of Contents 2.2.1 Document Control Format 2.2.2 Document Control Numbering System 2.2.3 Table of Contents 2.2.4 QAPP Identifying Information	• Table of Contents • QAPP Identifying Information	2	
2.3 Distribution List and Project Personnel Signoff Sheet 2.3.1 Distribution List 2.3.2 Project Personnel Sign-Off Sheet	• Distribution List • Project Personnel Sign-Off Sheet	3 4	
2.4 Project Organization 2.4.1 Project Organizational Chart 2.4.2 Communication Pathways 2.4.3 Personnel Responsibilities and Qualifications 2.4.4 Special Training Requirements and Certification	• Project Organizational Chart • Communication Pathways • Personnel Responsibilities and Qualifications Table • Special Personnel Training Requirements Table	5 6 7 8	
2.5 Project Planning/Problem Definition 2.5.1 Project Planning (Scoping) 2.5.2 Problem Definition, Site History, and Background	• Project Planning Session Documentation (including Data Needs tables) • Project Scoping Session Participants Sheet • Problem Definition, Site History, and Background • Site Maps (historical and present)	9 10	Waste Area Group (WAG) 6 RI Report C-400 Technical Evaluation
2.6 Project Quality Objectives and Measurement Performance Criteria 2.6.1 Development of Project Quality Objectives Using the Systematic Planning Process 2.6.2 Measurement Performance Criteria	• Site-Specific Project Quality Objectives • Measurement Performance Criteria Table	11 12	

QAPP Worksheet #2 (Continued)
QAPP Identifying Information

Required QAPP Element(s) and Corresponding QAPP Section(s)	Required Information	Worksheet No.	Crosswalk to Related Documents
2.7 Secondary Data Evaluation	• Sources of Secondary Data and Information • Secondary Data Criteria and Limitations Table	13	Paducah Oak Ridge Environmental Information System (OREIS) Database WAG 6 RI Report 2008 C-400 Interim Remedial Action (IRA) Remedial Design Report Attachment A2 of Appendix of the C-400 Revised Proposed Plan 2008 Update of the Sitewide Groundwater Flow Model C-400 Technical Evaluation Site Questionnaire Information Provided to TerraTherm, Inc. 2-D Simulations of C-400 Steam Heating 2-D and 3-D Simulations of C-400 Steam Heating

QAPP Worksheet #2 (Continued)
QAPP Identifying Information

Required QAPP Element(s) and Corresponding QAPP Section(s)	Required Information	Worksheet No.	Crosswalk to Related Documents
2.8 Project Overview and Schedule 2.8.1 Project Overview 2.8.2 Project Schedule	• Summary of Project Tasks • Reference Limits and Evaluation Table • Project Schedule/Timeline Table	14 15 16	*Data Management and Implementation Plan, Section 10, of the C-400 Remedial Action Work Plan* (DOE/LX/07-1271&D1) Sections 5.2 and 5.3 of the Treatability Study Work Plan
Measurement/Data Acquisition			
3.1 Sampling Tasks 3.1.1 Sampling Process Design and Rationale 3.1.2 Sampling Procedures and Requirements 3.1.2.1 Sampling Collection Procedures 3.1.2.2 Sample Containers, Volume, and Preservation 3.1.2.3 Equipment/Sample Containers Cleaning and Decontamination Procedures 3.1.2.4 Field Equipment Calibration, Maintenance, Testing, and Inspection Procedures 3.1.2.5 Supply Inspection and Acceptance Procedures 3.1.2.6 Field Documentation Procedures	• Sampling Design and Rationale • Sample Location Map • Sampling Locations and Methods/SOP Requirements Table • Analytical Methods/SOP Requirements Table • Field Quality Control Sample Summary Table • Sampling SOPs • Project Sampling SOP References Table • Field Equipment Calibration, Maintenance, Testing, and Inspection Table	17/18/19/20 21 22	

QAPP Worksheet #2 (Continued)
QAPP Identifying Information

Required QAPP Element(s) and Corresponding QAPP Section(s)	Required Information	Worksheet No.	Crosswalk to Related Documents
3.2 Analytical Tasks 3.2.1 Analytical SOPs 3.2.2 Analytical Instrument Calibration Procedures 3.2.3 Analytical Instrument and Equipment Maintenance, Testing, and Inspection Procedures 3.2.4 Analytical Supply Inspection and Acceptance Procedures	• Analytical SOPs • Analytical SOP References Table • Analytical Instrument Calibration Table • Analytical Instrument and Equipment Maintenance, Testing, and Inspection Table	23 24 25	
3.3 Sample Collection Documentation, Handling, Tracking, and Custody Procedures 3.3.1 Sample Collection Documentation 3.3.2 Sample Handling and Tracking System 3.3.3 Sample Custody	• Sample Collection Documentation Handling, Tracking, and Custody SOPs • Sample Container Identification • Sample Handling Flow Diagram • Example Chain-of-Custody Form and Seal	26 27	
3.4 Quality Control Samples 3.4.1 Sampling Quality Control Samples 3.4.2 Analytical Quality Control Samples	• Quality Control (QC) Samples Table • Screening/Confirmatory Analysis Decision Tree	28	
3.5 Data Management Tasks 3.5.1 Project Documentation and Records 3.5.2 Data Package Deliverables 3.5.3 Data Reporting Formats 3.5.4 Data Handling and Management 3.5.5 Data Tracking and Control	• Project Documents and Records Table • Analytical Services Table • Data Management SOPs	29 30	
Assessment/Oversight			
4.1 Assessments and Response Actions 4.1.1 Planned Assessments 4.1.2 Assessment Findings and Corrective Action Responses	• Assessments and Response Actions • Planned Project Assessments Table • Audit Checklists • Assessment Findings and Corrective Action Responses Table	31 32	
4.2 QA Management Reports	• QA Management Reports Table	33	
4.3 Final Project Report			

QAPP Worksheet #2 (Continued)
QAPP Identifying Information

Required QAPP Element(s) and Corresponding QAPP Section(s)	Required Information	Worksheet No.	Crosswalk to Related Documents
Data Review			
5.1 Overview			
5.2 Data Review Steps 5.2.1 Step I: Verification 5.2.2 Step II: Validation 5.2.2.1 Step IIa Validation Activities 5.2.2.2 Step IIb Validation Activities 5.2.3 Step III: Usability Assessment 5.2.3.1 Data Limitations and Actions from Usability Assessment 5.2.3.2 Activities	• Verification (Step I) Process Table • Validation (Steps IIa and IIb) Process Table • Validation (Steps IIa and IIb) Summary Table • Usability Assessment	34 35 36 37	
5.3 Streamlining Data Review 5.3.1 Data Review Steps To Be Streamlined 5.3.2 Criteria for Streamlining Data Review 5.3.3 Amounts and Types of Data Appropriate for Streamlining			

QAPP Worksheet #3
Minimum Distribution List

Controlled copies of the QAPP will be distributed according to the distribution list below. This list will be updated, as needed, and kept by the LATA Kentucky Records Management Department. Each person receiving a controlled copy also will receive any updates/revisions. If uncontrolled copies are distributed, it will be the responsibility of the person distributing the uncontrolled copy to provide updates/revisions.

Position Title	Organization	QAPP Recipients	Current Telephone Number	Current E-mail Address	Document Control Number
Acting Paducah Site Lead	DOE	Rachel H. Blumenfeld	(270) 441-6825	Rachel.blumenfeld@lex.doe.gov	1
Project Manager	DOE	Dave Dollins	(270) 441-6819	dave.dollins@lex.doe.gov	2
Environmental Remediation Project Manager	LATA Kentucky	Mark Duff	(270) 441-5030	mark.duff@lataky.com	3
Regulatory Manager	LATA Kentucky	Myrna Redfield	(270) 441-5113	myrna.redfield@lataky.com	4
Project Integration and Operations Manager	LATA Kentucky	Craig Jones	(270) 441-5114	craig.jones@lataky.com	5
FFA Manager	KDEP	Todd Mullins	(502) 564-6716	todd.mullins@ky.gov	6
FFA Manager	EPA	Jennifer Tufts	(404) 562-8513	tufts.jennifer@epamail.epa.gov	7
Risk Assessment Manager	LATA Kentucky	Joe Towarnicky	(270) 441-5134	joseph.towarnicky@lataky.com	8
FFA Manager	LATA Kentucky	Jana White	(270) 441-5185	jana.white@lataky.com	9
Quality Assurance Manager	LATA Kentucky	Michelle Dudley	(270) 462-4544	michelle.dudley@lataky.com	10
Acting Environmental Monitoring and Reporting Program Manager	LATA Kentucky	Lisa Crabtree	(270) 441-5135	lisa.crabtree@lataky.com	11
Environment, Safety, and Health Manager	LATA Kentucky	Dave Kent	(270) 441-5404	dave.kent@lataky.com	12
Regulatory Compliance Manager	LATA Kentucky	Michael Gerle	(270) 441-5069	michael.gerle@lataky.com	13
Sample/Data Management Manager	LATA Kentucky	Lisa Crabtree	(270) 441-5135	lisa.crabtree@lataky.com	14

QAPP Worksheet #3 (Continued)
Minimum Distribution List

Distribution is based on the position title. A change in the individual within an organization will not trigger a resubmission of this QAPP. DOE may choose to update the sheet and submit changes to the programmatic document holders. These managers will be responsible for distribution to their staff assigned to the treatability study for steam injection.

QAPP Worksheet #4
Project Personnel Sign-Off Sheet

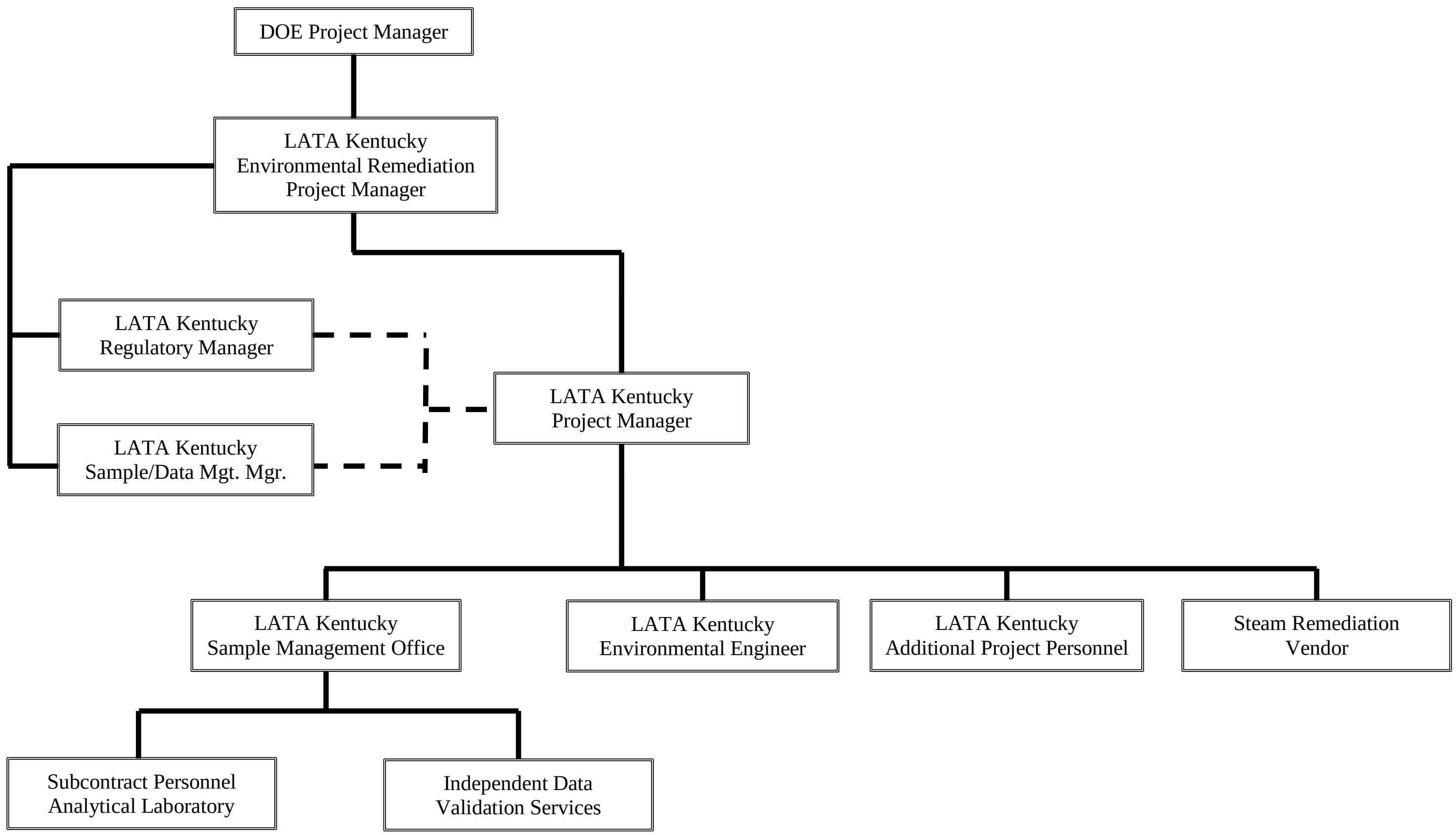
Personnel actively engaged in sample collection and data analysis for the projects are required to read applicable sections of this QAPP and sign a Personnel Sign-off Sheet. The master list of signatures will be kept by the Environmental Monitoring and Reporting Program Manager (or designee) and will be made available upon request.

Project Position Title	Organization	Signature	Date
Project Manager	LATA Kentucky		
Environmental Engineer	LATA Kentucky		
Sample/Data Management Manager	LATA Kentucky		
Steam Remediation Vendor Personnel [to be determined (TBD)]	Steam Remediation Vendor (TBD)		
Geotechnical Laboratory Project Manager	Geotechnical Laboratory (TBD)		

QAPP Worksheet #5
Project Contractor Organizational Chart

This portion of the QAPP addresses the project organization as it provides for QA/QC coordination and responsibilities.

Project-Level Organization Chart



QAPP Worksheet #6
Communication Pathways

NOTE: Formal communication across company or regulatory boundaries occurs via letter. Other forms of communication, such as e-mail, meetings, etc., will occur throughout the project.

Communication Drivers	Organizational Affiliation	Position Title Responsible	Procedure
Federal Facility Agreement, DOE/OR/07-1707	DOE Paducah Site Lead	Paducah Site Lead	All formal communication among DOE, EPA, and KDEP.
Federal Facility Agreement, DOE/OR/07-1707	DOE Paducah	DOE Project Manager	All formal communication between DOE and contractor for Environmental Remediation Projects.
All project requirements	LATA Kentucky	Environmental Remediation Project Manager	All formal communication among the project, the Site Lead, and the DOE Project Manager.
All project requirements	LATA Kentucky	Project Manager	All communication between the project and the LATA Kentucky Environmental Remediation Project Manager.
Project QA requirements	LATA Kentucky	Quality Assurance Manager	All project quality related communication between the QA department and LATA Kentucky project personnel.
FFA Compliance	LATA Kentucky	Regulatory Manager	All internal communication regarding FFA compliance with the LATA Kentucky Project Manager.

QAPP Worksheet #6 (Continued)
Communication Pathways

Communication Drivers	Organizational Affiliation	Position Title Responsible	Organizational Department Manager	Procedure
Sampling Requirements	LATA Kentucky	Sampling Lead	Project and Operations Manager	All internal communication regarding field sampling with the LATA Kentucky Project Manager.
Geotechnical Laboratory Interface	LATA Kentucky	Laboratory Coordinator	Environmental Monitoring	All communication between LATA Kentucky and geotechnical laboratory.
Analytical Laboratory Interface	LATA Kentucky	Laboratory Coordinator	Environmental Monitoring	All communication between LATA Kentucky and analytical laboratory.
Waste Management Requirements	LATA Kentucky	Waste Coordinator	Project and Operations Manager	All internal communication regarding project waste management with LATA Kentucky Project Manager.
Environmental Compliance Requirements	LATA Kentucky	Compliance Manager	Regulatory Manager	All internal correspondence regarding environmental requirements and compliance with the LATA Kentucky Project Manager.
Subcontractor Requirements (if applicable)	LATA Kentucky	Subcontract Administrator	Business Manager	All correspondence between the project and subcontractors, if applicable.
Health and Safety Requirements	LATA Kentucky	Environment, Safety, and Health Manager	Environment, Safety, and Health Manager	All internal communication regarding safety and health requirements with the LATA Kentucky Project Manager.

QAPP Worksheet #7
Personnel Responsibility and Qualifications Table

Position Title Responsible	Organization Affiliation	Responsibilities	Education and Experience Qualifications[1]
Project Manager	LATA Kentucky	Overall project responsibility	> 4 years relevant work experience
Environmental Engineer	LATA Kentucky	Project sampling and analysis plan	Bachelor of Science plus > 1 year relevant work experience
Environmental Compliance Manager	LATA Kentucky	Project environmental compliance responsibility	Bachelor's degree plus > 4 years work experience
FFA Manager	LATA Kentucky	Project compliance with the FFA	> 4 years work relevant experience
Environmental Monitoring and Reporting Program Manager	LATA Kentucky	Support project on sampling and reporting activities	> 4 years relevant work experience
Sample/Data Management Manager	LATA Kentucky	Project sample and data management	> 1 year relevant work experience
Health and Safety Representative	LATA Kentucky	Project safety and health responsibility	Bachelor's degree plus > 1 year relevant experience
Waste Coordinator	LATA Kentucky	Overall project waste management responsibility	> 4 years relevant experience
Data Validator	Independent third party subcontractor	Performing data validation according to specified procedures	Bachelor's degree plus relevant experience
Geotechnical Laboratory Project Manager	Geotechnical Laboratory	Sample analysis and data reporting	Bachelor's degree plus relevant experience
Analytical Laboratory Project Manager	Analytical Laboratory	Sample analysis and data reporting	Bachelor's degree plus relevant experience

[1] Candidates who do not have a certificate or required degree but demonstrate additional "equivalent relevant work experience" can be considered when evaluating qualifications. This assessment will be conducted by the project manager as he/she assembles the appropriate team for the project.

QAPP Worksheet #8
Special Personnel Training Requirements Table

Personnel are trained in the safe and appropriate performance of their assigned duties in accordance with requirements of work to be performed. Work control packages generated for the project will list specific project-level training requirements.

Project Function	Specialized Training—Title or Description of Course	Training Provider	Training Date	Personnel/Groups Receiving Training	Personnel Titles/ Organizational Affiliation	Location of Training Records/Certificates*
General Project Tasks	There will be no specialized training required for this program other than what normally is required for site work at PGDP. The contractor will evaluate specific tasks and personnel will be assigned training as necessary to perform those tasks. Training may address health and safety aspects of specific tasks as well as contractor-specific, site-specific, and task-specific requirements.	LATA Kentucky	Prior to sampling activities	Based upon required duties	LATA Kentucky staff, subcontractors	Training files are maintained by the LATA Kentucky training organization. A training database is utilized to manage and track training.
Steam Remediation Vendor	Extensive experience related to steam injection	Variety of steam injection projects	TBD	Steam Remediation Vendor Systems Design	Steam Remediation Vendor/TBD	TBD
Steam Remediation Vendor	Boiler Operator	Accredited Training Provider	TBD	Steam Remediation Vendor Operations	Steam Remediation Vendor/TBD	TBD
Drill Rig Operator	Kentucky Certified Well Driller	Commonwealth of Kentucky	TBD	Drill Rig Operator	Drill Rig Operator/TBD	TBD

*Training records are maintained by the LATA Kentucky training department. If training records and/or certificates do not exist or are not available, then this should be noted.

QAPP Worksheet #9
Project Scoping Session Participant Sheet

Project scoping is the key to the success of any project and is part of the systematic planning process. For this QAPP, this included review of past documents produced and an April 2013 DQO session for the steam injection treatability study. Regular meetings from April through June 2013 occurred to advance the group's understanding of treatability study scope, requirements, and options. Scoping discussions were concluded in mid-June and agreements were reached on key scoping concepts and draft DQOs for a treatability study. The adaptations for this QAPP address the focus of the treatability study.

Name of Project: C-400 VOC Contamination Interim Remedial Action ROD
Date of Session: April–June 2013
Scoping Session Purpose: C-400 Steam Injection Treatability Study

Position Title	Affiliation	Name	Phone #	E-mail Address	Project Role
Project Manager—DOE	U.S. Department of Energy	David Dollins	270-441-6819	dave.dollins@lex.doe.gov	DOE Project Manager
FFA Manager—EPA	U.S. Environmental Protection Agency	Jennifer Tufts	404-562-8513	tufts.jennifer@epa.gov	EPA FFA Manager
FFA Manager—KDEP	Kentucky Department for Environmental Protection	Todd Mullins	502-564-6716	todd.mullins@ky.gov	KDEP FFA Manager
Hydrologist—EPA	U.S. Environmental Protection Agency	Noman Ahsanuzzaman	404-562-8047	ahsanuzzaman.noman@epamail.epa.gov	EPA Subject Matter Expert
Hydrologist—EPA	U.S. Environmental Protection Agency	Eva Davis	580-436-8548	davis.eva@epamail.epa.gov	EPA Subject Matter Expert
Project Manager—KDEP	Kentucky Department for Environmental Protection	Brian Begley	502-564-8158 ex 4688	brian.begley@ky.gov	KDEP Project Manager
Project Manager—KDEP	Kentucky Department for Environmental Protection	Gaye Brewer	270-898-8468	gaye.brewer@ky.gov	KDEP Project Manager
Sr. Project Manager	Pro2Serve	Tracey Duncan	270-441-6803	tracey.ducan@lex.doe.gov	Project Manager

QAPP Worksheet #9 (Continued)
Project Scoping Session Participant Sheet

Position Title	Affiliation	Name	Phone #	E-mail Address	Project Role
Groundwater Operable Unit Manager	LATA Kentucky	Jeff Carman	270-441-5229	jeff.carman@lataky.com	Groundwater Operable Unit Manager
Project Engineer	LATA Kentucky	Mike Clark	270-441-5419	michael.clark@lataky.com	Project Manager
FFA Manager	LATA Kentucky	Jana White	270-441-5185	jana.white@lataky.com	FFA Manager
Manager of Projects	LATA Kentucky	Craig Jones	270-441-5419	craig.jones@lataky.com	Project Integration and Implementation Manager
Senior Scientist	Geosyntec Consultants	Dave Parkinson	206-496-1446	DParkinson@geosyntec.com	Principal author of Treatability Study Work Plan
Professor, Dept. of Environmental Engineering and Earth Sciences	Clemson University	Ronald Falta	864-656-0125	FALTAR@clemson.edu	Steam Remediation Expert—Consultant to LATA Kentucky

QAPP Worksheet #10
Problem Definition

The problem to be addressed by the project:

During the design of the original C-400 IRA Electrical Resistance Heating (ERH) system, DOE decided to divide the treatment system into two phases. Phase I was implemented in the source areas that are east and southwest of the C-400 Building: Phase I implementation was completed in December 2010. Based on the evaluation of the Phase I results and lessons learned, it was determined that the ERH base design was successful in reaching target temperatures in the subsurface and removing contaminants in the Upper Continental Recharge System (UCRS) and upper Regional Gravel Aquifer (RGA). The evaluation of Phase I also indicated that target temperatures were not achieved in the lower RGA, which has resulted in splitting the Phase II IRA for the southeast source areas into two separate actions:

1. UCRS and Upper RGA action (Phase IIa) and
2. Lower RGA action (Phase IIb).

The objective of the treatability study is to gather information on steam mobility in the RGA to inform the regulatory decision process for determining the applicability of steam-enhanced remediation for Phase IIb. The treatability study is designed to observe the movement and distribution of steam and provide data to refine the estimates of permeability, anisotropy/heterogeneity, and local groundwater velocity. The resulting information will be used to model steam injection and multiphase extraction (well spacing, locations, steam injection rates, and timing), to assess the technical implementability and cost-effectiveness of steam injection.

The environmental questions being asked:

1. How will steam flow in the RGA in the southeast treatment zone?
2. How does steam injection using two injection intervals (middle and lower RGA) differ from injection using a single deep injection interval?

Observations from any site reconnaissance reports:

Characterization data from the WAG 6 RI and focused sampling at C-400 in 2010 to confirm earlier membrane interface probe (MIP) logs indicate that significant trichloroethene contamination of soil and groundwater is present.

A synopsis of secondary data or information from site reports:

Operational experience from the C-400 Phase IIa IRA demonstrated that ERH would be ineffective at heating the lower RGA (see C-400 Technical Evaluation).

The possible classes of contaminants and the affected matrices:

Primarily, the contaminants are VOCs.

QAPP Worksheet #10 (Continued)
Problem Definition

The rationale for inclusion of chemical and nonchemical analyses:

Worksheet #11 presents rationale for inclusion of nonchemical analyses. The treatability study design will determine the need for the inclusion of chemical analyses.

Information concerning various environmental indicators:

Groundwater investigations have indicated that the Southeast C-400 block is a significant source of dissolved VOCs (primarily TCE) to the Northwest Plume.

Project decision conditions ("If…, then…" statements):

If technically effective steam front propagation in the RGA can be demonstrated, then the resulting information can be used to develop design and cost concepts for technology selection.

QAPP Worksheet #11
Project Quality Objectives/Systematic Planning Process Statements

This QAPP has been prepared to detail the minimum standards for data quality. The overall project quality objectives are to develop and implement procedures for field sampling, chain-of-custody, laboratory analysis, and reporting that will provide results that are legally defensible in a court of law. Specific procedures for sampling, chain-of-custody, instrument calibration/preventive maintenance, internal QC, reporting data, audits, and corrective actions are described in other sections of this QAPP.

QAPP Worksheet #11 details the project quality objectives developed through the systematic planning process.

Who will use the data? A DOE subcontractor, a steam-enhanced remediation vendor, will use the data to model steam injection with multiphase extraction performance in the RGA.

What will the data be used for? To determine the cost and performance of steam injection with multiphase extraction for the C-400 Phase IIb remedial action. Documentation of complete heating to steam temperatures throughout the target zone to the base of the RGA is required to demonstrate that technically effective steam front propagation has occurred. Results of steam modeling performed for the treatability study will refine estimates of permeability, anisotropy/heterogeneity, and local groundwater velocity by comparing temperature response and steam injection rate to the range of estimates for RGA hydraulic parameters.

What type of data is needed? (target analytes, analytical groups, field screening, on-site analytical or off-site laboratory techniques, sampling techniques) Grain size analyses of RGA soil samples, temperature profiles in the RGA, operational parameters (to be defined by the treatability study design), and VOC trends in recovered water (if an extraction well is used).

How "good" do the data need to be in order to support the environmental decision? American Society for Testing and Materials (ASTM) D422-63 (2007) produces adequate data quality for the grain size analyses. The accuracy of subsurface temperature measurements will be specified in the project design drawings and technical specifications package. Operations data quality is addressed by the steam remediation vendor in the final design drawings and technical specifications package. All fixed-laboratory analytical data will be verified and assessed with 10% validated at Level III. A Level III data package includes sample results; QC sample information (method blanks, LCS, MS/MSD, lab duplicate); calibration information; surrogate recoveries; internal standard results; and special instrumentation analysis requirements (i.e., bromofluorobenzene tune data or postdigestion spike results). A Level III validation evaluates all of these items. Level III validation of 10% of project data is the site's general standard for environmental investigations and has been demonstrated to provide adequate quality control for uses such as a treatability study.

Where, when, and how should the data be collected/generated? Samples for grain size analysis will be collected during the construction of the treatability study infrastructure. The steam remediation vendor will document sampling requirements to document temperature and operations in the final design drawings and technical specifications package.

Who will collect and generate the data? A sample team of individuals who are properly trained and skilled in screening and sampling procedures will perform field screening measurements for ES&H monitoring (VOC measurements and alpha and gamma activity) and collect samples. Subsurface temperature and operational parameter measurements will be automated (temperature data acquisition modules).

QAPP Worksheet #11 (Continued)
Project Quality Objectives/Systematic Planning Process Statements

How will the data be reported? Field data will be recorded on chain-of-custody forms, in field logbooks, and field data sheets. The fixed-base laboratory will provide data in an Electronic Data Deliverable (EDD). Project data following verification assessment will be placed into and reported from the OREIS.

How will the data be archived? Electronic data will be archived in OREIS. Hard-copy data will be submitted electronically to the Document Management Center.

QAPP Worksheet #12
Measurement Performance Criteria Table

Matrix	Water/Groundwater
Analytical Group	Volatile Organic Compounds
Concentration Level	High

Sampling Procedure	Analytical Method/SOP[1]	Data Quality Indicators (DQIs)	Measurement Performance Criteria	QC Sample and/or Activity Used to Assess Measurement Performance	QC Sample Assesses Error for Sampling (S), Analytical (A) or both (S&A)
PAD-ENM-2101, *Groundwater Sampling*	SW-846-8260	Precision–Lab	RPD–≤ 25%	Laboratory Duplicates	A
		Precision	RPD–≤ 25%	Field Duplicates	S
		Accuracy/Bias	% recovery[3]	Laboratory Sample Spikes	A
		Accuracy/Bias-Contamination	No target compounds > PQL	Method Blanks/Instrument Blanks	A
		Accuracy/Bias Contamination	No target compounds > PQL	Field Blanks	S
		Accuracy/Bias Contamination	No target compounds > PQL	Trip Blanks	S
		Accuracy/Bias Contamination	No target compounds > PQL	Equipment Rinseates	S
		Completeness[2]	90%	Data completeness check	S&A

PQL = practical quantitation limit; RPD = Relative Percent Difference;
[1] The most current version of the method will be used.
[2] Completeness is calculated as the number of samples planned to be collected divided by the number of sample results that were rejected.
[3] Percent recovery is laboratory-specific, calculated from studies performed every six months. Percent recovery ranges will be provided in the laboratory data packages based on the most current study.

QAPP Worksheet #13
Secondary Data Criteria and Limitations Table

Secondary Data	Data Source (Originating Organization, Report Title, and Date)	Data Generator(s) (Originating Org., Data Types, Data Generation/Collection Dates)	How Data Will Be Used	Limitations on Data Use
OREIS Database	Various	Various	Data will be for remedy selection and to support remedial design.	Data have been verified, assessed, and validated (if validation is required). Rejected data will not be used.
Historical Documentation	WAG 6 RI Report (DOE/OR/07-1727&D2)	DOE contractors, soil and water analyses, 1997	Information will be used in conjunction with newly collected data to help assess the initial mass of VOCs present in the southeast C-400 block.	Data have been verified, assessed, and validated (if validation required). Rejected data will not be used. VOC levels may have declined significantly since collection of the samples.
Historical Documentation	2008 C-400 IRA Remedial Design Report (DOE/LX/07-0005&D2/R1)	DOE contractors, MIP logs, 2005	Information will be used in conjunction with newly collected data to help assess the initial mass of VOCs present in the southeast C-400 block.	Data have been verified, assessed, and validated (if validation required). Rejected data will not be used. Twinned MIP logs of 2005 and 2010 cannot be reliably correlated.

QAPP Worksheet #13 (Continued)
Secondary Data Criteria and Limitations Table

Secondary Data	Data Source (Originating Organization, Report Title, and Date)	Data Generator(s) (Originating Org., Data Types, Data Generation/Collection Dates)	How Data Will Be Used	Limitations on Data Use
Historical Documentation	2008 Update of the Sitewide Groundwater Flow Model (PRS-ENR-0028)	DOE contractors, groundwater flow model, 2008	Information will be used in conjunction with newly collected data to help assess aquifer properties, including permeability and groundwater flow velocity.	Modeling was performed using vetted software in compliance with site QA procedures. Inherent limitations associated with use of computer modeling. Recent data available for recalibration of model.
Historical Documentation	C-400 Technical Evaluation for Phase I (DOE/LX/07-1260&D1)	DOE contractors, ERH Phase I performance evaluation, heat modeling, independent technical review team report, 2010	Information will be used in conjunction with newly collected data to help assess heating requirements for the lower RGA.	Data have been verified, assessed, and validated (if validation required). Rejected data will not be used.
Historical Documentation	Attachment A2 of Appendix of the C-400 Revised Proposed Plan (DOE/LX/07-1263&D1)	DOE contractors, soil and water analyses, and MIP logs, 2010	Information will be used in conjunction with newly collected data to help assess the initial mass of VOCs present in the southeast C-400 block. Soil conductivity logs, in conjunction with grain size analyses (to be collected) will help to assess formation anisotropy.	Data have been verified, assessed, and validated (if validation required). Rejected data will not be used. MIP logs of 2010 could not be correlated reliably with analytical data of twinned soil borings.

QAPP Worksheet #13 (Continued)
Secondary Data Criteria and Limitations Table

Secondary Data	Data Source (Originating Organization, Report Title, and Date)	Data Generator(s) (Originating Org., Data Types, Data Generation/Collection Dates)	How Data Will Be Used	Limitations on Data Use
Project Scoping	Site Questionnaire Information Provided to TerraTherm, Inc.	DOE contractors, site characterization, and site resources data	Information will be used to assess setting (regulatory, physical, and operational) for steam-enhanced remediation	Characterization data have been verified, assessed, and validated (if validation required). Rejected data will not be used. Site resources may be impacted by closure of uranium enrichment operations.
Project Scoping	2-D simulations of C-400 steam heating	TerraTherm, Inc,	Information will be used to assess design of the treatability study.	Modeling was performed using vendor's software, 2-D simulation only. Inherent limitations are associated with use of computer modeling.
Project Scoping	2-D and 3-D simulations of C-400 steam heating	Falta Environmental, LLC, 2-D and 3-D models of C-400 steam heating, 2013	Information will be used to assess design of the treatability study.	Modeling was performed using vetted software. Inherent limitations are associated with use of computer modeling.

QAPP Worksheet #14
Summary of Project Tasks*

Sampling Tasks: Collect and preserve samples, document field notes, complete chain of custody (COC), label samples, package/ship samples per standard operating procedures (see Worksheet #21).

Analysis Tasks: Receive samples, complete COC, perform grain size analysis, review data, report data per standard methods (see Worksheet #21).

Quality Control Tasks: QC will be per QAPP worksheets as follows:

- QC samples—Worksheets #20 and #28
- Equipment calibration—Worksheet #22
- Data review/validation—Worksheets #34, #35, #36, and #37

Secondary Data: See Worksheet #13.

Data Management Tasks: Data management will be per procedures PAD-ENM-5007, *Data Management Coordination,* and PAD-ENM-1003, *Developing, Implementing, and Maintaining Data Management Implementation Plans,* and the *Data Management and Implementation Plan,* Section 10, found in the C-400 RAWP, DOE/LX/07-1271&D1.

Documentation and Records: Documentation and records will be per procedure PAD-DOC-1009, *Records Management, Administrative Records, and Document Control.*

Assessment/Audit Tasks: Assessments and audits will be per procedure PAD-QAP-1420, *Conduct of Management Assessments.*

Prior to mobilization to perform fieldwork, an independent assessment (Internal Field Readiness Review) will be conducted to determine if the project is prepared to proceed (e.g., scope has been defined and is understood by workforce, scope has regulatory approval, scope properly contracts, personnel properly trained to complete). One management assessment will be performed during construction/sampling of the steam injection network to verify work is being performed consistent with the Sampling and Analysis Plan (SAP).

Data Review Tasks: Data review tasks will be per procedure PAD-ENM-5003, *Quality Assured Data* and the *Data Management and Implementation Plan,* Section 10, found in the C-400 RAWP, DOE/LX/07-1271&D1.

*It is understood that SOPs are contractor specific.

QAPP Worksheet #15
Reference Limits and Evaluation Table

Matrix: Water
Analyte Group: VOCs

VOCs	CAS Number	Project Action Limit/NAL[c] (µg/L)	Project Action Limit Reference[a]	Site COPC?[b]	Laboratory-Specific	
					PQLs (µg/L)	MDLs[d] (µg/L)
1,1-Dichloroethene	75-35-4	7/0.0511	MCL/NAL	Yes	5	
cis-1,2-Dichloroethene	156-59-2	70/1.25	MCL/NAL	Yes	1	
Trichloroethene	79-01-6	5/0.0465	MCL/NAL	Yes	1	
Vinyl Chloride	75-01-4	2/0.0725	MCL/NAL	Yes	2	

CAS = Chemical Abstracts Service
COPC = chemical of potential concern
MCL = maximum contaminant level
MDL = method detection limit
NAL = no action level for child resident scenario from the Risk Methods Document (DOE 2011)
PQL = practical quantitation limit
VOC = volatile organic compound

[a] This worksheet lists the NALs established by the Risk Methods Document for the child resident scenario.
[b] Analytes marked with COPC are from Table 2.1 of the Risk Methods Document (DOE 2011) and represent the list of chemicals, compounds, and radionuclides compiled from COPCs retained as contaminants of concern in risk assessments performed at PGDP between 1990 and 2008.
[c] The analytical laboratory may not be able to meet the child resident scenario NALs established by Methods for Conducting Risk Assessments and Risk Evaluations at PGDP (Risk Methods Document, DOE 2011). For cases where the PQL is above the Project Action Limit/NAL, LATA Kentucky will have the laboratory report to the MDL, qualifying the result as estimated. Standard practices for qualifying data will apply for any result reported below the laboratory PQL.
[d] MDLs will be provided in the project QAPP once the laboratory has been contracted.

QAPP Worksheet #16
Project Schedule/Timeline Table

Section 5.3 of the TSWP and Worksheet #17 of this QAPP describe the approach to sampling to be used to characterize the RGA temperature profiles for the C-400 Phase IIb treatability study. Section 5.2 provides the project planning schedule. Installation of Phase IIb treatability study components (and sampling) is scheduled to begin September 15, 2014. The total duration of the operations field sampling period is approximately 60 to 90 days. The EDD of fixed-laboratory analyses (soil grain size) is expected within 28 days of completion of the fieldwork for installation of the injection wells and temperature monitoring array.

Assuming groundwater samples are collected (pending inclusion of an extraction well in the treatability study design), the EDD of fixed-laboratory analyses for groundwater VOC concentrations is expected within 28 days of completion of the fieldwork. Summaries of preliminary VOC analyses will be provided to the agencies within 2 weeks following receipt of the data.

Activities	Organization	Dates (MM/DD/YY)		Deliverable	Deliverable Due Date
		Anticipated Date(s) of Initiation	Anticipated Date of Completion		
Installation	Steam Remediation Vendor	09/15/14	12/01/14	Construction of Treatability Study infrastructure	12/01/14
Testing	Steam Remediation Vendor	12/02/14	04/02/15	Treatability Study data collection	4/2/14
Reporting	Steam Remediation Vendor	04/03/15	09/30/15	D1 Treatability Study Report	9/30/15

QAPP Worksheet #17
Sampling Design and Rationale

- **Describe and provide a rationale for choosing the sampling approach (e.g., grid system, biased statistical approach):**

  Soil samples will be collected at 2-ft intervals throughout the thickness of the RGA in three soil borings to characterize the variation of grain size within the RGA.

  Subsurface temperature monitoring will be conducted using a judgmental sampling approach, with temperature monitoring throughout the depth of the RGA (and 2 ft above and below) along a line downgradient away from injection location to a distance of approximately 20 ft. An additional series of temperature monitoring locations will occur in a crossgradient and upgradient direction at variable distances up to approximately 20 ft from injection well.

  The closest temperature monitoring location will be adjacent to the steam injection well, with the remaining 10 locations spaced at various distances up to 20 ft from the injection location.

- To address the potential difference of steam injection using two injection intervals versus steam injection in a single deep injection interval, the treatability study design will incorporate two steam injection intervals. Tests will be conducted with steam injection in both intervals (simultaneously) and with steam injection in the single deep interval.

- **Describe the sampling design and rationale in terms of which matrices will be sampled:**

  The injection well soil boring and two outside temperature monitoring soil borings will be sampled at 2-ft intervals across the RGA thickness to document the vertical and areal variation of grain size within the RGA. Temperature sensors will be placed across the thickness of the RGA (and 2 ft above and below) in 11 temperature monitoring points (each with 16 temperature sensors). Temperature monitoring will be conducted automatically, via temperature data acquisition modules, during the treatability study to assess the extent of steam propagation.

- **What analyses will be performed and at what analytical limits?**

  Soil samples will be analyzed for grain size analyses using ASTM D422-63(2007).

  Temperature readings will be collected continuously using temperature sensors and temperature data acquisition modules during the first hour of steps of the steam injection tests and thereafter as migration rates dictate.

- **Where are the sampling locations (including QC, critical, and background samples)?**

  Sampling locations are within 20 ft of the steam injection well, in an upgradient-downgradient transect and crossgradient to the injection well. The design drawings and technical specifications package will document the location of the temperature monitoring points.

  How many samples to be taken?

  Soil samples will be collected at 2-ft intervals through the depth of the RGA (approximately 25 samples). Temperature measurements will be determined by the steam remediation vendor.

- **What is the sampling frequency (including seasonal considerations)?**

  Soil sampling is a one-time event (at the time of construction of the treatability study infrastructure). Temperature measurements will be made during the 60-90 day interval of the treatability study field test. The steam remediation vendor will determine the temperature measurement frequency.

QAPP Worksheet #18
Sampling Locations and Methods/Standard Operating Procedure Requirements Table for Screening Samples

Sampling Location/ID Number	Matrix	Depth (units)	Analytical Group	Concentration Level[a]	Number of Samples (Identify Field Duplicates)	Sampling SOP Reference[b]	Rationale for Sampling Location
Steam Injection Treatability Study Area/TBD	Soil	Subsurface	Grain Size	Clay to Gravel	~ 15 + 2 Duplicates in each of 3 soil borings	See Worksheet #21	See Worksheet #17
	Soil	Subsurface	Temperature	Ambient to > 100°C	TBD by steam remediation vendor		
	Groundwater	Subsurface	VOCs	TCE assumed 20,000- < 1,000,000 µg/L	TBD by steam remediation vendor		
		Subsurface	Temperature	18°-90° C[a]	TBD by steam remediation vendor		

[a] Groundwater temperature measurements will reflect the temperature at the extraction well.

QAPP Worksheet #19
Analytical SOP Requirements Table

Matrix	Analytical Group	Concentration Level	Analytical and Preparation Method/SOP Reference*	Sample Volume	Containers (number, size, and type)	Preservation Requirements (chemical, temperature, light protected)	Maximum Holding Time (preparation/ analysis)
Soil	Grain Size	N/A	ASTM D 422-63 (2007)	300 mL	300 mL or greater wide-mouth plastic jar	Cool to < 4°C	N/A
Groundwater	VOCs	High	624/8260B	120 mL	3 x 40 mL Glass VOA Vial	HCl; cool to < 4°C	14 days for preserved

NOTE: Sample volume and container requirements will be specified by the laboratory.
*See Analytical SOP References table (Worksheet #23).

QAPP Worksheet #20
Field Quality Control Sample Summary Table

Matrix	Analytical Group	Concentration Level	Analytical and Preparation SOP Reference	No. of Sampling Locations*	No. of Field Duplicate Pairs	Inorganic No. of Matrix Spike	No. of Field Blanks	No. of Equip. Blanks	No. of Proficiency Testing Samples	Total No. of Samples to Lab*
Soil	Grain Size	N/A	ASTM D422-63 (2007)	3	5%	N/A	N/A	N/A	N/A	~ 81
Groundwater	VOCs	High	624/8260B	1 Possible (extraction well)	5%	5%	5%	5%	N/A	TBD by Treatability Study Design

QAPP Worksheet #21
Project Sampling SOP References Table

Site-specific standard operating procedures (SOPs) have been developed for site sampling and data management activities.

Reference Number	Title and Number[a]	Originating Organization[b]	Equipment Type	Modified for Project Work? (Y/N)	Comments
1	PAD-ENM-2300, *Collection of Soil Samples*	Contractor	Sampling	N	
2	PAD-ENM-1001, *Transmitting Data to the Paducah Oak Ridge Environmental Information System (OREIS)*	Contractor	N/A	N	
3	PAD-ENM-2100, *Groundwater Level Measurement*	Contractor	Sampling	N	
4	PAD-ENM-2101, *Groundwater Sampling*	Contractor	Sampling	Y[c]	
5	PAD-ENM-2303, *Borehole Logging*	Contractor	Sampling	N	
6	PAD-ENM-2700, *Logbooks and Data Forms*	Contractor	N/A	N	
7	PAD-ENM-2702, *Decontamination of Sampling Equipment*	Contractor	Sampling	N	
8	PAD-ENM-2708, *Chain-of-Custody Forms, Field Sample Logs, Sample Labels, and Custody Seals*	Contractor	N/A	N	
9	PAD-ENM-5003, *Quality Assured Data*	Contractor	N/A	N	
10	PAD-ENM-5004, *Sample Tracking, Lab Coordination, and Sample Handling Guidance*	Contractor	N/A	N	
11	PAD-ENM-5007, *Data Management Coordination*	Contractor	N/A	N	
12	PAD-ENM-5105, *Volatile and Semivolatile Data Verification and Validation*	Contractor	N/A	N	
13	PAD-ENM-1003, *Developing, Implementing, and Maintaining Data Management Implementation Plans.*	Contractor	N/A	N	

[a] SOPs are posted to the LATA Kentucky intranet Web site. External FFA parties can access this site using remote access with privileges upon approval.
[b] The work will be conducted by LATA Kentucky staff or a subcontractor. In either case, SOPs listed will be followed.
[c] Groundwater samples will be collected at the production pumping rate of the extraction well.

QAPP Worksheet #22
Field Equipment Calibration, Maintenance, Testing, and Inspection Table

Field Equipment*	Calibration Activity	Maintenance Activity	Testing Activity	Inspection Activity	Frequency	Acceptance Criteria	Corrective Action	Responsible Person	SOP Reference
Electronic Water Level Meter	N/A	None	Check daily before each use	Upon receipt, successful operation	Check daily before each use	Pass/Fail	Return to rental company for replacement	Field Team Leader	Manufacturer's specifications
Field Equipment Global Positioning System/GPS	Daily check of known point beginning and end of each field day	Per manufacturers specifications	Measure known control points and compare values	Upon receipt, successful operation	Daily prior to use	Pass/Fail	Service by manufacturer	Field Team Leader	Manufacturer's specifications
Thermocouple	N/A	None	Check prior to installation	Upon receipt	Check prior to installation	$\pm$ 1°C	Return to thermocouple vendor for replacement	Implementa-tion vendor field project leader	Manufacturer's specifications

*Additional equipment may be needed: additional equipment will follow manufacturer's specifications for calibration, maintenance, inspection, and testing.
Calibration data will be documented in logbooks consistent with PAD-ENM-2700, *Logbooks and Data Forms*.

QAPP Worksheet #23
Analytical SOP References Table

Reference Number*	Title, Revision Date, and/or Number	Definitive or Screening Data	Analytical Group	Instrument	Organization Performing Analysis	Modified for Project Work? (Y/N)
ASTM D422-63 (2007)	Standard Test Method for Particle-Size Analysis of Soils	Definitive	Geotechnical	Sieve and Hydrometer	TBD	N
8260	VOCs by gas chromatography/mass spectrometry (GC/MS)	Definitive	VOA	GC/MS	TBD	N

*Information will be based on laboratory used. Analysis will be by the most recent revision.

QAPP Worksheet #24
Analytical Instrument Calibration Table

All laboratory equipment and instruments used for quantitative measurements are calibrated in accordance with the laboratory's formal calibration program. Whenever possible, the laboratory uses recognized procedures for calibration such as those published by EPA or ASTM. If established procedures are not available, the laboratory develops a calibration procedure based on the type of equipment, stability, characteristics of the equipment, required accuracy, and the effect of operation error on the quantities measured. Whenever possible, physical reference standards associated with periodic calibrations, such as weights or certified thermometers with known relationships to nationally recognized standards, are used. Where national reference standards are not available, the basis for the reference standard is documented. Equipment or instruments that fail calibration or become inoperable during use are tagged to indicate they are out of calibration. Such instruments or equipment are repaired and successfully recalibrated prior to reuse. All high resolution mass spectrometer instruments undergo extensive tuning and calibration prior to running each sample set. The calibrations and ongoing instrument performance parameters are recorded and reported as part of the laboratory data package.

No field test kits will be used during the course of this investigation.

QAPP Worksheet #25
Analytical Instrument and Equipment Maintenance, Testing, and Inspection Table

Instrument/ Equipment	Maintenance Activity	Testing Activity	Inspection Activity	Frequency	Acceptance Criteria	Corrective Action	Responsible Person	SOP Reference*
GC/MS	Replace/clean ion source; clean injector, replace injector liner, replace/clip capillary column, flush/replace tubing on purge and trap; replace trap	QC standards	Ion source, injector liner, column, column flow, purge lines, purge flow, trap	As needed	Must meet initial and/or continuing calibration criteria	Repeat maintenance activity or remove from service	Laboratory Section Manager	See Worksheet #23
GC	ECD/FID maintenance; replace/clip capillary column	QC standards	ECD, FID, injector, injector liner, column, column flow	As needed	Must meet initial and/or continuing calibration criteria	Repeat maintenance activity or remove from service	Laboratory Section Manager	See Worksheet #23

* The laboratory is responsible for maintaining instrument and equipment maintenance, testing, and inspection information per their QA Plan. This information is audited annually by DOECAP. Laboratory(s) contracted will be DOECAP audited
ECD = electron capture detector
FID = flame ionization detector

QAPP Worksheet #26
Sample Handling System

SAMPLE COLLECTION, PACKAGING, AND SHIPMENT	
Sample Collection (Personnel/Organization):	Sampling Teams/DOE Prime Contractor and Subcontractors
Sample Packaging (Personnel/Organization):	Sampling Teams/DOE Prime Contractor and Subcontractors
Coordination of Shipment (Personnel/Organization):	Lab Coordinator/DOE Prime Contractor
Type of Shipment/Carrier:	Direct Delivery or Overnight/Federal Express
SAMPLE RECEIPT AND ANALYSIS	
Sample Receipt (Personnel/Organization):	Sample Management/Contracted Laboratory
Sample Custody and Storage (Personnel/Organization):	Sample Management/Contracted Laboratory
Sample Preparation (Personnel/Organization):	Analysts/Contracted Laboratory
Sample Determinative Analysis (Personnel/Organization):	Analysts/Contracted Laboratory
SAMPLE ARCHIVING	
Field Sample Storage (No. of days from sample collection):	The fixed-base laboratory will archive samples for 4 months or less depending on project-specific requirements.
Sample Extract/Digestate Storage (No. of days from extraction/digestion):	Not applicable.
Biological Sample Storage (No. of days from sample collection):	Not applicable.
SAMPLE DISPOSAL	
Personnel/Organization:	Waste Disposition/Sample and Data Management Manager/DOE Prime Contractor and Subcontractors
Number of Days from Analysis	6 months

QAPP Worksheet #27
Sample Custody Requirements*

Chain-of-custody procedures are comprised of maintaining sample custody and documentation of samples for evidence. To document chain-of-custody, an accurate record of samples must be maintained in order to trace the possession of each sample from the time of collection to its introduction to the laboratory.

Field Sample Custody Procedures (sample collection, packaging, shipment, and delivery to laboratory):

Field sample custody requirements will be per DOE Prime Contractor procedures, PAD-ENM-2708, *Chain-of-Custody Forms, Field Sample Logs, Sample Labels, and Custody Seals*; and PAD-ENM-5004, *Sample Tracking, Lab Coordination, and Sample Handling Guidance.*

Laboratory Sample Custody Procedures (receipt of samples, archiving, disposal):

Procedures are per the laboratory's standard procedures. When the samples are delivered to the laboratory, signatures of the laboratory personnel receiving them and the courier personnel relinquishing them will be completed in the appropriate spaces on the COC record, unless the courier is a commercial carrier. This will complete the sample transfer. It will be every laboratory's responsibility to maintain internal logbooks and records that provide custody throughout sample preparation and analysis process.

Sample Identification Procedures:

Sample identification requirements will be specified in the Data Management Implementation Plan.

Chain-of-custody Procedures:

COC requirements will be per DOE Prime Contractor procedures, PAD-ENM-2708, *Chain-of-Custody Forms, Field Sample Logs, Sample Labels, and Custody Seals*; and PAD-ENM-5004, *Sample Tracking, Lab Coordination, and Sample Handling Guidance.*

*It is understood that SOPs are contractor specific.

QAPP Worksheet #28
QC Samples Table

Matrix: Aqueous	
Analytical Group/Concentration Level: VOCs	
Sampling SOP: PAD-ENM-2101, *Groundwater Sampling*	
Analytical Method/SOP Reference: 624/8260	
Sampler's Name/Field Sampling Organization: TBD	
Analytical Organization: TBD	
No. of Sample Locations: 1 Potential (Extraction Well)	

QC Sample	Frequency/Number*	Method/SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Field blank	Minimum 5%	≤ CRQL**	Verify results; reanalyze	Project manager or designee	Contamination—Accuracy/bias	See procedure PAD-ENM-5003, *Quality Assured Data*
Trip blank	1 per cooler containing VOC samples	≤ CRQL	Verify results; reanalyze		Contamination—Accuracy/bias	See procedure PAD-ENM-5003, *Quality Assured Data*
Equipment blank	Minimum 5%	≤ CRQL	Verify results; reanalyze		Contamination—Accuracy/bias	See procedure PAD-ENM-5003, *Quality Assured Data*
Spiked field samples (MS and/or MSD)	1 per analytical batch	See data validation procedure PAD-ENM-5105	Check calculations and instrument; reanalyze affected samples	Laboratory analyst	Accuracy/Precision	See procedure PAD-ENM-5003, *Quality Assured Data*

QAPP Worksheet #28 (Continued)
QC Samples Table

QC Sample	Frequency/Number*	Method/SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Laboratory spiked blanks (LCS)	1 per analytical batch	See data validation procedure PAD-ENM-5105	Check calculations and instrument; reanalyze affected samples	Laboratory analyst	Accuracy	See procedure PAD-ENM-5003, *Quality Assured Data*
Method blank	1 per analytical batch	See data validation procedure PAD-ENM-5105	Check calculations and instrument; reanalyze affected samples		Contamination Accuracy/bias	See procedure PAD-ENM-5003, *Quality Assured Data*
Surrogate standards	All samples, blanks, and QC samples	See data validation procedure PAD-ENM-5105	Check calculations and instrument; reanalyze affected samples		Accuracy	See procedure PAD-ENM-5003, *Quality Assured Data*
Internal standards	All samples, blanks, and QC samples	See data validation procedures PAD-ENM-5105	Check calculations and instrument; reanalyze affected samples		Accuracy	See procedure PAD-ENM-5003, *Quality Assured Data*
Field duplicate	Minimum 5%	None	Data reviewer will place qualifiers on samples affected	Project manager or designee	Homogeneity/ Precision	RPD ≤ 50% soils, RPD < 25% aqueous
Laboratory duplicate	Per laboratory procedure	See data validation procedure PAD-ENM-5105	Verify results reprepare and reanalyze	Laboratory analyst	Precision	See procedure PAD-ENM-5003, *Quality Assured Data*

* The number of QC samples will be determined by the treatability study design.
** Unless dictated by project-specific parameters, ≤ CRQL.

QAPP Worksheet #29
Project Documents and Records Table

All project data and information must be documented in a format that is usable by project personnel. The QAPP describes how project data and information shall be documented, tracked, and managed from generation in the field to final use and storage in a manner that ensures data integrity, defensibility, and retrieval.

Sample Collection Documents and Records	On-site Analysis Documents and Records	Off-site Analysis Documents and Records	Data Assessment Documents and Records*	Other
Data logbooks (electronic or paper) and associated completed sampling forms; sample COCs	Laboratory data packages, OREIS database, and associated data packages	OREIS database and associated data packages	PAD-ENM-5003, Att. G, Data Assessment Review Checklist and Comment Form	Form QA-F-0004, Management/ Independent Assessment Report

*It is understood that SOPs are contractor specific.

QAPP Worksheet #30
Analytical Services Table

Matrix	Analytical Group	Concentration Level	Sample Locations/ID Numbers	Analytical SOP*	Data Package Turnaround Time	Laboratory/Organization (Name and Address, Contact Person and Telephone Number)[1]	Backup Laboratory/Organization (Name and Address, Contact Person and Telephone Number)
Soil	Grain Size	N/A	3/TBD	ASTM D422-63 (2007)	28-day	TBD	TBD
Groundwater	VOCs	High	Possible Treatability Study extraction well/ID numbers yet TBD	8260	28-day	TBD	TBD

*Laboratory contracting will be subsequent to the completion of the TSWP.

QAPP Worksheet #31
Planned Project Assessments Table

LATA Kentucky will ensure that protocol outlined in the QAPP is implemented adequately. Assessment activities help to ensure that the resultant data quality is adequate for its intended use and that appropriate responses are in place to address nonconformances and deviations from the QAPP. Below is a list of assessments project teams may use.

Assessment Type	Frequency	Internal or External	Organization Performing Assessment	Person(s) Responsible for Performing Assessment (Title and Organizational Affiliation)	Person(s) Responsible for Responding to Assessment Findings (Title and Organizational Affiliation)	Person(s) Responsible for Identifying and Implementing Corrective Actions (CA) (Title and Organizational Affiliation)	Person(s) Responsible for Monitoring Effectiveness of CA (Title and Organizational Affiliation)
Independent Assessment/ Surveillance	A	Internal	Prime Contractor QA	QA Specialists, Contractor, or Independent Assessor	Project Management, Contractor	Project Management, Contractor	QA Specialist, Contractor
Laboratory Audit	Annual	External	DOE Consolidated Audit Program (DOECAP)	Laboratory Assessor	Laboratory	Laboratory	DOECAP
Management Assessments	Annual	Internal	Prime Contractor Project Management	Regulatory Management, Contractor	Regulatory Management, Contractor	Regulatory Management, Contractor	QA Specialist, Contractor
Management by Walking Around (MBWA)*	B	Internal	Project Management	Project Management	Project Management	Project Management	Project Management
MBWA Follow-up surveillances	Quarterly	Internal	Project Management	Project Management or designee, Contractor	Project Management/Designee, Contractor	Project Management, Contractor	Project Management

A = assessment frequency determined by QA Manager and conducted per PAD-QA-1420, *Conduct of Assessments*.
B = assessment frequency determined by regulatory manager and conducted per PAD-QA-1420.
*Reference: PAD-QA-1033 *Management by Walking Around (MBWA) Program*.

QAPP Worksheet #32
Assessment Findings and Corrective Action Responses*

All provisions shall be taken in the field and laboratory to ensure that any problems that may develop shall be dealt with as quickly as possible to ensure the continuity of the project/sampling events. Field modifications to procedures in the QAPP must be approved before the modifications are implemented and then documented. The process controlling procedure modification is PAD-PD-1107, *Development, Approval, and Change Control for LATA Kentucky Performance Documents*. Field modifications are documented through the work control process per PAD-WC-0021. Corrective action in the field may be necessary when the sampling design is changed. For example, a change in the field may include increasing the number or type of samples or analyses, changing sampling locations, and/or modifying sampling protocol. When this occurs, the project team shall identify any suspected technical or QA deficiencies and note them in the field logbook. Listed in Worksheet #32 is how project teams will address assessment findings.

Assessment Type	Nature of Deficiencies Documentation	Individual(s) Notified of Findings (Name, Title, Organization)	Time Frame of Notification	Nature of Corrective Action Response Documentation	Individual(s) Receiving Corrective Action Response (Name, Title, Org.)	Time Frame for Response
Management, Independent, and Surveillances	Form QA-F-004, Management/ Independent Assessment Report, and QA-F-0710, Issue Identification Form	Project management, issue owner, contractor	Upon issuance of Form QA-F-004, Management/ Independent Assessment Report, form QA-F-0710, Issue Identification Form, will be completed and attached to the assessment report	QA-F-0710, Issue Identification Form, documents the issue response and/or corrective actions	Action owner as designated by issue owner, contractor	Fifteen days for initial issue response, corrective action schedule determined by issue owner, per PAD-QA-1210

*It is understood that SOPs are contractor specific.

QAPP Worksheet #33
QA Management Reports Table

Reports to management include project status reports, field and/or laboratory audits, and data quality assessments. These reports will be directed to the QA Manager and Project Manager who have ultimate responsibility for assuring that any corrective action response is completed, verified, and documented.

Type of Report	Frequency (daily, weekly monthly, quarterly, annually, etc.)	Projected Delivery Date(s)	Person(s) Responsible for Report Preparation (Title and Organizational Affiliation)	Report Recipient(s) (Title and Organizational Affiliation)
Field Change Requests	As needed	Ongoing	Field staff	QAPP recipients
QAPP Addenda	As needed	Not Applicable	Project Manager	QAPP recipients
Field Audit Report	TBD as determined by QA Manager	30 days after completion of audit	QA Manager	LATA Kentucky Project Manager QA Manager
Corrective Action Plan	As needed	Within 3 weeks of request	Project Manager	QA Manager

QAPP Worksheet #34
Verification (Step I) Process Table

This section of the QAPP provides a description of the QA activities that will occur after the data collection phase of the project is completed. Implementation of this section will determine whether the data conforms to the specified criteria satisfying the project objectives.

Verification Input	Description[a]	Internal/ External	Responsible for Verification (Name, Organization)
Field Logbooks	Field logbooks are verified per DOE Prime Contractor procedure, PAD-ENM-2700, *Logbooks and Data Forms*, and PAD-ENM-5003, *Quality Assured Data*.	Internal	Project Management or designee, Contractor
Chains-of-custody	COCs are controlled by DOE Prime Contractor procedure, PAD-ENM-5004, *Sample Tracking, Lab Coordination and Sample Handling Guidance*. COCs will be included in data assessment packages for review as part of data verification and data assessment.	Internal	Sample and Data Management, Project Management, and QA Personnel, Contractor
Field and Laboratory Data	Field and geotechnical data are assessed per DOE Prime Contractor procedure, PAD-ENM-5003, *Quality Assured Data*. Data assessment packages will be created per this procedure. The data assessment packages will include field and geotechnical data, COCs, data verification and assessment queries, and other project- specific information needed for personnel to review the package adequately. Data assessment packages will be reviewed to document any issues pertaining to the data and to indicate if data met the DQOs of the project.	Internal	Sample and Data Management, Project Management, and QA Personnel,[b] Contractor
Sampling Procedures	Evaluate whether sampling procedures were followed with respect to equipment and proper sampling support using audit and sampling reports, field change requests and field logbooks.	Internal	Sample and Data Management, Project Management, and QA Personnel,[b] Contractor
Laboratory Data	All laboratory data will be verified by the laboratory performing the analysis for completeness and technical accuracy prior to submittal to LATA Kentucky. Subsequently, LATA Kentucky will evaluate the data packages for completeness and compliance.	External/ Internal	Laboratory Manager, LATA Kentucky Sample and Data Management
EDDs	Determine whether required fields and format were provided.	Internal	Sample and Data Management
QAPP	All planning documents will be available to reviewers to allow reconciliation with planned activities and objectives.	Internal	All data users

[a] It is understood that SOPs are contractor specific.
[b] QA specialist performs general QA review.

QAPP Worksheet #35
Validation (Steps IIa and IIb) Process Table

Step IIa/IIb	Validation Input	Description*	Responsible for Validation (Name, Organization)
IIa	Data Deliverables, Analytes, and Holding Times	The documentation from the contractual screening will be included in the data assessment packages, per DOE Prime Contractor procedure, PAD-ENM-5003, *Quality Assured Data*.	Sample and Data Management Personnel, Contractor
IIa	Chains-of-Custody, Sample Handling, Sampling Methods and Procedures, and Field Transcription	These items will be validated during the data assessment process as required by DOE Prime Contractor procedure, PAD-ENM-5003, *Quality Assured Data*, and PAD-ENM-1003, *Developing, Implementing, and Maintaining Data Management Implementation Plans.* The documentation of this validation will be included in the data assessment packages.	Sample and Data Management Personnel, Contractor
IIa	Analytical Methods and Procedures, Laboratory Data Qualifiers, and Standards	These items will be reviewed during the data validation process as required by DOE Prime Contractor data validation procedures. Data validation will be performed in parallel with data assessment. The data validation report and data validation qualifiers will be considered when the data assessment process is being finalized.	Data Validation Subcontractor, Sample and Data Management, Project, Contractor
IIa	Audits	The audit reports and accreditation and certification records for the laboratory supporting the projects will be considered in the bidding process.	QA Personnel
IIb	Deviations and qualifiers from Step IIa	Any deviations and qualifiers resulting from Step IIa process will be documented in the data assessment packages.	Sample and Data Management, Project, and QA Personnel, Contractor
IIb	Sampling Plan, Sampling Procedures, Collocated Field Duplicates, Project Quantitation Limits, Confirmatory Analyses, Performance Criteria	These items will be evaluated as part of the data verification and data assessment process per DOE Prime Contractor procedure, PAD-ENM-5003, *Quality Assured Data*. These items will be considered when evaluating whether the project met their Data Quality Objectives.	Sample and Data Management, Project, and QA Personnel, Contractor

*It is understood that SOPs are contractor specific.

QAPP Worksheet #36
Validation (Steps IIa and IIb) Summary Table

Step IIa/IIb	Matrix	Analytical Group	Concentration Level	Validation Criteria	Data Validator (title and organizational affiliation)
Step IIa/IIb	Soils	All	All	N/A	N/A
Step IIa/IIb	Groundwater	VOCs	High	National Functional Guidelines; Worksheets #12, #15, and #28; and PAD-ENM-5003, and PAD-ENM-5105	Data Validator*

[a] Validation is to be conducted by a qualified third party/subcontractor. Individuals performing validation will be independent of sampling, laboratory, project management, or other decision making personnel for the task.

QAPP Worksheet #37
Usability Assessment*

LATA Kentucky shall determine the adequacy of data based on the results of verification. The usability step involves assessing whether the process execution and resulting data meet project quality objectives documented in the QAPP.

Summarize the usability assessment process and all procedures, including interim steps and any statistics, equations, and computer algorithms that will be used: Field and geotechnical data are verified and assessed per procedure PAD-ENM-5003, *Quality Assured Data*. Data assessment packages will be created per this procedure. Data assessment packages will include field, geotechnical, and analytical data; COCs; data verification and assessment queries; and other project-specific information needed for personnel to review the package adequately. Data assessment packages will be reviewed to document any issues pertaining to the data and to indicate if data quality objectives of the project were met. For data selected for validation, the procedure, PAD-ENM-5105 will be used.

Describe the evaluative procedures used to assess overall measurement error associated with the project: PARCCS parameters (precision, accuracy, representativeness, comparability, completeness, and sensitivity) will be evaluated per procedure, PAD-ENM-5003, *Quality Assured Data*. This information will be included in the data assessment packages for review by project personnel. Data assessment also will include documentation of QC exceedances, trends, and/or bias in the data set. Data assessment will document any statistics used. Completeness goals for temperature sensors and operational parameters will be provided by the steam remediation vendor in the design drawings and technical specifications package.

Identify the personnel responsible for performing the usability assessment: Project personnel, as verified by QA personnel.

Describe the documentation that will be generated during usability assessment and how usability assessment results will be presented so that they identify trends, relationships (correlations), and anomalies: Data assessment packages will be created, which will include data assessment comments/questions, and laboratory comments. Data verification and assessment queries indicating any historical outliers also will be included in the data assessment packages.

*It is understood that SOPs are contractor specific.

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